Subsurface Waste Disposal By Means of Wells— A Selective Annotated Bibliography

By DONALD R. RIMA, EDITH B. CHASE, *and* BEVERLY M. MYERS

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FOREWORD

Subsurface waste disposal or injection is looked upon by many waste managers as an economically attractive alternative to providing the sometimes costly surface treatment that would otherwise be required by modern pollution-control law. The impetus for subsurface injection is the apparent success of the petroleum industry over the past several decades in the use of injection wells to dispose of large quantities of oil-field brines. This experience coupled with the oversimplification and glowing generalities with which the injection capabilities of the subsurface have been described in the technical and commercial literature have led to a growing acceptance of deep wells as a means of "getting rid of" the ever-increasing quantities of wastes.

As the volume and diversity of wastes entering the subsurface continues to grow, the risk of serious damage to the environment is certain to increase. Admittedly, injecting liquid wastes deep beneath the land surface is a potential means for alleviating some forms of surface pollution. But in view of the wide range in the character and concentrations of wastes from our industrialized society and the equally diverse geologic and hydrologic conditions to be found in the subsurface, injection cannot be accepted as a universal panacea to resolve all variants of the waste-disposal problem. There is a compelling need to examine critically the compatibility of specific wastes with specific injection zones and to discriminate the capability of potential injection zones to receive and retain waste waters. In essence, there is an urgent need to prove the feasibility as well as the absolute safety of injection before the use of any injection well can be undertaken with any degree of certainty of the results.

Proper decisionmaking on subsurface injection of wastes must begin with an adequate understanding of the underground and its response to waste injection. To this end, the U.S. Geological Survey has launched an investigative program to develop an adequate scientific and technological basis for predicting the environmental consequences of discharging wastes into the subsurface. This bibliography is the first step in that it summarizes the technological experience and information now available on this critical subject.

E. L. HENDRICKS,
Chief Hydrologist

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SUBSURFACE WASTE DISPOSAL BY MEANS OF WELLS– A SELECTIVE ANNOTATED BIBLIOGRAPHY

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INTRODUCTION

Subsurface waste disposal by means of wells is the practice of using drilled wells to inject unwanted substances into underground rock formations. The use of wells for this purpose is not a new idea. As long ago as the end of the last century, it was common practice to drill wells for the express purpose of draining swamps and small lakes to reclaim the land for agricultural purposes. A few decades later in the 1920's and 1930's many oil companies began using injection wells to dispose of oil-field brines and to repressurize oil reservoirs. During World War II, the Atomic Energy Commission began using injection wells to dispose of certain types of radioactive wastes. More recently, injection wells have been drilled to dispose of a variety of byproducts of industrial processes. The number of such wells has increased rapidly since Congress passed the Clean Streams Act of 1966, which restricted the discharge of waste into surface waters.

Many scientists and public officials question the propriety of using the term "disposal" when referring to the underground injection of wastes. Their reasons are that underground injection is not, as many advocates claim, "a complete and final answer" to the waste-disposal problem. Rather, it is merely a process wherein the injected wastes are committed to the subsurface with uncertainty as to their ultimate fate or limits of confinement. In effect, the wastes, undiminished and unchanged, are removed from the custody of man and placed in the custody of nature.

Although the concept of waste-injection wells is relatively simple, the effects of waste injection can be very complex, particularly when dealing with the exotic and complex components of some industrial wastes. Besides the physical forces of injection, there are many varied interactions between the injected wastes and the materials within the injection zone. Because these changes occur out of sight in the subsurface, they are difficult to assess and not generally understood. In addition, the various aspects of the problem involve a wide spectrum of science and engineering. Hence, articles published on the subject are widely dispersed in the technical and scientific literature.

Because of the current national and worldwide interest in waste-disposal problems, the increasing use of injection wells, and the need to understand the long-term effects of injecting wastes into underground rock formations, this bibliography was prepared to gather significant references into a single publication that would be a reference source for both scientific and waste-management needs. The bibliography, which contains 692 abstracts, was compiled from a selective review through 1969 of the following source materials:

Bibliography of North American Geology *and* Abstracts of North American Geology: U.S. Geological Survey

Geophysical Abstracts: U.S. Geological Survey

Bibliography of Hydrology and Sedimentation: Federal Water Resources Council

Selected Water Resources Abstracts: Water Resources Scientific Information Center (WRSIC), Office of Water Resources Research, U.S. Department of the Interior

Nuclear Science Abstracts: U.S. Atomic Energy Commission

Water Resources Abstracts: American Water Resources Association, Urbana, Ill.

Annotated Bibliography of Oil-Field Brine Disposal Wells, by S. J. Martinez, Tulsa University, Information Services Department, Tulsa, Okla. (Prepared under contract for the U.S. Geological Survey)

Annotated Bibliography on Artificial Recharge of Ground Water, 1955-67, by D. C. Signor, D. J. Growitz, and William Kam: U.S. Geological Survey Water-Supply Paper 1990

Bibliography on Artificial Recharge of Ground Water, by Arnon Arad: U.S. Geological Survey open-file report

References listed in recently published reports on this subject (*See* Galley, John E. 0039, 0454, 0605; Ives, R. E. 0212; Piper, A. M. 0468; and Warner, D. L. 0416)

About one-third of the abstracts included here pertain to the disposal of oil-field brines. These abstracts were selected because they deal mainly with the engineering problems of injection wells. The subjects covered include the design construction, operation, and maintenance of disposal or injection facilities. In effect, these abstracts summarize the technology that has been gained by the oil industry in nearly half a century of collecting, handling, treating, and injecting waste waters into the subsurface.

An additional third of the abstracts pertain to the research that has been done to find satisfactory methods for the disposal of radioactive wastes. The major emphasis of this research is on the interaction of radioactive materials with the natural environment. It deals chiefly with the natural processes and mechanisms of transport, retention, and dispersal of radioactive materials in the subsurface. Hence, this work has direct application to the problems of predicting and monitoring the post-injection movement of waste waters.

Most of the remaining abstracts describe actual case histories of various industries that are using one or more injection wells. In general, these references are based on activities that have been considered successful in terms of well operation.

The abstracts are arranged alphabetically by author name (by senior-author name if a publication has multiple authorship). The names of all junior authors also are listed alphabetically, with cross reference to the senior-author entry. Where more than one entry appears under an author's name, the arrangement is by accession number. (Each paper was assigned an accession number as it was received; but as all papers received were not included in this bibliography, some papers have an accession number that is higher than the total number of abstracts.) Within each entry the accession number is given first followed by the name(s) of the author(s) in bold type. The next line begins with the year of publication followed by the title and the remainder of the citation. Parenthetical notes are given at the end of some of the bibliographic citations to assist the reader in locating the publications. The notation CFSTI is used to indicate the availability of an article from the Clearinghouse for Federal Scientific and Technical Information (renamed the National Technical Information Service in 1970), Springfield, Va. Other parenthetical notations at the end of the citations are self-explanatory.

Abstracts from sources other than the original publications have been used freely in the interest of saving time. Those abstracts by the original authors are so indicated; others are credited where appropriate either to the individual, other than the author, who prepared the abstract or to the publication from which the abstract was taken. Where no credit is given, the abstract was prepared by the senior author of this bibliography. Abbreviations are used to identify the source of the abstract; where appropriate, the accession number used by the source publication for the abstract also is given. Abbreviations and examples of accession numbers are given below.

AWRA 08-0002–Water Resources Abstracts
Geophy. Abs. 266-095–Geophysical Abstracts
NAB–Abstracts of North American Geology
NSA 24-40855–Nuclear Science Abstracts
Tulsa Univ., Inf. Services Dept.–Tulsa University, Information Services Department
W68-00029–Selected Water Resources Abstracts
WSP 1990–U.S. Geological Survey Water-Supply Paper 1990

Abstracts that were obtained from sources outside the U.S. Geological Survey reflect the editorial style of the original publisher. This was done to avoid any possible misinterpretation of the original intent. In a few abstracts editorial insertions have been used to explain units of measure or uncommon abbreviations. Geologic names are used as they appeared in the original articles and thus their usage herein does not constitute acceptance by the U.S. Geological Survey.

Each abstract is concluded by a set of descriptors (key words) selected from the "Water Resources Thesaurus," which was published in 1966 by the Office of Water Resources Research, U.S. Department of the Interior. The descriptors are designed for computer storage and retrieval purposes, and are included here as an aid to the reader interested in computer retrieval of similar subjects.

The index to the bibliography consists of a "Geographic Index" and a "Subject Index." These indexes were compiled from the abstracts and not the original publications, thus they are only as complete as the information given in the abstracts. The reader is referrred to the case histories and the summary reports under the various types of wastes in the "Subject Index" as a starting point for the perusal of this volume. The reader interested in all types of waste disposal in specific areas is referred to the "Geographic Index."

The assistance of Mrs. Barbara O. Favor and the many other individuals who contributed to the preparation of this volume is gratefully acknowledged. Special thanks are due to Mr. Don Davis and Mr. John W. Norris of the Science and Technology Branch, Division of Technical Information Service, Oak Ridge National Laboratory, Oak Ridge, Tenn., for providing a computer search of the Nuclear Science Abstracts, volumes 16 through 23.

BIBLIOGRAPHY

0590 **Abbott, W. G.**
1960. Organization and operation of cooperative salt water disposal systems, *in* West Texas oil lifting short course, 7th Ann., Proc.: Lubbock, Tex., Texas Technol. Univ., Dept. Petroleum Eng., p. 103-104.

Since salt water disposal is a problem common to all the operators in an oil pool, co-operative participation in a disposal system should be practiced. In pools where large volumes of salt water are handled or reservoir conditions exist which indicate that future water volumes will be appreciable, subsurface disposal is the most satisfactory method. When such a disposal system is needed, operators will find that Articles of Agreement have previously been prepared by company attorneys and accountants. These provide for creating, putting in operation, and prescribing rules and regulations for the operation of a salt water system and are available to those who have use for them. Three requirements necessary when designing a system are: (1) define the area, (2) define a producing well, and (3) define the quantity of water to assign each well. The Agreement should contain three exhibits: a map of the area, a cost estimate, and a detailed accounting procedure. Good engineering design, proper material selection, and continued experienced supervision are major requisites for a properly functioning salt water disposal system.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, injection, management, cooperatives, facilities.

0591 **Abbott, W. G.**
1962. Salt water disposal system design considerations, *in* West Texas oil lifting short course, 9th Ann., Proc.: Lubbock, Tex., Texas Technol. Univ., Dept. Petroleum Eng., p. 183-184.

A salt water system should be designed to serve all the wells in the subject area until the last producing well is plugged. In designing the gathering system, it is necessary to assign a given quantity of water to each well. Bottomhole pressure history, potential tests, and productivity indices should be examined to select the proper design figure so that the line sizes can be determined. A gravity system is the most economical way to move the water. By installing gas boots at every pressure vessel that discharges water into the system, gas blockage problems can be eliminated. All materials used, including valves, fittings, and vessels, should be corrosion resistant. An accumulation tank or tanks should be located adjacent to the disposal well, and the tanks should be sized to provide adequate settling time for suspended solids, and to handle any fluctuations in water production. Other discussions are presented on disposal wells and maintenance of salt water disposal systems.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, injection, design criteria, operation and maintenance, cooperatives, facilities.

0592 **Abbott, W. G.**
1963. Salt water disposal system–design, construction, and operation, *in* West Texas oil lifting short course, 10th Ann., Proc.: Lubbock, Tex., Texas Technol. Univ., Dept. Petroleum Eng., p. 17-18.

Usually the design and even the organization of a disposal system falls upon the district, area, or field engineer. As soon as the first well in a field is completed, the engineer should recognize the type of reservoir and alert his management to the future possibilities for subsurface disposal, if this is warranted. Usually, however, even the most prudent oil operator waits until substantial amounts of water are produced before the organization of a system is attempted. The disposal well should be drilled or recompleted before the construction of the lines is started. An accurate injection test or tests, either by gravity or pressure, should be performed on the disposal well at this time. After the installation of a salt water disposal system, the operational phase begins. Lines should be inspected for scale and paraffin deposition and gas vents should be cleaned regularly. Terminal facilities should be checked, sometimes daily, to determine the volume of waste oil that accumulates; and the storage tank or tanks should be cleaned of any solids, B.S. or iron sulfide deposits accumulated. For economic operation throughout the life of an oil field, the salt water disposal system must be carefully designed, properly constructed, and maintained by experienced supervision.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, injection, design criteria, construction, operation and maintenance, cooperatives.

0597 **Abbott, W. G.**
1966. The operation of salt water disposal systems, *in* Southwestern petroleum short course, 13th Ann., Proc.: Lubbock, Tex., Texas Technol. Univ., Dept. Petroleum Eng., p. 141-143.

Rice Engineering and Operating, Inc. has designed and now operates 9 cooperative salt water disposal systems in the W. Texas and New Mexico area. These systems handle produced brine from 2,900 wells through about 260 miles of gathering line into 20 disposal wells. The volume of water disposed daily into these wells is over 100,000 bbl. It is necessary to inject this water by pressure pumps in only 3 of these 20 wells. The remaining 17 wells take water by gravity flow with a vacuum showing on the tubing gage under usual operating conditions. The cost per well for disposal averages approximately $1,700 for these 9 systems. This includes all costs such as construction of gathering lines, the drilling or workover of disposal wells, the purchase of necessary right-of-way, and all engineering fees. The disposal wells discussed herein range in total depth from 4,753 to 13,837 ft and are all completed in a limestone or dolomite formation. All of the disposal wells are equipped with injection tubing that has been internally plastic coated. To protect the exterior of the tubing and the interior of the casing from corrosion an "oil-balance" method is used.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, injection, cooperative, operation and maintenance, design criteria, New Mexico, Texas, costs.

0456 **Adams, J. R.**
1967. Dispersion in anisotropic porous media: Ann Arbor, Mich., Michigan State Univ. Ph.D. thesis, 100 p. [Abs. *in* Dissert. Abs., 1967, v. 28, no. 1, p. 190-B–191-B.]

The problem of dispersion in flow through porous media arises in coastal aquifers, underground waste disposal, chemical separation by filtration, and secondary recovery of petroleum. This study is motivated by the coastal aquifer problem in which the spread or dispersion of salt water into fresh water may limit the use of wells for drinking water. The dispersion process is described by the convective-diffusion equation with a coefficient depending on the flow and porous medium, as well as on the solvent and solute. The nature and functional form of the coefficient is the topic of direct interest. Experiments are conducted in which the dispersion of tracer spots is measured during flow in porous beds packed with nylon filaments. The filaments are kept parallel to make the bed anisotropic. Two filament sizes and 2 orientations are used. The experimental results are in reasonable agreement with previous experiments in isotropic media, but are not compatible with the existing theory.–Tulsa Univ., Inf. Services Dept.

Descriptors: Dispersion, porous media, anisotropy, diffusion, laboratory tests, flow characteristics.

0034 **Adinoff, A. M.**
1955. Disposal of organic chemical wastes to underground formations, *in* Industrial Waste Conference, 9th, Lafayette, Ind., 1954, Proc.: Purdue Univ. Eng. Ext. Ser. 87 (Purdue Univ. Eng. Bull., v. 39, no. 2), p. 32-38.

Deleterious wastes from the manufacture of chloromycetin at the Parke, Davis & Co. plant in Holland, Mich. are being injected through a deep well into the porous, brine-saturated Traverse limestone that underlies the plant site at a depth of 1,400 feet. The injection-well method was selected because of the low quantity of wastes involved and the inadequacy or high cost of other waste-treatment alternatives. In designing the well system, consideration was given to the compatibility of the wastes with limestone and brine and to the prevention of corrosion of the waste-handling equipment, in view of the known acidic nature of the wastes and the known presence of acetic bromide and chloride ions in the wastes. The static brine level in the completed well was only about 169 feet below grade, and the brine itself was found to have a strong sulfur odor and a specific capacity of 1.23. As a result, pumping pressures ranging from 110 to 150 psi are required to operate the injection well. The system has proven to be a very successful solution to the waste problem because very few maintenance or operational difficulties have been encountered and there seems to be little danger in contaminating potable underground water supplies. The injection well system is practical for a chemical plant where the volume of wastes is not excessive, the underground formations are of the proper nature, the chances of contamination are negligible, and where other treatment methods are either inadequate or unfeasible.

Descriptors: Waste water disposal, Michigan, chemical wastes, injection wells, limestones, geologic formations.

Albrecht, E. *See* Krause, H. 0832.

0035 **Alciatore, A. F.; Harris, M. B.; Wallin, W. E.**
1955. Diatomaceous earth filtration of water for subsurface injection: Petroleum Engineer, v. 27, no. 5, p. B57-B58, B60, B62.

Pressure filtration of water for subsurface injection utilizing diatomaceous earth (diatomite) filter aids is a process of considerable merit and increasing interest. This type of filtration, long established in general industrial production, is a primary means of clarifying such products as sugar liquors, syrups, antibiotics, other pharmaceuticals, beer, heavy chemicals, oils of all kinds, and many others. The system of filtering injection waters with diatomite has several advantageous features. First, it offers a means of obtaining as high a degree of clarity as may be desired. Second, the filter system is flexible. It can be installed in small or large units, singly or in multiples, to form a system to suit the size of the project. It offers a high ratio of filtering surface to size of filter and is, therefore, compact, so as to be easily and economically enclosed for protection from the weather. It requires less backwash water to clean than the conventional sand filter. Due to the high absorption properties of diatomite, it can handle small amounts of oil which would under the same circumstances plug a sand filter system.–*from* Authors' introduction.

Descriptors: Injection, waste water treatment, filtration, diatomaceous earth, benefits.

0036 **Alcorn, I. W.**
1943. Salt water disposal injection systems: Oil Weekly, v. 110, no. 13, p. 20.

It is claimed that the mechanical problems involved in building closed systems for collecting and filtering salt water to be disposed of underground are more complex than those involved in open systems, but the expenses of installation and maintenance are lower for the closed system, because it requires a smaller filtering capacity and few chemicals, and can be built of less expensive metals (because the salt water is less corrosive in the absence of air). The two closed water disposal systems operated by the Pure Oil Co., one in Louisiana and the other in Texas, illustrate the differences in equipment required depending on whether there is one or a number of leases and royalty ownerships. In 19 months of operation the only difficulty encountered by Pure Oil is the precipitation of iron sulfide believed to be formed by the action of *Sporovibrio desulfricans* and being combatted by periodic injection of 15% inhibited hydrochloric acid into the injection well.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, design, injection, piping systems (mechanical), facilities, Louisiana, Texas.

0038 **American Association of Petroleum Geologists.**
1964. Radioactive waste-disposal potentials in selected geologic basins–a reconnaissance study: U.S. Atomic Energy Comm. San Francisco Operations Office [Rept.] SAN-413-2, 31 p.

The advantage of deep permeable formations for the storage of large volumes of low-level wastes from a fuel reprocessing plant are pointed out. Descriptions are presented of the subsurface geology and hydrology of six basin provinces for the preliminary evaluation of their use for waste storage. The basins studied include the Appalachian, Valley-and-Ridge, Michigan, Salina, Denver, and San Juan–NSA 19-14894.

Descriptors: Radioactive waste disposal, groundwater basins, evaluation, United States, hydrogeology.

0717 **American Journal of Public Health.**
1937. Disposal of oil field brines in the Arkansas River drainage area in western Kansas: Am. Jour. Public Health, v. 27, no. 1, p. 49.

This report presents the results of a study of the oil producing fields within the Arkansas River drainage area west of Hutchinson, Kans., with reference to the disposal of oil field brines. Available information has been gathered on the present methods of disposal, their advantages and disadvantages. Details on the difficulties encountered in disposing of brines in subsurface disposal systems also have been included, which will be used as a basis for continued study. A summary of the findings in this study is given.–Tulsa Univ., Inf. Services Dept.

Descriptors: Kansas, brine disposal, injection, water pollution, data collections.

0043 **American Petroleum Institute.**
1960. Subsurface salt-water disposal: Dallas, Tex., Am. Petroleum Inst. Div. Production [Pub.], 92 p. [Book 3 of the vocational training ser.]

This manual outlines with appropriate discussions the recognized methods, systems, and practices of salt-water disposal in oil fields by subsurface injection, as prepared by a special subcommittee of the American Petroleum Institute. Prepared especially for those associated directly with design, installation, and, in particular, the operation and maintenance of disposal facilities, the manual is considered a handbook reference rather than a technical treatise. It presumes that injection into underground formations is the most positive method of handling salt water produced with crude oil except where surface discharge does not create pollution threats. Contains 23 figures, 19 references, and a glossary of terms.

Descriptors: Brine disposal, oil fields, methodology, injection wells, facilities, operation and maintenance.

0044 **American Petroleum Institute.**
1965. Recommended practice for biological analysis of subsurface injection waters: Dallas, Tex., Am. Petroleum Inst. Div. Production R. P. 38, 2d ed., 7 p.

An API study committee has set up standards of tests for determination of the effectiveness of chemicals for treating injection waters to control microorganism growth and to develop procedures for the biological analysis of injection waters. A standard procedures outline is presented which will allow comparison of data from various water-flood operations. Sampling methods and microscopic examination of water samples are described, an evaluation of chemicals for control of microbial growth is made, and an appendix is given explaining special apparatus and alternative techniques for estimating microbial population and sulfate-reducing bacteria.

Descriptors: Brine disposal, injection wells, microorganisms, analytical techniques, oil fields, waste water treatment.

0046 **American Water Works Association.**
1953. Findings and recommendations on underground waste disposal: Am. Water Works Assoc. Jour., v. 45, no. 12, p. 1295-1297.

This paper itemizes the findings, conclusions and recommendations of a task group that was organized to study and assess the effects of industrial waste disposal in or on the ground upon ground-water supplies. The findings indicate that underground disposal of wastes is becoming more attractive to many industries and is nationwide in distribution. As a result, ground-water supplies are threatened in many parts of the Nation. In order to protect this important resource from irrevocable damage, statutory control measures are recommended wherein a State agency would be authorized to issue and enforce orders to stop or restrict waste disposal into or on the ground.

Descriptors: Waste disposal, groundwater, water pollution control, legislation.

0047 **American Water Works Association.**
1957. Underground waste disposal and control: Am. Water Works Assoc. Jour., v. 49, no. 10, p. 1334-1342.

Underground pollution is a national problem and many states have a wide range of contamination problems. But, it is further evident that the factors which determine pollution potentials and the proper degree of concern are so variable that area

comparisons on a national scale are unjust. It would be difficult, if not impossible, to apply a standardized set of waste disposal principles to the wide range of geologic, hydrologic, economic, industrial, and population variables which occur throughout the United States. Because of these variables, a great degree of intimacy with the area being studied is required for an accurate cause-and-effect study of waste disposal practices.–Author's summary.

Descriptors: Waste disposal, United States, groundwater, water pollution control, regulation.

0048 **American Water Works Association.**
1960. Underground waste disposal and ground-water contamination: Am. Water Works Assoc. Jour., v. 52, no. 5, p. 619-622.

Industries and legislative bodies are becoming more aware of the problems concerned with liquid-waste disposal and ground-water contamination. Many problems are being eliminated, but new ones are developing. Much work must be accomplished and constant precautions taken to insure the continued satisfactory conditions developed by present facilities. Standards should be developed for guides in evaluating disposal techniques and detecting unsatisfactory disposal practices. The increasing complexity of liquid wastes may require that standards be made flexible in order that they may be adapted to changing conditions.–Author's conclusions.

Descriptors: Water pollution, waste disposal, United States, groundwater, legislation.

0481 **American Water Works Association.**
1952. Control of underground waste disposal: Am. Water Works Assoc. Jour., v. 44, no. 8, p. 685-689.

The pollution of ground waters by waste disposal is a serious problem in Michigan. It is as widespread, either presently or potentially, as the use of ground water for private or public supply. Oil and gas field brine disposal is under satisfactory control. Probably future attention should be directed primarily toward prevention of pollution by wastes from small industries. From information the task group has received from other states, it seems evident that the problem is of rather wide distribution, but that it varies considerably in severity from region to region. Much more data will have to be assembled, however, before the task group's assignment can be completed. Information on occurrences of ground-water pollution will be welcomed from any source by the task group, which is faced with a difficult job in approaching a rather new field.–Author's summary.

Descriptors: Michigan, waste disposal, groundwater, industrial wastes, water pollution control.

0611 **Ames, L. L., Jr.; Hajek, B. F.**
1966. Statistical analysis of cesium and strontium sorption on soils: Richland, Wash., Battelle Memorial Inst. Pacific Northwest Lab. [Rept.] BNWL-CC-539, 11 p. [Available from CFSTI.]

A statistical design to study removal of radioisotopes by a soil was tested. A simple two-level factorial utilizing $NaNO_3$, KNO_3, HNO_3 and $Ca(NO_3)_2$ as independent variables yielded satisfactory cesium and strontium removal results. A regression equation was used to predict cesium and strontium removal results, given the level of independent variables. The results indicate that statistical treatment and prediction of radioisotope removal by soils is feasible.–Authors' abstract, NSA 21-34331.

Descriptors: Regression analysis, radioisotopes, sorption, soils.

Ames, L. L., Jr. *See* Nelson, J. L. 0533.

0851 **Amramy, A.**
1964. Waste treatment for groundwater recharge: Water Pollution Control Federation Jour., v. 36, no. 3, pt. 1, p. 296-298.

Wastewater reclamation by way of groundwater recharge has been inadvertently carried out for years, chiefly through seepage pits. Planned projects, however, have only recently been attempted, notably in California. In such projects, the wastewater is recharged either through injection wells, or by applying it on spreading areas at ground level. In connection with a project to reclaim the wastewater produced in the Tel Aviv metropolitan area, some of the main points investigated were (1) the infiltration capacity of the dune-sand surface; (2) the rate and mechanism of clogging; (3) rate of accumulation of organic matter along the soil profile; (4) influence of ferrous-sulfide formation on the percolation rate; (5) effect of liquid depth on the infiltration rate; and (6) the effect of intermittent liquid application on the unclogging mechanism. On the basis of the research carried out to date, to be supplemented by studies now underway, it is concluded that, for the Tel Aviv conditions, biological treatment is not necessary in order to produce an effluent suitable for groundwater recharge by spreading.—Tulsa Univ., Inf. Services Dept.

Descriptors: Waste water treatment, reclamation, injection wells, foreign countries, water reuse.

0049 **Anderson, John R.; Dornbush, James N.**
1968. Investigation of the influence of waste disposal practices on ground water qualities: South Dakota State Univ. Water Resources Inst. Tech. Completion Rept., 41 p. [U.S. Dept. Interior, Office Water Resources Research Proj. A-003-S. Dak.]

An evaluation of the effects of its landfill on the groundwater quality was initiated by the city of Brookings, S. Dak. in 1960, and incorporated in a comprehensive study by this project in 1964. The initial phase of the project concluded that the most useful parameters for detecting contamination were chlorides, sodium and specific conductance, with the next phase concluding that seasonal rainfall intensified leaching. Increased ionic concentrations during rainy periods implied that effects of leaching overrode those attributed to dilution. It appeared that as the water moved downstream from the landfill the quality improved and was suitable as a domestic water supply and for irrigational purposes before it left the landfill area. Inasmuch as it was found that a pond seemed to improve the quality of the degraded groundwater, a trench was constructed to intercept the groundwater as it moved from the fill area. It was shown that chemical constituents that were leached from the refuse were modified by the trench and water quality exhibited an improvement. The trench also modified the concentrations of organic materials and the threshold odor levels. General recommended practices were made for disposing of refuse into abandoned gravel pits located in a region of high water table.—W69-03178.

Descriptors: Waste disposal, groundwater, water quality, landfills, solid wastes, South Dakota.

0718 **Andresen, K. H.; Gardner, F. T.**
1950. The use and requirements of subsurface injection water in oil production: Oil and Gas Jour., v. 49, no. 18, p. 72-76.

Fundamental problems associated with conditioning water for subsurface injection either for water flood or disposal purposes are outlined. The various methods of subsurface water injection are described. The principle requirements of the water are

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that it remains free of suspended solids, that it forms no precipitates with the brine present in the reservoir or reacts unfavorably with components of the solid formation, and that it causes no corrosion of the mechanical equipment.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, injection, pre-treatment (water), chemical reactions.

0612 **Archambault, J.; Lemoine, J.**
1963. Conditions du stockage souterrain des residus radioactifs [Underground storage conditions for radioactive wastes], *in* La retention et la migration des ions radioactifs dans les sols–Colloque international, Saclay, France, 1962: Paris, Presses Universitaires de France, p. 21-23. [In French with English abs.]

Underground storage of radioactive wastes is discussed. Principal methods considered are: drum storage in natural or artificial cavities (mines, tunnels), fixation of liquid effluents by the soil in the active circulation area of tracts, injection in the porous layers of deep structures, injection by hydraulic fracturing of impermeable shales, and storage in solution cavities created in soluble salt formations.

Descriptors: Radioactive waste disposal, underground storage, injection, methodology.

0001 **Argonne National Laboratory.**
1961. Waste disposal: Reactor Fuel Processing, v. 4, no. 1, p. 46-54.

Soil-chemistry studies are being carried on at Hanford, Wash., in support of the disposal of low- and intermediate-level liquid wastes into the ground. It has been learned that temperature can have a significant effect on the soil sorption of radionuclides. The storing of liquid radioactive waste products in salt mines and shallow sedimentary formations has been proposed. A University of Texas study indicates that it is feasible to store reactor fuel wastes in washed-out cavities or salt domes to a depth less than 3,000 feet. The Bureau of Mines concludes that the use of shallow sedimentary formations is feasible.–Randolph, USGS.

Descriptors: Radioactive waste disposal, Washington, soil chemistry, sorption, soil temperature.

0052 **Arlin, Z. E.**
1962. Deep well disposal of uranium tailing water, *in* Morgan, J. M., Jr., Jamison, D. K., Stevenson, J. D., eds., Ground disposal of radioactive wastes conference, 2d, Atomic Energy of Canada Limited and U.S. Atomic Energy Comm. Div. Reactor Devel., Chalk River, Canada, 1961, Proc., Book 2: U.S. Atomic Energy Comm. Div. Tech. Inf. [Rept.] TID-7628, p. 356-362.

A deep-well injection system is used for the disposal of uranium mill tailing water by The Anaconda Company near Grants, New Mexico. A 2,511-foot hole was cored and tested through Triassic, Permian, and Pennsylvanian (?) sediments and bottomed in Precambrian granite gneiss. The disposal well was completed to a total depth of 1,830 feet in 563 feet of sandstones in the Yeso Formation of Permian age. No reservoir capacity was available in formations below this depth. The reservoir sandstones contain impotable water, and are isolated from overlying fresh-water aquifers by a "barrier zone" of impermeable evaporites and shales. Mill tailing water is decanted, filtered, and introduced into the well by gravity flow at injection rates up to 400 gallons per minute. The reservoir has a life expectancy of 10 years.–Author's abstract.

Descriptors: Radioactive waste disposal, New Mexico, injection wells, geohydrologic units, flow rates, geologic formations.

Arlin, Z. E. *See* Lynn, R. D. 0257.

Arlin, Z. E. *See* Lynn, R. D. 0258.

Armstrong, F. E. *See* Watkins, J. Wade. 0432.

0055 **Arnold, E. D., (editor).**
1957. Compilation and analysis of waste disposal information: U.S. Atomic Energy Comm. Oak Ridge Natl. Lab. [Rept.] CF-57-2-20 (Del.), 295 p., Mar. 13.

A summary of waste processing, treatment, and disposal information as extracted from many documents on the various aspects of the general problem is measured. The material in this report is intended to serve as background for a program proposal at ORNL covering waste processing for fission product recovery, waste treatment and handling, and ultimate disposal of high-level, intermediate-level, and low-level radioactive wastes. In addition to an introduction to the complex of problems in waste treatment and handling, a summary of various ultimate disposal schemes, and related studies, the report catalogs information papers on phases of: waste solution characteristics; economics; predictions of activity and volume buildup in a nuclear power economy; potential health hazards of fission and transmutation products; waste storage, decay, and shipment prior to ultimate disposal; fission product recovery processes and utilization; treatment and disposal of intermediate- and low-level wastes; reviews of engineering studies of problems at existing processing plant waste disposal sites; disposal of wastes in tanks; disposal of wastes in deep wells; disposal of wastes in salt-domes, underground formations, and the ocean; self-sintering at elevated temperatures as a method of ultimate disposal; and a master reference list of pertinent documents.–Author's abstract.

Descriptors: Radioactive waste disposal, waste treatment, chemical properties, economics, design criteria, United States.

0676 **Arnold, W. D.; Crouse, J. D.**
1965. Radium removal from uranium mill effluents with inorganic ion exchangers: Indus. Eng. Chemistry, Process Design and Devel., v. 4, no. 3, p. 333-337.

The concentration of ^{226}Ra in uranium mill waste solutions is normally too high to permit their direct discharge to the environment. Radium was efficiently removed from simulated lime-neutralized acid waste by adsorption on a number of inorganic ion exchange materials, including barytes, Decalso (synthetic zeolite), and clinoptilolite (natural zeolite). In column tests, radium breakthrough was not significant until many thousands of bed volumes of aqueous feed had passed through the column. Adsorption efficiency decreased with increases in exchanger mesh size and in aqueous throughput rate. However, the radium capacity of the column was not changed appreciably by a fivefold change of radium concentration in the aqueous feed. Radium adsorption from highly contaminated acid wastes was not efficient. Ammonium nitrate (2*M*) eluted radium readily from clinoptilolite but less completely from barytes and Decalso.–Authors' abstract, NSA 19-34273.

Descriptors: Radioactive wastes, waste treatment, ion exchange, adsorption.

0031 **Bachmat, Y.**
1967. On the similitude of dispersion phenomena in homogeneous and isotropic porous mediums: Water Resources Research, v. 3, no. 4, p. 1079-1083.

A procedure of simulating, by means of a physical model, the dispersion of a solute in ground water flowing through a homogeneous and isotropic aquifer is considered. Ground water is a solution of variable density and viscosity owing to variations of solute concentration. The model has a very restricted application owing to the required simultaneous invariancy of four nondimensional criteria of similitude: a macroscopic Reynolds number, a macroscopic Peclet number, the criterion of geometrical similarity of the medium, and the criterion of physiochemical similarity of the solution. However, at certain conditions, which are common in practice, some of these criteria can be waived, and the model becomes a useful device for the solution of field problems. These conditions occur in the range of validity of Darcy's law (small Reynolds numbers), at relatively high Peclet numbers, and at very small variations of relative solute concentration (ideal solute).–AWRA 08-0070.

Descriptors: Model studies, dispersion, Darcys law, groundwater, solutes, porous media.

Bachmat, Y. *See* Bear, Jacob. 0562.

0045 **Back, William; Hanshaw, Bruce B.**
1967. Hydrogeology of the northern Yucatan Peninsula, Mexico, *in* Yucatan field trip guide book (2d edition)–Geol. Soc. America, 1967 Ann. Mtg., Field Trip 7: New Orleans, La., New Orleans Geol. Soc., p. 64-78.

The Yucatan Peninsula is similar to Florida in its thick sequences of flat Tertiary limestones and abundant but shallow ground water. Due to lack of soil cover in northern Yucatan, rain infiltrates rapidly without surface drainage, and in this karst area, great sinks and caves form reservoirs. Some were sites for waste disposal or sacrifices by the ancient Mayans. In the higher, more tropical southern part, ponds perch above the water table in shallow depressions which are naturally sedimented or were lined with clay by Mayan slaves; in city centers, aqueducts and cisterns were developed. Many homes have dual dug wells, one drawn by windmill, the other for waste disposal. Chemical analyses show the resulting contamination, as well as salt-water intrusion and limestone solution effects. A safer modern system is being developed.–NAB.

Descriptors: Hydrogeology, karst, groundwater, waste disposal, sinks, foreign countries.

0040 **Baetsle, L. H.; Maes, W. F.; Souffriau, J.**
1965. Transport van radioisotopen in de bodem [Transportation of radioisotopes in the soil]: Mededelingen van de Landbouwhogeschool en de Opzoekingstations van de staat te Gent, v. 30, no. 2, p. 933-940. [In Flemish with French, English and German abs.]

Transport of radioelements in the soil is closely dependent on hydrologic and physico-chemical conditions in the soil. Study of the hydrology of the ground-water table forms the basis for calculation and evaluation of migration of radioelements in soil. Classical methods for measuring the direction and speed of ground-water flow are explained and illustrated by data obtained at this Center. By measurement of the coefficient of distribution of a radioelement under natural conditions of the medium, it is possible to obtain an indication of the relative migration of a radioactive point source in relation to the ground water. These coefficients are determined for ^{137}Cs, ^{90}Sr, and ^{144}Ce in sandy soil in which ^{144}Ce as a rare earth behaves as a colloid, ^{137}Cs is displaced from the soil at 1/50 the rate of the water molecules, and ^{90}Sr is transported by water in the soil at low pH but retarded by a factor of 2 to 3 at high pH. The dispersion coefficients express numerically the degree of dispersion of radioelements in soil materials. Two types of extension of soil contamination are discussed: that after continuous and discontinuous application of a radioactive solution. Continuous application gives a cigar-shaped dispersion zone and discontinuous application a spherical or ellipsoidal one. The use of chemical barriers, such as HF and $K_2H_2Sb_2O_7$, to block migration of radionuclides in soil around nuclear installations is discussed.–NSA 21-03181.

Descriptors: Radioisotopes, migration, porous media, dispersion, hydrodynamics, sorption.

0056 **Baetsle, L. H.; Souffriau, J.**
1967. Fundamentals of the dispersion of radionuclides in sandy aquifers (SM-83/41), *in* Isotopes in Hydrology–International Atomic Energy Agency and International Union Geodesy and Geophysics, Vienna, 1966, Symposium Proc.: Vienna, Internat. Atomic Energy Agency (STI/PUB/141), p. 617-627.

Injections of radioactive trace substances into homogeneous aquifers may be designed under well-defined conditions. If the radiotracer is not absorbed by the solid phase the pulse shape has a symmetric form that may be described mathematically by the classical diffusion equations. The magnitude of the dispersion coefficients and how they must be determined are discussed in detail. The problem of asymmetric pulse shapes occurring with slightly delayed isotopes is approached from two directions. The leading and trailing parts of the distribution curve may be considered as forming part of two different normal distributions with two dispersion coefficients. An example of this approach is worked out in detail. The asymmetric pulse-shape can be described analytically as a homogeneous concentration/distribution curve but the computation method is very complicated. Some limitations of this approach are discussed from the fundamental as well as from the computational point of view.–AWRA 08-0032.

Descriptors: Radioisotopes, tracers, diffusion, dispersion, porous media, mathematical studies.

0613 **Baetsle, L. H.; de Jonghe, P.**
1962. Investigations on the movement of radioactive substances in the ground–Part III, Practical aspects of the program and physicochemical considerations, *in* Morgan, J. M., Jr., Jamison, D. K., Stevenson, J. D., eds., Ground disposal of radioactive wastes conference, 2d, Atomic Energy of Canada Limited and U.S. Atomic Energy Comm. Div. Reactor Devel., Chalk River, Canada, 1961, Proc., Book 1: U.S. Atomic Energy Comm. Div. Tech. Inf. [Rept.] TID-7628, p. 198-210.

The physiochemical characteristics of numerous samples of soil from the Mol [Belgium] site were determined. Distribution coefficients were determined in equilibrium conditions for the radioelements Sr, Cs, and Eu in different chemical media such as demineralized water, HNO_3 tapwater, and groundwater. An attempt was made to calculate approximately the volume of active solution that may percolate through the soil layers before the radionuclides reach the groundwater. The dynamic conditions of the ion exchange phenomena and the degree of water saturation of the profile were taken into account. An insolubilization method was tested using petroleum tar as a protective agent.–NSA 16-25050.

Descriptors: Radioisotopes, ion exchange, sorption, soil investigations.

0677 **Baetsle, L. H.; Maes, W. F.**
1964. Disperse van de radio-isotopen in de bodem [Dispersion of radioisotopes in the soil] : Pedologie, v. 14, no. 2, p. 205-227. [Paper in Flemish.]

The migration of radionuclides in soils may be described by two easily determinable parameters: the distribution coefficient and the dispersion coefficient. Studies of ionic equilibria in soils have led to the formulation of the distribution coefficient (Kd:ml/g) which is directly related to the velocity of the migration of radio elements in soils. The degree of dispersion of migrating radionuclides in porous media can be expressed quantitatively by the dispersion coefficient (D:cm^2/sec), which takes into account the physical characteristics of the medium and the phenomena due to molecular diffusion. Longitudinal as well as transversal dispersion is discussed. From the undertaken investigations it appears that in isotropic porous media and at low migration velocity a moving point source transforms into a spherical cloud and into an ellipsoid when velocity rises. Injections with radionuclides in nature have confirmed the above conceptions.—Authors' abstract, NSA 22-10372.

Descriptors: Radioisotopes, migration, dispersion, porous media, diffusion.

0822 **Baetsle, L. H.; Souffriau, J.**
1967. Installation of chemical barriers in aquifers and their significance in accidental contamination (SM-93/17), *in* Disposal of radioactive wastes into the ground—International Atomic Energy Agency and European Nuclear Energy Agency, Vienna, 1967, Symposium, Proc.: Vienna, Internat. Atomic Energy Agency (STI/PUB/156), p. 229-240.

After the principles of chemical barrier formation are reviewed, the principal results of laboratory research on the system 'Silica-HF-Antimonic acid' are discussed in some detail. Field experiments have delineated the zone created by injecting reagents traced with ^{82}Br into an aquifer. The economics of barrier formation are discussed in the conclusions. Finally a description is given of the most suitable experimental procedure for the injection of the reagents HF and $K_2H_2Sb_2O_7$ into the aquifer. The retention capacity of the installed barrier for Sr is also discussed in relation to its significance for environmental safety at reprocessing plants.—Authors' abstract.

Descriptors: Radioactive waste disposal, injection, laboratory tests, chemical reactions, test procedures, barriers, economics.

Baetsle, L. H. *See* de Jonghe, P. 0636.

Baetsle, L. H. *See* Souffriau, J. 0696.

0486 **Baffa, John J.; Bartilucci, Nicholas J.**
1967. Wastewater reclamation by groundwater recharge on Long Island: Water Pollution Control Federation Jour., v. 39, no. 3, pt. 1, p. 431-445.

The stratigraphy of the Cretaceous-Quaternary beds under Long Island is reviewed and shown in diagrams. All of the communities in Nassau and Suffolk Counties draw their water from this ground-water reservoir, with a sustained water table under unsewered areas and a falling water table under sewered areas. The availability of waste-water effluents offers a means of supplementing the natural supply and preventing salt-water intrusion, important because the piezometric pressure is only a few feet above sea level. Methods of waste water renovation for various ultimate uses are described. Recharge wells are compared with recharge basins, and preliminary results on the Riverhead, N. Y., injection well research project are given.—NAB.

Descriptors: New York, hydrogeology, waste water disposal, groundwater recharge, injection wells.

Bagretsov, V. F. *See* Spitsyn, V. I. 0844.

Bagretsov, V. F. *See* Zakharov, S. I. 0848.

0030 **Bailey, George W.**
1968. Reactions of nitrogenous and phosphatic compounds with soils and geologic strata, pt. 1 *of* Role of soils and sediment in water pollution control: Federal Water Pollution Control Adm., Southeast Water Lab. [rept.], 90 p.

Literature on the reaction, nature, fate and behavior of nitrogenous and phosphatic compounds in soils and geologic strata was reviewed in relation to the use of soil and geologic strata as media for municipal and industrial disposal. Principles of soil science are discussed in terms of soil-forming processes, soil physico-chemical, mineralogical, and biological properties, and their interrelationships. The quantitative and qualitative aspects of nitrogen and phosphorus in both raw sewage and treated effluent are indicated. The mobility of inorganic and organic nitrogen in soils is discussed, as well as the reaction mechanisms by which inorganic forms can be removed from percolating solutions and fixed. The factors affecting fixation, subsequent release, and degradation are also discussed. The immobile nature of phosphorus in soils compared to nitrogen, the generally high phosphorus fixation power of soil, and factors affecting the fixation of phosphorus by soils are discussed. The fixation mechanisms for both inorganic and organic forms of phosphorus are treated in detail. A glossary of soil science terms is included.–W69-03080.

Descriptors: Soil chemical properties, soil physical properties, waste water disposal, nitrogen, phosphorus.

0614 **Baker, B. L.**
1960. Soil percolation studies, pt. 2 *of* Department of chemical engineering progress report no. 4, October 31, 1958-January 31, 1960: U.S. Atomic Energy Comm. Div. Tech. Inf. [Rept.] TID-19188, 14 p.

Seepage or percolation rates through soil samples from well drillings from the seepage basin areas in the Savannah River Plant were measured. Seepage solutions were demineralized water at pH 6 and water adjusted to pH 3 with nitric acid. Correlation of flow rates were attempted by a modification of the Poiseuille equation for laminar flow based on soil particle diameters and porosity. The correlation showed a definite pattern, but varied over the very wide limits of three orders of magnitude indicating that other effects need to be evaluated.–Author's abstract, NSA 17-36996.

Descriptors: Flow rates, soil physical properties, liquids, seepage.

0615 **Baker, B. L.**
1960. Soil percolation studies, pt. 2 *of* Department of chemical engineering progress report no. 6, February 1, 1960- September 1, 1960: U.S. Atomic Energy Comm. Div. Tech. Inf. [Rept.] TID-19186, 5 p.

The seepage of liquids through soils is studied by correlating the effects of particle diameter of the soils on flow. Particle diameters are calculated to make the data fit the Carman and Kozeny equations as modified by Ergun for flow through porous media. If the effective diameters of the particles are known for the narrow ranges of sieve sizes, then it may be possible to predict the flow through soil mixtures of all particle sizes provided the effective diameters of all ranges of sieve sizes in the soil are known. The results of the work thus far indicate that this method of approach to the problem

of predicting flow rates of liquids through soils looks very promising. It was found in the tests on the individual range of sieve sizes that there was little difference between the flow rates of neutral water and water with pH 3. This was also true of water of pH 10 through the range 40-45. With particles smaller than 40-45 mesh, flow of water at pH 10 continued to decrease indicating that complete plugging of the samples would eventually occur.—NSA 17-36994.

Descriptors: Flow rates, liquids, soil physical properties, seepage.

0059 **Baker, W. M.**
1963. Waste disposal well completion and maintenance: Indus. Water and Wastes, v. 8, no. 6, p. 43-47. [Also in Purdue Univ. Eng. Bull., v. 48, no. 3, p. 66- 73.]

Many of the practices and principles that have been developed and used in the drilling and producing of oil wells over the past years have been adapted for use in disposal wells. Among these practices are casing cementing and well stimulation. The equipment, tools and materials used in casing cementing are described. Proper planning of the cement job should include a consideration of surface equipment, mechanical aids, and the selection of the cementing slurry to best accomplish specific aims. Failure to maintain or obtain sufficient disposal rates may be due to one or more of several reasons. Proper analysis of the conditions should yield a clue as to what type stimulation treatment should be beneficial in obtaining or restoring the desired disposal rates. A broad selection of techniques is available for increasing disposal rates.—Tulsa Univ., Inf. Services Dept.

Descriptors: Injection wells, construction, grouting, maintenance, technology.

Baltz, E. H. *See* Clebsch, Alfred, Jr. 0101.

Balukova, V. D. *See* Spitsyn, V. I. 0843.

Balukova, V. D. *See* Spitsyn, V. I. 0844.

0057 **Banks, H. O.**
1952. Utilization of underground storage reservoirs: Am. Soc. Civil Engineers Proc., v. 78, separate no. 114, p. 1-15.

Planned utilization and operation of underground storage offers the most economic means of conservation of waste waters in many areas. In Ventura County [Calif.] many millions of dollars can be saved by such utilization combined with regulatory surface storage, as compared to use of surface storage only. For sewage reclamation, underground reservoirs must be used for dilution and storage in most instances. Utilization of underground storage is by no means a simple matter, and thorough hydrologic investigation is necessary.—Author's abstract.

Descriptors: Underground storage, water reuse, conservation, waste water treatment.

0617 **Barbreau, A.**
1963. Depositif pour l'etude de la retention des radioisotopes par les rockes meubles, en fonction de la permeabilite [Device designed to study radioisotope retention by soft earth material, according to the permeability], *in* La retention et la migration des ions radioactifs dans les sols—Colloque international, Saclay, France, 1962: Paris, Presses Universitaires de France, p. 117-121. [In French with English abs.]

A device designed for performing preliminary permeability measurements on samples of soft-earth materials, such as sand, is described. The sand is then examined for its ability to retain radioisotopes. The apparatus involves a Plexiglas cylinder, in which the sample is placed, and a permeability meter. The two pieces are connected. After the permeability is measured and the retention capacity is examined, the sample is removed, divided into sections, and autoradiographed.–*from* Author's abstract.

Descriptors: Sorption, radioisotopes, earth materials, laboratory equipment.

0823 **Barbreau, A.; Escalier des Orres, P.**
1967. Stockage de dechets radioactifs dans des cavites formees dans le sel par dissolution–Etudes prealables (SM-93/36) [Radioactive waste storage in cavities formed by dissolution in salt–Preliminary studies], *in* Disposal of radioactive wastes into the ground–International Atomic Energy Agency and European Nuclear Energy Agency, Vienna, 1967, Symposium, Proc.: Vienna, Internat. Atomic Energy Agency (STI/PUB/156), p. 495-508. [In French with English abs.]

The possibilities of storing radioactive waste in cavities formed by dissolution in salt deposits are described. This method is particularly attractive because of the characteristics of rock salt and the degree of safety offered. The geological and technological conditions and the safety criteria are described. The salt deposit must be thick enough to enable a cavity to be formed, but if thick deposits are not available, diapiric structures would seem to be most suitable. The method of forming cavities by dissolution, their optimum shape and size, and the problems posed by salt dissolution are discussed showing that the content of insolubles must be relatively low. The cavity should possess good stability, and for this purpose should preferably be conical in form. In order to ensure safe storage, it is necessary to choose a formation with adequate overburden and permanent isolation from ground water outside the salt mass. The areas of metropolitan France suitable for such storage are being surveyed.–Authors' abstract.

Descriptors: Radioactive wastes, waste storage, salts, feasibility studies, design criteria.

0824 **Barbreau, A.**
1967. Possibilites d'injecter des dechets radioactifs dans des formations geologiques permeables profondes (SM-93/44) [Possibilities of injecting radioactive waste into deep, permeable geological formations], *in* Disposal of radioactive wastes into the ground–International Atomic Energy Agency and European Nuclear Energy Agency, Vienna, 1967, Symposium, Proc.: Vienna, Internat. Atomic Energy Agency (STI/PUB/156), p. 607- 620. [In French with English abs.]

The injection of radioactive effluents into deep, permeable geological formations can be a very satisfactory method of disposing of certain wastes, particularly as experience in using this method in the petroleum industry and with other industrial wastes is already available. The author discusses the different factors involved in the economic and safe injection of waste, with particular reference to injection techniques and the conditions of containment of effluents. The latter depend on the nature and structure of the soil and the hydrodynamic characteristics of deep water bodies. The possibility of entraining effluents in certain structures is considered. The slowness of circulation of certain deep water bodies is an important safety factor. Because of the size of the strata which can be used as a reservoir, it may be possible to inject large quantities of waste. The author points out that it will be necessary to carry out further research on a number of insufficiently explored aspects of the problem. In France the geological structures which may prove suitable for this type of waste storage are being surveyed.–Author's abstract.

Descriptors: Radioactive waste disposal, injection, geohydrologic units, hydrodynamics, feasibility studies.

0060 **Bardwell, George E.**
1966. Some statistical features of the relationship between Rocky Mountain Arsenal waste disposal and frequency of earthquakes: Mtn. Geologist, v. 3, no. 1, p. 37-42.

Some aspects of the statistical problem of relating frequency of earthquakes in the Denver area [Colorado] to injection of waste water by the Rocky Mountain Arsenal are discussed. Behavior of cumulative time series for earthquake frequency and volume of water are analyzed. A regression-correlation analysis leads to an exponential model approximating the relationship between these two variables. Also considered are statistical tests of the differences in mean number of earthquakes per month for three periods of waste injection.—Author's abstract, NAB.

Descriptors: Earthquakes, injection wells, waste water disposal, regression analysis, Colorado.

0062 **Barraclough, J. T.**
1966. Waste injection into a deep limestone in northwestern Florida: Ground Water, v. 4, no. 1, p. 22-24.

During a 3-month trial period, 70 million gallons of industrial wastes were successfully injected at moderate pressures into a deep limestone in the westernmost part of Florida. The movement of these wastes is expected to be predominantly southward toward the natural discharge area which is presumed to be far out in the Gulf of Mexico. The limestone lies between two thick beds of clay (aquicludes) and contains 13,000 parts per million salty water. A series of aquifers and aquicludes appear capable of preventing contamination of the overlying fresh-water aquifers.—Author's abstract.

Descriptors: Industrial wastes, injection, Florida, limestones, deep wells.

0618 **Barraclough, J. T.; Teasdale, W. E.; Robertson, J. B.; Jensen, R. G.**
1967. Hydrology of the National Reactor Testing Station, Idaho, 1966: U.S. Geol. Survey open-file rept. (IDO-22049), 95 p. [Also AEC Rept. TID-4500; available from CFSTI.]

The hydrologic effects of disposal of radioactive waste to the ground at the National Reactor Testing Station were studied. Tritium is the primary radioactive waste product discharged to the subsurface at the TRA (Test Reactor Area) and the ICPP (Idaho Chemical Processing Plant) areas. The distribution of waste tritium in the Snake Plain aquifer was mapped, and background levels were determined to range from 0.05 to 0.1 pCi/ml (picocuries per milliliter). Waste tritium in water from the Snake Plain aquifer was detected 4½ miles south of the ICPP. Dissolved Cr was used to trace TRA pond waste water in perched ground-water bodies and downgradient 2½ miles in the Snake Plain aquifer. Concentrations of hexavalent Cr ranged as high as 1.7 ppm in the perched water and 0.4 ppm in the water from the Snake Plain aquifer. Chromium serves as a good tracer of TRA wastes because it does not occur in nearby ICPP wastes, is not usually present in natural waters, and can be determined in very low concentrations. Natural fluoride in the water of the Snake Plain aquifer was used to trace the ground-water flow downgradient from the northeast end of the Snake River Plain. The fluoride, which is dissolved from certain rocks, indicates recharge areas and flow paths in the aquifer. Studies made on several wells which had vertically flowing borehole water indicated that the physical and chemical properties of the water are influenced by the flow. One well with downward flow had a head difference of 0.01 to 0.07 foot between two permeable zones throughout the year.—*from* Authors' abstract, NSA 22-02192.

Descriptors: Radioactive waste disposal, tritium, tracers, groundwater movement, Idaho.

Barraclough, J. T. *See* Morris, D. A. 0282.

Bartilucci, Nicholas J. *See* Baffa, John J. 0486.

Battle, J. L. *See* Jessen, F. W. 0508

0063 **Batz, M. E.**
1964. Deep well disposal of nylon waste water: Chem. Eng. Prog., v. 60, no. 10, p. 85-88.

Subsurface disposal of waste appears to date to be an extremely efficient method for disposal of concentrated waste. The capital and operational costs are approximately one-tenth that of the conventional bio-oxidation system; there are no refractory or low-level BOD wastes discharged to the river; there is no sludge disposal problem, as compared with conventional bio-oxidation systems. Short range experience shows that nylon waste, without surface treatment, can be injected into the lower Floridan limestone formation at low pressures and high rates. The ground-water resources study by the USGS, the design of the geological model, and the successful development of the injection system, should contribute to further improvement in the surface water resources and provide means for further industrialization of Northwest Florida by providing an inexpensive method of disposing of industrial waste. Although this method for waste disposal has limitations, it should be considered and evaluated in waste treatment planning, along with other methods of waste treatment.–Author's summary.

Descriptors: Waste water disposal, injection wells, Florida, pollution abatement, chemical wastes.

Bazhenov, Yu. M. *See* Sobolev, I. A. 0841.

0561 **Bear, Jacob; Jacobs, Martin.**
1965. On the movement of water bodies injected into aquifers: Jour. Hydrology, v. 3, no. 1, p. 35-57.

The paper deals with artificial replenishment through wells and with the movement of water bodies injected into confined aquifers. Two cases have been investigated: (1) Injection through a single well under steady flow, and (2) the movement of injected water bodies under nonsteady flow conditions. The recovery ratio of injected water to native ground water in the water pumped through the same well and the extent of mixing in the pumped water were determined.–*from* Authors' abstract, WSP 1990.

Descriptors: Injection, groundwater movement, steady flow, unsteady flow, confined water.

0562 **Bear, Jacob; Bachmat, Y.**
1967. A generalized theory on hydrodynamic dispersion in porous media [with French abs.]: Internat. Assoc. Sci. Hydrology Pub. 72, p. 7-16.

The phenomenon of hydrodynamic dispersion occurs in problems of underground mixing of waters of different quality. In these problems, any identifiable solute may serve as a tracer whose concentration distribution indicates the mixing. A review is given of the microscopic and macroscopic factors of the medium and the liquid, which affect the mixing phenomenon. The paper presents a generalized macroscopic

dispersion theory based on the hydrodynamics of the microflow through a porous medium model and on statistical averaging procedures. The macroscopic parameters appearing in the averaged transport equations and their interrelations are analyzed. The problem of determining the tracer concentration distribution, under field conditions encountered in the practice, is stated mathematically in the form of a set of equations and boundary and initial conditions.—Authors' abstract, WSP 1990.

Descriptors: Hydrodynamics, dispersion, groundwater, tracers, equations.

0595 **Bear, Jacob.**
1961. On the tensor form of dispersion in porous media: Jour. Geophys. Research, v. 66, no. 4., p. 1185-1197.

The variance of the bivariate normal distribution, which approximately defines the concentration distribution resulting from a tracer point injection into a uniform field of flow in a porous medium, is a second-rank tensor. When a point injection is subjected to a sequence of uniform movements in various directions, the final concentration distribution can be obtained by a summation of the tensors corresponding to the various movements. The concentration distribution across a transition zone, which develops when an abrupt interface between two miscible fluids is subjected to a sequence of uniform movements, can be determined by integrating the result for a single point injection over the entire tracer region. The property of isotropic porous media to disperse a tracer fluid is defined by the constant of dispersion which is shown to be a fourth-rank tensor. If the displacement is defined as a second-rank tensor, the variance of the distribution is obtained by the product of twice the constant of dispersion and this displacement tensor.—Author's abstract.

Descriptors: Injection, dispersion, porous media, mathematical studies, theoretical analysis.

0596 **Bear, Jacob.**
1961. Some experiments in dispersion: Jour. Geophys. Research, v. 66, no. 8, p. 2455-2467.

The aim of the experiments was to study the tracer distribution caused by dispersion in one- and two-dimensional fields of flow and to compare the experimental results with the theoretical formulas developed previously by the author. Two models were employed: a one-dimensional sand column and a two-dimensional Christiansen filter. It has been experimentally verified that the growth of the transition zone which develops when an initially abrupt interface is displaced from its original position depends upon the path of the mean point and is independent of the flow velocity. The variance which was used to define the tracer concentration distribution was shown to be directly proportional to the total distance traveled by the mean point of the distribution. The constant of dispersion of the porous medium was determined experimentally. The effect of the lateral constant of dispersion for cases where the interface makes an angle with the direction of the uniform flow was demonstrated. Experimental results agree with theory.—Author's abstract.

Descriptors: Hydrodynamics, dispersion, porous media, test procedures.

Bear, Jacob. *See* Harpaz, Y. 0573.

Beardon, P. *See* Talbot, J. S. 0389.

Beasley, R. P. *See* Curry, R. B. 0572.

Beeson, Carrol M. *See* Johnson, Norris. 0219.

0066 **Beikman, H. M.**
1962. Geology of the Powder River basin, Wyoming and Montana, with reference to subsurface disposal of radioactive wastes: U.S. Geol. Survey Trace Elements Inv. Rept. TEI-823, 85 p.

Permeable sandstone beds that may be possible reservoirs for storage of radioactive waste are present throughout the Powder River basin. These include sandstone beds in the Flathead Sandstone and equivalent strata in the Deadwood Formation, the Tensleep Sandstone and equivalent strata in the Minnelusa Formation, and the Sundance Formation in rocks of pre-Cretaceous age. However, most of the possible sandstone reservoirs are in rocks of Cretaceous age and include sandstone beds in the Fall River, Lakota, Newcastle, Frontier, Cody, and Mesaverde Formations. Problems of containment of waste such as clogging of pore space and chemical incompatibility would have to be solved before a particular sandstone unit could be selected for waste disposal. Several thick sequences of impermeable shale such as those in the Skull Creek, Mowry, Frontier, Belle Fourche, Cody, Lewis, and Pierre Formations, occur in rocks of Cretaceous age in the basin. Limited storage space for liquid waste might be developed in impermeable shale by fracturing the shale, and space for calcined or fused waste could be developed by mining cavities.—Author's abstract, NSA 17-03155.

Descriptors: Wyoming, radioactive waste disposal, geologic formations, Montana.

0678 **Belitskii, A. S.; Orlova, E. I.**
1968. Okhrana podzemnykh vod ot radioaktivnykh zagryaznenii [Protection of ground waters from radioactive contamination]: Moscow, Izdatel'stvo Meditsina, 208 p.

The protection of ground waters from radioactive contamination is discussed. Possible methods of radioactive contamination of water-bearing formations and the principal factors which determine the movement of radioactive materials in ground waters are considered. Undesirable consequences caused by the contamination of ground waters can be eliminated if the necessary conditions are observed in the disposal of radioactive wastes. It is necessary to take these conditions into account in order to estimate the migration of radioactive materials in ground waters. Published data on hydrodynamic concepts, chromatographic studies, and data obtained by the authors provide methods for the preliminary determination and evaluation of the migration of radioactive materials in contaminated ground waters. However, the requirements for the protection of ground waters from radioactive contamination cannot be based on the results of approximate calculations. More precise data are presented for the estimation of ground-water contamination. The work was done to assist sanitation specialists, hydrogeologists, engineers, and various other specialists working in the field of ground-water protection. An extensive bibliography is included.—Translation of Authors' abstract, NSA 23-35324.

Descriptors: Radioactive waste disposal, water pollution, groundwater movement, migration, hydrodynamics.

0679 **Belot, Y.; Gailledreau, C.**
1962. Effect of column length on the Sr-90 removal by a calcite-phosphate column, *in* Morgan, J. M., Jr., Jamison, D. K., Stevenson, J. D., eds., Ground disposal of radio-

active wastes conference, 2d, Atomic Energy of Canada Limited and U.S. Atomic Energy Comm. Div. Reactor Devel., Chalk River, Canada, 1961, Proc., Book 1: U.S. Atomic Energy Comm. Div. Tech. Inf. [Rept.] TID-7628, p. 211-213.

Results are reported from studies on the effect of column length on Sr^{90} removal from solutions by a calcite-phosphate column. Reaction mechanisms are discussed.–NSA 16-25051.

Descriptors: Laboratory tests, chemical reactions, strontium radioisotopes, sorption.

Belot, Y. *See* Caron, C. 0633.

0487 **Belter, W. G.**
1963. Ground disposal–Its role in the U.S. radioactive waste management operations [with French abs.], *in* La retention et la migration des ions radioactifs dans les sols–Colloque international, Saclay, France, 1962: Paris, Presses Universitaires de France, p. 3-10.

Ground disposal in the U.S. is reviewed. Some of the most important aspects of the Hanford [Wash.] operation are considered briefly, and the monitoring program required is outlined. Three types of geologic formations that may be technically feasible for the discharge of liquid radioactive wastes are recommended for investigations: salt dome or bed; deep permeable formations containing connate brine; and excavation in impermeable formations. Development work accomplished to date in this field is summarized. Basic geochemical and geophysical studies have been developed to obtain better understanding of fission products movement in the ground in order to provide a basis on which sound waste disposal practices can be established.–NSA 18-17337.

Descriptors: United States, feasibility studies, radioactive waste disposal, monitoring, Washington.

0488 **Belter, W. G.**
1963. Waste management activities in the Atomic Energy Commission: Ground Water, v. 1, no. 1, p. 17-24.

The varieties of radioactive wastes are categorized in a general way on the basis of their hazard potential to emphasize that the problem of radioactive waste management has numerous facets and is not amenable to a single, universal solution. The role of specific environments in waste disposal practices is summarized and the basic approaches ("dilute and disperse" and "concentrate and contain") to effluent control are defined. Distinction is made between basic radiation protection standards or guides, and operating or performance criteria that must be established in connection with effluent control operations in order to assure the protection of public health and safety. Examples of radioactive waste disposal practice and experience in the United States for different types of wastes are described and tentative conclusions are drawn regarding the capabilities and limitations of these practices. The scope and objectives of the research and development program in this field are summarized. The status of work in major waste disposal development projects is noted. Economic factors related to handling and disposal of radioactive wastes are noted, including relation of nuclear plant location to disposal requirements. It is pointed out that, although total costs for treatment and disposal are substantial, the cost per unit of electrical energy produced is a rather small percentage of the total cost per unit of energy.–*from* Author's abstract, NAB.

Descriptors: Radioactive waste disposal, United States, research and development, legal aspects, economics.

0619 **Belter, W. G.**
1962. New developments in the USAEC ground disposal program 1959-1961, *in* Morgan, J. M., Jr., Jamison, D. K., Stevenson, J. D., eds., Ground disposal of radioactive wastes conference, 2d, Atomic Energy of Canada Limited and U.S. Atomic Energy Comm. Div. Reactor Devel., Chalk River, Canada, 1961, Proc.; Book 1: U.S. Atomic Energy Comm. Div. Tech. Inf. [Rept.] TID-7628, p. 12-16.

Investigations were made of the possibility of ground waste disposal in salt domes or beds, deep permeable formations, and excavations in impermeable formations. Preliminary results are reported from geochemical and geophysical studies.– NSA 16-25040.

Descriptors: Radioactive waste disposal, geochemistry, geophysics, geohydrologic units, underground storage, United States.

0620 **Bennett, Edwin Rupert.**
1967. Diffusional and convective transport of miscible fluids in granular media: Berkeley, Calif., California Univ., 185 p. [Thesis.]

The problem of disposal of radioactive gaseous wastes is approached on the basis of ground injection. The character of gaseous wastes from nuclear power reactors under different conditions is reviewed, as well as the gas cleaning and disposal techniques in present use. Four concepts of ground injection disposal are discussed and evaluated in relation to geologic conditions of the reactor site and character of the waste discharge to be handled. The experimental studies deal specifically with mass transport of miscible fluids in homogeneous, isotropic, nonsorbing, granular media. A one-dimensional flow regime is used to investigate the interrelationship of longitudinal molecular diffusion and convective dispersion in the mass transport of gases through selected granular media and to relate those properties to the physical characteristics of the media. The results of the laboratory studies are used as a basis for describing the movement of injected waste gases through unsaturated earth media above the ground water table.–Author's abstract, NSA 22-27914.

Descriptors: Radioactive waste disposal, gases, injection, diffusion, dispersion, porous media.

Bennett, R. R. *See* da Costa, J. A. 0109.

Bensen, D. W. *See* Nelson, J. L. 0521.

Bensen, D. W. *See* Nelson, J. L. 0671.

0621 **Beranek, J.; Roberts, I. C.**
1962. An international programme of ground disposal research and development [with French abs.], *in* La retention et migration des ions radioactifs dans les sols– Colloque international, Saclay, France, 1962: Paris, Presses Universitaires de France, p. 17-20.

Ground disposal is discussed in relation to an international program for encouraging the development and utilization of nuclear energy. Emphasis is given to discussion of: direct support of needed research and development work; co-ordination of national research and development programs; dissemination of information; technical as-

sistance requirements of developing countries; and preparation of manuals of suggested practice by panels of experts.–NSA 18-17339.

Descriptors: Radioactive waste disposal, underground, foreign research, coordination programs.

Beranek, J. *See* Honstead, J. F. 0849.

0002 **Bergstrom, Robert E.**
1968. Feasibility of subsurface disposal of industrial wastes in Illinois: Illinois Geol. Survey Circ. 426, 18 p.

The factors bearing on feasibility and legality of industrial waste disposal wells are described, with main emphasis on geologic conditions and natural resources. The geologic conditions range from favorable for deep-well disposal in the Illinois basin, where the section is thick, many aquifers are confined, and deep groundwaters are highly mineralized, to unfavorable or questionable in the north where the section is thin and mainly permeable. Groundwater is fresh to great depth in the north and the deep aquifers are heavily pumped. The most promising disposal reservoirs in the south are the Ordovician St. Peter Sandstone and the Cambrian Ironton-Galesville and Mt. Simon Sandstones. These are important aquifers in the north. Other possible disposal zones include Pennsylvanian and Mississippian sandstones, Devonian and Silurian limestones, and Ordovician and Cambrian dolomites. Of the 3 disposal wells in the State, one is in the Mt. Simon Sandstone, one in a Devonian limestone, and one in a Cambrian dolomite.–W68-00530.

Descriptors: Waste water disposal, injection wells, Illinois, industrial wastes, groundwater basins, regulation, technical feasibility.

0003 **Bergstrom, Robert E.**
1968. Feasibility criteria for subsurface waste disposal in Illinois: Ground Water, v. 6, no. 5, p. 5-9.

The criteria for feasibility of waste disposal by injection wells in Illinois and the suitability of various geologic formations for disposal are reviewed. Favorable geohydrologic conditions–specifically the presence of a variety of permeable formations that contain nonpotable water and are well confined from shallow to great depth–make waste disposal by wells feasible in much of the southern two-thirds of Illinois. Natural safeguards permit disposal wells to be planned with conventional engineering precautions and only a minimal program of preoperational testing. In much of the northern third of the State, the permeable rocks contain potable water to great depth, and there is moderate to high development of the groundwater resource because of urban and industrial concentration. Exhaustive testing, substantial proof of acceptable site conditions, and incorporation of optimum engineering safeguards are considered necessary before the State regulatory agency can authorize installation.–W69-03251.

Descriptors: Injection wells, waste disposal, Illinois, technical feasibility, geohydrologic units.

0068 **Bernard, G. C.**
1955. Effect of reactions between interstitial and injected waters on permeability of rocks: Producers Monthly, v. 20, no. 2, p. 26-32.

Various waters were injected into Berea sandstone which were incompatible with the interstitial waters that had been used to saturate the sandstone. In no case was a

change in permeability of the rock observed. It is concluded that there is no danger of plugging a rock by injecting into it a water which is incompatible with the interstitial waters in the rocks.—Author's abstract, WSP 1990.

Descriptors: Injection, connate water, water chemistry, permeability.

Bhaskaran, T. R. *See* Subrahmanyan, K. 0388.

Bierschenk, W. H. *See* Raymond, J. R. 0598.

0069 **Bierschenk, William H.**
1958. Hydrological aspects of radioactive waste disposal: Am. Soc. Civil Engineers Proc. Paper 1835, Jour. Sanitary Eng. Div., v. 84, no. SA 6, 11 p.

Under natural conditions, the regional body of unconfined water at Hanford [Wash.] is perennially recharged by precipitation upon Rattlesnake Hills and Yakima Range. All natural ground-water movement is to the north and east toward the Columbia River with discharge into that stream, except at high river stage. However, the infiltration of large volumes of plant effluents has considerably altered the natural conditions. Thus the formation of two distinct ground-water mounds has increased and locally reversed the natural hydraulic gradients and consequently has accelerated the movement of much of the ground water. A variety of hydrologic and geologic data have indicated three areas or channels of highly permeable glacio-fluviatile deposits; these also are zones of rapidly moving ground water. Determination of the location, extent, and hydraulic characteristics of such zones permits the advantageous positioning of monitoring wells by which waste disposal criteria may be validated. From these data then, it is possible to predict with reasonable accuracy the behavior of low-level radioactive wastes discharged to the ground and to regulate the disposal procedures in order to provide conservatively safe operation for the plant, its environment, and its neighboring communities. It is most significant that at no time in the history of the plant has the underground movement of radioactive fission products resulted in detectable quantities reaching points of human access or beneficial use. Obviously, waste disposal operations demand a multitude of approaches to assure safe operation; a most important one is the ability to determine empirically the behavior of at least some wastes in the zone of saturation. Experience here, while based on specific local conditions, may prove useful for guidance in safe and economical waste disposal methods at other locations.—Author's summary and conclusions.

Descriptors: Radioactive waste disposal, Washington, hydrologic aspects, groundwater movement, effects.

0070 **Bierschenk, William H.**
1959. Aquifer characteristics and ground-water movement at Hanford [Wash.]: U.S. Atomic Energy Comm. Div. Tech. Inf. [Rept.] TID-4500, 77 p.

At Hanford [Wash.] an estimated 3.8 billion gallons of intermediate-level waste containing about 2,500,000 gross beta curies have been discharged to ground since startup in 1944 through December 1958. In addition to these wastes, approximately 35 billion gallons of normally uncontaminated process cooling water has been discharged into open ponds or swamps. The semiarid climate, the permeable surficial sediments, and the deep water table combine to produce a situation wherein most of the radioactive materials in the waste are trapped by electrochemical bonds in the sediments as the waste percolates down to the water table. Those wastes that reach the water table move with the ground water toward the Columbia River, the direction and rate of movement being dependent upon the aquifer characteristics. Hydraulic studies show

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that wastes which reach the water table beneath disposal sites will potentially move in a general southeastern and westward direction some 20 miles to the Columbia River. Average rates of ground-water flow indicate that travel along this estimated mean lateral path of ground-water contamination could conceivably be completed in an average time in the order of 180 years. Such factors as heterogeneity and anisotropy of the aquifers, and dispersal of wastes in the ground water, however, assume great importance in determining the path, and ultimately, the concentration of radioactive wastes in the water.

Descriptors: Washington, aquifer characteristics, groundwater movement, flow rates, radioactive waste disposal.

0563 **Biggar, J. W.**

1962. Considerations in the use of chloride and tritium in ground-water recharge operations, *in* Schiff, Leonard, ed., Bienn. conf. on ground-water recharge, 3d, Berkeley, Calif., 1961, Proc.: Fresno, Calif., U.S. Dept. Agriculture, Soil and Water Conserv. Research Div., Southwest Br., Ground-Water Recharge Lab., 3 p.

The tracer-medium interaction results in serious error when estimating the velocity and volume of flow in the medium. Furthermore, reliable dispersion coefficients for a medium can be obtained only when the investigator considers spreading of the tracer by molecular diffusion as well as velocity dispersion and the interaction of these two processes.—Author's conclusions, WSP 1990.

Descriptors: Tracers, chlorides, tritium, groundwater recharge.

0444 **Bignell, L. G. E.**

1935. Salt water disposal wells: Oil and Gas Jour., v. 34, no. 16, p. 45-46.

The Kansas statutes now permit salt water to be returned to any formation not containing domestic water that will take it. Special wells are drilled to sand formations below the potable water supply, casing strings are cemented in above the salt water disposal sand formations, and salt water returned to these formations. Where brackish water in upper level sand formations is encountered and causes corrosion of the casing, the wells in some cases have been recased and specially prepared mud circulated behind the casing and allowed to remain there in place of cement; corrosive action has been effectively retarded. To avoid the danger of returned salt water breaking through into producing wells, some producers are drilling the disposal wells outside the producing area so that if water does move updip it will only serve to drive the oil ahead of it into the wells.—Tulsa Univ., Inf. Services Dept.

Descriptors: Kansas, brine disposal, injection wells, corrosion control.

0071 **Billings, Norman.**

1950. Ground-water pollution in Michigan: Sewage and Indus. Wastes, v. 22, p. 1596-1600, Dec.

This article considers the polluted conditions of ground waters. If certain wastes are not permitted to be put into the streams, they can be disposed of only into the ground. For some wastes this is undoubtedly preferable and even desirable. For others, however, it is very undesirable and highly dangerous. Formerly, it generally was felt that the passage of contaminated water through porous sands and gravels would purify it. However this purifying action has its limitation.—Birdsall, USGS.

Descriptors: Groundwater, water treatment, water pollution, sewage, Michigan.

0073 **Birch, Francis.**
1958. Thermal considerations in deep disposal of radioactive waste: Natl. Acad. Sci.–Natl. Research Council Pub. 588, 22 p.

The thermal problems in disposing of large quantities of radioactive waste in geologic formations is treated in terms of simplified, undoubtedly artificial models, which may, nevertheless, retain the principal features of the real situations, so long as the temperatures remain within some poorly understood limits. The results suggest that nearly any quantity of waste-producing heat at the rate of 0.01 watts per gallon, if distributed in a layer of the order of 100 meters thick, can be accommodated without undue rise of temperatures. Concentrations much above this level would raise questions exceedingly difficult to answer. It does not appear that any decisive advantage is gained by burial at excessive depths (greater than a few thousand feet, for example), provided that potable water supplies and other natural resources are adequately protected. Some real geologic formations which are potential reservoirs should be studied in detail with respect to lithology, stratigraphy, structure, proximity to cities or towns, nature of contained water, relations to potable water, etc. A major difficulty comes in deciding when and how the reservoir condition will breakdown as the content of the reservoir heats up.–*from* Author's summary.

Descriptors: Radioactive waste disposal, model studies, temperature, geologic formations, heat.

Black, H. H. *See* Klassen, C. W. 0753.

0074 **Black, W. B.**
1958. Underground waste disposal: Sewage and Indus. Waste, v. 30, no. 5, p. 669-672.

This paper deals with pumping industrial wastes through deep wells, drilled for this specific purpose, into carefully tested rock horizons far underground. An important step is to make a laboratory-compatibility test of the reaction between the waste materials and rocks similar to those known to occur deep underground, to determine whether the wastes can be safely stored in the rocks. If the results are satisfactory, one or more test wells should be drilled to obtain samples of the actual rocks for laboratory testing to find which of the rock strata are possible reservoirs and how effective the adjacent strata will be as barriers to confine the wastes in the proper place. The test well can be used for injecting harmless fluids similar in viscosity to the waste materials to determine the tightness, capacity, injection rate, and flow characteristics of the rock formations. These procedures provide an economic basis for the waste-handling system. It is encouraging to note that wastes of many types can be stored underground. For example, fracturing techniques make it possible to split open rock layers at a given point, while fluids containing considerable volumes of matter in suspension are pumped into the newly formed cavities. However, before any waste material is injected underground, a careful and thorough test of the operation should be made both in the laboratory where actual waste materials are forced through the reservoir rock samples under full pressure, and in the field wells where harmless fluids are forced into the reservoir rocks under high pressure. In truth, underground fluid injection is not a panacea for all waste disposal problems; it is only one more tool to be used by engineers when economic conditions are favorable.

Descriptors: Injection wells, waste water disposal, industrial wastes, chemical reactions, test procedures.

0075 **Blair, John V.**
1951. Treatment of produced salt water prior to underground disposal in sand formations: Oil and Gas Jour., v. 49, no. 42, p. 176-179, 181, 183, 185.

A method of disposing of salt water described from a chemical engineering viewpoint and dealing mainly with East Texas disposal systems starts with the study of the disposal formation as a filter, the type and size of the material which plugs the formation and the mechanism of the plugging. The method used in treating salt water includes aeration, sedimentation, and filtration. Reasons for aeration are summarized, together with essential phases of the process. Precipitates occurring during aeration are described primarily in relationship to their control. The problems encountered in these operations, their practical solutions and related importance of chemical laboratory work are outlined. Chemical treatment vs. mechanical cleanout with a summary of the chemical treatments commonly used in salt water disposal wells is discussed also. Specific methods of treatment are listed along with the results achieved and some of the risks involved.–Tulsa Univ., Inf. Services Dept.

Descriptors: Chemical engineering, brine disposal, injection, waste water treatment.

0622 **Blanco, R. E.; Parker, F. L.**
1963. Waste treatment and disposal quarterly progress report: U.S. Atomic Energy Comm. Oak Ridge Natl. Lab. [Rept.] ORNL-TM-482, 90 p.

Progress on waste treatment and disposal is reported. Topics covered include: high-activity-waste calcination, design of pilot plant, fixation of waste in glass, low-activity-waste treatment, engineering, economics, safety evaluation, disposal by hydraulic fracturing, disposal in natural salt formation, Clinch River study, fundamental studies of minerals, White Oak Creek basin study, and foam separation–NSA 17-17619.

Descriptors: Radioactive waste disposal, waste treatment, programs, Tennessee.

0623 **Blanco, R. E.; Cowser, K. E.**
1969. Waste treatment and disposal semiannual progress report, July-December 1967: U.S. Atomic Energy Comm. Oak Ridge Natl. Lab. [Rept.] ORNL-TM-2294, 134 p. [Available from CFSTI.]

Research progress is reported under the following headings: treatment of high-level radioactive waste; treatment of intermediate-level radioactive waste; engineering, economic, and safety evaluation; separation of noble gases from air using permselective membranes; disposal in natural salt formations; safety evaluation of waste management system; disposal by hydraulic fracturing; and fate of radionuclides in terrestrial environment.–NSA 23-13828.

Descriptors: Radioactive waste disposal, waste treatment, programs, Tennessee.

Blanco, R. E. *See* Parker, F. L. 0672.

0489 **Blomeke, J. O.; Boegly, W. J., Jr.; Bradshaw, R. L.; and others.**
1963. Disposal in natural salt formations, sec. 3 *of* Radioactive waste disposal *in* Health Physics Division annual progress report for period ending January 30, 1963: U.S. Atomic Energy Comm. Oak Ridge Natl. Lab. [Rept.] ORNL-3492, p. 19-37.

A 2-ft-high by 8-ft-wide model room was cut into a pillar to a depth of 10 ft, and closure rates were measured both before and during heating of the room to 160°C. The floor-to-ceiling closure rate after 40 days of heating (5×10^{-3} in./day) was two orders of magnitude higher than that at ambient temperature. Continued flow at this rate would completely close the room in 12 yr. Measurements of creep closure in the Hutchinson, Kansas, mine in rooms ranging in age from about 1 to 27 yr indicated that closure rates decrease with the age but increase with increased salt extraction. The floor-to-ceiling closure rates range from 8×10^{-4} to 1×10^{-4} in./day. A demonstration of disposal of high-level radioactive waste solids is being designed for the Carey Salt Company Mine in Lyons, Kans. The purposes of the demonstration are to perfect equipment and techniques and to investigate the synergistic effects of heat, radiation, and pressure on plastic flow, salt stability, and chlorine production. The demonstration consists of a seven-can array of fuel assemblies, an electrical-heat-equivalent array, and two sets of electrical heaters to heat a pillar between the two arrays. Fourteen irradiated Engineering Test Reactor fuel assemblies will provide radiation in lieu of actual solidified waste. The test will last 2 yr; then all fuel assemblies will be returned to the Idaho Chemical Processing Plant for recovery of unfissioned fuel.–*from* Authors' abstract.

Descriptors: Radioactive waste disposal, Kansas, salts, test procedures, rock properties.

Blomeke, J. O. *See* Bradshaw, R. L. 0627.

Blomeke, J. O. *See* Bradshaw, R. L. 0629.

Blomeke, J. O. *See* de Laguna, Wallace. 0116.

Blomeke, J. O. *See* Perona, J. J. 0674.

Blyth, C. R. *See* Bredehoeft, John D. 0083.

0054 **Boegly, W. J., Jr.; Bradshaw, R. L.; Empson, F. M.; and others.**
1964. Disposal in natural salt formations, *in* Health Physics Division annual progress report for period ending July 31, 1964: U.S. Atomic Energy Comm. Oak Ridge Natl. Lab. [Rept.] ORNL-3697, p. 19-31.

Renovation of the topside facilities at the Carey Salt Mine, Lyons, Kansas, is essentially complete. Drilling has started on the 19.1-in.-ID waste-charging shaft. Cleanup of the main access tunnels in the mine is in progress. Plastic flow gages are being installed along the access tunnels and near the experimental area to determine the effect of increased temperature on stability of the mine. Design and fabrication of equipment for handling and storing the radioactive fuel assemblies is essentially complete. Laboratory tests of 1000-hr duration on pillar models made from Lyons salt were run at pillar stresses ranging from 4000 to 10,000 psi. From the results of these tests, an empirical equation was derived which correlates well with measured vertical closure rates in the Lyons and Hutchinson mines in openings up to 70 years old. The isolated $2 \times 8 \times 10$ ft heated model room (wall temperature approximately 140°C), after more than a year of heating, has a closure rate ten times higher than it had at ambient temperature.–Authors' abstract, NSA 19-08675.

Descriptors: Radioactive waste disposal, Kansas, salts, test procedures, rock properties.

0490 **Boegly, W. J., Jr.; Bradshaw, R. L.; Empson, F. M.; and others.**
1965. Project Salt Vault–Radioactive waste disposal in a salt mine, *in* Industrial Waste Conference, 20th, Lafayette, Ind., 1965, Proc.: Purdue Univ. Eng. Ext. Ser. 118 (Purdue Univ. Eng. Bull., v. 19, no. 41), p. 398-409.

The findings of studies on the disposal of high-level wastes in salt formations are summarized. Project Salt Vault is a field experiment for demonstrating the feasibility of storing solid wastes in a salt mine, and for determining any possible radiation effects or salt creep. The experiment will be carried out using irradiated ETR fuel assemblies to simulate solidified wastes. An engineering description of the experiment is given.–NSA 19-42195.

Descriptors: Radioactive waste disposal, Kansas, sedimentary rocks, underground storage, feasibility studies, salts, solid wastes.

0600 **Boegly, W. J., Jr.; Jacobs, D. G.; Lomenick, T. F.; Sealand, O. M.**
1969. The feasibility of deep-well injection of waste brine from inland desalting plants: U.S. Atomic Energy Comm. Div. Tech. Inf. [Rept.] TID-25081, 76 p.

Deep-well injection was proposed as a method for disposal of brine effluents from inland desalting plants. A review of pertinent literature reveals that deep-well injection is technically feasible, if satisfactory pretreatment is provided. Industrial waste can be disposed of in this manner for about $1.00 to $2.00 per 1000 gallons. Brine disposal from oil-field operations is less costly, ranging from $0.25 to $0.70 per 1000 gallons, primarily because of the magnitude of the operations and because less extensive pretreatment is required. In order to prevent damage to the receiving formation, it will be necessary to inject waste solution without plugging the formation. This requires that the solution be free of suspended solids and be chemically stable with regard to formation of precipitates. Treatment may also be required to prevent biological growths that can plug the injection face. A suitable site for deep-well injection requires a permeable sedimentary formation, such as sandstone or limestone, capped by an impermeable formation, such as shale, to prevent pollution of neighboring potable waters. Such sequences of formations are most likely to be situated in the closed basins, but suitable sites may be found throughout wide geographic areas of the country. Even when preliminary screening suggests that the general area is highly favorable for deep-well injection, more detailed geologic and hydrologic investigations will be required to assure that the site is satisfactory and to provide data to be used as the basis for designing an injection system.–Authors' abstract.

Descriptors: Brine disposal, injection wells, feasibility studies, economics, waste water treatment, water pollution control.

0607 **Boegly, W. J., Jr.; Bradshaw, R. L.; Empson, F. M.; and others.**
1966. Project Salt Vault–A demonstration disposal of high-level radioactive solids in Lyons, Kansas salt mine: Health Physics, v. 12, no. 3, p. 417-424.

The demonstration of the disposal of high-level radioactive waste solids in salt mines is reported. Fourteen irradiated fuel assemblies from the Engineering Test Reactor will serve as a source of radiation, since high-level solidified wastes do not exist at the present time. The assemblies will be placed in a circular array of holes in the floor of a newly mined area (14 ft above the existing mine floor) with one can in the center and the other six cans located peripherally, spaced 5 ft on centers. During the course of the 2-year test, four sets of assemblies will be used to achieve a peak dose in the salt of about 8×10^8 rad and the temperature of the salt adjacent to the center hole will be maintained at 200°C with supplementary electrical heaters. A second radioactive

array, located in the existing mine floor, will receive the fuel canisters which are removed from the main array at the end of each 6-month period. The purpose of this array is to study the problems that may be encountered if the waste containers are located in salt interbedded with water-bearing shale. A third array, consisting only of heaters, will be operated as a control to determine those effects due solely to heat. In addition to the radioactive and control arrays, a rib-pillar located between the main radioactive array and the control array will be heated electrically around its base to produce significant information on salt flow characteristics and mine stability at elevated temperatures. Preparation of the four experimental rooms will involve the mining of approximately 19,000 tons of salt. Placing of the first fuel assembly cans in the mine is expected to take place in November 1965.–Authors' abstract, NSA 20-18169.

Descriptors: Radioactive waste disposal, Kansas, mining engineering, temperature, test procedures, salts.

0624 **Boegly, W. J., Jr.; Parker, F. L.; Struxness, E. G.**
1966. Disposal of radioactive wastes in geologic formations: U.S. Atomic Energy Comm. Oak Ridge Natl. Lab. [Rept.] ORNL-P-2537, 24 p. [Available from CFSTI.]

Field scale demonstrations have shown that it is possible to safely and economically store high-level solidified wastes in salt formations and intermediate-level wastes in the slightly permeable shales at Oak Ridge. Disposal of low-level liquid wastes in permeable formations has not yet been demonstrated in field scale plants but the concept has been proven on laboratory scale models.–Authors' abstract, NSA 21-03230.

Descriptors: Radioactive waste disposal, sedimentary rocks, solid wastes, liquid wastes, salts, shales.

0625 **Boegly, W. J., Jr.; Empson, F. M.; McClain, W. C.; Parker, F. L.**
1968. Disposal of high activity power reactor wastes in salt mines–Mine renovations required for Project Salt Vault: Nuclear Eng. Design, v. 8, no. 3, p. 360-366.

Project Salt Vault is a field-scale demonstration of the disposal of high-level radioactive wastes in a salt mine. Preparations required for the experiment included construction of a new headframe for the main mine shaft, renovation of the existing surface and underground facilities, mining of about 19,000 tons of salt to prepare the experimental area, and drilling of a 19.1-in. di. waste-charging shaft from the surface to the mine level, 1000 ft below.–Authors' abstract, NSA 23-17736.

Descriptors: Radioactive waste disposal, mining engineering, underground storage, Kansas, salts, test procedures.

Boegly, W. J., Jr. *See* Blomeke, J. O. 0489.

Boegly, W. J., Jr. *See* Bradshaw, R. L. 0491.

Boegly, W. J., Jr. *See* Bradshaw, R. L. 0627.

Boegly, W. J., Jr. *See* Bradshaw, R. L. 0628.

Boegly, W. J., Jr. *See* Bradshaw, R. L. 0629.

Boegly, W. J., Jr. *See* Empson, F. M. 0141.

Boegly, W. J., Jr. *See* Empson, F. M. 0509.

Boegly, W. J., Jr. *See* Empson, F. M. 0609.

Boegly, W. J., Jr. *See* Empson, F. M. 0610.

Boegly, W. J., Jr. *See* Schaffer, W. F., Jr. 0698.

Boehme, G. *See* Krause, H. 0832.

0719 **Bonet, E. J.**
1969. Aquifer behavior with injection: Jour. Petroleum Technology, v. 21, p. 1210-1216, Sept.

When produced water is injected into an aquifer that is displacing oil, asymmetric pressure and velocity distributions at the oil-water interface result. The resulting pressures, streamlines and areal sweeps depend on the proximity of the injection well to the water-oil interface, relative production rates, patterns, etc. Time-dependent analytical expressions are developed, and tables and dimensionless figures are presented, showing the cumulative water influx, velocity and pressure distributions for several linear and radial injection systems where water is reinjected into an aquifer displacing oil. The results are given in dimensionless times, pressures, locations, etc. The presence of multiple wells and the area performance with water injection is presented by superposition. It is shown that the injection of water at substantial distances from the water-oil contact may result in only 10 to 50% of the injected water actually advancing the oil-water contact. The remainder of the water increases the pressure in the aquifer and is dissipated in the pore volume-compressibility term.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, hydrodynamics, oil-water interfaces, injection wells.

0078 **Bookman, Max.**
1959. Waste water role in meeting water requirements: Am. Soc. Civil Engineers Proc. Paper 2255, Jour. Sanitary Eng. Div., v. 85, no. SA 6, p. 111-125.

In the water-deficient area in the southern part of California, the recharging of ground-water basins by spreading or injection is the most promising market for reclaimed water. This indirect use of reclaimed water would serve all prevailing beneficial uses to which water secured by pumping from ground-water basins is put.–WSP 1990.

Descriptors: California, reclaimed water, groundwater recharge, injection, water spreading.

Boresi, Arthur P. *See* Deere, Don U. 0113.

0004 **Borowczyk, M.; Mairhofer, J.; Zuber, A.**
1967. Single-well pulse techniques (SM-83/35), *in* Isotopes in Hydrology–International Atomic Energy Agency and International Union Geodesy and Geophysics, Vienna, 1966, Symposium Proc.: Vienna, Internat. Atomic Energy Agency (STI/PUB/141), p. 507-519.

The paper deals with some theoretical and experimental problems of the single-well pulse technique proposed in Israel. The single-well technique is based on a traced injection, pause and pumping. Knowing the thickness of an aquifer as well as the pumping rate, it is possible to find a distance travelled by a tracer during the pause from the measurement of tracer concentration in pumped water. The ratio of distance and duration of the pause gives natural groundwater velocity. It is shown in the paper that the problem may sometimes be solved by a two-layered aquifer. A new method for interpreting the arrival time of the tracer is proposed. It is based on the time of 50% recovery of recovered amount of an injected tracer. This method seems to be essential when very high dispersion of tracer is observed. Many limitations of the technique and an example of complex interpretation are discussed in detail. Final results are compared with those obtained from classical and other tracer methods. A general interpretation of all the data leads to some conclusions and hypotheses which suggest that the main part of water in the investigated aquifer (part of the Vienna Basin) flows very quickly through highly permeable zones and that the movement of water probably takes place mainly in the upper layers of the aquifer.–AWRA 08-0034.

Descriptors: Tracers, injection, dispersion, groundwater movement.

Botset, H. G. *See* Wycoff, R. D. 0449.

0626 **Bovard, P.; Grauby, A.**
1963. Etude de la migration des radioelements dans les sols en place [Study of radioelement migration in the "in-place" soils], *in* La retention et la migration des ions radioactifs dans les sols–Colloque international, Saclay, France, 1962: Paris, Presses Universitaires de France, p. 123-129. [In French with English abs.]

The problems of protection of media against radioactive contamination hazards led to a study of the behavior of ions in soils. A simple, direct method was developed for study of in-place soils contamination. However, a principal drawback remains, the necessity to extrapolate from one or two reduced size samples to a more or less larger area. This is a problem of sampling, and is not specific of the method. However, a choice justified by classical pedological data allowed a sufficient number of results and a suitable accuracy to be obtained.–*from* NSA 18-16216.

Descriptors: Radioisotopes, migration, soil investigations, methodology.

0104 **Bowen, B. M., Jr.; Selby, J. M.; Edgerton, J. H.**
1959. Geology and hydrology in the dispersal of radioactive wastes: Georgia Acad. Sci. Bull., v. 17, no. 4, p. 145-152.

The problems of radioactive waste disposal and the talents needed to solve them are varied. Solid, liquid, and gaseous wastes must be handled in different ways. Many of the methods are in the realm of the earth sciences. Ground disposal of solid as well as low- and intermediate-level liquid wastes is an efficient, safe, and economical method when effected under carefully controlled conditions. Geological and hydrological parameters are of utmost importance in this method. Other means of radioactive

waste disposal of concern to geologists are being investigated, and more research and development needs to be done on these projects.–Tulsa Univ., Inf. Services Dept.

Descriptors: Radioactive waste disposal, methodology, geology, hydrology.

0852 **Boyce, Ernest.**
1937. The disposal of brines from oil drilling and petroleum operations: Am. Water Works Assoc. Jour., v. 29, no. 3, p. 362-369.

The elimination of any contaminating impurity from the water supply is important, especially when drought conditions are considered. Brines from oil fields are a serious problem. Two methods of disposal exist. One involves impounding the wastes in reservoirs to be discharged into the stream so as to be properly diluted; the other involves increasing the flow of the stream carrying the wastes by controlled fresh water above the source of such wastes. Neither method is entirely satisfactory. The construction of large storage reservoirs, disposal by evaporation, and returning the brines to the underground formations, represent other methods. More study is necessary.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, injection wells, pollution abatement.

0081 **Brace, William F.**
1960. An extension of the Griffith theory of fracture to rocks: Jour. Geophys. Research, v. 65, no. 10, p. 3477-3480.

The Griffith theory of fracture has recently been extended by McClintock and Walsh to include the closing of Griffith cracks during compression with the development of frictional forces along crack surfaces. This modified Griffith theory can be used to predict failure of any brittle material, such as rock, for a general stress state. The predicted failure condition is shown to be of the form

$$\pm\tau = 2K - \mu\sigma$$

in the Mohr diagram (in the region of compression), where K is the tensile or one-eighth of the compressive strength of the material and μ is the coefficient of sliding friction at crack surfaces. For a coefficient of friction of 0.8 to 1.0 this failure condition is nearly identical with the empirical Coulomb failure law observed for rocks (in the region of compression). This suggests that the Griffith mechanism of crack growth plays an important part in the fracture of rocks at low confining pressures.–Author's abstract.

Descriptors: Rock properties, fractures (geology), equations.

Bradford, Albert. *See* Evans, David M. 0601.

0491 **Bradshaw, R. L.; Boegly, W. J., Jr.; Empson, F. M.; and others.**
1963. Ultimate storage of high-level waste solids and liquids in salt formations [with French abs.], *in* La rentention et la migration des ions radioactifs dans les sols–Colloque international, Saclay, France, 1962: Paris, Presses Universitaires de France, p. 257-268.

Salt formations offer an attractive site for ultimate storage of high-level liquid and solid wastes. Salt formations are impermeable, have good structural strength, and good thermal conductivity. Elevating the temperature of 3000 gal of waste in a 7-1/2-ft square cavity to 65°C did not upset the structural stability of a mine room, even though the floor-to-ceiling dimensions decreased by a half in. at a distance of 5 ft from the cavity. Evaporation of solution with subsequent condensation on the walls produces some alteration of the cavity. Adsorption of the waste solution onto crushed salt appears to retard both cavity alteration and the production of radiolytic decomposition gases. Radiation doses to be expected in an actual disposal operation will not be great enough to affect the structural stability of the rooms significantly. The major remaining uncertainty is the effect on structural stability of elevating the temperature of large areas of a mine. A theoretical and experimental investigation of this problem is currently under way. Temperature rise calculations were performed for the storage of wastes from a 6 ton per day fuel processing plant. For liquids, the waste was assumed to be adsorbed onto granular salt in rooms with recessed floors. The net mine area required to limit the waste temperature rise to 70°C varied from 34 acres per yr for 120-day-old wastes to 5 acres per yr for 30-year-old wastes. If the wastes are stored in solid form above the mine floor, the acreage requirements are reduced by a factor of 2.3. For cylindrical vessels stored in holes in the mine floor, calculations showed that for wastes cooled longer than 3 years the space requirements are the same as for solids above the floor.–*from* Authors' abstract.

Descriptors: Radioactive waste disposal, salts, liquid wastes, solid wastes, subsurface investigations.

0492 **Bradshaw, R. L.; Lomenick, T. F.; McClain, W. C.; Empson, F. M.**
1966. Model and underground studies of the influence of stress, temperature, and radiation on flow and stability in rock salt mines [with French and German abs.], *in* Internat. Soc. Rock Mechanics Cong., 1st, Lisbon, 1966, Proc., v. 2: Lisbon, Portugal, Laboratorio Nacional Engenharia Civil, p. 429-433.

For purposes of studying the effects of disposal of radioactive waste in salt mines, laboratory and salt mine tests have been carried out. Several different types of gages were used to measure convergence, strain, strain rate, and stress change due to high temperature and radiation effects. Model test results correlated well with underground measurements. Immediately after insertion of radioactive heat sources into the mine floor thermal stresses were transmitted to the roof and resulted in a fivefold increase in rate of sag of the 2-ft salt layer. Radiation produced minor changes in salt properties but thermal effects are much more important under mine conditions.–NAB.

Descriptors: Rock mechanics, radioactive waste disposal, stress, temperature, salts, effects.

0627 **Bradshaw, R. L.; Blomeke, J. O.; Boegly, W. J., Jr.; and others.**
1965. Disposal of high activity power reactor wastes in salt mines–A concept and field scale demonstration: Nuclear Structural Eng., v. 2, no. 4, p. 438-446.

One of the most important advantages of a natural salt formation as a repository for radioactive wastes is its essential impermeability due to its plastic properties. To prove the feasibility of disposal in salt mines a conceptual design has been developed and a demonstration of the storage concept is being prepared in a 1000 ft deep inactive mine in Lyons, Kansas. Economic studies show that costs for an actual disposal operation would fall well within the range allowable for competitive nuclear power.–NSA 20-08483.

Descriptors: Radioactive waste disposal, nuclear wastes, salts, Kansas, feasibility studies.

0628 **Bradshaw, R. L.; Empson, F. M.; Boegly, W. J., Jr.; and others.**
1968. Properties of salt important in radioactive waste disposal: Geol. Soc. America Spec. Paper 88, p. 643-659.

Tests have been conducted relating to ultimate disposal of highly radioactive power reactor wastes in salt mines. A number of laboratory and field tests have been conducted on properties of salt which are important in the design and operation of a waste-disposal facility. In situ heat transfer properties are sufficiently close to the values determined in the laboratory that confidence can be placed in theoretical heat-transfer calculations. Most bedded salt contains trapped moisture which is released with violence at temperatures above about 250°C. Radiation exposure doses of 5×10^8 roentgens produce some changes in structural properties, but the effect on mine stability should be negligible. Rock salt is approximately equivalent to concrete as a gamma-radiation shield. Stability of a waste-disposal mine at ambient temperature can be predicted from observed conditions in existing salt mines. Elevated temperatures will cause accelerated creep, but the exact effects on structural stability cannot yet be predicted accurately.—NSA 23-43407.

Descriptors: Radioactive waste disposal, nuclear wastes, salts, thermal stress, laboratory tests.

0629 **Bradshaw, R. L.; Perona, J. J.; Blomeke, J. O.; Boegly, W. J., Jr.**
1969. Disposal of solid wastes in salt formations, pt. 6 *of* Evaluation of ultimate disposal methods for liquid and solid radioactive wastes: U.S. Atomic Energy Comm. Oak Ridge Natl. Lab [Rept.] ORNL-3358, 90 p. [Available from CFSTI.]

The cost of disposing of high-level solidified wastes in bedded salt formations was studied. A conceptual design of a salt mine is developed for disposal of wastes from the recovery of spent uranium and thorium reactor fuels from a 15,000-MW(e) nuclear power economy. The waste products are contained in "pots" 6, 12, and 24 in. in diameter by 10 ft long and are buried in vertical holes in the floor of a mine 1 sq mile in area and located 1000 ft below the surface. The operating life of this mine and the costs of the mining and disposal operations are calculated, using rather conservative mine stability criteria, for various waste ages, pot sizes, and waste compositions. The life of the mine was found to range from about 12-1/2 years for wastes aged 1 year at the time of burial to about 70 years for wastes aged 30 years at burial. The initial capital outlay required to start waste disposal operations ranged from about $8.4 million to $10.7 million. The annual capital and operating costs for the facility are dependent on waste combinations and pot sizes and vary from about $2.6 million for a 1-year-old waste to about $1.2 million for 30-year-old wastes. Using present worth considerations, the money to be set aside annually at the time of waste generation ranges from about $2.5 million for a 1-year-old waste to about $400,000 for a waste 30 years old at the time of disposal. In terms of the cost per kilowatt-hour of electricity generated, these amounts correspond to about 19×10^{-3} mill and 3×10^{-3} mill, respectively.—Authors' abstract, NSA 23-17731.

Descriptors: Radioactive waste disposal, nuclear wastes, solid wastes, thermal stress, economic feasibility, salts.

Bradshaw, R. L. *See* Blomeke, J. O. 0489.

Bradshaw, R. L. *See* Boegly, W. J., Jr. 0054.

Bradshaw, R. L. *See* Boegly, W. J., Jr. 0490.

Bradshaw, R. L. *See* Boegly, W. J., Jr. 0607.

Bradshaw, R. L. *See* Empson, F. M. 0141.

Bradshaw, R. L. *See* Empson, F. M. 0509.

Bradshaw, R. L. *See* Empson, F. M. 0609.

Bradshaw, R. L. *See* Empson, F. M. 0610.

Bradshaw, R. L. *See* McClain, W. C. 0657.

Bradshaw, R. L. *See* Perona, J. J. 0674.

0083 **Bredehoeft, John D.; Blyth, C. R.; White, W. A.; Maxey, G. B.**
1963. Possible mechanism for concentration of brines in subsurface formations: Am. Assoc. Petroleum Geologists Bull., v. 47, no. 2, p. 257-269.

Brines with concentrations three to six or more times the concentration of present sea water occur in subsurface formations. A mechanism is suggested whereby such concentrations can develop, if given time of such magnitude as recognized in geology. Recent work has shown that clay membranes may restrict the transfer of ions in ion-containing water transmitted through them. Under artesian conditions common in geologic basins, water enters aquifers near the outcrop area and is discharged slowly through confining layers in areas where the hydraulic head in the aquifer exceeds the head in the adjoining beds. If either fresh water containing small quantities of ions or formation water containing higher concentrations of ions is transmitted through an argillaceous layer, the transfer of dissolved ions is impeded. The ions that fail to pass the clay membranes thus become concentrated in the aquifer. The mathematical model presented here predicts the distribution of ions within a particular formation under ideal conditions. Although the model is idealized, the theoretical concentrations show a striking similarity to observed concentrations, indicating that this mechanism could explain some of the highly concentrated subsurface brines.—Authors' abstract.

Descriptors: Brines, hydrogeology, ion transport, groundwater movement, membrane processes, mathematical models.

Bredehoeft, John D. *See* Cooper, Hilton H. 0011.

Bremser, Shirley M. *See* White, W. Arthur. 0546.

0005 **Briggs, Louis L., Jr.**
1968. Geology of subsurface waste disposal in Michigan basin, *in* Subsurface disposal in geologic basins—A study of reservoir strata: Am. Assoc. Petroleum Geologists Mem. 10, p. 128-153.

A study was made of the suitability of rocks in the Michigan basin for disposal of waste by injection wells. The almost circular and symmetrical structural basin contains, in the deepest part, approximately 14,000 ft of Paleozoic sedimentary rocks. The autogeosyncline developed as a tectonic element in Late Silurian time, during which the middle third of the sedimentary section was deposited. The strata dip generally less than 1 deg toward the center of the basin, although locally there are gentle open folds and a few high-angle faults. The sedimentary formations can be classified into 4 generalized sequences (1) the sandstone sequence of the Cambrian, (2) the carbonate-evaporite sequence of the Ordovician to Middle Devonian, (3) the shale-sandstone sequence of the Late Devonian to Mississippian, and (4) the coal-

bearing sequence of the Pennsylvanian. The Cambrian sandstones (Mount Simon) have the most favorable properties for high-volume liquid-waste disposal. They are suitably thick and reasonably shallow principally in southeastern Michigan near Detroit. The Mount Simon is a typical blanket feldspathic, quartzose sandstone; it is characterized by quartz and feldspar cement, present as grain overgrowths, and detrital and matrix carbonate minerals. Where measured, the porosity averages about 10% and the permeability about 30 millidarcies. The Cambrian sandstone beds are overlain by a thick extensive shale layer (Utica)and salt beds (Salina), which are of secondary importance to liquid- and solid-waste disposal.–W69-04945.

Descriptors: Injection wells, waste disposal, Michigan, groundwater basins, geohydrologic units, technical feasibility.

Brinkley, F. S. *See* McClain, W. C. 0460.

Brogdon, B. R. *See* Knox, J. A. 0543.

Brooks, N. H. *See* List, E. J. 0249.

0493 **Brown, D. J.; Brown, R. E.; Haney, W. A.**
1963. Appraisal of Hanford's [Wash.] waste disposal by integration of field techniques [with French abs.], *in* La retention et la migration des ions radioactifs dans les sols–Colloque international, Saclay, France, 1962: Paris, Presses Universitaires de France, p. 181-188.

Low- and intermediate-level liquid radioactive wastes have been discharged to the ground at Hanford [Wash.] for the past 16 years. Field methods and techniques developed to help trace and define the movement of waste liquids through the soil are reviewed. The value is stressed of integrating data from several sources in evaluating ground water contamination patterns and movement. Data on vertical flow in wells, concentrations of specific β emitters in the ground water, temperature gradients, and data on the hydrology and geology of the region all provide valuable data applicable in predicting the movement of radioactive wastes.–NSA 16-32619.

Descriptors: Washington, hydrogeology, radioactive waste disposal, groundwater, water pollution.

0495 **Brown, D. J.; Raymond, J. R.**
1962. Radiologic monitoring of ground water at the Hanford project: Am. Water Works Assoc. Jour., v. 54, no. 10, p. 1201-1212.

The waste disposal policy established at Hanford [Wash.] to safeguard the human population and the environment in this region has been maintained at a high level of confidence. Results of a well organized monitoring program provide the primary basis for assessing the present and continued safety of the radioactive liquid waste ground disposal operations. Since the beginning of disposal operations significant strides have been made in increasing the knowledge of ground water flow beneath the project and in developing equipment and methods for determining the status of radiocontaminants in the ground water more accurately. It is expected that much of Hanford's work will be of assistance in establishing and evaluating ground water monitoring procedures at future plants as they are constructed and integrated into the atomic energy industry.–Authors' abstract, NSA 17-08457.

Descriptors: Washington, radioactive waste disposal, groundwater movement.

0630 **Brown, D. J.; Raymond, J. R.**
1962. Hanford [Wash.] experience in the radiological monitoring of ground water: Richland, Wash., General Electric Company, Hanford Atomic Products Operation [Rept.] HW-SA-2566, 23 p.

Investigations of ground water hydrology and water monitoring methods were needed in order to study the behavior of wastes discharged to the ground. A discussion is presented of some of the monitoring methods and ground water flow concepts developed at Hanford [Wash.]. A brief description is given of the radiochemical techniques and evaluation methods.–NSA 17-10822.

Descriptors: Washington, hydrogeology, monitoring, radioactive waste disposal, groundwater movement, radioactivity techniques.

0825 **Brown, D. J.**
1967. Migration characteristics of radionuclides through sediments underlying the Hanford Reservation (SM-93/16), *in* Disposal of radioactive wastes into the ground–International Atomic Energy Agency and European Nuclear Energy Agency, Vienna, 1967, Symposium Proc.: Vienna, Internat. Atomic Energy Agency (STI/PUB/156), p. 215-225.

The U.S. Atomic Energy Commission's Chemical Separations Plants at Hanford [Wash.] have discharged large volumes of intermediate- and low-level radioactive liquid waste to the ground for more than twenty years. The information acquired by tracing the movements of radionuclides through the underlying sediments via an extensive network of monitoring wells and sophisticated monitoring equipment has increased our knowledge of the migration characteristics of radionuclides associated with these wastes. Sediment samples, obtained by core drilling a disposal facility at the time it was removed from service and again ten years later, show that over 99.9% of the long-lived radionuclides are contained within the first ten meters of the 60-meter partially saturated sediment column underlying the disposal facility. All radionuclides with half-lives of less than one year, except ruthenium-103 and strontium-89, decay to below detection limits before they reach the regional groundwater table. The relative permanency of fixation of the long-lived radionuclides is attested to by leaching studies. For cesium-137 and strontium-90, the data show that after passing 50 column volumes of ground water through sediments, obtained from beneath an abandoned disposal site, 11% of the cesium is removed and 4% of the strontium; 500 column volumes removes an additional 4% of the cesium and 27% of the strontium. Equilibrium coefficient and soil column tests indicate that the trace amounts of strontium-90 and cesium-137, leached from sediments underlying a disposal facility, are resorbed in the saturated zone below the water table. The distribution coefficients determined in these saturated sediments were approximately 300 for cesium-137 and 50 for strontium-90. Three radionuclides (ruthenium-106, technetium-99 and tritium), not readily sorbed on sediments, enter the ground water at about the same concentration as that measured in the waste stream prior to release. The movements of these nuclides are traced in the ground water for distances up to fifteen miles by routine analysis of well water samples. At distances of only two and a half miles from the disposal sites, all radionuclide concentrations in the ground water are below the established drinking water limits.–Author's abstract.

Descriptors: Radioactive waste disposal, radioisotopes, migration patterns, Washington, monitoring, ion transport.

0084 **Brown, K. E.; Jessen, F. W.**
1959. Effects of pressure and temperature on cavities in salt: Am. Inst. Mining Metall. Petroleum Engineers Trans., v. 216, Tech. Paper 8097, p. 341-345.

It is deemed feasible to store atomic reactor fuel wastes in salt dome cavities when the differential pressure acting on the cavity does not exceed 3,000 psi and the temperature is less than 400°F. Tests at pressure increments of 1,000 psi were conducted on a 2-in., cylindrical cavity contained in a 6-in. long X 6-in. diameter salt core. The cavity exhibited stability under pressures up to 3,000 psi and temperatures to 300°F. At temperature ranges of 100 to 400°F and with pressures of 5,000 psi and above continuous deformation of the cavity resulted. Initial movement of the salt was observed at all pressures. This was evidenced by vertical deformation and cavity size reduction.—Authors' abstract.

Descriptors: Radioactive waste disposal, nuclear wastes, salts, laboratory tests, stress analysis.

0564 **Brown, P. G.**
1965. Potential uses of reclaimed municipal waste water, *in* Bienn. microbiology symposium, 2d, Anaheim, Calif. 1964, Proc.: Am. Petroleum Inst., Paper 18, p. 144-155.

A need is stated for closer working relationships between petroleum engineering and sanitary engineering personnel, particularly as to use of reclaimed domestic sewage and industrial waste for industrial purposes, including oil-field repressurization. Listed potential uses of reclaimed sewage and domestic wastes which are described include agricultural reuse, recreational reuse, industrial reuse, and indirect general reuse. Emphasis is placed on necessary quality and treatment of such reclaimed water for artificial injection into aquifers supplying water for general purposes. A description is given of a proposed project in Orange County, Calif., similar to the successful demonstration in Los Angeles County, to create a ground-water mound and trough to halt a dangerous intrusion of ocean water into the valuable ground-water basins underlying the coastal plain of Orange County.—WSP 1990.

Descriptors: Reclaimed water, injection, groundwater basins.

0088 **Brown, R. E.; McConiga, M. W.; Rowe, P. P.**
1956. Geological and hydrological aspects of the disposal of liquid radioactive wastes, *in* Seminar on sanitary engineering aspects of the Atomic Energy Industry—U.S. Atomic Energy Comm. and U.S. Public Health Service, [held at] Robert A. Taft Engineering Center, Cincinnati, Ohio, 1955, Proc: U.S. Atomic Energy Comm. Div. Tech. Inf. [Rept.] TID-7517, pt. 1b, p. 413-425.

The geological and hydrological factors that influence the rate and direction of flow of the Hanford [Wash.] ground waters are described with emphasis on their application toward the ground disposal of liquid radioactive wastes. Experimental and mathematical studies are supplemented by field tests and by observation of the effects of the disposal operations so far permitted. Microgeologic and microhydrologic procedures and concepts have been adopted to define the probable behavior of the waters and the radioisotopes more adequately than by the use of classical concepts.—Authors' abstract.

Descriptors: Hydrogeology, Washington, radioactive waste disposal, groundwater movement, test procedures, mathematical studies.

0497 **Brown, R. E.; Raymond, J. R.**
1965. Geophysical seismic evaluation study at Hanford [Wash.]: Richland, Wash., Battelle Memorial Inst. Pacific Northwest Lab. [Rept.] BNWL-47, 40 p.

Seismic exploration was carried out in the vicinity of Hanford, Wash., to obtain detailed geological and hydrological information in this area, already explored by

more than 700 wells, for radioactive waste disposal purposes. The basalt surface and some individual flows were readily detected along two of three refraction lines and along reflection lines where it was below 600 feet deep. The surface of the Pleistocene Ringold Formation also was detected but not individual beds within it nor the Pleistocene-Recent glaciofluvial sediments. The ground-water table was not detected. Refraction methods proved the most usable and least expensive techniques. Rotary drilling and in-hole logging gave good control on geology at tie points.–NAB.

Descriptors: Washington, seismic studies, radioactive waste disposal, hydrogeology, basalts.

0608 **Brown, R. E.**

1961. Proposed disposal to ground of NPR decontamination wastes at an inland site: Richland, Wash., General Electric Company, Hanford Atomic Products Operation [Rept.] HW-69426, 9 p.

Geologic and hydrologic studies were made to select a site for disposal of phosphoric acid decontamination wastes from the NPR primary coolant loop. It is concluded that wastes discharged to ground at a crib site at coordinates N64,000 and W49,500 will flow with the ground waters into the Columbia River downstream from the 100-F Area. However, the crib site is less ideal because of short travel times to Columbia River.–NSA 17-35241.

Descriptors: Radioactive waste disposal, Washington, groundwater movement, subsurface flow.

0631 **Brown, R. E.; Raymond, J. R.**

1962. The measurement of Hanford's geohydrologic features affecting waste disposal, *in* Morgan, J. M., Jr., Jamison, D. K., Stevenson, J. D., eds., Ground disposal of radioactive wastes conference, 2d, Atomic Energy of Canada Limited and U.S. Atomic Energy Comm. Div. Reactor Devel., Chalk River, Canada, 1961, Proc., Book 1: U.S. Atomic Energy Comm. Div. Tech. Inf. [Rept.] TID-7628, p. 77-79.

Movement of radioisotopes in the ground is almost wholly through ground waters. Understanding of the principles of ground water movement is thus necessary if safe storage locations are selected and effective surveillance is achieved. Five basic ground-water concepts that are important in waste disposal include the vertical component of ground-water movement, quantitative dispersion of ground-water contaminants, the effect of aquifer anisotropism, the range of ground-water flow rates within the average rate usually calculated, and the hydrologic continuity between well and aquifer. Ground waters rarely can be observed directly. Methods are described that are used at the Hanford Atomic Products Operation for the measurement of geohydrologic features affecting waste disposal.–NSA 16-25042.

Descriptors: Hydrogeology, Washington, groundwater movement, radioactive waste disposal, dispersion.

Brown, R. E. *See* Brown, D. J. 0493.

0090 **Brown, R. W.; Spalding, C. W.**

1966. Deep-well disposal of spent hardwood pulping liquors: Water Pollution Control Federation Jour., v. 38, no. 12, p. 1916-1925.

The economic necessity of switching from softwood to hardwood pulping at Hammer-

mill's Erie, Pa., plant brought about a spent pulping liquor treatment or disposal problem. The method chosen involves injecting suspensoid-free liquid wastes into deep, underground, permeable, brine-bearing geological formations by deep wells. Wastes are confined within the injection formation. Diatomaceous earth, pressure leaf filtration was selected to treat pulping liquor before injection. A full-scale disposal well in a limestone formation at 1,600-1,700 ft (490-520 m) was found to accept fluids at practical injection pressures. Injection of over 66 mil gal (250,000 cu m) without appreciable pressure increases has proved the method successful. A second well has been completed in a deeper formation at 5,900 ft (1,800 m).–Authors' abstract.

Descriptors: Waste water disposal, injection wells, Pennsylvania, industrial wastes, pretreatment (water), limestones.

Brownlow, A. D. *See* Champlin, J. B. F. 0503.

0006 **Bruch, John C.; Street, Robert L.**
1967. Two-dimensional dispersion: Am. Soc. Civil Engineers Proc. Paper 5636, Jour. Sanitary Eng. Div., v. 93, no. SA 6, p. 17-39.

The dispersion of a pollutant solution in a flow through a porous medium was investigated. A theoretical solution was obtained for the general, two-dimensional, convective-dispersion equation that describes the dispersion of a miscible, second fluid through a seepage flow. Application of the theoretical results requires knowledge of the basic seepage flow, the pollutant (second fluid) source concentration, and the longitudinal and lateral dispersion coefficients of the porous medium. A simplified theory and experiments were conducted to determine the coefficients. Their values found in the present study are in agreement with previously published results. Theoretical and experimental breakthrough curves for the general theory are presented and appropriate comparisons made. The unsteady growth of the dispersion front is shown, and the significant effects of both the longitudinal and lateral dispersion phenomena are clearly demonstrated.–AWRA 08-0105.

Descriptors: Dispersion, groundwater movement, porous media, theoretical analysis, pollutants.

Bruns, Hayo. *See* Lang, Alexander. 0240.

Buckham, J. A. *See* Slansky, C. M. 0108.

Burgy, Robert H. *See* Lewis, David C. 0029.

0720 **Burke, R. G.**
1966. Texas toughens antipollution line: Oil and Gas Jour., v. 64, no. 1, p. 47-48.

A study of Texas Railroad Commission orders in its cut-down on pollution across the state indicates that the interpretation of rules is getting stiffer–especially for new production. About the safest prediction for operators in any troublesome area is for injection of oil-field brines, either into a formation that does not contain fresh water, or as a material for water-flooding oil-producing beds. Since Jan. 1965, the commission is requiring operators in polluting areas to fill all existing pits used for salt-water disposal and to remove the water before the pits are filled. The commission still

allows lined pits even in some areas where all pits are outlawed, but only for emergency or temporary use. The commission hopes to control pollution in the following manner: place greater emphasis on proper well completions; encourage operators to dispose of produced salt water in underground formations; eliminate earthen pits; strictly enforce plugging procedures; and closely inspect completion techniques of water injection wells. The commission apparently would like to see practically all oil-field brine put to useful work.–Tulsa Univ., Inf. Services Dept.

Descriptors: Texas, brine disposal, injection wells, water pollution control.

0632 **Burns, R. H.**

1962. British thoughts on ground disposal of radioactive wastes, *in* Morgan, J. M., Jr., Jamison, D. K., Stevenson, J. D., eds., Ground disposal of radioactive wastes conference, 2d, Atomic Energy of Canada Limited and U.S. Atomic Energy Comm. Div. Reactor Devel., Chalk River, Canada, 1961, Proc., Book 2: U.S. Atomic Energy Comm. Div. Tech. Inf. [Rept.] TID-7628, p. 583-589.

In Great Britain ground disposal is not practiced. This is not because it is considered an unsatisfactory process. The difficulties are in finding a suitable area, and persuading other people that the process is safe. In the United Kingdom both of these are real difficulties. Burial of solid waste can be considered as a form of ground disposal and a limited amount is carried out in Great Britain. Experiments are being carried out to investigate the possibility of converting solid waste, including chemical sludges, into a nonleachable form. This may be achieved by melting with suitable fluxes or, as the Belgians have proposed, by incorporation in asphaltic material. If the process is found to be satisfactory it is hoped that authorizations for burial may be revised and/or objections to sea dumping removed.–Authors' abstract, NSA 16-25075.

Descriptors: Radioactive waste disposal, solid wastes, waste treatment, foreign countries.

0091 **Butler, R. G.; Orlob, G. T.; McGauhey, P. H.**

1954. Underground movement of bacterial and chemical pollutants: Am. Water Works Assoc. Jour., v. 46, no. 2, p. 97-111.

In view of the importance of water to the growth and prosperity of the arid southwest, the modern concept of water usage includes the multiple reuse of water. In many instances waste waters are being returned underground to take advantage of the filtering and diluting effect of ground water. As a result, the underground movement of pollutants is a matter of great concern to public health authorities. To learn more about underground travel of pollutants, studies of the movement of bacterial and chemical pollutants both above and below the water table are being made. Above the water table, bacteria will travel little more than 5 feet in fine soils and somewhat greater distances in coarse soils; chemical pollutants are little altered by passing through as much as 13 feet of unsaturated soil. Below the water table, evidence is reported that coliform organisms in ground water have been observed to travel from 10 to 232 feet; chemical pollutants in ground water were found to travel farther (up to several miles) and faster than bacterial pollutants. Incidents are reported wherein chemical pollutants traveled 2 to 30 times as far as coliform bacteria introduced at the same time.

Descriptors: Water reuse, groundwater movement, pollutants, porous media, investigations.

Calberg, B. L. *See* Felsenthal. M. 0145.

Calhoun, G. H. *See* Carroll, F. M. 0007.

0501 **California Department of Water Resources.**
1965. Dispersion and persistence of synthetic detergents in ground water, San Bernardino and Riverside Counties [California]: California Water Quality Control Board Pub. 30, 67 p.

The San Jacinto Fault and the Rialto-Colton barrier affect the movement of ground water in a reach of the Santa Ana River. Older alluvium, containing several aquifers, is the the primary water-bearing zone. The report includes chapters on: development of methods and sampling techniques; ABS (alkyl benzene sulfonate) concentrations in waste, surface, and ground waters; transport and degradation of ABS in surface and ground waters; mixing and dispersion in a ground-water basin; and findings, conclusions, and recommendations. Appendixes include a bibliography, analyses of selected constituents of ground water, general geology of the area, and test well logs.–NAB.

Descriptors: California, hydrogeology, water pollution, detergents, groundwater movement, dispersion.

0502 **California Department of Water Resources.**
1965. Fresno-Clovis metropolitan area water quality investigation: California Dept. Water Resources Bull. 143-3, 54 p.

The quality of ground and surface water in this area is excellent. Effluents from waste disposal systems are discharged on or under the land surface, and lower quality ground water is found near the Fresno sewage treatment plant. The gradient is from northeast to southwest, but if the water table beneath Fresno's downtown area continues to be lowered, a reversal of flow may occur, carrying water from the sewage treatment plant area toward the city. Recommendations are made for conservation measures.–NAB.

Descriptors: California, hydrogeology, surface waters, groundwater, water quality, sewage effluents.

0565 **California Department of Water Resources.**
1958. Reclamation of water from sewage and industrial wastes–Progress report, July 1, 1953-June 30,1955: California Dept. Water Resources Bull. 68, 24 p.

The report presents basic data concerning sewage treatment facilities and the status of reclamation projects. Proposed waste-water reclamation projects include using reclaimed water to supply injection wells to prevent sea-water intrusion, and spreading basins to recharge the San Luis Rey ground-water basin.–WSP 1990.

Descriptors: Reclaimed water, injection wells, saline water intrusion, California.

0566 **California University Sanitary Engineering Research Laboratory.**
1954. Investigation of travel of pollution: California Water Pollution Control Board Pub. 11, 218 p.

This study of travel of pollution from direct recharge used a well field consisting of a 12-inch gravel-packed recharge well and twenty-three 6-inch observation wells located in Richmond, Calif. The wells penetrate a confined aquifer, about 5 feet thick, overlain by about 90 feet of overburden. Both fresh water and water degraded with settled sewage were injected at various rates. Rates of travel of recharged water were deter-

mined by chemical, bacteriological, and radiological means. The nature of well clogging was determined, and methods of well redevelopment were studied.–WSP 1990.

Descriptors: Water pollution, migration patterns, injection, groundwater, California.

0567 **California University Sanitary Engineering Research Laboratory.**
1955. Studies in water reclamation: California Univ. Sanitary Eng. Research Lab. Tech. Bull. 13, 65 p.

This report attempts to bring together and evaluate the pertinent studies conducted in water reclamation, primarily through the procedure of artificial recharge. The methods and some statistics of recharge by spreading and injection are reviewed; tabulated data of infiltration rates and pollution travel are cited. The report concludes with an appraisal of the engineering and economic aspects.–WSP 1990.

Descriptors: Reclaimed water, groundwater, artificial recharge, injection, migration patterns.

Callahan, J. T. *See* Stewart, J. W. 0538.

0826 **Capitant, B.; Grison, G.; Leveque, P.**
1967. Etude experimentale de l'injection a haute pression d'effluents radioactifs dans des couches geologiques diaclasees (SM-93/46) [Experimental study of the high-pressure injection of radioactive effluents into fractured geological layers], *in* Disposal of radioactive wastes into the ground–International Atomic Energy Agency and European Nuclear Energy Agency, Vienna, 1967, Symposium Proc.: Vienna, Internat. Atomic Energy Agency (STI/PUB/156), p. 621-650. [In French with English abs.]

Radioactive effluents can be satisfactorily stored by injecting them, in the form of a cement or clay grout, into closed geological structures. An attempt has been made to reproduce in a superficial geological formation some of the effects of fracturing at depth. High-pressure injection tests were carried out with inert elements in surface layers. The work consisted of: (1) the high-pressure injection of various types of grout in weathered and fractured granites and a subsequent examination of their movement by excavating trenches; and (2) a study of the radioactive anion and cation retention by the grouts, and by the ground into which they are injected, with the following isotopes: ^{45}Ca, ^{89}Sr, ^{204}Tl, ^{95}Zr, and ^{106}Ru. A study was made of the main parameters in the adsorption mechanism, i.e. the petrographic nature of the soil, the grain size and shape of the voids and fractures, the nature and concentration of the radioactive ion and the composition of the grouts. The authors describe the results obtained, together with further applications of the method, using well-known mineral–oil formations as specific examples.–Authors' abstract.

Descriptors: Radioactive waste disposal, injection, test procedures, effects, fractures (geology), ion transport.

Carlile, W. C. *See* Knox, J. A. 0543.

0633 **Caron, C.; Gailledreau, C.; Belot, Y.**
1963. Principe du rejet direct dans le sol des boues radioactives [Principle of "ground disposal injection" of radioactive sludge], *in* La retention et la migration des ions radioactifs dans les sols–Colloque international, Saclay, France, 1962: Paris, Presses Universitaires de France, p. 167-180. [In French with English abs.]

Research on radioactive sludges and cement-mixed grouts injected according to miscellaneous techniques is described. The characteristics of several grouts studied in terms of the kind of sludge incorporated and of the ground to be injected are given along with grout behavior in lixiviation by natural waters.–NSA 18-17346.

Descriptors: Radioactive waste disposal, grouting, injection, methodology, fractures (geology).

Carpenter, H. S., Jr. *See* Spalding, C. W. 0381.

0007 **Carroll, F. M.; Calhoun, G. H.**
1956. Effect of tubing size on disposal well may be more than you think: World Oil, v. 143, no 6, p. 182, 185-186, 189.

The capacities of disposal wells with various size tubing can be determined by charts based upon the "receptivity index" of the sand. The charts show that wells with a high normal intake will react most favorably to increase in tubing size. The method of constructing tubing-capacity charts is outlined.–Arad, USGS.

Descriptors: Injection wells, waste disposal, design data, well casings.

Carter, R. F. *See* Stewart, J. W. 0538.

0721 **Case, L. C.**
1949. Chemical problems in salt water injection, pt. 2 *of* Problems of water injection in wells and corrective methods: World Oil, v. 128, no. 12, p. 142-144, 152.

Chemical problems encountered during the injection of waste oil field brine into disposal wells do not differ greatly from those in water flooding. Chemical relationships as well as physical factors are somewhat more favorable to salt water injection. Data on individual salt water injection wells are summarized in tables and discussed. After years of operating disposal wells, it is now indicated that proper selection of disposal formations and use of semi-closed or closed systems make brine coagulation and filtration unnecessary. It is possible to predict from laboratory analyses that certain brines will tend to deposit calcium carbonate and sulfur when aerated, while others will tend to deposit hydrated oxides of iron; the degree of precipitation, however, may not be predicted. Sludge deposits in brine injection systems in general have constitutions corresponding to the chemical nature of the water being injected and accompanying physical conditions. Three typical analyses are tabulated. A troublesome sludge observed where formaldehyde is used to combat corrosion in wells is thought to be derived from a reaction between hydrogen sulfide and formaldehyde.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, injection wells, chemical reactions, methodology.

0092 **Caswell, Charles A.**
1970. Underground waste disposal–Concepts and misconceptions: Environmental Sci. and Technology, v. 4, no. 8, p. 642-647.

The technology, hydrology, and legal status of deep disposal wells are briefly reviewed. Injection is ultimate disposal in the sense that wastes are held out of contact with the surface environment for a very long time, long enough to render many wastes harmless by geochemical processes before they reach the surface again. In many cases wastes are made safe enough that underground disposal is a valuable source of aquifer recharge. In many cases, however, injection is not feasible because wastes are too

long-lived or the hydrogeology of the disposal horizon is not favorable for safety, long retention, or degradation of the wastes. Legal problems include underground trespass, liability for damage, and ownership of aquifers and groundwater.

Descriptors: Injection wells, hydrogeology, waste disposal, legal aspects, safety, environmental engineering.

0093 **Cecil, L. K.**
1950. Underground disposal of process waste water: Indus. Eng. Chemistry, v. 42, no. 4, p. 594-599. [Also published in Am. Water Works Assoc. Jour., v. 42, no. 11, p. 56.]

Disposal of oil field brines by injection into a suitable underground formation has proved a satisfactory solution to a difficult disposal problem. The same method can be applied to disposal of manufacturing plant process liquid wastes. The Magnolia Petroleum Co. is successfully disposing of 150 gallons per minute of waste water into a 3000-foot deep dense sandstone well at its Seeligson natural gasoline plant near Premont, Texas. Data are presented to show the composition of raw water, cooling tower blowdown, gas condensate, boiler blowdown, combined wastes, before and after treatment, and connate water. Treatment to prevent plugging of the formation by suspended material or reaction with the connate water requires clarification, stabilization of calcium carbonate and wood degradation products, pH control, and sterilization to prevent formation of bacterial slime on the face of the injection sandstone. Tannin type compounds from tower wood prevented coagulation but the problem was solved by a unique use of chlorine compounds. The disposal system is described briefly in the abstract.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, industrial wastes, injection wells, chemical engineering, pre-treatment (water), Texas.

0008 **Champlin, J. B. F.; Eichholz, G. G.**
1968. The movement of radioactive sodium and ruthenium through a simulated aquifer: Water Resources Research, v. 4, no. 1, p. 147-158.

The interaction of water solutions with the particulate matter composing a natural aquifer is of steadily increasing interest with the new emphasis on pollution of our natural resources. As a means of studying the contribution made by water to the transport of ionic materials through soils, radioactive solutions were injected into a model aquifer containing 725 kilograms of sand with dimensions of 1 X 2 X 0.25. As the radioactivity passed through the sand, its progress was followed by a collimated Geiger-Mueller tube situated on the exterior of the bed. The appearance of the radioactivity in the effluent, which marked the arrival of the sodium front, was found to be correlated with an increase in suspended particulate matter, potassium and calcium concentrations, and overall conductivity. Of particular significance was that portion of the radioactivity shown to be related directly to the filterable mass of particles in the effluent, despite the high solubility of the ion used. The results with the sodium were compared with those of similar tests on the movement of trivalent ruthenium, which is not soluble at the pH of the solutions used. Both the sodium and ruthenium studies indicated that a significant amount of radioactivity was transported through the test bed on particulate matter which was large enough to be trapped on 0.45 micron membrane filters.–AWRA 08-0111.

Descriptors: Groundwater movement, model studies, tracers, radioisotopes.

0503 **Champlin, J. B. F.; Thomas, R. D.; Brownlow, A. D.**
1967. Laboratory testing and evaluation of porous permeable rock for nuclear waste disposal: U.S. Bur. Mines Rept. Inv. 6926, 33 p.

Simulated nuclear production plant waste fluids were injected into samples of sedimentary rock. High-level acidic wastes generally increase permeability, in contrast to low-level aqueous wastes which generally reduce permeability. Shales and clays have higher cation-retention capacity than sandstones, but much less permeability. The sandstones satisfy the requirements for reservoir rock for the subsurface disposal of nuclear waste and the shales and clays would make excellent confining formations.–NAB.

Descriptors: Radioactive waste disposal, injection, laboratory tests, sedimentary rocks, permeability, porosity.

0635 **Champlin, J. B. F.**

1962. Research on field problems on injecting solutions into permeable rocks, *in* Morgan, J. M., Jr., Jamison, D. K., Stevenson, J. D., eds., Ground disposal of radioactive wastes conference, 2d, Atomic Energy of Canada Limited and U.S. Atomic Energy Comm. Div. Reactor Devel., Chalk River, Canada, 1961, Proc., Book 2: U.S. Atomic Energy Comm. Div. Tech. Inf. [Rept.] TID-7628, p. 324-326.

The continued development of the nuclear industry in the United States requires a program of waste disposal that insures against the release of large amounts of radioactivity to the environment. Results are described from research on one proposed means of disposal of this waste, that of injection into geologic formations at depth. Nuclear production plant wastes were simulated and injected into samples of sedimentary rock obtained from outcrops, quarries, and deep wells. Changes in the chemiphysical characteristics of the rocks caused by the interaction of ions and suspended particles in the waste solutions with the cementing material and clay-like particles in the rock are discussed. Laboratory tests show that injectivity can be maintained over a longer period of waste injection by monitoring the ionic balance and particle size distribution of the waste stream.–Author's abstract, NSA 16-25056.

Descriptors: Radioactive waste disposal, United States, injection, nuclear wastes, sorption, chemical reactions.

0819 **Chappelear, J. E.; Volek, C. W.**

1969. The injection of a hot liquid into a porous medium: Soc. Petroleum Engineers Jour., v. 9, no. 1, p. 100-114.

The injection of a hot liquid into initially cool porous media, saturated with the same liquid and surrounded by two impermeable but heat-conducting media (cap and base rock), has been studied both experimentally and theoretically. The temperature dependence of the viscosity was included in the theoretical model, but it was assumed that the specific heats and densities of the various materials were independent of the temperature. Solutions to the theoretical model were approximated by numerical methods. Both theoretical and experimental results indicate that centerline temperatures are significantly higher than boundary temperatures. Comparison of experimental and theoretical results with a cold/hot viscosity ratio of 19:1 were in reasonable agreement. Theoretical calculations show that the effect of the temperature dependence of viscosity was very significant at ratios of 100:1 to 1000:1, which are typical of those that occur when injecting hot water to flood heavy oil reservoirs.–Authors' abstract.

Descriptors: Injection, porous media, theoretical analysis, laboratory tests.

Chase, G. H. *See* Morris, D. A. 0282.

0094 Chemical and Engineering News.
1963. Spent pulping liquors to be discharged underground: Chem. and Eng. News, v. 41, no. 35, p. 128-129.

Hammermill Paper Co., early in 1964, plans to inject up to 2 million gal per day of pulping liquors from its Erie, Pa., mill into underground limestone deposits, more than 1,600 ft below the surface. Currently, spent pulping liquors are discharged without treatment into Lake Erie. Hammermill proposes to drill several wells into the vast limestone formations beneath its mill. An experimental well, called Hammermill No. 1, will discharge into the Bass Island strata. The effective portion of this layer is about 35 ft thick. If Hammermill No. 1 proves out, the company plans to explore deeper limestone formations that theoretically have almost limitless capacity. Injection of Hammermill's pulping waste into the experimental well will be based on Dow Chemical Co.'s design recommendations. Wastes will be pumped through a double-cased, cement-grouted steel pipe to the Bass Island formation. The inner pipe is 4 in. in diameter and 1,600 ft long. Relatively high pressure is required to force the spent pulping liquors into the limestone. Surface pumping pressure will be about 900 psi.–Tulsa Univ., Inf. Services Dept.

Descriptors: Industrial wastes, waste disposal, Pennsylvania, limestones, injection wells, geologic formations.

0096 Chemical Week.
1965. Learning to whip well woes: Chem. Week, v. 96, no. 15, p. 113, 115.

For its Michoud plant in New Orleans, where the gigantic Saturn launch vehicles for the Apollo program are being assembled, NASA has sunk the second-deepest disposal well in the U.S., and the only one that discharges into a water-sand stratum. Because the city of New Orleans was planning to drill 4,700-ft wells in Lake Ponchartrain–N. of Michoud–to augment municipal water supplies, the Michoud well had to be at least 5,700 ft deep to avoid possible contamination of the city system. The well was drilled to 7,000 ft and finished in a sand layer at 6,500 ft. The Michoud well began receiving wastes about a year ago, and operating problems showed up in about 30 days. While the original difficulty was overcome, the well eventually had to be rerigged. The well is now discharging into a different water-sand layer, about 6,300 ft deep. The sand there is more porous, sand grains are larger, there is no clay (partly the cause of the first trouble) in the layer, and the water has a much lower mineral content. The experience indicates that successful sinking and operating of a disposal well in water-sand requires foreknowledge of the geology of the receiving layers and the chemistry of their waters.–Tulsa Univ., Inf. Services Dept.

Descriptors: Louisiana, injection wells, hydrogeology, chemical reactions, waste water disposal.

0161 Chemical Week.
1967. Coaters go to the well: Chem. Week, v. 100, no. 6, p. 79-80.

Increasing national concern with waste control could prove to be a bonanza for specialty coaters of steel pipe, now used mainly in oil production. Pipe coaters believe that many chemical makers will be disposing of future waste in deep-injection wells, and that will require the same sort of corrosion-resistant pipe that is the coaters' stock in trade. The corrosion-resistant plastics allow customers to use low-cost carbon steel rather than expensive alloy-steel pipe for the tubing and casing put into drilled wells. For this reason, almost all drill pipe used anywhere is protected internally with baked-on plastic. Combinations of resin, both thermosetting and thermoplastic, are used where special protection is required. Examples include salt water disposal, handling of water, oil and high caustic solutions.–Tulsa Univ., Inf. Services Dept.

Descriptors: Waste disposal, injection wells, piping systems (mechanical), corrosion control.

0634 **Christenson, C. W.; Thomas, R. G.**

1962. Movement of plutonium through Los Alamos tuff, *in* Morgan, J. M., Jr., Jamison, D. K., Stevenson, J. D., eds., Ground disposal of radioactive wastes conference, 2d, Atomic Energy Comm. Div. Reactor Devel., Chalk River, Canada, 1961, Proc., Book 1: U.S. Atomic Energy Comm. Div. Tech. Inf. [Rept.] TID-7628, p. 248-281.

Early work at Los Alamos under the Manhattan Project was geared for speed. Liquid radioactive wastes from the plutonium processing plant were allowed to percolate through seepage pits constructed in the porous tuff. Data are presented from a series of studies on the movement of Pu through the tuff. Under field conditions, Pu species were shown to penetrate at least 28 ft in Los Alamos tuff. Data indicate the dangers associated with the practice of uncontrolled and uncontained ground disposal of radioactive waste.–NSA 16-25054.

Descriptors: Radioactive waste disposal, New Mexico, radioisotopes, liquid wastes, migration.

0504 **Christl, R. J.**

1964. Storage of radioactive wastes in basement rock beneath the Savannah River plant: E. I. du Pont de Nemours Savannah River Lab. Rept. DP-844, 39 p. and App. A-G [67 p.].

A three-square-mile area of this plant near Aiken [S. C.] was explored to determine the attitude, continuity, types, and character of the basement rocks, their hydrology, and that of the overburden. The Precambrian basement is overlain by sediments ranging in age from Cretaceous to Recent, of which the most important with respect to the storage of wastes in the basement rocks is the Cretaceous Tuscaloosa Formation, 600 to 700 feet thick and consisting of two aquifers and three aquicludes. The virtually impermeable basement rock contains fractures that appear to connect its ground water into one system. Drillers' logs and geophysical exploration seemed to agree on the feasibility of a 5,000,000-gallon chamber 1,300 to 1,700 feet beneath the surface.–NAB.

Descriptors: South Carolina, radioactive waste disposal, hydrogeology, fractures (geology), rock excavation, geologic formations.

0097 **Civil Engineering.**

1966. Production waste goes underground at Holland-Suco: Civil Eng., v. 36, no. 5, p. 92.

Some 36,000 gpd of waste from the production of color pigment will be pumped into a porous sandstone through a 5,896-ft deep well at the Holland-Suco Color Co. (a Chemetron Corp. subsidiary) plant in Holland, Mich. The deep well cost $100,000 and eliminates the need for expensive neutralization of waste prior to disposal. The Michigan State Water Resource Commission is satisfied with the safeguards against contamination of ground and surface waters. The details of well construction and preinjection waste treatment are described.

Descriptors: Injection wells, Michigan, waste water disposal, industrial wastes, economics, design data.

Clark, F. R. *See* Holland, H. R. 0193.

0098 **Clark, Joseph R.; Pohl, Herbert A.**
1956. Earth disposal of radioactive wastes at SRP [Savannah River Plant] [S.C.], *in* Seminar on sanitary engineering aspects of the Atomic Energy Industry–U.S. Atomic Energy Comm. and U.S. Public Health Service [held at] Robert A. Taft Engineering Center, Cincinnati, Ohio, 1955, Proc.: U.S. Atomic Energy Comm. Div. Tech. Inf. [Rept.] TID-7517, pt. 1a, p. 162-169.

Radioactive wastes of low specific activity are being stored in soil columns at the Savannah River Plant. Waste liquors containing the activity are permitted to seep into the soil from three large seepage systems. A total of approximately 130,000 gallons per day of waste liquors is handled in this manner. This paper describes the basis of their operation and some of the results obtained so far. It is concluded that the operation has been quite satisfactory.–Authors' abstract.

Descriptors: Radioactive waste disposal, operations, South Carolina, effects, seepage.

0711 **Cleary, E. J.; Warner, D. L.**
1969. Perspective on the regulation of underground injection of wastewaters: Cincinnati, Ohio River Valley Water Sanitation Comm. [rept.], 88 p. Dec.

The eight states of the Ohio River Valley Water Sanitation Commission (ORSANCO) commissioned a study of policies, procedures and other matters allied to the practice of subsurface disposal. Perspective and guidelines are offered in a monograph on the regulation of underground injection of wastewaters. The first section provides background on public policy issues associated with environmental factors and subsurface resources, including legislative and legal aspects. Part II discusses administrative procedures, geological evaluation and technical criteria relating to injection-well practice, specifically in the Ohio Valley. There is growing concern that wastewater injection may be proceeding faster than warranted by knowledge and regulatory procedures. A deep-well disposal system near Denver may have triggered earth tremors in the area. Legal concern exists with respect to underground trespass. No state prohibits underground disposal, but nine states subscribe to a policy of either rejecting applications or discouraging them. Only Ohio, West Virginia and Texas have specific legislation pertaining to the regulation of industrial wastewater injection. There is no specific federal legislation on deep-well disposal. Only small areas of the Ohio Valley would appear to be eliminated or significantly limited for waste injection on the basis of the most general consideration of the rock units that are present, their geologic structure, and the groundwater circumstances. For abandonment of an injection system, it is suggested that wells be completely plugged with cement and that a permanent monument be constructed at the well site.–W70-05521.

Descriptors: Waste water disposal, injection wells, hydrogeology, water law, environmental engineering, administration.

0099 **Cleary, J. M.**
1958. Hydraulic fracture theory–Part 1, Mechanics of materials; Part 2, Fracture orientation and possibility of fracture control: Illinois Geol. Survey Circ. 251 (24 p.) and 252 (19 p.).

This study takes up the problem of hydraulic fracture mechanics, orientation of fractures, and whether their control is possible. In Part I, some theories on the mechanics of materials were adapted for use in dealing with mechanical problems of hydraulic fracture and also to help in describing conditions of stress in porous sediments. Part II summarizes some current notions of hydraulic fracture mechanics, including my own view. It sets forth sample problems based on the theory developed

in Part I. Hydraulic fracture orientation and distribution are controlled by the condition of stress underground. The horizontal stress underground is altered by the pore pressure. Thus the magnitude of the pore pressure may influence the orientation and distribution of hydraulic fractures.–Author's abstract.

Descriptors: Rock mechanics, fractures (geology), theoretical analysis, underground structures, stress.

0101 **Clebsch, Alfred, Jr.; Baltz, E. H.**
1967. Progress in the United States of America toward deep-well disposal of liquid and gaseous radioactive wastes (SM-93/43), *in* Disposal of radioactive wastes into the ground–International Atomic Energy Agency and European Nuclear Energy Agency, Vienna, 1967, Symposium Proc.: Vienna, Internat. Atomic Energy Agency (STI/PUB/156), p. 591-606.

The basic technology for deep-well disposal of liquid wastes developed and used by the petroleum industry and adapted by the chemical industry is discussed. Requirements for disposal of radioactive wastes include an understanding of physical and geologic characteristics of the disposal reservoir, effects of chemical reactions between waste and reservoir rock, and hydraulic effects of long-term injection on rate and direction of mass transport and integrity of geologic units bounding the disposal reservoir. Deep-well disposal is not feasible at many existing waste-generating sites because of unsuitable geologic environments. Gas injection research concerns rapid disposal of relatively large volumes of fission-product gases into water-saturated or unsaturated rocks. Mathematical models of gas flow, definition of the problems of dispersion, laboratory studies of gas sorption on earth materials, the role of barometric changes in bringing injected gases back into the atmosphere, engineering and economic evaluations, and field tests of the method have all been studied. As a safeguard for the rapid disposal of fission-product gases and other gases after major reactor accident, the injection method is severely limited in saturated rocks by dependence on favorable hydrogeologic conditions, the need to prepare the disposal reservoir in advance and maintain it by continuous injection of air, and the cost. The prospects are better for using the method in unsaturated rocks and for routine disposal of waste gases that can be separated as a low-volume stream.–W69-03688.

Descriptors: Injection wells, radioactive waste disposal, gases, United States, geohydrologic units, mathematical models.

0505 **Clebsch, Alfred, Jr.; Peckham, A. E.**
1963. Research by the United States Geological Survey related to the movement of radionuclides in the earth environment [with French abstract], *in* La retention et la migration des ions radioactifs dans les sols–Colloque international, Saclay, France, 1962: Paris, Presses Universitaires de France, p. 189-197.

Geologic and hydrologic research by the U.S. Geological Survey related to the movement or retention of radionuclides embraces several scientific disciplines, a wide variety of geohydrologic terranes, and various types of radioactive materials. Field studies have been completed or are in progress at all the major nuclear energy installations in the United States where large releases of radioactivity have been made, either in the form of radioactive wastes or as the consequence of nuclear explosions. Much of this work is designed to develop an understanding of the influences of geologic and hydrologic features on radionuclide movement. Chemical studies include supporting services for field projects as well as research on reactions between radioactive substances and earth materials. Descriptive geochemical research on the distribution of stable elements, such as strontium, and naturally occurring radioactive elements, such as radium and uranium, has been a small but important part of the work. Theoretical and laboratory investigation of the basic mechanisms of fluid movement as they affect

the transport and dispersion of radionuclides has emphasized the effects of the abundant departures in nature from idealized systems. Work related to the development of new techniques for disposal of wastes, such as deep-well injection, ultimate storage of fluids in cavities mined in rocks of low permeability, and storage of solids or fluids in salt, ranges from the compilation of broad summaries of the geology of geologic basins to detailed geologic and hydrologic investigations at the particular site. 111 references are included.–NSA 18-16207.

Descriptors: Radioactive waste disposal, radioisotopes, groundwater movement, United States, hydrogeology, migration.

0722 **Cloud, W. F.**
1937. Oil field water problems, chap. 14 *of* Petroleum production: Oklahoma City, Oklahoma Univ. Press, p. 483-511.

Chemical analyses of various oil-field brines are tabulated and present methods of salt-water disposal are reviewed with some data.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, chemical analysis, methodology.

Coats, K. H. *See* Katz, Donald L. 0576.

0010 **Cocanower, R. D.; Morris, Billy P.; Dillingham, Mat.**
1969. Computerized temperature decay–an asset to temperature logging: Jour. Petroleum Technology, v. 11, no. 8, p. 933-941.

By measuring borehole temperature change rates after shut-in and using computer extrapolation of the data, zones of injection may be defined precisely. Methods of calculation are illustrated with examples and results are presented in graphs and charts.–W69-09138.

Descriptors: Geophysics, temperature, injection wells, subsurface investigations, logging (recording), test procedures.

0568 **Cohen, Philip; Durfor, C. N.**
1966. Design and construction of a unique injection well on Long Island, New York, *in* Geological Survey Research 1966, Chap. D: U.S. Geol. Survey Prof. Paper 550-D, p. D253-D257.

An injection well of unique design and construction recently completed on Long Island, N.Y., will be used in making a series of artificial recharge experiments with highly treated sewage-plant effluent. The well, about 500 feet deep, consists of two adjacent fiberglass casings (18 inches and 4 inches in diameter) and seven auxiliary pipes, four of which are made of fiberglass and three of polyvinyl chloride. Fiberglass was used because of its advantageous chemical and strength characteristics. A stainless-steel well screen, 62 feet long, is attached to the bottom end of each casing. Water will be injected into the aquifer through the large casing and screen, and hydraulic-head changes will be measured at several points within the well and filter-pack. Geochemical reactions related to the head changes will be monitored by means of instruments in each screen.–Authors' abstract, WSP 1990.

Descriptors: Injection wells, sewage effluents, New York, artificial recharge.

0569 **Cohen, Philip; Durfor, C. N.**

1967. Artificial-recharge experiments utilizing renovated sewage-plant effluent–à feasibility study at Bay Park, New York, U.S.A. [with French abs.]: Internat. Assoc. Sci. Hydrology Pub. 72, p. 193-199.

The U.S. Geological Survey, in cooperation with the Nassau County Department of Public Works, is conducting a series of artificial-recharge experiments on Long Island, N.Y. The experiments are designed to obtain scientific and economic data needed to evaluate the feasibility of injecting highly treated sewage-plant effluent into a proposed network of "barrier" injection wells that are intended to prevent or retard the landward movement of salty water from the Atlantic Ocean into major aquifers beneath Long Island. A tertiary sewage-treatment process has been developed to upgrade the quality of the effluent so that it meets the requirements that are commonly accepted for potability in the United States. In addition, a uniquely designed experimental injection well and injection plant have been completed. The injection-well complex, which is about 500 feet deep, consists of two adjacent fiberglass casings that surmount stainless-steel screens and of seven auxiliary plastic pipes. The casings and pipes, equipped with remote-sensing down-hole geochemical probes, permit the measurement of hydraulic-head changes and related geochemical changes at several points within the injection well and the filterpack. Data from the experimental injection well and from 13 nearby observation wells are providing information regarding several aspects of the proposed artificial recharge, most notably: (1) the design and hydraulic characteristics of injection wells, (2) hydraulics of the leaky artesian aquifers, and (3) geochemical controls on artificial ground-water recharge through wells.–Authors' abstract, WSP 1990.

Descriptors: Injection, reclaimed water, artificial recharge, saline water intrusion.

0103 **Colton, G. W.**

1961. Geologic summary of the Appalachian basin, with reference to the subsurface disposal of radioactive waste solutions: U.S. Geol. Survey Trace Elements Inv. Rept. TEI-791, 121 p.

The Appalachian basin is an elongate depression in the crystalline basement complex which contains a great volume of predominantly sedimentary stratified rocks. As defined in this paper it extends from the Adirondack Mountains in New York to central Alabama. From east to west it extends from the west flank of the Blue Ridge Mountains to the crest of the Findlay and Cincinnati arches and the Nashville dome. It encompasses an area of about 207,000 square miles, including all of West Virginia and parts of New York, New Jersey, Pennsylvania, Ohio, Maryland, Virginia, Kentucky, Tennessee, North Carolina, Georgia, and Alabama. The waste-disposal possibilities of the stratified rocks in the Appalachian basin are considered in terms of the gross lithology of the sequences, general lithology of the rock units composing the sequences, and the structural attitude of the sequences in different parts of the basin. The degree of exploitation of economically significant mineral resources is considered briefly where such exploitation may affect waste-disposal possibilities. Hydrologic aspects are not in general considered.–Author's abstract, NSA 16-15001.

Descriptors: Appalachian Mountain region, crystalline rocks, radioactive waste disposal, hydrology.

0570 **Columbus, Nathan.**

1966. The design and construction of Hele-Shaw models: Ground Water, v. 4, no. 2, p. 16-22.

This paper deals with the model most frequently used in ground-water studies, the vertical Hele-Shaw model. Both the water table and the piezometric surface may be observed visually and recorded with photographic equipment whether the problem

involves the steady or the unsteady state. Since the model is transparent, the progressive movement of streamlines can be studied with the use of injected dye. The Hele-Shaw model has recently been used in place of sand models because of some of the advantages listed. One such important advantage of the Hele-Shaw model is in studies involving two liquids with two differing viscosities and specific weights. By dyeing the liquids, the movement of the interface can be studied and problems of salt-water intrusion solved satisfactorily. Although a variety of flow situations can be studied with a Hele-Shaw model, it is most advantageous with problems involving two-phase flow. Sea-water intrusion, tidal fluctuations and recharge through variable permeabilities are some of the problems that can be studied effectively.–WSP 1990.

Descriptors: Model studies, groundwater movement, steady flow, unsteady flow, tracers, porous media.

0723 **Conger, H. C.**
1967. Evaluation of oxygen corrosion in waterflood and disposal water systems–Paper presented at Rocky Mountain Regional Meeting, Casper, Wyo., May 22-23, 1967: Am. Inst. Mining Metall. Petroleum Engineers Preprint no. SPE-1775. 6 p.

The case histories presented illustrate how specially polished pipe nipples have been used and examined in the field to evaluate the seriousness of an oxygen corrosion problem. The case histories also illustrate how these test pipe nipples have been used to evaluate actual, not relative, effectiveness of a chemical treatment program to control oxygen corrosion. Data are presented and discussed showing the relationship between corrosion rates of test pipe nipples and actual in-service equipment. The case histories show how corrosion rates based on pipe test nipple data were used to project equipment life under no chemical treatment vs. chemical treatment. A comparative study of corrosion rates between the use of pipe nipples and coupons as a means of measuring oxygen corrosion is discussed. A further comparative study is made between coupon corrosion rates based on weight loss and pit depth penetration.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, injection wells, corrosion control, waste treatment, test procedures.

0616 **Conway, E. R.**
1962. Soil percolation studies, pt. 2 *of* Department of chemical engineering progress report no. 7, January 31, 1961-February 1, 1962: U.S. Atomic Energy Comm. [Rept.] TID-19189, p. 17-58.

The Ergun equation for flow through a packed bed was tested for its applicability to flow of water through soil beds in flow equipment developed for this purpose. Samples of soil were screened into various narrow size cuts and values of the shape factor were found for each cut. The form of the Ergun equation was found to be applicable to flow through the soil cuts. Blends of several cuts of soil were also tested and the Ergun equation with the shape factor values already determined was found to predict accurately the flow characteristics for the mixtures. Spherical glass beads were also tested and the Ergun equation was found to fit a bed of such particles quite accurately. A microscopic study of the various soil cuts used showed shape factors 17% greater that those found from the Ergun equation.–NSA 17-36997.

Descriptors: Flow rates, liquids, soil physical properties, seepage.

0011 **Cooper, Hilton H.; Bredehoeft, John, D.; Papadopulos, Istavros S.**
1967. Response of a finite-diameter well to an instantaneous charge of water: Water Resources Research, v. 3, no. 1, p. 263-269.

A solution is presented for the change in water level in a well of finite diameter after a known volume of water is suddenly injected or withdrawn. A set of type curves computed from this solution permits a determination of the transmissibility of the aquifer.–W69-03057.

Descriptors: Hydrodynamics, injection wells, transmissivity, mathematical models.

Costello, D. C. *See* Morgan, J. M., Jr. 0667.

Cowser, K. E. *See* Blanco, R. E. 0623.

Cowser, K. E. *See* Tadmor, Jacob. 0702.

0012 Cozzeus, F. R.
1940. Tracing underground water by means of dyes: Am. Dyestuff Reporter, v. 29, p. 169-170 [Apr.].

Tracing of water found in drilling for oil is done by placing packages of dyes in wells about to be abandoned.–Arad, USGS.

Descriptors: Groundwater movement, tracers, methodology.

0506 Crain, Leslie J.
1969. Ground-water pollution from natural gas and oil production in New York: New York Water Resources Comm. Rept. Inv. RI-5, 15 p.

Natural gas is produced throughout the central and western part of New York State, whereas oil production has been limited mainly to Allegany and Cattaraugus Counties. Oil production, and particularly secondary recovery by the water-flooding method, has resulted in pollution of ground- and surface-water supplies with oil and salt water. Pollution from active oil fields has been caused by separator units that dispose wastes on the ground, by leakage and spillage from wells, and in abandoned fields by upward movement of oil and salt water under artesian pressure through uncapped or leaking wells. Oil pollution has been reported only from areas where active or abandoned fields are populated. Pollution problems are expected to increase as areas become populated or are developed for sources of water supply. Additional study is needed for delineation, occurrence, and elimination of pollution.–*from* Author's abstract, NAB.

Descriptors: New York, hydrogeology, groundwater, water pollution, oil wastes.

0107 Crawford, P. B.
1962. How to locate casing leaks and thief zones in water injection wells: Producers Monthly, v. 26, no. 9, p. 6-7.

To locate places of leakage from water injection wells, a method is described using radioactive compounds and the gamma ray log. Sketches are used to show location of leakage into thief sands or through casing leaks. Gamma ray intensity through the steel casing can detect leaks into the formation, although leakage may occur behind the pipe.

Descriptors: Injection wells, methodology, radioactive well logging, test procedures, well casings.

0571 **Crawford, P. B.**
1966. Importance of chemical composition of the injected water on effective permeability: Producers Monthly, v. 30, no. 6, p. 11-12.

According to F. O. Jones, Jr. (Pan American Petroleum Corp.), the influence of the chemical composition of water on flooding is a most important item. The cation exchange state of a clay mineral has a strong bearing on its capability to disperse and affect permeability. Clays in the sodium exchange state resist dispersion upon exposure to fresh water. Owing to phenomena related to ordinary mass-action behavior, calcium and magnesium are accepted more readily than sodium by the clays. The result is that comparatively small portions of divalent cations are able to maintain clays in a substantially divalent cation exchange state in the presence of large excesses of sodium ion on the solutions bathing the clays. The laboratory work has shown that as little as a tenth of the salt solutions being divalent cation salts is sufficient to prevent trouble. Often as little as a twentieth suffices. Consequently, potentially sensitive cores can be exposed to fresh water with little significant change in permeability if the required proportions of divalent cation are present in both native and invading waters.—WSP 1990.

Descriptors: Injection, chemical reactions, permeability, ion exchange, clays.

0724 **Crooker, J. T.; Schnoor, F. H.**
1946. Waste water injection in the Stevens zone, Greeley field [abs.]: Oil Weekly, v. 121, no. 7, p. 56.

The injection of waste salt water in the Greeley field, begun in 1943, has steadily increased in installation size. The project was designed primarily to dispose of large quantities of salt water to prevent the contamination of surrounding farm-land, but some wells have increased their production since injection began. The water is injected through two wells without treatment, except that the oil is skimmed off. Preliminary results indicate that this method of waste water disposal compares favorably with other methods.—Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, injection wells, California, pollution abatement.

Crouse, J. D. *See* Arnold, W. D. 0676.

0572 **Curry, R. B.; Beasley, R. P.**
1962. Flow of colloidal suspensions through porous media as related to reservoir sealing: Am. Soc. Agr. Engineers Trans., v. 5, no. 2, p. 160-164.

Relationships of porous media particle size, colloidal suspension concentration, and hydraulic gradient were investigated. The porous media were composed of carborundum and the colloidal suspensions of Wyoming bentonite and distilled water. The electrokinetic property of the zeta potential using the Helmholtz-Smoluchowski equation was determined. Particle sizes of the carborundum ranged from 63 to 775 microns; hydraulic gradient ranged from 0.10 to 2.00 inch per inch; and suspension concentrations of 0.10 and 1.00 percent were used. Conclusions included: (1) Mechanical filtering is the main process by which the bentonite particles are removed from suspension by the carborundum column, (2) degree of sealing increased with decreasing particle size, increasing hydraulic gradient, and increasing concentration of the suspension, (3) the shape of the particles of the media had a considerable effect on the sealing process, and (4) the calculated zeta potential of the carborundum can be correlated with the degree of sealing.—WSP 1990.

Descriptors: Colloids, porous media, groundwater, flow characteristics.

0109 da Costa, J. A.; Bennett, R. R.
1960. The pattern of flow in the vicinity of a recharging and discharging pair of wells in an aquifer having areal parallel flow [with French abs.]: Internat. Assoc. Sci. Hydrology Pub. 52, p. 524-536.

A theoretical analysis of the flow patterns in the vicinity of recharging and discharging wells is presented. The relationships describing the flow patterns are important because of the need to dispose of various liquid contaminants, such as some types of radioactive waste, and the return of ground water after it has been warmed from use in air conditioning.—WSP 1990.

Descriptors: Waste disposal, injection wells, groundwater movement, porous media.

0013 Dagan, G.
1967. Hydrodynamic dispersion in a nonhomogeneous porous column: Jour. Geophys. Research, v. 72, no. 16, p. 4075.

A miscible flow in a porous column is considered. The one-dimensional dispersion equation is solved for the case of a porous medium whose porosity varies linearly but only slightly with distance. The solution is obtained by an expansion in a small parameter that represents the difference between the actual porosity and a uniform porosity.—AWRA 08-0003.

Descriptors: Hydrodynamics, porous media, dispersion, porosity.

0110 Davids, H. W.; Lieber, Maxim.
1951. Underground water contamination by chromium wastes: Water and Sewage Works, v. 98, no. 12, p. 528-534.

This report describes the occurence of chromium contamination of ground-water supplies in Nassau County, Long Island, New York. The first incident was reported in June 1942 in South Farmingdale when water from a well at the Liberty Aircraft plant was found to contain 0.1 parts per million chromium. A year later water from another well at the Gruman Aircraft plant in Bethpage was found to contain 3.5 ppm chromium. After World War II the Nassau County Health Department began an investigation of the problem and found the source of the contamination to be diffusion wells and shallow pits used by the local aircraft manufacturing plants to dispose of plating wastes. To correct the situation, all large industrial consumers of chromic acid were required to install treatment facilities to remove hexavalent chromium from their waste streams prior to disposal. The results are encouraging. Existing treatment facilities for handling the hexavalent chromium wastes are capable of almost completely removing this toxic element before the wastes are returned to the ground. The quality of the ground water in the contaminated areas should continually improve because hexavalent chromium is no longer entering the ground and the contaminated water is continually being diluted by recharge from rainfall and by diffusion as the water travels through the ground.

Descriptors: Industrial wastes, New York, pollutant identification, chromium, groundwater.

Davies, D. W. *See* Wright, C. C. 0817.

Davis, L. E. *See* Stiff, H. A., Jr. 0385.

Davis, Theodore F. *See* Voress, H. E. 0412.

Davis, W. B. *See* Elliston, H. W. 0727.

0725 **Davis, W. J.**
1945. West Edmond Salt Water Disposal plant initiates service to member operators: Petroleum Engineer, v. 17, no. 3, p. 106, 108, 110, 112, 114.

The organization of the West Edmond Field Salt Water Disposal Assoc. [Canada] is described. Sinclair-Prairie Oil Co. was chosen to construct and operate the system, the construction of which is discussed in detail, with the aid of photographs. Salt water is introduced through the 7-in. casing of the injection well, testing of which has shown that it will take approximately 8000 bbl./day at an injection pressure of 750 p.s.i. at the wellhead.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, injection wells, installation, operation and maintenance, foreign countries.

0636 **de Jonghe, P.; Baetsle, L. H.; Maes, W. F.; Staner, P.**
1963. Etat d'avancement du programme d'etudes sur le mouvement de radioelements dans le sol au C.E.N. a Mol [Status report of the Belgian studies programme on the movement of radioelements in soil], *in* La retention et la migration des ions radioactifs dans les sols–Colloque international, Saclay, France, 1962: Paris, Presses Universitaires de France, p. 25-40. [In French with English abs.]

The most important subjects of the study are to predict the consequences of an accidental discharge of radioelements into the soil and to evaluate the reception capacity of the soil for solid materials with a known solubility and elution degree. The program consists of two essential parts, and more specifically, of the study of the water movement in the soil and the influence of retention due to the soil materials on the transportation of radioelements by the water. Injection of radiotracers and sampling of the groundwater were developed on a micro scale. In one case samples were taken by lowering copper rods or sheets that were activated by chemisorption of the radiotracer. Equipment for direct soil- and groundwater sampling was also developed. A thorough study was carried out on the retention phenomena of radioelements by sorption on the earth materials. This leads to the determination and calculation of relative velocities. Finally for the Mol [Belgium] site a first evaluation of the storage capacity was made for materials with known solubility and containing ^{137}Cs and ^{90}Sr. Actually relatively important injections into the soil of ^{89}Sr and ^{137}Cs were prepared in order to verify the agreement between theory and field observation.–NSA 18-17341.

Descriptors: Radioisotopes, groundwater movement, sorption, soil environment, tracers, ion transport.

de Jonghe, P. *See* Baetsle, L. H. 0613.

de Jonghe P. *See* Souffriau, J. 0696.

0115 **de Laguna, Wallace**
1968. Importance of deep permeable disposal formation in location of a large nuclear-fuel reprocessing plant, *in* Subsurface disposal in geologic basins–A study of reservoir strata: Am. Assoc. Petroleum Geologist Mem. 10, p. 21-31.

The most important disposal problem in location of a large nuclear-fuel reprocessing plant is that of low-level waste. Disposal into large bodies of surface water was once common, but underground disposal into deep permeable formations seems to offer the best possibilities for disposal of low-level waste. The best method for disposal of medium-level waste is into hydraulically fractured shale, which is generally found in basin areas. A favored method for disposal of high-level waste is storage in solid form in mined cavities in salt. Thus the selection of a site that also has salt beds is advantageous, but not required, because alternate means for disposal of high-level waste can be found. Maximum permissible concentrations of radioactive nuclides in air and water have been determined. As more information is gained, the values may be increased or decreased, and this may alter the requirements for a plant site. Disposal of radioactive wastes into deep permeable formations is now practicable only for low-level waste, but it holds potential for disposal of certain medium- and high-level wastes, and also of such gaseous wastes as krypton-85.–W69-04942.

Descriptors: Radioactive waste disposal, injection wells, shales, fractures (geology), hydraulic properties, nuclear wastes.

0116 **de Laguna, Wallace; Blomeke, J. O.**
1957. The disposal of power reactor waste into deep wells: U.S. Atomic Energy Comm. Oak Ridge Natl. Lab. [Rept.] CF-57-6-23, 48 p. [Available from CFSTI]

Disposal of wastes from the processing of solid fuel elements and from solid blanket elements is discussed. The subjects considered include extraction of uranium by several methods, the removal of element jackets, the treatment of uranium-zirconium fuel elements, disposal into deep wells, the hydraulics of wells, thermal considerations of disposal aquifers, regional hydrology, potential deep-well disposal areas in the U.S., and the cost of disposal.–NSA 12-12344.

Descriptors: Radioactive waste disposal, waste treatment, hydrodynamics, economics.

0118 **de Laguna, Wallace; Sexton, R. C.; Struxness, E. G.; and others.**
1962, Disposal by hydraulic fracturing, pt. 1 *of* Radioactive waste disposal, *in* Health Physics Division annual progress report for period ending July 31, 1962: U.S. Atomic Energy Comm. Oak Ridge Natl. Lab. [Rept.] ORNL-3347, p. 5-10.

Water injections were made in the injection well at 986 and 966 ft. These tests confirmed that a fluid loss additive is not a necessary component of the mix to be used in the waste injections. On the last water injection, the sand-erosion technique for slotting failed to cut the casing after 20 min at a jet pressure of 2600 psi. An estimate of the probable operating cost of the shale-fracturing plant shows that the cost of the mix and the well life are the significant variables. The well life can be significantly extended by making the batch size large. The Densometer controlled the density of the slurry to within 0.1 lb/gal of the desired density, which is entirely acceptable. Following construction of the surface plant, a series of five injections was made to determine the performance of the plant and the underground behavior of waste slurries of different compositions. In general, the operation of the surface plant was smooth and satisfactory.–Authors' abstract, NSA 19-08674.

Descriptors: Tennessee, radioactive waste disposal, injection wells, hydrodynamics, deep wells, fractures (geology).

0119 **de Laguna, Wallace.**
1968. Radioactive waste disposal by hydraulic fracturing [Abs. of paper presented at Natl. Water Works Assoc. Ann. Mtg., 1968, Washington, D. C.]: Ground Water, v. 6, no. 6, p. 47.

The nuclear power industry produces a wide variety of radioactive wastes, including solids, liquids, and gases, and so has not just one waste-disposal problem, but many. The nuclear power plants themselves produce very little waste and represent no problem. Large quantities of waste arise only at the chemical plants where spent nuclear fuel is reprocessed to recover the remaining fissionable material and to remove the fission products—the "ashes" of the nuclear power industry. The solid waste, most of which is low level, is satisfactorily disposed of by burial in the ground. The gaseous wastes are, at present, discharged into the air; this is not entirely satisfactory, but practical alternatives have been hard to find. The liquid wastes fall into three fairly distinct categories. (1) The low-level wastes are decontaminated, usually by chemical treatment, ion exchange, or evaporation, and are then discharged to the environment. (2) The high-level wastes, at present, are being held in tank storage while safe methods to convert them into solids for ultimate disposal in mined cavities in salt are being perfected. (3) The medium-level wastes could also be converted to solids, but the cost is disproportionate. However, these wastes contain too much radioactive material for discharge to the environment, even after treatment, although this has been attempted at some remote installations. The method now in operation at the Oak Ridge National Laboratory for disposing of these wastes grew directly out of the process of hydraulic fracturing as practiced by the petroleum industry. We have drilled a well about a thousand feet deep into a strong, virtually impermeable shale. A horizontal slot is cut through the steel casing near the bottom of the well, and a mixture of medium-level radioactive waste and Portland cement is pumped down under sufficient pressure to fracture and force open the shale parallel to the bedding. The waste-cement mixture moves out in a thin horizontal sheet deep underground, where it hardens into a new layer of "rock." The whole overlying rock mass is gently uplifted to make room for the injected material. When sufficient material has been injected into one fracture, the bottom of the well is plugged with cement and a new fracture started at a slightly higher level. The method is not unduly expensive, and where the geology is favorable, it provides a relatively simple method for placing the medium-level wastes where they can do no harm and where they require no further attention.—Author's abstract.

Descriptors: Radioactive waste disposal, injection wells, fractures (geology), methodology.

0507 de Laguna, Wallace.
1962. Engineering geology of radioactive waste disposal, *in* Reviews in engineering geology, V. 1: New York, Geol. Soc. America, p. 129-160.

Three possible methods for future waste disposal are now being investigated: fixation in or as solids, disposal into salt, and disposal into deep porous formations. The fixation methods now under investigation all involve heating the waste, are expensive, and are dangerous to the operators, but the solid product once formed would probably be no further hazard. Disposal into salt can be arranged by mining the salt through shafts, which is expensive and will require shaft maintenance. Alternatively, cavities can be dissolved in salt by pumping fresh water down wells, but either such cavities must be small, or their use must be restricted to the disposal of medium-level waste if they are not to overheat. Cavities in salt should provide safe storage, for salt is quite impermeable, but the use of salt as a structural material raises questions. Disposal through deep wells also appears to have serious limitations. The wastes will have to be filtered and diluted and perhaps treated to reduce corrosion of the disposal wells. Heat-generation problems will prevent the disposal of fresh, high-level waste. However, the very large potential storage capacity of deep porous formations suggests that the method may be applicable for the very large amounts of waste that will eventually be produced. Recently an investigation has begun of the possibility of disposing of waste mixtures into shale by fracturing. The subject is controversial, and although the initial experiments look promising it will take much experience with low-level waste before the future of the method can be evaluated.–NAB.

Descriptors: Radioactive waste disposal, methodology, waste treatment, injection, engineering geology.

0637 de Laguna, Wallace; Tamura, Tsuneo; Sexton, R. C.; and others.
1963. Disposal by hydraulic fracturing, sec. 2 *of* Radioactive waste disposal, *in* Health Physics Division annual progress report for period ending January 30, 1963: U.S. Atomic Energy Comm. Oak Ridge Natl. Lab. [Rept.] ORNL-3492. p. 13-18.

An acceptable waste mix was developed that is usable with waste solutions having a wide range of concentrations and chemical compositions. It is probable that an equally acceptable, cheaper mix can be developed that will require less of the expensive fluid-loss additive. An injection and an observation well were drilled, logged, cased, and cemented. These wells are 1080 ft deep; the main casing string of the injection well is 5.5 in. OD, and the main casing string of the observation well is 2.875 in. OD. The design of the injection plant is virtually complete. The equipment consists of waste storage tanks, a waste transfer pump, four bulk storage tanks to store the solid constituents of the mix, a jet mixer, a high-pressure injection pump, and a standby injection pump and mixer. The mixer, injection pump, and wellhead valving will be installed in cells to reduce radiation exposure and limit the area of possible contamination. In the proposed experiments several 40,000-gal batches of intermediate-level waste solution will be mixed with cement and injected into a shale formation at an approximate depth of 900 ft. At some time after the completion of the third injection the formation will be core drilled to verify the location of the grout sheets and to evaluate the various mixes.–Authors' abstract, NSA 17-39297.

Descriptors: Fractures (geology), injection, hydrostatic pressure, Tennessee, radioactive waste disposal, hydrodynamics.

0638 de Laguna, Wallace; Tamura, Tsuneo; Weeren, H. O.; and others.
1968. Engineering development of hydraulic fracturing as a method for permanent disposal of radioactive wastes: U.S. Atomic Energy Comm. Oak Ridge Natl. Lab. [Rept.] ORNL-4259, 261 p. [Available from CFSTI.]

The development of the process to dispose of radioactive waste by injection in the earth is described. Subsequent experiments are explained. The geologic setting in the experimental Oak Ridge waste injection area is described. The engineering design of equipment and facilities is given.–NSA 22-48916.

Descriptors: Radioactive waste disposal, injection wells, fractures (geology), hydrodynamics, Tennessee.

0129 de Witt, Wallace, Jr.
1960. Geology of the Michigan basin with reference to subsurface disposal of radioactive wastes: U.S. Geol. Survey Trace Elements Inv. Rept. TEI-771, 100 p.

The Michigan basin covers about 122,000 sq miles and has an aggregate thickness of 14,000 ft of sedimentary rocks in the center of the basin. The rocks represent 47% carbonate, 23% sandstone, 18% shale, and 12% evaporite. The lithology, which indicates several closely related depositional environments, consists of Late Cambrian near-shore clastics, Early Ordovician to Middle Devonian carbonate-evaporites, Late Devonian and Mississippian basinal clastics, and coal-bearing Pennsylvanian and possibly Permian sediments. The thick sequences of undeformed shale and thick beds of evaporites, may serve for possible subsurface disposal of liquid or solid radioactive

waste. Liquid radioactive waste might be disposed of in cavities or hydraulically fractured shale or anhydrite sequences. The possible migration of waste upward into potable water supplies would demand extreme caution and careful study.–Tulsa Univ., Inf. Services Dept.

Descriptors: Radioactive waste disposal, Michigan, injection, sedimentary rocks, hydrogeology, groundwater basins.

0111 **Dean, B. T.**
1965. The design and operation of a deep-well disposal system: Water Pollution Control Federation Jour., v. 37, no. 2, p. 245-254.

At Pensacola, Fla., a deep injection well is being operated by Chemstrand Co. for the disposal of aqueous process wastes from the manufacture of nylon. The design criteria (especially the casing program), the construction, and operation of this system are described in detail. The geological formations involved in this disposal system are shown in a cross-section map. Disposal is into the lower limestone of the Floridan aquifer. In this aquifer, the direction of flow of formation water is from the surface outcrop in southern Alabama to some subsurface discharge in the Gulf of Mexico. The presumed flow of waste as it is ejected into the well is along this course. Protection is offered by clay layers to the surface strata of sand and gravel, from which potable water supplies are drawn.–WSP 1990.

Descriptors: Injection wells, Florida, industrial wastes, waste disposal.

0680 **DeBuchananne, George D.; LaMoreaux, Philip E.**
1962. Geologic controls related to ground-water contamination: Water Well Jour., v. 16, no. 3, p. 8, 40-44.

Geology exercises a dominant control over the occurrence and movement of ground water. Since a contaminant or contaminated ground water is subject to the same physical laws as pure water, then geology actually controls ground-water contamination. If a contaminant is released to the natural environment the extent to which it will affect the ground water will depend to a large extent on the geologic factors that affect the movement of the water and the capacity of rock materials to absorb and adsorb the contaminant. As the movement of most ground water is very slow, varying from less than an inch to a few feet per day, time also is a major factor.–*from* Authors' summary.

Descriptors: Groundwater, water pollution, geology, migration, groundwater movement.

0113 **Deere, Don U.; Langhaar, Henry L.; Boresi, Arthur P.**
1959. An evaluation of the factors influencing the stability of a large underground cavity: U.S. Atomic Energy Comm. Oak Ridge Natl. Lab. [Rept.] AECU-4654, 85 p.

The factors that influence the state of stress surrounding a deep underground cavity are discussed and evaluated relative to their effects on the stability of a cavity in granite, salt rock, or other hard rock. The importance of knowing the initial state of stress in the rock and of the presence of geologic discontinuities is discussed. A theoretical analysis of the stress distribution around various shaped cavities in an elastic medium is presented. The depth of the plastic zone developed around cavities under certain conditions is studied.–NSA 15-0545.

Descriptors: Rock properties, evaluation, theoretical analysis.

0594 **deJosselin de Jong, G.**
1958. Longitudinal and transverse diffusion in granular deposits: Am. Geophys. Union Trans., v. 39, no. 1, p. 67-74.

The flow of liquids through porous media is defined by Darcy's law when bulk movement is considered. In several cases, however, it is of interest to know how elements of volume or discrete particles carried by the liquid will travel. For instance, in the study of ground-water movement, radioactive salts are injected into the soil. The salt will travel through different pores and after a given interval of time will arrive at different places, their distance from the starting point being dependent upon how tortuous was the path they followed. This results in a dispersion of the injected salt which is additional to the molecular diffusion. This dispersion caused by the geometry of the pore canal system also has the character of a diffusion with a greater value in the mean direction of flow than perpendicular to this direction. Therefore, two different concepts, longitudinal diffusion and transverse diffusion have been introduced by others in order to indicate this phenomenon. In this paper, the pore system of a packed bed is represented by a system of canals in order to permit probability computations for a foreign particle carried by the pore liquid movement to arrive at a certain place in a certain time. The computations lead to explicit values for the coefficient of longitudinal and transversal diffusion. A test device is described which permits the determination of the longitudinal diffusivity. The relationship between test result and theory is discussed.—*from* Author's introd. and abs.

Descriptors: Diffusion, dispersion, porous media, groundwater movement, probability.

0827 **deJosselin de Jong, G.**
1961. Dispersion in flow through porous media, *in* Kaufman, W. J., ed., Ground disposal of radioactive wastes conference, Berkeley, Calif., Aug. 25-27, 1959, Proc.: U.S. Atomic Energy Comm. Div. Tech. Inf. [Rept.] TID-7621, p. 123-130.

A discussion of the causes of dispersion is presented. The aspect of dispersion examined is exemplified by the case in which a fluid in a porous medium is displaced by another fluid and the interface between the two fluids becomes diffuse. The macrostructural and microstructural causes of dispersion are discussed along with the effects of molecular diffusion.—NSA 15-30325.

Descriptors: Porous media, dispersion, interfaces, diffusion.

0127 **Deutsch, Morris.**
1963. Ground-water contamination and legal controls in Michigan: U.S. Geol. Survey Water-Supply Paper 1691, 79 p.

Manmade and natural contaminants have entered many of the aquifers in Michigan either by percolation through the zone of aeration or by direct injection into the aquifers. In addition naturally occurring saline waters have been induced into other aquifers by overpumping or unrestricted flow from artesian wells. In spite of the contamination that has occurred, however, the total amount of ground water that has been spoiled is only a small part of the total resource. Overall legal authority to control most types of ground-water contamination in the State has been assigned by the Michigan Legislature to the Water Resources Commission, although the Department of Conservation and the Health Department also exercise important water-pollution control functions. The Michigan Supreme Court, in an important case upholding the power of the Water Resources Commission to control pollution of ground water, in effect has introduced the doctrine of reasonable use into the law of the State. Excluding controls administered by the Department of Conservation on activities of the oil and gas industry, however, legal controls have not been used to abate

intrusion of natural saline waters into fresh-water aquifers in response to pumping and other manmade changes in the hydrologic regimen.–*from* Author's abstract.

Descriptors: Michigan, groundwater, water pollution, legal aspects, injection, waste disposal.

0128 **Deutsch, Morris.**
1965. Natural controls involved in shallow aquifer contamination: Ground Water, v. 3, no. 3, p. 37-40.

Shallow-water aquifers, commonly the most important ground-water sources, are also the most susceptible to contamination. Contaminants enter directly, through wells or secondary openings in consolidated rocks, by percolation through the zone of aeration, by induced infiltration through the zone of saturation, or by interaquifer leakage or flow through open holes. Natural removal or degradation of contaminants takes place by filtration, dispersion, sorption, ion exchange, oxidation, and biochemical processes, with all these phenomena controlled by the physical environment, structure, mineralogy, and hydraulic characteristics of earth materials contacted by the liquid wastes. All these factors must be considered in any attempt to solve ground-water contamination problems.–NAB.

Descriptors: Water pollution, waste disposal, hydrodynamics, groundwater, hydraulic properties, chemical reactions.

Devine, J. M. *See* Schmidt, Ludwig. 0358.

Devine, J. M. *See* Schmidt, Ludwig. 0794.

0114 **Dial, L. H.**
1943. Salt water disposal in the east Texas field: Petroleum Engineer, v. 15, no. 2, p. 59-62.

The total permissible oil withdrawals in the East Texas field amount to 383,000 bbl. per day, necessitating the handling of 365,000 bbl. salt water. This water must be injected back into the formation to maintain reservoir pressure and to avoid pollution of surface streams. There are now 61 salt-water disposal wells in the field, more than one-third of which are owned and operated by the East Texas Co. This company gathers the water from a number of adjacent leases and runs it through central treating plants to salvage out oil and to remove dissolved solids and microorganisms that cause trouble if put back in the pay formation. Injection wells become plugged in spite of clarification and sterilization of the input water, and are cleaned out by backflowing under high pressure, followed by acid treatment. If such procedure is unsuccessful, the pay section is underreamed to remove the plugging substances. The sand will not take sufficient quantities of water by gravity feed alone, so pumps are used.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, injection wells, Texas, operation and maintenance, waste treatment, pollution abatement.

0130 **Dial, L. H.**
1944. Design, construction and operation of a salt water disposal system: Petroleum Engineer, v. 15, no. 12, p. 51-56.

The W. S. Morris disposal system recently put into operation by the East Texas Salt Water Disposal Co. is described. The system comprises an oil skimming unit, an aeration unit for removing gases and oxidizing the iron and bacteria in the skimmed water, chlorinating and alum treating pits, and pressure sand filters for removal of solids.—Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, injection wells, Texas, design, construction, waste treatment.

Dial, L. H. *See* Morris, W. S. 0285.

Dietrich, J. A. *See* Hoover, D. B. 0472.

Dillingham, Mat. *See* Cocanower, R. D. 0010.

0133 **Dolan, John P.; Einarsen, Charles A.; Hill, Gilman A.**
1957. Special applications of drill-stem test pressure data: Am. Inst. Mining Metall. Petroleum Engineers Trans., v. 210, Tech. Paper 4667, p. 318-324.

Drill-stem testing is a procedure designed for sampling the formation fluid and for determination of hydrodynamic force acting on the fluid in the formation. This paper discusses how the following formation characteristics can be determined mathematically from drill-stem test pressure charts: true formation pressures, effective permeability of the entire section tested, well productivities, wellbore damage, and possible detection of barriers (faults, pinchouts, etc.). This paper also presents a practical method for immediate determination of effective permeability and wellbore damage from successful double shut-in pressure tests. A list of recommendations for improving the reliability of drill-stem test pressures is also presented.—Authors' abstract.

Descriptors: Drill holes, test procedures, permeability, deep wells, hydrostatic pressure, hydrogeology.

Dolgikh, P. F. *See* Mal'tsev, E. D. 0685.

0134 **Donaldson, E. C.**
1964. Subsurface disposal of industrial wastes in the United States: U.S. Bur. Mines Inf. Circ. 8212, 34 p.

Gives results of study of subsurface disposal in the United States showing that in eight States a wide variety of industrial wastes is being injected into formations ranging in age from Precambrian to Recent. More than 30 wells ranging in depth from 300 to 12,000 feet are used for waste disposal into subsurface formations, which include unconsolidated sand, sandstone, vugular limestone, and fractured gneiss.—Randolph, USGS.

Descriptors: Waste disposal, United States, injection wells, geologic formations, data collections.

Dornbush, James N. *See* Anderson, John R. 0049.

Doty, L. F. *See* Warner, D. L. 0588.

Dracka, Oldrich. *See* Mackrle, Vladimir. 0850.

0135 **Drescher, William J.**
1965. Hydrology of deep-well disposal of radioactive liquid wastes, *in* Fluids in subsurface environments—a symposium: Am. Assoc. Petroleum Geologists Mem. 4, p. 399-406.

Except for small quantities, disposal of radioactive liquid wastes by containment is not practical and may be possible in only a few areas. Deep disposal will probably be by confinement in certain geologic horizons through which wastes move at measured rates. Movement of fluids tends to be restricted in the basal parts of sedimentary basins, but any assumption that wastes introduced there would not eventually move out needs careful scrutiny. Anomalous low-pressure zones should not be considered safe until or unless the reason for the low pressure can be explained. Geochemical factors may greatly influence movement. A system of monitoring is a prime requisite.—NAB.

Descriptors: Groundwater, water pollution, radioactive waste disposal, injection wells, sedimentary basins (geological).

0513 **Drescher, William J.**
1963. Hydrologic considerations in deep-well disposal of radioactive liquid wastes [abs.]: Am. Assoc. Petroleum Geologists Bull., v. 47, no. 12, p. 2073.

Disposal of radioactive liquid wastes through deep wells may be categorized as containment or confinement. Containment means the placement of wastes under conditions that preclude their movement out of a definable zone. Confinement means the placement of wastes in a zone where movement may take place under restricted conditions that can be controlled or monitored. Disposal of liquid wastes on a continuing basis by containment probably is not practical except for small quantities and may be possible in only a few areas. It is probable, therefore, that any deep disposal of radioactive liquid wastes will be confinement of wastes in certain geologic zones through which they will move at measured rates. Hydrologic principles applied to the available data indicate that there is circulation of fluids in almost all sediments. Movement of fluids tends to be restricted in the basal parts of sedimentary basins, but any assumption that wastes introduced into a basin would not eventually move out of the basin or to the near-surface formations should be carefully scrutinized. Introduction of wastes into an anomalously low-pressure zone should not be considered safe unless the reason for the low pressure can be explained. Data necessary to define the hydrodynamics of fluids injected through deep wells will be expensive to obtain, and many of them will have to be collected for each particular disposal site. Geochemical factors may influence greatly the movement of radioactive material in deep formations. A system of monitoring, and possibly removal, is a prime requisite of deep-well disposal of radioactive wastes. Initial disposal activities necessarily will be on an experimental basis pending the results of such monitoring.—*from* Author's abstract, NAB.

Descriptors: Radioactive waste disposal, injection wells, hydrodynamics.

0726 **Dunlop, A. K.; Howard, R. L.; Raifsnider, P. J.**
1969. ODASA–oxygen scavenger and inhibitor: Materials Protection, v. 8, no. 3. p. 27-30.

The dual nature (part oxygen scavenger and part inhibitor) of ODASA, a water-soluble alcoholic solution of the sulfur dioxide adduct of oleyl diamine, made possible 3 years of successful use of annular salt-water disposal systems, which previously had been plagued by aggravated pitting attack due to trace oxygen contamination and by serious general corrosion because of acid. Laboratory compatibility studies on ODASA disclosed an adverse effect of high sulfate ($\geqslant$1,000 ppm), combined with low chloride content ($<$3,000 ppm), and influence of other variables (calcium, pH, and impurities).–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, injection wells, corrosion control.

Durfor, C. N. *See* Cohen, Philip. 0568.

Durfor, C. N. *See* Cohen, Philip. 0569.

Eakin, J. L. *See* Eckard, W. E. 0451.

Eastwood, E. R. *See* Tamura, Tsuneo. 0704.

0451 **Eckard, W. E.; Eakin, J. L.; Heath, L. J.**
1968. Improving permeability in underground formations–A progress report: Producers Monthly, v. 32, no. 3, p. 54.

Two new research projects have been initiated to achieve increased fluid flow capacity in oil and gas reservoirs, underground gas-storage reservoirs, and in oil shale formations using technology from the explosives and space industries. Bureau of Mines petroleum research engineers have injected and detonated a chemical explosive in an underground fracture system to alter formation permeability. To obtain some idea of the effectiveness of thermal methods in altering permeability, they have injected and burned a high-energy fuel-oxidant mixture in porous reservoir rock samples. Explosive fracture experiments have been conducted at depths to about 148 ft. in an oil shale formation using from 40 to 190 qt. of explosives. After detonation, average air injection rate between wells, at essentially the preshot injection pressure, was improved from threefold to eightfold. Laboratory experiments have proven that combustion of a monopropellant within the rock interstices in two different types of sandstone specimens is technically feasible. Permeability increases have been achieved from 1.5- to 10.3-fold although matrix temperature was raised only to approximately 450°C. Sandstone samples have been chemically altered and essentially complete disaggregation has been accomplished.–Authors' abstract.

Descriptors: Permeability, rock properties, injection, underground storage, fractures (geology).

0136 **Eddy, G. E.**
1965. The effectiveness of Michigan's oil and gas law is preventing pollution of the State's ground waters: Ground Water, v. 3, no. 2, p. 35-36.

With the exception of a few special cases, there has been no pollution of fresh ground water from oil wells, gas wells and dry holes drilled in Michigan since 1925. This is

especially significant since water for over 90 percent of Michigan's rural population and about 70 percent of the total population, exclusive of the Detroit metropolitan area, is supplied by ground-water sources. The most classic exception is in the Saginaw Valley where abandoned wells drilled for salt, coal and oil remain unplugged. Special emphasis is given to the proper plugging of wells as the most important phase of the program to protect fresh water. The present protective oil and gas conservation law—Public Act 61 of 1939—is good. Its flexibility allows needed rules and regulations to be adopted as the necessity arises without having to go to the legislature.—Author's abstract.

Descriptors: Water pollution, groundwater, conservation, legal aspects.

0179 **Eddy, G. E.**
1967. Subsurface disposal of industrial wastes: Interstate Oil Compact Comm. Comm. Bull., v. 9, no. 2, p. 71-79.

The results of a study performed by the Interstate Oil Compact Commission on underground disposal of industrial waste are reported. The report is divided into 4 parts, the first of which is a discussion of general pollution problems with information on the nature and seriousness of the pollutants and the treatment methods being used. Some subsurface disposal problems are discussed next. The problems include such topics as compatibility of fluids and rock, contamination, geological aspects, injection pressures, and legal aspects. A summary is then presented on the disposal systems and wells now in use in various states. The final portion of the report is intended to establish some guidelines for processing applications for disposal systems, drilling, monitoring, and abandonment of wells.—Tulsa Univ., Inf. Services Dept.

Descriptors: Industrial wastes, waste disposal, pollution abatement, injection, chemical reactions, geology.

Eddy, G. E. *See* Ives, R. E. 0212.

Edgerton, J. H. *See* Bowen, B. M., Jr. 0104.

0467 **Edigarov, G. N.**
1958. Sostoyaniye ochistnykh sooruzheniy kanalizatsii na promyslakh npu Bavlyneft' [Status of waste purification and disposal in the oil fields of Bavlyneft], *in* Konferentsia po bor'ba zagryazneniem vodoemov, Moscow, 1956 [Conference on struggle with pollution of reservoirs by waste waters]: Moscow, Gosudarstvennoe Nauchno-Tekhnicheskoe Izdatel'stvo Neftyanoi i Gorno-Toplivnoi Literatury [State Scientific—Technical Publishing House of Petroleum and Mining Industry], p. 40-43. [In Russian.]

Oilfield waste waters are collected at the Bavly oil-gathering station and, after preliminary settling, are pumped into a 915 m deep disposal well which extends into the saccharoidal dolomites of the Serpukhov substage of the Lower Carboniferous. The oil concentration in the waste waters is ≤30 mg/l after settling. The waters are supplied at 2 atm gage. The disposal rate is 100-200 cu m/day. It is shown that purification may be effected by coagulation and filtering, to reduce the oil concentration from 150 mg/l to trace amounts, and the iron concentration from 70 to 0.1 mg/l.—Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, foreign countries, injection, operations, waste treatment.

0014 **Edmund, R. W.; Goebel, Edwin D.**
1968. Subsurface waste-disposal potential in Salina basin of Kansas, *in* Subsurface disposal in geologic basins–A study of reservoir strata: Am. Assoc. Petroleum Geologist Mem. 10, p. 154-164.

The Salina basin, Kansas, was studied to determine its suitability for waste disposal by injection wells. Cambrian sandstones, Pennsylvanian shales, and Permian salt beds are good potential storage reservoirs. The direction of natural fluid flow in the basin appears to be southward. The basin is a simple asymmetric syncline with a uniform gentle southward axial tilt, and is deepest on the SW flank. In most of the basin, Pennsylvanian and Permian rocks crop out. Basin rocks range in age from Cambrian to Tertiary. Water is found in all deep porous rocks penetrated by exploratory drilling.–W69-04946.

Descriptors: Injection wells, waste disposal, Kansas, groundwater basins.

Eichholz, G. G. *See* Champlin, J. B. F. 0008.

Einarsen, Charles A. *See* Dolan, John P. 0133.

0137 **Elliott, A. M.**
1967. Subsurface waste disposal problems, *in* Industrial Water and Waste Conference. 7th, Texas Water Pollution Control Assoc., Austin, Tex., June 1-2, 1967, Proc.: Austin, Texas Univ., p. III-37–III-47.

This paper discusses some of the problems that arise in the design, completion and operation of a subsurface waste injection well by tracing the history of an actual well. The well used by the Plastics Department of the E. I. du Pont de Nemours and Company at Orange, Tex., is 5,194 feet deep and consists of a stainless steel casing to resist the corrosive effects of the acid waste. Originally, the three lowest aquifers were to be perforated. However, a fourth was also included when sand came back into the casing during the perforating operation. This sand was removed and the well was placed in operation. Well head pressure increased over a two-month period and finally reached the operating limit. Field checks indicated that sanding back was the cause of malfunction. The decision was made to remove the sand from the well and gravel pack the formations in an attempt to block the entry of fine formation sands. The gravel-packing operation was complicated by a rupture in the work-over rig tubing used to introduce the mixture. The tubing became imbedded within the casing and it was necessary to cut it off, wash out the residual gravel, and fish out the broken tubing. Subsequent operation proved gravel packing to be unsuccessful as was an extended period of low injection flow rates. The lower three aquifers were finally abandoned by setting a plug above them. A new zone was perforated above the remaining zone using a very small diameter hole in the casing. This configuration has operated successfully for the past several months.–*from* Author's summary.

Descriptors: Injection wells, Texas, design criteria, operation and maintenence, construction.

0015 **Ellis, W. R.; Kevi, L.; Wiebenga, W. A.**
1968. The investigation of water flow through porous mediums by means of radiotracers: Water Resources Research, v. 4. no. 2, p. 413-416.

The radioisotope bromine 82 was used to measure the flow of water through a packed sand column. It was shown that the commonly accepted Dupuit-Forchheimer

assumption did not apply under these conditions. Some information was also obtained on lateral dispersion using iron gauzes and copper 64 solution.–AWRA 08-0116.

Descriptors: Flow rates, porous media, dispersion, radioisotopes, tracers, laboratory tests.

0138 **Elliston, H. H.**
1946. Design and operation of subsurface salt-water disposal system: Oil Weekly, v. 122, no. 2, p. 34-38.

In the first article of a series the reasons for unitized underground salt-water disposal and a discussion of the economic and legal problems involved are presented. Special engineering problems involved are discussed briefly. A nonprofit association is favored over a corporation for this purpose. Articles of agreement for a salt water disposal association are discussed. In order to simplify accounting and metering and thereby reduce overhead, it is recommended that charges should be based on the number of producing wells of each operator, regardless of the amount of salt water produced, number of producing zones, or distance from the disposal well. Future articles will cover (1) separation of oil, water, and gas at tank batteries, (2) gathering systems, (3) injection water treating plants, (4) injection well, (5) company owned system, (6) salt water disposal associations.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, legal aspects, injection wells, organizations.

0728 **Elliston, H. H.**
1943. Salt-water disposal systems: Am. Petroleum Inst. Drilling and Production Practice, 1942, p. 98-117.

Salt water incident to the production of oil and gas should be disposed of through a large abandoned well located near the center of the producing area at an elevation such that the water need not be pumped. Liners should be set in the well by running a full string of casing having a welded bottom section and forcing the cement back of the casing the required distance. Full strings of cement-lined tubing may be run in the well and set with a packer. The gathering lines should be laid to exact grade and be of non-corrosive pipe, such as cement-asbestos, coal-tar wood fiber, cement-lined cast iron, cement-lined steel, or salt-glazed vitrified clay. The pump should be so constructed that dissimilar metals do not come into contact with each other in the presence of salt water. The water may be treated before injection by chemical treatment, sedimentation, filtration, or by a combination of these methods. A method for determining the proper size of the sedimentation tank (preferably rectangular) is given. Tables listing details on "various" salt-water disposal plants are included.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, injection wells, design criteria, equipment, waste treatment.

0727 **Elliston, H. W.; Davis, W. B.**
1944. A method of handling salt-water disposal including treatment of water: Oil and Gas Jour., v. 43, no. 4, p. 59-61.

A survey of 256 salt-water disposal systems having an initial investment of $4,204,965.86 and 86 systems having an operating cost of $1,213,253.05 is reported. The open type of disposal system generally involves the steps of: (1) aeration, (2) coagulation, (3) sedimentation, and (4) filtration. In some areas where bacteria are thought to be aiding in plugging lines, chlorination is also a step in the treating process. Each of these steps is discussed briefly. The closed type system, semiclosed

system and stabilization of water are also discussed briefly. Pertinent data on 22 selected disposal systems are tabulated.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, injection wells, operating costs, waste treatment.

Emara, S. *See* Mitry, E. 0158.

0729 **Embshoff, A. C.**
1936. Treating oil-field waters: Oil and Gas Jour., v. 34, no. 52, p. 199, 202.

There is no one method of treatment applicable to all waters or brines to render them suitable for flooding purposes or for disposal underground. Some require no treatment; some require only clarification for the removal of suspensions; some require aeration to remove hydrogen sulfide and to oxidize and precipitate any iron present with subaddition of alkali before filtering to establish equilibrium when the liquid is undersaturated with regard to calcium carbonate; some require stabilization to overcome supersaturation with respect to the calcium carbonate by the introduction of carbon dioxide or of acid previous to filtration, or by bringing the liquid into contact with precipitated calcium carbonate. The use of calcium carbonate is probably the most practical as it in itself cannot result in under or supersaturation with respect to the calcium carbonate.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, injection wells, waste treatment.

0141 **Empson, F. M.; Boegly, W. J., Jr.; Bradshaw, R. L.; and others.**
1963. Radioactive waste disposal in salt [abs.]: Geol. Soc. America Spec. Paper 73, p. 273-274.

Studies of radioactive waste disposal into salt are designed to define and to solve problems involved in the storage of liquid and solid wastes in natural salt deposits. The variables studied have included the chemical reactions of salt-saturated liquid waste, the stability of cavities excavated in salt structures when influenced by heat, and the flow of heat through salt. Field experiments have been carried out in a mine using simulated fuel-processing waste in excavated cavities. Heat transfer rates agreed with the computations on which the experiments were based. Gaseous reaction products could be controlled by maintaining acidity below 4.0 *M* or temperature below 60°C. Continuing studies emphasize the thermal and plastic-flow problems involved in disposal of packaged high-level solids produced by calcination of fuel-processing waste. Computations have been made of temperatures expected for containers of waste of various ages placed in salt. Heat-dissipation experiments in salt using electrical heaters have been carried out, and salt temperatures confirm computations. Field experiments with 6-5/8 inch OD cylindrical heaters in which salt reaches temperatures greater than 200°C confirm laboratory studies showing that salt shatters in the temperature range of 200°-300°C. No other damaging effects have been found in either the floor or the wall of a mine which has slightly different chemical composition and different stress patterns. Computations of gamma dose show that only in small areas immediately adjacent to the waste containers does the integrated dose become greater than 1×10^8 rad, approximately the level at which physical properties are affected.–Authors' abstract.

Descriptors: Radioactive waste disposal, underground storage, salts, feasibility studies, chemical reactions, rock properties, thermal properties.

0509 **Empson, F. M.; Boegly, W. J., Jr.; Bradshaw, R. L.; and others.**
1966. Demonstration of disposal of high-level radioactive solids in salt, *in* Symposium on salt, 2d,–V. 1, Geology, geochemistry, mining: Cleveland, Ohio, Northern Ohio Geol. Soc., p. 432-443.

Use of salt formations as a disposal site has been under investigation since 1956. Plans are presented for a demonstration of the disposal of solid radioactive wastes in salt of Permian age in the Hutchinson Member of the Wellington Formation, using the inactive mine of the Carey Salt Company at Lyons, Kans. Objectives of this Project Salt Vault include: determination of stability of salt under influence of heat and radiation, and information on creep and plastic flow of salt needed for the design of an actual disposal facility.–NAB

Descriptors: Kansas, radioactive waste disposal, salts, underground storage, feasibility studies, geologic formations.

0609 **Empson, F. M.; Boegly, W. J., Jr.; Bradshaw, R. L.; and others.**
1964. Demonstration of disposal of high-level radioactive solids in salt: U.S. Atomic Energy Comm. Oak Ridge Natl. Lab. [Rept.] ORNL-P-1568, 33 p. [Available from CFSTI.]

A description is given of Project Salt Vault, a demonstration using irradiated ETR fuel assemblies and the inactive mine of the Carey Salt Company at Lyons, Kansas. The engineering and scientific objectives of Project Salt Vault are outlined. The instrumentation and the canning and shipment of the ETR fuel assemblies are described. The status of Project Salt Vault is given.–NSA 19-45689.

Descriptors: Radioactive waste disposal, test procedures, Kansas, salts, underground storage, feasibility studies.

0610 **Empson, F. M.; Bradshaw, R. L.; Boegly, W. J., Jr.; and others.**
1966. Project Salt Vault–Design and operation: U.S. Atomic Energy Comm. Oak Ridge Natl. Lab. [Rept.] ORNL-P-2058, 20 p. [Available from CFSTI.]

The demonstration disposal of high-level radioactive solids, initiated in November 1965 in the Carey salt mine at Lyons, Kansas, is known as Project Salt Vault. The objectives of the demonstration are: confirmation of feasibility and safety of disposal in salt mines; demonstration of required waste-handling equipment and techniques; determination of the stability of salt under the influence of heat and radiation; and collection of information on creep and plastic flow of salt, which is needed for the design of an actual disposal facility. Fourteen irradiated fuel assemblies from the Engineering Test Reactor serve as a source of radiation in lieu of actual solidified wastes. The assemblies, contained in seven cans, have been placed in an array of holes in the floor. During the course of the 2-year test, four sets of assemblies will be used to achieve a peak dose to the salt of about 8×10^8 rad and the temperature of the adjacent salt will be raised to 200°C with auxiliary electrical heaters. A second array will be installed in less pure salt at the end of the first 6 months, using the fuel assemblies which are now in the main array. A third array, consisting only of heaters, is being operated as a control to determine those effects due solely to heat. In addition to the radioactive and control arrays, a ribpillar will be heated by electrical heaters at its base to produce additional information on salt flow characteristics at elevated temperatures.–Authors' abstract, NSA 20-20347.

Descriptors: Radioactive waste disposal, Kansas, test procedures, design criteria, salts, feasibility studies, underground storage.

Empson, F. M. *See* Boegly, W. J., Jr. 0054.

Empson, F. M. *See* Boegly, W. J., Jr. 0490.

Empson, F. M. *See* Boegly, W. J., Jr. 0607.

Empson, F. M. *See* Boegly, W. J., Jr. 0625.

Empson, F. M. *See* Bradshaw, R. L. 0491.

Empson, F. M. *See* Bradshaw, R. L. 0492.

Empson, F. M. *See* Bradshaw, R. L. 0628.

Empson, F. M. *See* McClain, W. C. 0657.

0050 **Engineering News Record.**
1960. Waste well goes down over two miles: Eng. News Rec., v. 165, no. 24, p. 32.

The deepest waste-disposal well ever sunk will be constructed shortly by the Omaha District Corps of Engineers for waste effluent from the Rocky Mountain Arsenal near Denver. The well will be drilled, starting with a 24-inch diameter at the surface to a depth of approximately 11,400 ft to Precambrian granite. The well represents the third go-round in handling a waste problem that dates back to the establishment of the Rocky Mountain Arsenal in the early days of World War II. The plant, which produces nerve gas, is on a standby except for a portion leased to Shell Oil Company for insecticide production. Both processes result in waste whose dominant chemical constituent is sodium chloride. Waste outflow is 165 gpm. The waste will be injected into the Fountain Formation, a porous sandstone about 1,000 feet thick, barren of value and overlain by an impermeable shale stratum. Prior to injection, the wastes will be treated to remove colloidal material that could quickly plug the well.

Descriptors: Injection wells, waste water disposal, Colorado, sandstones, waste treatment, geologic formations.

0555 **Engquist, M. A.; Ryan, V. H.**
1953. An economical method of preparing oil well brines for disposal, *in* American Chemical Society, Petroleum Chemists Div. and Water, Sewage Sanitation Chemists Div. Joint Symposium, Los Angeles, Calif., 1953, Proc.: Washington, D.C., Am. Chem. Soc., p. 169-176.

A high magnesia crystalline limestone is used to separate oil from oil well brines prior to disposal. Water preferentially wets the limestone and passes through the pores while the oil is stopped. Capital and operating costs are low. Soluble sulfide is a problem that is being studied. A diagram of a filtering unit and costs are given.—Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, injection, pre-treatment (water), limestones, costs.

0016 **Environmental Science and Technology.**
1968. Deep well injection is effective for waste disposal: Environmental Sci. and Technology, v. 2, no. 6, p. 406-410.

A survey made of past and present waste disposal by injection indicates that deep wells are effective and that industry should make use of this method. Of about 40,000 brine disposal wells in use, 20,000 are in Texas. In the past 4 years wells drilled for disposal of other industrial wastes have doubled in number to 110. Surface disposal methods are becoming restricted, and deep injection is perhaps the cheapest alternative. For very toxic wastes it is often the only feasible technique. A survey by FWPCA shows 32 wells in Texas, 24 in Louisiana, 21 in Michigan, 9 in Indiana, and 5 or less in each of 12 other States. Only Texas and Ohio have legislation referring specifically to industrial waste injection. Porous confined rock strata are required for injection; about half the U.S. is underlain by suitable rocks, predominantly in the central plains and southeastern coastal areas. Wastes must be low in solids and precipitable dissolved-solids content. Heat generation can present problems in radioactive or chemical reactive wastes. Some controversy exists in Denver, where injection may be related to earthquake activity. The history and economics of Vistron's well in Lima, Ohio are given. Legal restrictions on well construction and operation must be studied before any construction is started.—W68-00326.

Descriptors: Injection wells, waste disposal, legal aspects, water pollution control.

0639 **Erickson, M. D.; Walker, R. A.**
1964. Ground water analog test model: Richland, Wash., General Electric Company, Hanford Atomic Products Operation [Rept.] HW-80086, 14 p.

A test model of an electric analog simulation of the ground water beneath the Hanford Project [Washington] was constructed to determine the safety of radioactive waste ground disposal operations. The 662-node model operated satisfactorily, and no major problems were encountered in the construction. The analog data were compared with predicted results with a maximum error of 10%; an intergrid reaction was found to be causing errors, and a uniform grid size should be used throughout the network.—NSA 18-14066.

Descriptors: Radioactive waste disposal, Washington, analog models, groundwater basins.

Escalier des Orres, P. *See* Barbreau, A. 0823.

0017 **Esmail, Omar J.; Kimbler, Oscar K.**
1967. Investigation of the technical feasibility of storing fresh water in saline aquifers: Water Resources Research, v. 3, no. 3, p. 683-695.

Preliminary studies indicate that the underground storage of fresh water in saline aquifers may be feasible from a technical viewpoint. Such a process would involve injection of fresh water, storage until needed, and subsequent production from the same well. This work, based upon theoretical considerations and model studies, leads to a computer technique by means of which the recovery of stored fresh water may be estimated. Calculations involving five hypothetical aquifers indicate recoveries ranging from 25 to 85%, depending upon aquifer and fluid properties. Loss of fresh water as a result of both dispersion (mixing) and gravitational segregation was considered. Results obtained in porous flow models indicate that gravitational segregation is significantly retarded by the development of a mixed zone. Such a zone is developed naturally during injection and production as a result of fluid movement and to a lesser

degree during the storage portion of the cycle as a result of diffusion. Economic considerations and well problems were not treated in the study.–AWRA 08-0064.

Descriptors: Underground storage, potable water, technical feasibility, model studies.

0140 Esmaili, Houshang; Scott, Verne H.

1968. Unconfined aquifer characteristics and well flow: Am. Soc. Civil Engineers Proc. Paper 5872, Jour. Irrigation and Drainage Div., v. 94, no. IR 1, p. 115-136.

Ground water is the second largest source of fresh water, and increased extraction has resulted in overdrafts in many parts of the world. Accurate knowledge of storage coefficients and hydraulic conductivities is imperative for planning projects involving the underground flow of water. Procedures are presented to determine these coefficients by measuring the discharge from a single well under constant drawdown pumping conditions without recourse to an observation well. Derivation and solution of the basic differential equation of flow in an unconfined aquifer, initial and boundary conditions, and calculation of the average rate and the accumulative volume of flow from a pumped well are explained. Numerographical solutions are developed for determining unconfined aquifer characteristics and unsteady flow through injection wells under constant drawdown or injection pressure conditions. Has 25 references.–W68-202936.

Descriptors: Aquifer characteristics, hydrodynamics, injection wells, equations, unsteady flow.

0484 Esmaili, Houshang.

1966. A solution for determination of aquifer characteristics and unsteady flow through injection wells by numerical methods: Davis, California Univ., D. Eng. thesis, 112 p.[Abs. in Dissert. Abs., 1967, v. 27, no. 11, p. 3923-B.]

The problem considered in this study is to determine aquifer characteristics and obtain a solution for unsteady flow through injection wells in unconfined and confined aquifers. In order to solve this problem, the basic differential equations of flow are set up and boundary and initial conditions are specified. These equations are nondimensionalized by introducing appropriate dimensionless parameters. The resulting dimensionless differential equations are solved numerically or analytically depending on whether they are nonlinear or linear. From these solutions the volume of revolution created by the area under the piezometric head distribution curve is obtained by numerical or analytical integration. Since the accumulative volume of flow at any time is this volume multiplied by the storage coefficient, the average rate of flow can be calculated.–WSP 1990.

Descriptors: Aquifer characteristics, unsteady flow, injection wells, equations, numerical analysis.

0640 Essig, T. H.

1969. Radiological status of the ground water beneath the Hanford Project, January-June 1968: Richland, Wash., Battelle Memorial Inst. Pacific Northwest Lab. [Rept.] BNWL-984, 20 p. [Available from CFSTI.]

An evaluation of the status of the Hanford [Wash.] area ground-water contamination resulting from disposal of plant effluents is presented. The data were collected during the first six months of 1968. Total beta concentrations in the unconfined and confined ground-water aquifers are presented. Results are tabulated for well-water

samples in which total beta concentrations exceeded the analytical limit.–NSA 23-13854.

Descriptors: Groundwater, Washington, radioactive waste disposal, radiochemical analysis, water pollution, data collections.

0470 **Evans, David M.**
1966. The Denver area earthquakes and the Rocky Mountain Arsenal disposal well: Mtn. Geologist, v. 3, no. 1, p. 23-36.

During 1961, a deep well was drilled at the Rocky Mountain Arsenal northeast of Denver, Colo., to dispose of contaminated waste water. The well is bottomed in 75 feet of highly fractured Precambrian gneiss. Pressure injection of waste water into the fractured Precambrian rock was begun in March 1962. Since the start of fluid injection, 710 Denver-area earthquakes have been recorded. The majority of these earthquakes had epicenters within a five-mile radius of the Arsenal well. The volume of fluid and pressure of fluid injection appear to be directly related to the frequency of earthquakes. Evidence also suggests that rock movement is due to the increase of fluid pressure within the fractured reservoir and that open fractures may exist at depths greater than previously considered possible.–Author's abstract, Geophys. Abs. 238-261.

Descriptors: Earthquakes, Colorado, injection wells, waste water disposal.

0601 **Evans, David M.; Bradford, Albert.**
1969. Under the rug: Environment, v. 11, no. 8, p. 3-31.

Rapidly increasing numbers of industries and government agencies are taking advantage of the present gap in pollution laws to dump diverse types of waste underground through injection wells. Although proponents of waste injection wells suggest that only concentrated and untreatable wastes should be injected underground, many wastes not in either category are being pumped down wells because it is the cheapest means of dumping. Although the concept of deep-well injection is theoretically sound, the required geological and engineering conditions are practically nonexistent. Several examples are cited to show the kinds of problems that can occur when wastes are injected under pressure into the subsurface. Some experts suggest that most of the problems can be overcome by the exercise of proper precautions and advanced technology, but the cost of such carefully made wells would make them less attractive to operators than cheaper methods of surface treatment.

Descriptors: Injection, deep wells, waste water disposal, regulation, legal aspects.

Ewing, B. B. *See* Kaufman, W. J. 0541.

0730 **Fagin, K. M.**
1951. Salt water injection projects in Oklahoma: Petroleum Engineer, v. 23, no. 4, p. B72.

Salt water injection projects in Oklahoma recently authorized for several oil companies are briefly reviewed. A table is presented listing these projects, the authorized oil companies, the well name, location, depth and description of disposal formations and size of casing used.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, injection, Oklahoma, deep wells, data collections.

0144 **Fair, Gordon Maskew; Geyer, John Charles; Okun, Daniel Alexander.**
1966. Groundwater flow, chap. 9 *of* Water supply and wastewater removal, v. 1 *of* Water and wastewater engineering: New York, John Wiley and Sons, p. 9-1–9-35.

This chapter evaluates the hydrologic, geologic, and hydraulic properties of groundwater sources and analyzes their influence on ground-water capture for water supply. Factors governing the availability of ground water are difficult to evaluate, but measurable. Available quantitative information is generally meager and fragmentary. Principles are outlined and diagrammed, and equations given for various conditions.–NAB

Descriptors: Hydrogeology, groundwater movement, water supply, hydrodynamics, equations.

Farah, M. Y. *See* Mitry, E. 0158.

Farvolden, R. N. *See* Maxey, G. B. 0519.

Farvolden, R. N. *See* Williams, R. E. 0853.

0731 **Fellows, F. G.**
1951. Removing oils, tars, alkalis from refinery wastes: Wastes Eng., v. 22, no. 9, p. 468-470.

The most satisfactory method of disposal of oil field wastes is underground disposal through an injection well back to suitable underground strata. For refinery wastes, immiscible liquids such as oil and settleable solids are removed by a separator of the gravity-differential type which is equipped with a skimming device. Slop recovery is desirable since it recovers a usable product and acts as a watch dog on proper operating procedures. Neutralization of spent caustic soda waste solution with carbon dioxide, by passing it through a tower countercurrent to a flue gas, is recommended. Acid tar sludges can be disposed of by burning in rotary type burners similar to the Duncan type burner.–Tulsa Univ., Inf. Services Dept.

Descriptors: Waste disposal, injection wells, waste treatment, industrial wastes.

0145 **Felsenthal, M.; Calberg, B. L.**
1956. Measuring quality of injection waters: Petroleum Engineers, v. 28, no. 12, p. B53-B55.

An apparatus has been devised to determine the plugging tendencies of injection water. Using a "Millipore" filter, the method gives data on the amount of solids held in the water. The observed through-put rates will also indicate the type of suspended matter, although chemical analysis is generally necessary.–Arad, USGS.

Descriptors: Injection, water quality, suspended load, test procedures.

Feltis, Richard C. *See* Goode, Harry D. 0549.

Fenimore, J. W. *See* Reichert, S. O. 0528.

0146 **Ferris, John G.**
1951. Ground-water aquifers as waste-disposal reservoirs–an outline of the basic hydrologic problems involved, *in* Pollution Abatement Conf., 6th Ann., New York, N.Y., Apr. 16-17, 1951, Proc.: Washington, D. C., Manufacturing Chemists Assoc., Inc., p. 68-74.

The use of injection wells for industrial waste disposal is briefly discussed, with a warning that unless carefully planned and controlled, this practice will lead only to transferring pollution underground. Detailed knowledge of local and regional hydrogeology are prerequisites for adequate planning. Wells must be properly drilled, cased, and constructed to prevent leakage to aquifers. All test holes which penetrate the disposal formation must be properly plugged. The disposal formation must be hydrologically isolated from aquifers to prevent leakage into them. Though ground-water aquifers are by no means a panacea for industry's waste-disposal problems, in some areas they can serve a very useful and economic purpose as storage reservoirs or underground transmission mains. The economic feasibility of waste disposal to any aquifer can be adequately appraised by techniques of ground-water hydrology.

Descriptors: Waste water disposal, industrial wastes, injection wells, hydrogeology, hazards.

0732 **Ferry, H. C.**
1955. Disposal of wastes from California oil fields [abs.]: Petroleum World, v. 52, no. 17, p. 12.

Laws, rules, and regulations respecting the disposal of oil field wastes, and the procedures and enforcement adopted by government agencies, are discussed, including a history of oil field operations, accomplishments of the petroleum industry, review and analysis of applicable federal, state, and local legislation and procedure, cooperation within the petroleum industry and with government agencies, and future outlook.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, California, pollution abatement, legal aspects.

0681 **Fineman, Phillip.**
1967. Progress in waste-disposal research and development: Power Reactor Technology, v. 10, no. 2, p. 176-179 (Spring).

Incorporation of intermediate-level-activity wastes in asphalt, the phosphate-glass process for conversion of high-level-activity wastes to solids, disposal by hydraulic fracturing into shale, calcined storage in salt mines, and thermal analysis of buried tanks containing solidified radioactive wastes are discussed.–NSA 22-08189.

Descriptors: Radioactive waste disposal, solid wastes, research and development.

0143 **Fink, Bruce E.**
1967. State regulation of subsurface disposal in Texas, *in* Industrial Water and Waste Conference, 7th, Texas Water Pollution Control Assoc., Austin, Tex., June 1-2, 1967, Proc.: Austin, Texas Univ., p. III-58–III-66. [Also in Water and Sewage Works, v. 116, no. 5, p. I/W-20–I/W-22.]

Responsibility for the regulation of subsurface waste disposal was not clearly defined prior to September 1961, when the 57th Texas Legislature designated the Water Development Board as the permit-issuing agency for all injection wells to dispose of waste other than waste arising out of the drilling for, or the producing of, oil or gas.

The procedures that have been established to request a permit are outlined in the Rules and Regulations of the Texas Water Development Board. Upon receipt of the application at the regulating agency, a field inspection is made and a report summarizing the pertinent information with regard to the application is prepared and transmitted to the Executive Director through the Board's General Counsel. The Director has the option of issuing the permit or referring the matter to the Board for final action. The permit is not final until the Board confirms that the construction and operation of the injection well and related facilities have been accomplished in accordance with the permit and any amendment thereto.

Descriptors: Legal aspects, injection wells, Texas, waste water disposal, well permits, regulation.

0510 **Fink, Bruce E.**
1965. Investigation of ground- and surface-water contamination near Harrold, Wilbarger County, Texas: Texas Water Comm. Rept. LD-0365, 22 p.

In this area of the Osage plains, wells are completed in alluvial sedimentary deposits and in thin, near-surface Permian sandstone beds. Highly mineralized contaminants may come from subsurface disposal of oil-field brines, poor casing or cementing in oil wells, inadequately plugged abandoned wells, and seepage from unlined pits formerly used for brine disposal. Chemical analyses were made of water from water and oil wells and from sites along a creek. Contamination may be corrected by prohibiting brine injection into oil wells that permit upward migration, stopping use of unlined disposal pits, and conducting tracer surveys periodically on all disposal wells.–NAB.

Descriptors: Groundwater, Texas, water pollution, brine disposal, chemical analysis.

Finklea, E. E. *See* Moran, J. H. 0281.

0153 **Fox, C.**
1952. Radioactive isotopes trace underground waters: Public Works, v. 83, p. 57-58, Jan. [Also published in Municipal Utilities, v. 90, no. 4 p. 30-32, 1952.]

The author describes his experience in using radioactive rubidium chloride to trace an underground brine in Egypt's desert. The half life of rubidium-86 is about 19 days which was ample for the experiment performed because radioactivity showed up at the outflow springs within 5 days.–Arad, USGS.

Descriptors: Radioisotopes, tracers, groundwater movement, brines, foreign countries.

0154 **Fox, J. K.**
1969. Policies for effective and economic control of the environment–Paper presented at Executive Management Seminar, Washington, D.C., Feb. 7-9, 1969: Madison, Wisconsin Univ. Water Resources Research Center, 22 p.

This paper is concerned with the physical and biological environment of man and the influences of waste disposal practices, incidental contamination and development upon this environment. Environmental problems arise because many economic activities impose costs or damages on others, many of the effects are difficult to measure in quantitative terms, and numerous uncertainties exist as to the nature and significance of some environmental effects. Environmental problems can be effectively studied in accordance with the following classification of situations: (a) Wastes and contaminants in urban-industrial areas; (b) patterns of urban design; (c) the effects of

contaminants and wastes on the biological environment; (d) degradation of unique natural areas; (e) deterioration of the countryside. Six policy directions are suggested: (1) Foster regional systems for managing wastes and contaminants; (2) develop economic incentives which encourage environmental preservation; (3) prohibit use of contaminants having uncertain long range consequences; (4) ration use of unique environmental areas; (5) enlarge efforts to preserve the rural countryside; (6) make better provision for representing the general public in decisions relating to the environment.–W69-09023.

Descriptors: Waste disposal, planning, environmental effects, municipal wastes, industrial wastes, rural areas, hazards.

0155 **Freeze, R. Allan; Witherspoon, P. A.**
1966. Analytical and numerical solutions to the mathematical model, pt. 1 *of* Theoretical analysis of regional groundwater flow: Water Resources Research, v. 2, no. 4, p. 641-656.

It is possible to represent steady-state regional groundwater flow in a three-dimensional, nonhomogeneous, anisotropic basin by a mathematical model. The numerical finite-difference approach can be used to solve the general case; the analytical separation of variables technique is restricted to two-dimensional layered mediums. The numerical method is more versatile, mathematically simpler, and well suited to computer oriented methods of data storage. Computer results are in the form of plotted potential nets from which flow patterns can be constructed.–AWRA 08-0017.

Descriptors: Groundwater movement, anisotropy, mathematical models, numerical analysis.

0733 **Fuellhart, D. E.**
1938. Subsurface disposal of oil field brines: Oil and Gas Jour., v. 36, no. 34, p. 46, 48-50.

A survey is given of subsurface disposal of oil field brines in southern Louisiana, indicating the various practices in seven fields. A map is included of southern Louisiana showing location of subsurface salt-water disposal projects, as compiled by the Louisiana Geological Survey.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, Louisiana, injection, sites, data collections.

0641 **Gailledreau, C.**
1962. French studies of adsorption by soils: Nuclear Safety, v. 4, no. 1, p. 86-88.

It is noted that at present the more highly radioactive waste sludge in France is stored in drums. Investigations concerning ultimate disposal of this and other waste are described. Discussions of site surveys and investigation of ground disposal are included.–NSA 17-02536.

Descriptors: Radioactive waste disposal, soil environment, investigations, adsorption, sites, foreign countries.

0642 **Gailledreau, C.**
1963. Reactions physico-chimiques lors du mouvement souterrain des radioisotopes [Physico-chemical reactions in the underground movement of radioisotopes], *in* La retention et la migration des ions radioactifs dans les sols–Colloque international,

Saclay, France, 1962: Paris, Presses Universitaires de France, p. 269-275. [In French with English abs.]

The physico-chemical state of the radioelements moving underground can influence considerably their migration velocity. In the case of ^{90}Sr, held on by montmorillonites, apatites, and activated aluminum oxide, the occurrence of electronegative colloids, selectively sorbing ^{90}Sr results in an immediate breakthrough of this isotope. The phenomenon was demonstrated in the case of the calcite phosphate reaction. A high pH is generally favorable to ^{90}Sr sorption (apatite, aluminum oxide). The occurrence of Ca^{+2} ions acts very unfavorably on ^{90}Sr sorption by minerals specific of this isotope (apatite, aluminum oxide). The same thing occurs with organic matters; ^{137}Cs sorption, attributed to illitic clays, is not very sensitive to the nature of the solution. ^{166}Ru seems to move underground chiefly as a nitrosyl-ruthenium hydroxide complex. This complex would be weakly sorbed on soil colloids by London–Van der Waals forces.–Author's abstract, NSA 18-16208.

Descriptors: Radioisotopes, migration, physicochemical properties, sorption, soil environment, industrial wastes.

Gailledreau, C. *See* Belot, Y. 0679.

Gailledreau, C. *See* Caron, C. 0633.

0039 **Galley, John E.**
1965. Fluids in subsurface environments, *Introduction to* Fluids in subsurface environments–a symposium: Am. Assoc. Petroleum Geologists Mem. 4, p. 1-10.

"Environmental geology" is a term which is becoming widely used and misused. The rocks that contain fluids and through which they pass, together with the fluids themselves, physical conditions such as temperature and pressure, and various chemical and biologic factors, define the subsurface environment. The present characters of rocks and fluids in the subsurface are the result of the influences of many changing environments which affected them during their geologic histories. The papers in this volume discuss important subsurface fluids, their origins, movements, and evolution in geologic environments.–Author's abstract.

Descriptors: Environmental effects, hydrogeology, hydrodynamics, chemical properties, biological properties.

0454 **Galley, John E.**
1968. Economic and industrial potential of geologic basins and reservoir strata, *in* Subsurface disposal in geologic basins–A study of reservoir strata: Am. Assoc. Petroleum Geologists Mem. 10, p. 1-10.

One potential value of subsurface strata in geologic basins is the available space for storage or disposal of industrial waste liquids and solids. Disposal methods which are being developed include the injection of liquids into deep permeable formations, the storage of solids in caverns constructed in salt beds, and the incorporation of liquids in cement slurries which are injected into artificially produced fractures in shale and allowed to harden. Six of the papers in this volume describe geologic basins where such disposal methods might be used successfully. Physical limitations on the use of these methods include restricted space capacities in reservoir strata, pressure limits, possibilities of escape through pressure-induced fractures, adverse hydrodynamic conditions, and possible plugging of rock pores by precipitates or other materials.

These limitations, and the principles governing subsurface-disposal techniques, are discussed in the three papers following this introductory paper.—Author's abstract.

Descriptors: Geologic formations, subsurface mapping, industrial wastes, waste disposal, injection wells, United States.

0605 **Galley, John E. (editor).**
1968. Subsurface disposal in geologic basins—A study of reservoir strata: Am. Assoc. Petroleum Geologists Mem. 10, 253 p.

Contains a collection of 10 papers. Four of these papers discuss the principles and limitations governing subsurface-disposal techniques. The remaining papers discuss the possibilities for subsurface disposal in six regions of the United States.

Descriptors: Underground, waste disposal, geologic formations, United States.

0643 **Galley, John E.**
1962. Geologic basin studies as related to deep-well disposal, *in* Morgan, J. M., Jr., Jamison, D. K., Stevenson, J. D., eds., Ground disposal of radioactive wastes conference, 2d, Atomic Energy Comm. Div. Reactor Devel., Chalk River, Canada, 1961, Proc., Book 2: U.S. Atomic Energy Comm. Div. Tech. Inf. [Rept.] TID-7628, p. 347-355.

Developments are reported in an investigation of sites for the disposal of radioactive wastes in deep wells. Results are summarized from a preliminary survey on the geology of the Appalachian, Michigan, Salina, Denver, and San Juan Basins.—NSA 16-25057.

Descriptors: Radioactive waste disposal, deep wells, sites, groundwater basins, United States.

Galley, John E. *See* Young, Addison. 0854.

0018 **Garbarini, George S.; Veal, Harry K.**
1968. Potential of Denver basin for disposal of liquid wastes, *in* Subsurface disposal in geologic basins—A study of reservoir strata: Am. Assoc. Petroleum Geologists Mem. 10, p. 165-185.

A reconnaissance subsurface geologic study shows that 3 types of reservoirs are available for liquid-waste disposal in the Denver basin: fractured Precambrian rocks, porous sandstone reservoirs, and thick shale suitable for disposal by the hydraulic-fracturing technique. From early 1962 through early 1966, fractured Precambrian rocks at a depth of 12,000 ft were used as a disposal reservoir for toxic effluent produced at the Rocky Mountain Arsenal near Denver. The disposal well is now shut in, pending investigation of the possible relationship of waste injection to Denver-area earthquakes which increased in frequency and magnitude during the injection period. Sandstone reservoirs most favorable for waste disposal are the Permian Lyons Sandstone, the Triassic Dockum, the Triassic-Jurassic Jelm-Entrada, and sandstones in the Cretaceous Dakota Group and the Hygiene zone of the Pierre Shale. The Lyons, Dockum, and Dakota are best suited for waste disposal in the southern part of the basin. The Dockum sandstone, potentially the best disposal reservoir volumetrically, is limited to the southeast part of the basin. The Jelm-Entrada and Hygiene-zone sandstones are potential disposal reservoirs along the heavily populated strip between Denver and Cheyenne. Cretaceous marine black shale suitable for disposal by the hydraulic-fracturing technique is present everywhere in the basin. The shale crops out

over large areas. Beneath the populous strip along the Front Range, the shale is covered locally by as much as 2,000 ft of Upper Cretaceous and Tertiary rocks transitional to continental strata. The basin has good potential for disposal of liquid wastes through wells.–W69-04947.

Descriptors: Injection wells, waste disposal, Colorado, Wyoming, groundwater basins.

Gardner, F. T. *See* Andresen, K. H. 0718.

0734 **Gardner, T. D.**
1952. Fibercast plastic pipe finds use as oil well tubing: World Petroleum, v. 23, no. 9, p. 42-44.

Setting in the well and use of 3,500 ft. of plastic tubing (Fibercast) by Superior Oil Co. for salt water disposal in an exhausted oil well is described. Fibercast, made by Perrault Bros., is resistant to corrosion by soil, alkali, acids, oil, salt solutions, etc. It is made from two resins and glass fiber. The well tubing has a tensile strength of 7,000 to 10,000 lbs. It is good structural material between 64 and 300°F. The tubing costs more than steel pipe but freight, labor, and other costs are lower.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, injection wells, well casings, corrosion control.

Gardner, T. R. *See* Lasater, R. M. 0712.

Garrett, A. A. *See* Piper, A. M. 0478.

Garrett, J. H. *See* Mecham, O. E. 0271.

Gawad, A. *See* Mitry, E. 0158.

0548 **Gemmel, L.; Pearsall, S. G.**
1963. Transport of fission products through the soil following injection from a well and methods used for removal [with French abs.], *in* La retention et la migration des ions radioactifs dans les sols–Colloque international, Saclay, France, 1962: Paris, Presses Universitaires de France, p. 199-206.

In the summer of 1960 one of the wells on the Brookhaven National Laboratory site became accidentally contaminated with radioactive material. Procedures used in tracking the spread of the contamination through the soil are described. Data are presented on the radioactivity in water from test wells and soil samples taken over a 2-year period. In 1961 approximately 227,000 gal of water were pumped from the test wells, decontaminated by means of an ion exchange column, and returned to the environment. The cost of this decontamination was approximately 1.06 mills/gal.–Authors' abstract.

Descriptors: Radioactive waste disposal, injection wells, ion transport, New York, water pollution control, costs.

0159 **Genet, Edgar.**
1954. Note sur des determinations de cheminements liquides souterrains par la methode chimique [Determination of ground-water flow routes by a chemical method]: Terres et Eaux Supplement Scientifique no. 3, p. 73-81. [Supplement to Terres et Eaux, v. 6, no. 23, 1954.]

Sodium dichromate ($Na_2Cr_2O_7$) makes a good ground-water tracer. It is relatively low in cost, is not absorbed by clay or marl, and is easily detected by means of the colorimetric reaction with diphenylcarbazide. Because sodium dichromate does not occur naturally, a large number of samples can be collected and tests run on combined samples. If the test is negative, all the samples can be thrown out; if positive, further tests can easily determine which samples contain chromate. Thus, many of the determinations can be eliminated that would otherwise be needed.–Vorhis, USGS.

Descriptors: Groundwater movement, chemical analysis, colorimetry, tracers.

0160 **George, W. J.**
1959. Treating and disposing of radioactive wastes: Chem. Eng., v. 66, no. 25, p. 151-160.

Although handling and disposing of radioactive wastes is not too serious a problem now (1959), it will become more and more critical because the amount of such wastes is certain to increase in the future and our present storage facilities are definitely limited. For this reason, high priority must be given to the development of ultimate disposal systems that are shown by preliminary evaluation to be promising. The outstanding examples in this category are disposal into various geological formations, such as excavations in salt or shale, and injection into deep-seated porous formations by means of deep wells. Solutions to nuclear waste disposal problems must be found if we are to attain the maximum benefits from the atom.

Descriptors: Radioactive waste disposal, facilities, underground storage, injection wells, salts, excavation, shales.

Geyer, J. C. *See* Morgan, J. M., Jr. 0667.

Geyer, John Charles. *See* Fair, Gordon Maskew. 0144.

0735 **Gibbon, A.**
1945. Salt water disposal rules: Oil Weekly, v. 117, no. 12, p. 52-56.

The salt water disposal methods specified by various oil-producing states are outlined. Strict enforcement of these rules is necessary because of the great potential damage in carelessly handled brines. Repressuring the pool and storage in settling tanks are the most common methods of disposal. Illustrations of proper and improper control methods are included.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, pollution abatement, methodology.

0736 **Gibbon, A.**
1952. Glass fiber installed in salt water disposal wells: World Oil, v. 135, no. 4, p. 203, 205.

Properties and installation of 3,293 ft. of 3-1/2-in. outside diam. glass fiber-reinforced plastic tubing in a Continental Oil Co. salt water disposal well in Ellsworth County, Louisiana, are described.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, Louisiana, injection wells, well casings, corrosion control.

Glasscock, F. M. *See* Lasater, R. M. 0712.

Gloyna, E. F. *See* Reynolds, T. D. 0341.

Goebel, Edwin D. *See* Edmund, R. W. 0014.

0549 **Goode, Harry D.; Feltis, Richard C.**
1962. Water production from oil wells of the Uinta Basin, Uintah and Duchesne Counties, Utah: Utah Geol. and Mineralog. Survey Water-Resources Bull. 1, 29 p.

Water production from individual oil wells in the Uinta Basin ranges from 0 to 2,920,000 bbl (about 380 acre-ft) per yr. The total dissolved solids in the water range from 500 to 26,000 ppm. The Ashley Valley oil field is the main water producer in the Uinta Basin; in this field, during 1960, more than 18,700,000 bbl (2,4000 acre-ft) of water was obtained from 27 wells. The dissolved solids in the water range from 500 to 2,000 ppm. Water production in the Red Wash oil field increased from 0.6% of the total Uinta Basin production in 1952, to 7.8% in 1960. Total dissolved solids in the water range from 4,500 to 26,000 ppm, with sodium chloride the principal constituent. When a pilot project, begun in February 1961, is put into full operation, all water now produced by wells in the western part of the field will be reinjected into the producing formation.–Tulsa Univ., Inf. Services Dept.

Descriptors: Utah, hydrogeology, brine disposal, injection wells, water quality.

Gotaas, H. B. *See* Krone, R. B. 0578.

0164 **Grandone, P.; Schmidt, Ludwig.**
1943. Survey of subsurface brine-disposal systems in western Kansas oil fields: U.S. Bur. Mines Rept. Inv. 3719, 20 p.

The results of a cooperative survey by the Bureau of Mines and the Kansas State Board of Health on the type of brine-disposal systems and on practices used by the oil operators of western Kansas for subsurface injection of oil-field brines show that this type of disposal is now a routine oil-production operation. The details of the system are discussed and data are tabulated.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, Kansas, injection wells, data collections.

Grauby, A. *See* Bovard, P. 0626.

0165 **Graves, B. S.**
1961. Underground disposal of sour water, *in* Short course for superintendents and operators of water, sewerage, and industrial waste disposal systems, 24th Ann., Baton Rouge, La., 1961, Proc.: Louisiana State Univ. Eng. Expt. Sta. Bull. 67, p. 74-80.

Sour water or process water ladened with sulfides, mercaptans, and phenols is considered to be one of the most offensive waste streams produced in an oil refinery. It contributes significantly to the phenol content of the final effluent. Laboratory tests showed that the sour water produced at Shell Oil Co.'s refinery in Norco, La., based on sulfide and phenol concentration as well as suspended solids, was suitable for injection underground. In this area the underground method of disposal offers a complete solution to the problem of toxic liquid wastes. Its use has precluded further operation or expansion of the sour water stripper; hence, eliminated its operating and maintenance expense. Sour water formerly charged with spent caustic to the flue gas carbonator is also included in the charge to the disposal well. The installation of a disposal well for injection of sour water to a subterranean stratum was completed at the Norco Refinery in September 1959. All sour water which was formerly steam stripped is now being pumped into the well. Operating experience to date has been entirely satisfactory with an average flow of 190 gpm, and a well head pressure varying between 50-60 psig. This effort, together with the disposal of waste caustic to the Gulf, has eliminated the need for the sour water stripper and the flue gas carbonator and has reduced the phenol content of the refinery effluent to 0.6 ppm.–*from* Author's summary.

Descriptors: Industrial wastes, Louisiana, injection wells, operation and maintenance.

0166 **Graves, B. S.**
1964. Underground disposal of industrial waste in Louisiana: Soc. Mining Engineers preprint no. 64-H-315, Am. Inst. Mining Metall. Petroleum Engineers, 7 p. [Available only from Shell Oil Co. Norco Refinery, Norco, La.]

Deep well disposal of selected industrial wastes has been proved feasible and acceptable in the New Orleans area by several industries including Shell Oil Company's Norco Refinery and Chemical Plant where three of the six successful disposal wells in this area are operating. Well design and procedures for restoration of capacity are based, in most cases, on the principles of brine injection developed by oil producers in south Louisiana. Geological formations in the gulf coast area are suited to this type of injection because receiving strata are porous, isolated from sources of potable water and their water is compatible with the liquid wastes to be injected. This method of disposal is a simple, complete and economical solution to the problems presented by certain hard to treat wastes.–Author's summary.

Descriptors: Injection wells, industrial wastes, Louisiana, design criteria, methodology, economics.

Greenberg, A. E. *See* Maehler, C. Z. 0760.

Griggs, D. T. *See* Healy, J. H. 0022.

Grison, G. *See* Capitant, B. 0826.

0019 **Ground Water Age.**
1968. Replenishing the aquifer with treated sewage effluent: Ground Water Age, v. 2, no. 8, p. 30-35.

Treated sewage from a recently completed tertiary-treatment plant is being used experimentally at Bay Park, N. Y., to recharge aquifers artificially. The purpose is to see if a barrier can be created to retard the intrusion of salt water into the heavily pumped aquifers. After treatment the effluent which meets potable-water standards is

stored in a 50,000 gal storage tank where the pH and Eh of the water are adjusted chemically. Then it moves through a vacuum degasifier to remove air and other gases before it is pumped into the injection well. The well is a 36-in. hole, 508 ft deep, with a 15-ft thick cement plug at the bottom. It contains 62 ft of 16-in. stainless steel screen attached to 420 ft of 18-in. fiberglass casing. In the annular space the well has two 3-in. tremie pipes for adding filter-pack material, a 4-in. water injection pipe entering the casing 192 ft below the surface, and a 5-in. observation well. At a pumping rate of 1,000 gpm, the specific capacity of the well is 35 gpm per ft. Injection tests are at 400 gpm (576,000 gpd). If the project is feasible, similar wells will be constructed along 15 mi of ocean front and ultimately 27 mgd of treated sewage will be injected.–W68-00029.

Descriptors: Injection wells, groundwater barriers, New York, water reuse, tertiary treatment.

0167 **Ground Water Age.**

1968. Injection well incorporates many safeguards: Ground Water Age, v. 2, no. 10, p. 34-37.

To avoid damaging potable ground water, many safeguards were incorporated into the design and construction of an injection well for "pickle liquor" from an Indiana steel mill. The Mount Simon Sandstone was selected as the injection zone because it is a nonused aquifer that is saturated with salt water and capped by a solid shale formation. Three sets of casing were used, with the innermost casing extending all the way from the surface through the cap rock and into the Mount Simon at a depth of 2,440 feet below the surface. Concrete was forced into the space between the hole wall and the casings. A 2-7/8 inch fibercast chemical injection tube was inserted through the innermost casing to a depth of 2,550 feet and the annular space was filled with fresh water under constant pressure so that in the event of a leak in the injection tube water would be forced into the tube rather than allow the highly corrosive wastes to escape. Prior to use, the well was tested and found to have a capacity of approximately 62 gpm of 1.2 specific gravity "pickle liquor" under gravity flow. A rate of 150 gpm for the same specific gravity fluid would require an injection pressure of 577 psi. Cost of the well was more than $2,500,000.

Descriptors: Injection wells, industrial wastes, brine disposal, design data, geologic formations, Indiana.

0550 **Hackett, J. E.**

1965. Ground-water contamination in an urban environment: Ground Water, v. 3, no. 3, p. 27-30.

The most widespread potential sources of ground-water contamination in the Chicago metropolitan area are disposal of wastes or storage of contaminating materials at or essentially at the ground surface, storage of such materials or disposal of wastes in the subsurface, and waste discharge into aquifers. The aquifers in the area range in age from Cambrian through Pleistocene. The deepest is the Mount Simon Sandstone of Cambrian age, which furnishes potable water only to the western part of the area because of brackish water encroachment in other parts. The major source of water is a Cambrian-Ordovician aquifer, which includes beds from the lowest Eau Claire Sandstone to the Galena-Platteville unit. The decline of its water level, more than 650 feet in some pumpage areas, and the decreased pressure will make it susceptible to contamination by overlying polluted waters or underlying brackish ones unless preventive steps are taken.–NAB.

Descriptors: Illinois, hydrogeology, aquifers, waste disposal, groundwater, water pollution, geologic formations.

0169 **Hadsell, F. A.**
1968. History of earthquakes in Colorado, *in* Geophysical and geological studies of the relationships between the Denver earthquake and the Rocky Mountain Arsenal well, Pt. A: Colorado School Mines Quart., v. 63, no. 1, p. 57-72. [Also published in Mines Mag., v. 58, no. 6, p. 20-27, 1968.]

A qualitative evaluation in terms of intensity based on felt reports recorded in the press is presented for the period 1870 to 1967. After 1962 short period instruments of high magnification were available for quantitative evaluation. This report concludes that: (1) The majority of earthquake activity in Colorado occurs west of the mountain front. (2) No earthquake with intensity greater than VII on the Modified Mercalli Scale has occurred in Colorado in the past 100 years. (3) The VII intensity earthquake of November 7, 1882 could have been similar in magnitude and location to the August 9, 1967 quake discussed in the preceding report [*see* Major, M. W., 0320]. This would be consistent with the idea that significant strain energy is stored near Denver and while its release can conceivably be triggered by fluid injection in the Arsenal well, it can also occur spontaneously.–Author's abstract, Geophys. Abs. 266-095.

Descriptors: Earthquakes, Colorado, injection wells, effects.

0644 **Hajek, B. F.**
1965. Adsorption, migration, and dispersion of strontium and cesium in an N-area soil: Richland, Wash., Battelle Memorial Inst. Pacific Northwest Lab. [Rept.] BNWL-CC-208, 20 p. [Available from CFSTI.]

Experimental and mathematically derived results are presented which characterize the adsorption, migration and dispersion in an N-area soil of Sr and Cs present in a simulated emergency waste water. Experimental results from laboratory soil columns and equilibrium studies showed that the soil at the proposed disposal site is more selective for Cs than Sr. The distribution coefficients were 420 and 43 ml/g for Cs and Sr respectively. Extrapolation of column breakthrough data showed that 42 and 12 column volumes of influent were required for 0.01 percent breakthrough for Cs and Sr respectively. Calculations based on theoretical equations and equilibrium distribution coefficients indicated that the average migration rate of Cs through a soil column should be 1/10 the rate of Sr. The actual migration rate of Cs through the column was 1/11 of the Sr rate. Migration rates in ground water were determined relative to ground-water movement: migration rate of Sr = 1/100 rate of ground-water movement, and migration rate of Cs = 1/1000 rate of ground-water movement. Diffusion coefficients determined for Sr and Cs in soil material indicate that spreading of these adsorbed radionuclides by this mechanism is negligible. The average infiltration rate was determined to be 170 gpd/ft^2.–Author's abstract, NSA 22-08206.

Descriptors: Adsorption, migration, dispersion, radioisotopes, groundwater movement, soil environment.

Hajek, B. F. *See* Ames, L. L., Jr. 0611.

Halevy, E. *See* Mercado, A. 0273.

Halko, D. L. *See* Spalding, C. W. 0381.

0645 **Halligan, E. G.**
1962. Deep well fluid waste disposal, *in* Morgan, J. M., Jr., Jamison, D. K., Stevenson, J. D., eds., Ground disposal of radioactive wastes conference, 2d Atomic Energy of Canada Limited and U.S. Atomic Energy Comm. Div. Reactor Devel., Chalk River, Canada, 1961, Proc., Book 2: U.S. Atomic Energy Comm. Div. Tech. Inf. [Rept.] TID-7628, p. 363-373.

The construction of two deep well fluid chemical waste disposal facilities is described. The treatment of fluids and wells, operating procedures, and cost factors are discussed.–NSA 16-25059.

Descriptors: Waste disposal, injection wells, chemical wastes, construction, operation and maintenance, costs, Colorado, Indiana.

0170 **Halloway, H. D.; McSpadden, T. W.**
1961. How we are fighting corrosion: Oil and Gas Jour., v. 59, no. 22, p. 146-148, 150.

This paper traces the history of early oil-field brine disposal operations and describes the development of corrosion-resisting materials and practices used in gathering and injecting oil-field brines into disposal or input wells. The five methods generally used to mitigate corrosion in water floods or brine disposal systems are (1) use of coated or nonmetallic pipes and equipment, (2) cathodic protection of equipment, (3) use of chemical inhibitors, (4) treatment to change the chemical properties of the brine, and (5) use of metals that resist corrosion. The use of coated or nonmetallic equipment is the most popular, but its success is dependent on the quality of workmanship in the manufacture of the equipment. Constant replacement of equipment is often the result of inadequate planning for corrosion protection. This is evident in the operation of many disposal systems where less thought is given to corrosion than is given to chemical treatment to avoid formation plugging. Such emphasis seems impractical because formation plugging is generally less expensive than collapsed casing caused from corrosion.

Descriptors: Brine disposal, corrosion control, injection wells, methodology.

Haney, W. A. *See* Brown, D. J. 0493.

Haney, W. A. *See* Nelson, J. L. 0521.

Haney, W. A. *See* Nelson, R. W. 0522.

Hannah, S. A. *See* Warner, D. L. 0417.

Hanshaw, Bruce B. *See* Back, William. 0045.

0021 **Hardaway, John E.**
1968. Possibilities for subsurface waste disposal in a structural syncline in Pennsylvania, *in* Subsurface disposal in geologic basins–A study of reservoir strata: Am. Assoc. Petroleum Geologists Mem. 10, p. 93-127.

Results of a study of a small structural syncline on the western perimeter of the central Appalachian Mountains of Pennsylvania suggest that the area may be suitable for the injection of liquid wastes into deep subsurface reservoirs. The bowl-shaped syncline forms a basin just north of Bedford, Bedford County, and occupies about 45 sq mi (116.5 sq km) of the county. The total thickness of Paleozoic strata is more than 7,000 ft (2,134 m). The reservoir aquifer considered suitable for disposal is the Lower Silurian Tuscarora Sandstone, a clean quartzose sandstone. The investigation showed that the syncline has sufficient structural closure to warrant consideration as a reservoir. The selected sandstone aquifer crops out along two-thirds of the syncline's perimeter and is approximately 3,700 ft (1,128 m) beneath the center of the basin. It apparently is not faulted, and it may be treated as a confined aquifer because it is bounded by shale and shaly, silty sandstone which probably have much lower permeability. Porosity measurements of Tuscarora and Juniata sandstones gave values of 15 and 10 percent, respectively. The probability of the presence of connate brine in the Tuscarora is enhanced by the fact that it is present in a deep well near Bedford. The Tuscarora strata are described as a "salaquifer" which will not promote harmful chemical interactions. The shale beds of the area were studied similarly and are regarded as favorable for the injection, into artificially created fractures, of wastes that have been incorporated in cement slurries. However grouting in shale appears less promising for large-scale injection than disposal in permeable sandstone.—W69-04944.

Descriptors: Injection wells, waste disposal, Pennsylvania, fractures (geology), geohydrologic units, porosity.

0171 **Harleman, D. R. F.; Mehlhorn, P. F.; Rummer, R. R.**
1963. Dispersion-permeability correlation in porous media: Am. Soc. Civil Engineers Proc. Paper 3459, Jour. Hydraulics Div., v. 89, no. HY 2, p. 67-85.

Longitudinal dispersion and permeability tests were performed in the Darcy flow regime using uniform porous media consisting either of spheres or sand grains. The dimensionless ratio of the longitudinal coefficient of dispersion to the kinematic viscosity is correlated with a grain size Reynolds number $R_{d_{50}} = u\, d_{50}/\nu$ and a permeability Reynolds number, $R_k = u\sqrt{k}/\nu$ in which u is the seepage velocity, d_{50} is the 50% grain size, and k is the intrinsic permeability. For the uniform media investigated, the correlations delineate the shape effect and provide a means for predicting the longitudinal dispersion coefficient based on a knowledge of the more easily measured permeability coefficient. Additional data are needed for nonuniform media.—Authors' synopsis.

Descriptors: Porous media, dispersion, permeability, uniform flow, aquifer characteristics.

0172 **Harleman, D. R. F.; Rummer, R. R.**
1963. Longitudinal and lateral dispersion in an isotropic porous medium: Jour. Fluid Mechanics, v. 16, pt. 3, p. 385-394, July.

Coefficients of longitudinal and lateral dispersion were measured for steady uniform laminar flow through an isotropic porous medium. A unique experimental method for measuring lateral dispersion is described. It is found that the ratio of the coefficient of longitudinal dispersion D_1 to the coefficient of lateral dispersion D_2 is given by $D_1/D_2 = \lambda \mathcal{R}^n$, where λ and n are dimensionless coefficients dependent upon the pore-system geometry, and $\mathcal{R}$ is the Reynolds number based on the seepage velocity, the average grain diameter, and the kinematic viscosity. This relationship is valid in the laminar flow range above a Reynolds number of the order of 10^{-3}. At lower Reynolds numbers mass flux due to molecular diffusion becomes important relative to the mechanical mixing of the dispersion process. Much remains to be investigated in the phenomenon of dispersion. Lateral dispersion should be investigated over a wide range of seepage velocities, particularly for Reynolds numbers greater than ten.

Non-uniform media composed of angular particles and anisotropic media remain to be investigated, as well as the influence of a density difference on the lateral mixing.—*from* Authors' abstract and conclusions.

Descriptors: Porous media, dispersion, test procedures, equations, Reynolds number.

Harleman, D. R. F. *See* Hoopes, John A. 0025.

Harleman, D. R. F. *See* Hoopes, John A. 0026.

Harleman, D. R. F. *See* Hoopes, John A. 0027.

Harleman, D. R. F. *See* Shamir, Uri Y. 0365.

Harleman, D. R. F. *See* Shamir, Uri Y. 0366.

0174 **Harmon, Burt.**
1941. Contamination of ground-water resources: Civil Eng., v. 11, no. 6, p. 345-347.

Many types of industrial waste when introduced into an underground supply will force its abandonment for domestic use. In the Pacific Southwest, where stream beds may be totally dry for 8 or 9 mo. in a yr., attempts to trace contamination to its source may develop into a problem that, to use army phraseology, "has no approved solution." In 1927 a series of pumps were constructed along the east bank of the Los Angeles County Flood Control Channel, about 3.5 miles from the ocean, for the purpose of reclaiming such oil as remained in waste waters. Attention was called to the possible danger arising from the operation of the pumps when private wells more than 1 mile west of the channel were becoming too salty for irrigation use. Contamination spread slowly, but not uniformly, on both sides of the channel. In some cases, the increase of salinity in wells was gradual, and in others very rapid. Test holes showed ground water with varying degrees of chlorine concentration, but of such irregular occurrence that it was hopeless to attempt to trace the source. Tests did show conclusively that the bottom and sides of unlined ditches were not sealed by drilling mud, and oil emulsions were being carried by the waste waters. While a portion of the solutions that percolated into the loose sands of the channel of the Los Angeles River may be carried to sea by infrequent floods, studies in Long Beach showed that most do not remain in the channel to be washed away, but penetrates great distances in all directions. Cities of the industrial districts lying south of and adjacent to the city of Los Angeles have a population of approximately 100,000. Water supply of this area is entirely from deep wells. No indication that contamination has yet percolated to the underground water supply was found. Nevertheless, the menace is there. Procedures followed by oil companies in the Santa Fe Springs-Whittier-Montebello district for disposal of waste waters point to a logical solution—piping of such wastes to the sea instead of utilization of stream beds as industrial sewers and of water-bearing gravels as cesspools.—AWWA abstract.

Descriptors: Pollutant identification, California, groundwater movement, industrial wastes, brines.

0573 **Harpaz, Y.; Bear, Jacob.**
1964. Investigations on mixing of waters in underground storage operations [with French abs.]: Internat. Assoc. Sci. Hydrology Pub. 64, p. 132-153.

At the more advanced stages of water development, ground-water aquifers are being used not only as sources of natural water but also as stores for water introduced by artificial means as reserves under various supply projects. During such underground storage operations, water of varying quality and composition is introduced into the aquifer, and intermixing occurs between the injected water and the indigenous water. Displacement and mixing phenomena within the ground and in pumping wells are analyzed. Laboratory and analytical studies are described in which solutions have been found for breakthrough times and breakthrough concentrations in wells (assuming immiscible liquids) for various well arrangements as well as for various recharge and pumping regimes. A graphical solution for complex systems is developed and demonstrated. First results of dispersion studies performed on a sectorial sand model are presented. Results of recent mixing experiments conducted in productive well fields exploiting limestone and sandstone aquifers are described and analyzed. The effect on the mixing process produced by several factors such as hydrodynamic dispersion, natural ground-water flow, and downward percolation of fresh replenishment water is discussed and evaluated. The testing of a proposed field technique for determining the mixing characteristics of aquifers (and dispersivity) is reported.—Authors' abstract, WSP 1990.

Descriptors: Mixing, underground storage, water quality, dispersion, immiscibility.

0574 **Harpaz, Y.**
1965. Field experiments in recharge and mixing through wells: Tel Aviv, Tahal—Water Planning for Israel, Ltd., Tech. Rept. 17, Pub. 483, 54 p.

Up to 1964, an extensive program of recharge and mixing experiments was carried out in more than 20 production wells, drilled in sandstone, limestone, and basalt formations. The experiments were aimed at determining: (1) the capacity of the formations and the wells to absorb recharge water, (2) the shape a recharged body of water takes in the aquifer and the way it spreads, and (3) the mixing process that takes place when water which is different from the native ground water is recharged. Injection was found to sustain rates of between 300 and 800 cu m per hr in sandstone wells and of between 1,000 and 2,000 cu m per hr in ordinary limestone wells. Conclusions as to the planning of a controlled underground storage and mixing project are presented.—*from* Author's abstract, WSP 1990.

Descriptors: Mixing, artificial recharge, injection wells, migration patterns, underground storage, foreign countries.

Harris, M. B. *See* Alciatore, A. F. 0035.

0175 **Hartman, C. D.**
1968. Deep-well disposal of steel-mill wastes: Water Pollution Control Federation Jour., v. 40, no. 1, p. 95-100.

The cost of operating waste treatment facilities at the Midwest Steel mill in Portage, Ind., has been substantially reduced by the use of deep wells to dispose of waste pickle acids. The well is finished in the Mount Simon Sandstone, a porous and permeable water-filled sandstone that occurs at a depth of 1,900 feet beneath the mill site and has adequate shale cover to prevent vertical migration. The details of well construction include the use of acid-resistant cement, fiber-cast injection tubing and external pressure around the injection tube. Number 6 fuel oil is pumped into the well to protect the cement seal at the top of the Mount Simon Sandstone. On completion of the well, 35 million gallons of fresh water treated with both chlorine and a biocide were pumped into the well to provide a buffer zone between the injected waste and the native water in the injection zone. During the first 18 months of operation of the deep-well system, some 23 million gallons (87,000 cu m) of acid waste has been injected into the Mount Simon Sandstone with no apparent change in well-head injection pressure. The waste stream is composed of sulfuric pickling acid, sodium dichromate, and chromic acid solutions. The use of the deep-well disposal method has reduced the accumulation of sludge by 70 percent and virtually eliminated the cost of operating the lime neutralization facilities.

Descriptors: Waste disposal, Indiana, industrial wastes, injection wells, economics, geologic formations.

0176 **Hartman, C. D.**
1966. Deep well waste disposal at Midwest Steel: Iron and Steel Eng., v. 43, no. 12, p. 118-121.

Details are given of the construction of a deep well below the Midwest plant of National Steel Corp. at Portage, Ind., for sludge disposal. The well went into operation in February 1965 and since then 2.3×10^7 gallons of acid have been discharged into it. Thus waste elements are eliminated by storing in a suitable underground formation which will retain the solutions and not give rise to contamination of potable water and mineral resources. A description of the pumping mechanism is given and cost comparison of the installation indicates a considerable saving over normal methods of disposal.

Descriptors: Waste disposal, Indiana, industrial wastes, injection wells, economics.

Hatfield, J. R. *See* Hicks, L. B. 0737.

0646 **Hawkins, D. B.**
1966. A system for the evaluation of liquid waste disposal: U.S. Atomic Energy Comm. Idaho Operations Office [Rept.] IDO-12052, 46 p. [Available from CFSTI.]

A system is discussed which attempts to combine the cost-hazard aspects of a waste-disposal operation in a logical and useful manner and which shows promise for the evaluation of a dynamic waste-disposal operation. A test case in which waste is discharged either to the ground via a seepage pond or to the water table via a well was evaluated. In this example, the hazards were appraised; the fixed costs including monitoring costs were tabulated; and the probable costs, i.e., those costs which ensue if a given event occurs, were evaluated using estimates of the probability of occurrence of various hazardous events. The probability estimates were subjective estimates of the evaluator who drew upon the geologic, hydrologic, and chemical information available. The probable costs and fixed costs were tabulated in a statistical cost table, which was used in conjunction with the hazard evaluation to choose the optimum method of disposal.–NSA 20-28852.

Descriptors: Radioactive waste disposal, Idaho, injection wells, economics, hazards, probability.

0828 **Hawkins, D. B.**
1963. Mineral reaction studies at National Reactor Testing Station [Idaho], *in* The use of inorganic exchange material for radioactive waste treatment–a working meeting held in Washington, D.C., Aug. 13-14, 1962: U.S. Atomic Energy Comm. Div. Tech. Inf. [Rept.] TID-7644, p. 151-175.

An outline of the NRTS program for waste processing by mineral reactions is presented. Work is in progress on a reconnaissance study concerning the

decontaminating properties of ion exchange materials such as lignite, bentonite, rock phosphate, montmorillonite-enriched sediments, and clinoptilolite-bearing vitric tuff. Disposal of small-volume wastes in cribs in one or more of these materials is being considered. Other work is reported on the capacity of alluvial sediments which underlie the basalt of NRTS to decontaminate low-level liquid waste.–NSA 17-19709.

Descriptors: Idaho, waste treatment, radioactive wastes, ion exchange, feasibility studies.

0647 **Hawkins, R. H.**

1962. Improved burial of solid radioactive wastes, *in* Morgan, J. M., Jr., Jamison, D. K., Stevenson, J. D., eds., Ground disposal of radioactive wastes conference, 2d, Atomic Energy of Canada Limited and U.S. Atomic Energy Comm. Div. Reactor Devel., Chalk River, Canada, 1961, Proc., Book 2: U.S. Atomic Energy Comm. Div. Tech. Inf. [Rept.] TID-7628, p. 462-468.

An evaluation was made of materials that will prevent leaching of buried solid radioactive wastes. A number of materials were considered on the basis of low moisture permeability and long life in the soil. Bentonite, in a sodium saturated form from commercial deposits in Wyoming, gave best results on preliminary tests. Results are reported from tests conducted to provide further permeability information and to gain experience in the actual application of bentonite on a large scale.–NSA 16-25066.

Descriptors: Radioactive waste disposal, solid wastes, leaching, laboratory tests, earth materials.

0177 **Haywood, R. W.**

1958. Basic data for chemical waste disposal: Sewage and Indus. Wastes, v. 30, no. 9, p. 1156-1159.

Industry has come a long way in recent years in finding answers to problems of waste treatment and disposal of ever-increasing complexity. The need for clearer definition of the characteristics of both wastes and receiving waters is being recognized. New techniques for providing such data are being discovered and there is broader and more comprehensive understanding of old ones. It is axiomatic that increasing restrictions and stream quality requirements necessitate continuing advances in this area if industry is to continue to grow and expand.–Author's summary.

Descriptors: Chemical wastes, chemical properties, waste water disposal, data collections.

0022 **Healy, J. H.; Rubey, W. W.; Griggs, D. T.; Raleigh, C. B.**

1968. The Denver earthquakes: Science, v. 161, no. 3848, p. 1301-1310.

Statistical evidence is presented for correlating the injection of chemical waste fluid into a deep disposal well in the Denver basin with a series of earthquakes in the vicinity. The possibility of a coincidental occurrence of earthquakes with the onset of fluid injection is remote. The mechanism by which fluid injection triggered the earthquakes is the reduction of frictional resistance to faulting which occurs with increase in pore pressure. There is no longer any assurance that a destructive earthquake will not occur in the Denver area. It might be possible to reduce the risk by removing substantial quantities of fluid from the reservoir, but the engineering difficulties and cost might be prohibitive. Removal of fluid by means of a second well drilled into the currently active focal zone is recommended.–Geophys. Abs. 265-101.

Descriptors: Earthquakes, Colorado, waste disposal, pore pressure, seismic studies, injection wells.

Heath, L. J. *See* Eckard, W. E. 0451.

Heemstra, R. J. *See* Watkins, J. Wade. 0432.

0575 **Hem, J. D.**
1960. Chemical equilibrium diagrams for ground-water systems [with French abs.]: Internat. Assoc. Sci. Hydrology Bull. 19, p. 45-53.

Chemical equilibrium in water in contact with calcite is expressed by means of a pH grid overlay in a log-log plot of activities of bicarbonate versus calcium ions. Solubility of ferrous iron and the solid-phase minerals that would be stable in a solution containing activities of 10 ppm of sulfate and 100 ppm of bicarbonate or related species is expressed by means of a stability-field diagram with pH as abscissa and redox potential as ordinate. The diagrams can be used to tell whether water injected in recharge wells may form precipitates that could plug the aquifer and have other uses in studies of natural water chemistry.–Author's abstract, WSP 1990.

Descriptors: Water chemistry, chemical reactions, injection wells, groundwater.

0185 **Henkel, H. O.**
1953. Surface and underground disposal of chemical wastes at Victoria, Texas: Sewage and Indus. Wastes, v. 25, no. 9, p. 1044-1049.

The waste disposal system at the Du Pont Company's adiponitrile plant near Victoria, Tex., utilizes a 4,800-ft deep well to inject concentrated aqueous wastes into subterranean sands. The waste stream flows at the rate of 80,000 lbs. per hr. and contains 18 percent sodium chloride, along with traces of metallic salts and organic compounds. To make the brine acceptable for underground injection, it must be free of suspended solids, stable, sterile, and unreactive with the natural brine and the rock materials in the underground formation tapped by the well. The treatment consists of aeration to cool the brine and to oxidize the dissolved metals, followed by the addition of sodium sulfide to precipitate the metals. Most of the precipitates are removed in a settling basin, and the remaining solids are removed by pressure filters packed with anthracite. Following filtration, the brine is chlorinated to prevent algae and bacterial growth. Although the injection well is yet to be proven, there is every indication that it will work satisfactorily. If so, a significant milestone will have been passed in the ever-advancing science of waste disposal.

Descriptors: Chemical wastes, injection wells, Texas, waste disposal, pre-treatment (water).

0186 **Henkel, H. O.**
1955. Deep-well disposal of chemical wastes: Chem. Eng. Prog., v. 51, no. 12, p. 551-554.

This paper describes the Du Pont Company's first venture in subsurface waste injection and relates how it has fared to date. A system of underground disposal was devised to handle certain wastes from Du Pont Company's adiponitrile plant near Victoria, Tex. The waste stream being put underground is an aqueous concentrated sodium chloride brine containing small amounts of dissolved metallic salts and organic compounds. The flow is in the range of 100 to 150 gpm or about one tank car per hour. Before the waste is injected, it is treated to remove all suspended solids and to render it unreactive with the natural brine underground. It is cooled, neutralized, and placed in a holdup basin before it is finally filtered and pumped into either of two disposal wells. Both disposal wells are finished so as to inject the treated wastes into

the lower part of the brine-filled Catahoula Tuff between depths of 4,048 and 4,100 ft in well no. 1, and 4,076 and 4,116 ft in well no. 2. Previous attempts to inject wastes into deeper sands were unsuccessful. During the 2-1/2 years that these wells have been in operation, 100 million gallons of waste brine have been injected underground.

Descriptors: Texas, chemical wastes, waste disposal, injection wells, pre-treatment (water), geologic formations.

0187 **Henkel, H. O.**
1968. Deep well disposal of chemical waste water: Power, v. 112, no. 3, p. 82-85.

The petroleum industry's long-established practice of pumping oil field brines into subsurface wells has application in the chemical industry and possibly elsewhere. Before chemical wastes are pumped into disposal wells, they are treated to remove suspended solids and to prevent chemical reactions underground that could interfere with their drainage into surrounding sand formations. The former is accomplished at Du Pont's Victoria plant [Texas] with a 50-ft-diam., 32-ft-deep settling tank. Solids which remain suspended in the liquid are then removed in two pressure leaf horizontal filters. These are equipped with facilities for precoating and body feeding with diatomaceous earth. Clear waste leaving the leaf filters is given final polishing filtration through three 250-sq ft porocarbon tube filters and precoated before being pumped into the wells. Injection is done by 2-stage, 250-gpm centrifugal pumps at 1,000-ft head. Well construction of waste disposal wells is dictated by local geology. The well-completion method, together with the reworking of the well, is described. These techniques include perforation, acid treatment, hydraulic fracturing, and high-pressure CO_2 treatment.–Tulsa Univ., Inf. Services Dept.

Descriptors: Chemical wastes, waste disposal, injection, chemical reactions, pre-treatment (water), equipment, Texas.

Hewett, P. S. *See* Lansing, A. C. 0242.

0737 **Hicks, L. B.; Hatfield, J. R.**
1949. Salt water disposal practices in Kansas: Oil and Gas Jour., v. 47, no. 50, p. 113-114, 116.

Equipment and operating techniques used in the handling and disposal of the large volumes of salt water from the Arbuckle lime which are associated with crude production in Kansas are discussed with details of the drilling program and the tanks, piping, and casing used in the completion of input wells. Disposal is usually made into the lower Arbuckle lime, Granite wash, Reagan sand or Dakota formations.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, Kansas, injection wells, piping systems (mechanical), operation and maintenance, geologic formations.

0190 **Hieple, L. R.**
1959. Effectiveness of coarse-grained media for filtration: Am. Water Works Assoc. Jour., v. 51, no. 6, p. 749-760.

The effectiveness of filtration with coarse-grained media as filtering agents for colloidal and noncolloidal particles has been investigated. It has been established that at low filtration rates gravel removes a substantial portion of suspended particles in water drawn from surface sources.–Author's abstract.

Descriptors: Filtration, colloids, gravels, water treatment, suspended load.

Hill, Gilman A. *See* Dolan, John P. 0133.

Hilton, W. O. *See* Metzler, D. F. 0761.

0738, **Hochhausen, E.**
1955. Operators cooperate in water disposal system: Petroleum Engineer, v. 27, no. 2, p. B75-B77, B80.

The operators at the Redwater field near Edmonton, Alberta [Canada], formed the Redwater Disposal Co., Ltd. to devise a salt water disposal system for the field. This gravity system is now about 80% complete and consists of 65 mi. of gathering lines which collect water from 60 batteries and 185 water-producing wells. Six disposal wells return water to the formation.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, injection wells, construction, piping systems (mechanical), foreign countries.

0739 **Hochhausen, E.**
1955. Redwater water disposal system: Canadian Oil and Gas Industries, v. 8, no. 9, p. 52-56.

To protect surface plant and animal life, all produced water in excess of 2% of total production has to be returned to the formation in the Redwater Field [Alberta, Canada]. A disposal company, formed jointly by the operators of the field, installed disposal wells to return the salt water produced. The Hazen-Williams equation was used in designing the gravity-gathering system. It consists of 65 miles of 4-, 6-, and 8-inch pipe, collecting water from 60 batteries and 185 water-producing wells. Problems encountered in completing and operating the system are discussed, and the solutions to them are presented.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, injection wells, installation, operation and maintenence, foreign countries.

0740 **Hochhausen, E.**
1959. Salt water disposal: Canadian Oil and Gas Industries, v. 12, no. 1, p. 79-80.

In the last ten years the quantity of oil field brine produced in Alberta [Canada] has risen from a negligible amount to 1,500,000 bbl monthly. Water containing more than 1000 ppm of dissolved salts is regarded as saline in Alberta, and all saline water is either disposed of in already contaminated areas, e.g., salt beds, alkali lakes, etc., or returned to subsurface salt water bearing formations or the formation from which it was produced. In general, the cost of a gravity system for wells on 40-acre spacing with disposal capacity from 150 to 300 bbl of water per day will be between $2500 and $3500 per producing well. Corrosion is a problem in maintaining a disposal well. Wooden tanks are generally the most efficient settling tanks, as steel tanks are subject to corrosion, and poured concrete pits are more costly and difficult to install. Several different materials and arrangements are used for gathering systems.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, injection wells, operation and maintenance, corrosion control, foreign countries.

0023 **Hoeger, Roger L.**
1968. Hydrodynamic study of the western Denver basin, Colorado, *in* Geophysical

and geological studies of the relationships between the Denver earthquake and the Rocky Mountain Arsenal well, Pt. A: Colorado School Mines Quart., v. 63, no. 1, p. 245-251.

The original hydrostatic pressure in the fracture system of Precambrian basement rocks in the Rocky Mountain Arsenal well was far below normal. In an effort to understand the reasons for the subnormal pressure, a study of hydrodynamic pressure gradients in overlying sedimentary rocks of the western Denver basin was considered necessary. An analysis of all available data on the major deep aquifers is presented. A barrier trend, which may be caused by a fault system of regional extent, is present between the areas of high potential and most of the area studied which is typically at much lower potential.–W69-07414.

Descriptors: Fractures (geology), injection wells, waste disposal, Colorado, hydrostatic pressure.

0193 **Holland, H. R.; Clark, F. R.**
1964. A disposal well for spent sulfuric acid from alkylating iso-butane and butylenes, *in* Industrial Waste Conference, 19th, Lafayette, Ind., 1964, Proc., Pt. 1: Purdue Univ., Eng. Ext. Ser. 117 (Purdue Univ. Eng. Bull., v. 49, no. 1), p. 195-199.

The problem of disposing of 1,500 tons per year of spent sulfuric acid from a Calgary, Alberta [Canada], plant for the alkylation of isobutane and butylenes was solved by the conversion of a well in an abandoned oil field into a waste injection well. The well, which is located in the Joffre Field at Red Deer on the Edmonton Highway about 90 miles north of Calgary, had been plugged with cement, but the casing had not been pulled, so that reconditioning was relatively cheap. Permission to use the well for the disposal of spent acid at a rate not exceeding 1,000 barrels per month was obtained from the Alberta Oil and Gas Conservation Board. The cement plug was drilled out to a depth of 5,128 ft and perforated with four shots per foot from 5,087 to 5,103 feet in the Viking Formation. The first injection of spent acid was made with high pressure pumps to fracture the formation. The maximum well head pressure obtained was 2,000 psi at a rate of over 200 barrels per hour. After gravity flow ceased, a second high pressure injection was made in which a pressure of 800 psi was required to inject 200 barrels per hour. Subsequently, a satisfactory rate of injection has been obtained with a constant pressure of 50 psi. The chief variables in this method are the cost of the well and transportation of the wastes. By reconditioning an abandoned well and moving the spent acid at a backhaul rate in the trucks which carry fresh acid from Edmonton to Calgary, total fixed and operating costs are less than the cost of fuel for incineration.

Descriptors: Foreign countries, waste water disposal, chemical wastes, injection wells, design criteria, geologic formations.

Holliman, W. C. *See* Taylor, S. S. 0392.

Holliman, W. C. *See* Taylor, S. S. 0394.

0024 **Hollister, John C.; Weimer, Robert J.**
1968. General summary and conclusions, *in* Geophysical and geological studies of the relationships between the Denver earthquake and the Rocky Mountain Arsenal well, Pt. A: Colorado School Mines Quart., v. 63, no. 1, p. 1-8.

Earthquakes at Denver, Colorado, cause public concern because they are apparently related to the operation of a deep waste-disposal well at the Rocky Mountain Arsenal.

Seismograph studies, geological investigations, and study of deep-well records were financed to determine the origin and mechanisms of the earthquakes. It is the belief of the majority of the investigators that injection of liquid wastes contributes to earthquake activity. The effect of injection on earthquakes could not have been predicted when the well was drilled in 1961. The reservoir should be allowed to come to equilibrium without further injection or withdrawal of fluids.–W69-07410

Descriptors: Earthquakes, injection wells, waste disposal, Colorado, hydrostatic pressure, fractures (geology).

0471 **Hollister, John C.; Weimer, Robert, J. (editors).**
1968. Geophysical and geological studies of the relationships between the Denver earthquake and the Rocky Mountain Arsenal well: Colorado School Mines Quart., v. 63, no. 1, Pt. A (papers) 251 p.; Pt. B (maps).

The geophysical portion of this study evaluates both the place of origin and the time of occurrence of the earthquakes in the Denver area. The history of earthquake activity in Colorado and its possible relationship to the recent Denver quakes is reviewed, and the relation between the Denver quakes and the reservoir into which fluids were injected via the Rocky Mountain Arsenal well is examined in detail. Geologic studies presented describe the regional structure and stratigraphy, surface geology, and regional and local characteristics of the fractured Precambrian rocks into which fluid was injected at the Arsenal well. [Pertinent papers are cited individually.] –Geophys. Abs. 266-092.

Descriptors: Earthquakes, Colorado, injection, deep wells, geophysics, geology.

0741 **Holmstrom, L.**
1969. How Kansas-Nebraska Natural completes its disposal wells: Drilling, v. 30, no. 6, p. 45, 48.

To overcome the waste of gas utilized in dewatering gas wells, the Kansas-Nebraska Natural Gas Co., Inc., decided to drill a disposal well to the Glorietta Formation at each of the 4 gas wells which was scheduled for drilling in 1964. These gas wells were equipped with pumping equipment to lift the water and pump it directly to the disposal well. The procedure was to drill the 6-1/4-in. hole to at least 60 ft below the deepest porosity in the Glorietta. Total depth ranged from 1,350 to 1,560 ft. No surface casing was set and 3-3/8 in. or 2-7/8 in. tubing was used for the disposal string. The disposal strings were cemented with 200 sacks of cement containing 4% gel, followed by 100 sacks of cement which was salt-saturated. The disposal wells were perforated and stimulated. On the basis of satisfactory operation of 6 wells with individual disposal wells, the company drilled 12 gas wells in 1965, each with its own disposal system. To date, there has been no failure of the disposal wells.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, injection wells, Kansas, installation.

0648 **Honstead, J. F.**
1963. The role of "ground disposal" in radioactive waste management [with French abs.], *in* La retention et la migration des ions radioactifs dans les sols–Collogue international, Saclay, France, 1962: Paris, Presses Universitaires de France, p. 11-15.

The importance of understanding the specific role of a waste management process such as ground disposal is examined. The role must be specified before objective research and development is possible and is a prerequisite for communicating research progress. A general analysis of a schematic waste management situation was made to identify the purpose of its several components. Two situations are pointed out where the results of research into the retention and migration of radioactive ions in soils may be usefully applied. The first is in evaluation of subsurface, high level waste storage facilities. The second involves the discharge of low-level waste water. The utility of the ground disposal in each case is pointed out. The importance of a full understanding of the purpose and place of this technique in waste management philosophy to assure its acceptance and profitable application to specific problems is emphasized.–Author's abstract, NSA 18-17338.

Descriptors: Radioactive waste disposal, underground storage, management, research and development.

0849 **Honstead, J. F.; Beranek, J.**

1963. Waste management implications in nuclear site selection, *in* Siting of reactors and nuclear research centres–International Atomic Energy Agency, Bombay, 1963, Symposium Proc.: Vienna, Internat. Atomic Energy Agency (STI/PUB/72), p. 201-207. [In English with French, Russian, and Spanish abs.]

The part played by waste management considerations is discussed with particular emphasis on the interaction of site characteristics with waste management operations. In general, site selection will ultimately be guided by other factors, but the decision can have considerable influence on the waste problem, including the cost of the operation. Three general philosophies are followed dealing with waste problems: absolute containment of hazardous quantities of radioisotopes, delay storage of short-lived isotopes to permit decay, and discharge of waste water containing subhazardous concentrations of radioisotopes with assurance of safe dispersal in the environment. Each of these philosophies is affected to some degree by particular characteristics of the site, a study of the selected site providing the proper basis for designing the appropriate waste management system. The information that may be useful in an evaluation of the consequences of waste management operations on several local environments is discussed. In examining surface streams near the installation, it is suggested that a survey be made of the utilization of the water on a seasonal basis, and that attention be directed toward regulatory, administrative, and public relations problems that may arise. In addition, technical information should be obtained concerning the physical characteristics of the stream. Similar information should be obtained with regard to the ground surface and ground water where contamination might become a problem as a result of accident or malfunctioning of the waste handling operations. These studies should continue as monitoring programs after the facility is constructed.–Authors' abstract.

Descriptors: Radioactive waste disposal, management, project planning, design criteria, water pollution control, radioisotopes.

0025 **Hoopes, John A.; Harleman, D. R. F.**

1965. Waste water recharge and dispersion in porous media: Massachusetts Inst. Technology Hydrodynamics Lab. Rept. 75, 166 p.

The effects of dispersion and diffusion of waste-water solutes in aquifers near the injection wells are incorporated in a mass conservation equation. Solutions are derived to predict the tracer distributions resulting from various recharge and disposal operations. For uniform flow, the longitudinal and lateral dispersion coefficients are related to the seepage velocity, particle size, and media structure. These coefficients are determined from experimental measurements of the distribution of a dilute salt tracer in flow through a sand column. Convection and dispersion determine the tracer distribution near the well. At larger distances from the well, molecular diffusion and convection alone are important. With a pair of wells, one recharging tracer fluid and the other pumping the mixture of tracer and native groundwater, the solution for the tracer distribution indicates that lateral dispersion has a negligible influence on the tracer distribution, except very near the line joining the two wells. Molecular diffusion is also shown to be insignificant, except for small flow rates and large well-spacings. Longitudinal dispersion determines the shape of the tracer distribution within the media, whereas convection dominates the tracer distribution at the pumping well, except for short times.—W69-07554.

Descriptors: Groundwater movement, diffusion, dispersion, model studies, hydrodynamics, injection wells.

0026 **Hoopes, John A.; Harleman, D. R. F.**
1967. Dispersion in radial flow from a recharge well: Jour. Geophys. Research, v. 72, no. 14, p. 3595-3607.

The recharge and disposal of treated and untreated waste waters in groundwater aquifers results in a mixing of these waters with the natural groundwater. The distribution and boundaries of the ensuing mixture are determined by the combined mechanisms of convection, dispersion, diffusion, and sorption. In this study, the mass conservation equation for a dissolved substance in two-dimensional groundwater flow is developed. An analytical solution and a numerical solution of this equation are obtained for the radial and temporal distribution of a conservative, dissolved substance, which is injected into a homogeneous, isotropic confined aquifer by a single recharging well. Experimental measurements of the concentration distributions of a dilute salt water tracer support the theoretical solutions. It is found that, for homogeneous media, the dispersed or mixed region may be less than one percent of the volume of fluid recharged at distances of only 30-60 meters from the well. Finally, from the experimental results it is shown that the dispersion coefficient along the streamlines is the same for both uniform and nonuniform flows at the same velocity.—AWRA 08-0002.

Descriptors: Hydrodynamics, dispersion, groundwater movement.

0027 **Hoopes, John A.; Harleman, D. R. F.**
1967. Wastewater recharge and dispersion in porous media: Am. Soc. Civil Engineers Proc. Paper 5425, Jour. Hydraulics Div., v. 93, no. HY 5, p. 51-71.

For steady flow between a recharging and a pumping well, in an infinite, confined aquifer of homogeneous, isotropic media, theoretical expressions are developed for the spatial and temporal distributions of a conservative substance introduced at the recharge well. From these expressions, the relative influences of convection, dispersion, and diffusion on the substance distribution are deduced. To test the analytical results, experimental measurements of the distribution of a dilute salt-water tracer in a sand model are presented. The model tests and field problem show that lateral dispersion has a negligible influence on the substance distributions, and that molecular diffusion, though not important in the model tests, may be important in field problems. Longitudinal dispersion is important in determining the shape of the tracer distribution within the aquifer, but it has a significant influence on the concentration in the pumping well only for short times when the ratio of total to observed concentration is less than 0.1.—AWRA 08-0090.

Descriptors: Dispersion, diffusion, model studies, porous media, steady flow.

0472 **Hoover, D. B.; Dietrich, J. A.**
1969. Seismic activity during the 1968 test pumping at the Rocky Mountain Arsenal disposal well: U.S. Geol. Survey Circ. 613, 35 p.

During 1968 pumping tests at the Rocky Mountain Arsenal disposal well, the U.S. Geological Survey was responsible for monitoring earthquakes occurring in the area and making chemical analysis of fluids removed. Three criteria based on frequency, magnitude, and location of local earthquakes were established to suspend pumping if anomalous earthquake activity occurred. During pumping periods, earthquake activity remained within acceptable limits; after each of the two major pumping periods an increase in frequency of small earthquakes occurred. Most 1968 earthquakes occurred northwest of the arsenal; however, in the 2-1/2-month period after the start of the test, a larger percentage of the earthquakes occurred at the arsenal than in the previous 8-month period. Temperature in the cooled zone at the well bottom was 12°F warmer two weeks after pumping stopped than it was in January 1968. Preliminary chemical analyses indicate very little mixing between waste fluids and connate water.—*from* Authors' abstract, Geophys. Abs. 273-116.

Descriptors: Earthquakes, Colorado, deep-well pumping, chemical analysis.

0197 **Horton, R. E.**
1905. The drainage of ponds into drilled wells, *in* Fuller, M. L., Contributions to the hydrology of Eastern United States: U.S. Geol. Survey Water-Supply Paper 145, p. 30-39.

In glaciated regions where kettle holes and ponds are common no direct runoff to the streams takes place over a considerable percentage of the area nominally tributary to the rivers. Such ponds disfigure farmland and, if drained, the rich, mucky soil reclaimed is of great value. Drainage into deep-drilled wells has been successfully tried in a number of cases in Jackson County, Mich. The successful wells are described and factors affecting drainage well efficiency are emphasized.

Descriptors: Michigan, drainage wells, reclamation, design criteria.

0199 **Hough, L. W.**
1964. Injection wells—Hazards and State regulations, *in* Short course for superintendents and operators of water, sewerage, and industrial waste disposal systems, 26th Ann., Baton Rouge, La., 1963, Proc.: Louisiana State Univ., Eng. Expt. Sta. Bull. 75, p. 108-114. [Also published as Hough, L. W., 1965, Salt water and waste disposal wells—State regulations and geological problems: Baton Rouge, Louisiana Geol. Survey, 10 p. (revised 1968).]

The Louisiana Department of Conservation has the responsibility of protecting fresh-water sands from contamination by oil, gas, and salt water. The Department requires that salt water from oil fields be injected into a sand which carries salt water, but does not produce oil and gas. It also requires that the injected water must not displace any fresh water which may be carried in the sand at a higher level. Authority for the regulation of the disposal of other waste material (including sewage) is the responsibility of the Louisiana State Board of Health. Hence, the two agencies work very closely together in approving applications for underground disposal of sewage and industrial wastes. Waste injection is not permitted where it could possibly contaminate a fresh water supply. The approval procedure and typical disposal well installations are described. A list of requisites for successful underground disposal is also given.

Descriptors: Brine disposal, waste disposal, Louisiana, injection, legal aspects, regulation.

Howard, R. L. *See* Dunlop, A. K. 0726.

Hubbard, Thomas N., Jr. *See* Voress, H. E. 0412.

0201 **Hubbert, M. King; Willis, David G.**

1957. Mechanics of hydraulic fracturing: Am. Inst. Mining Metall. Petroleum Engineers Trans., v. 210, Tech. Paper 4597 p. 153-168.

A theoretical examination of the fracturing of rocks by means of pressure applied in boreholes leads to the conclusion that, regardless of whether the fracturing fluid be of the penetrating or nonpenetrating type, the fractures produced should be approximately perpendicular to the axis of least stress. The general state of stress underground is that in which the three principal stresses are unequal. For tectonically relaxed areas characterized by normal faulting, the least stress should be horizontal; the fractures produced should be vertical with the injection pressure less than that of the overburden. In areas of active tectonic compression, the least stress should be vertical and equal to the pressure of the overburden; the fractures should be horizontal with injection pressures equal to or greater than the pressure of the overburden. Horizontal fractures cannot be produced by hydraulic pressures less than the total pressure of the overburden. These conclusions are compatible with field experience in fracturing and with the results of laboratory experimentation.–Authors' abstract.

Descriptors: Fractures (geology), theoretical analysis, injection wells, stress.

0420 **Hughes, Richard F.**

1968. Denver's man-made earthquakes–Fact or fancy: Mines Mag., v. 58, no. 7, p. 22-24.

To date there is nothing other than coincidence to prove that water injection into the Rocky Mountain Arsenal disposal well has caused earth tremors in the Denver area. Inasmuch as the Precambrian rocks through which the well penetrates may be considered incompressible at the wellhead pressures used at the Arsenal well, and that injection waste waters could not have increased the lubrication of the fracture surfaces, it is concluded that all past and future tremors in the vicinity must be self-triggered.–Geophys. Abs. 274-117.

Descriptors: Earthquakes, Colorado, injection, deep wells, waste disposal.

Hulse, B. T. *See* Selm, R. P. 0363.

0204 **Hundley, C. L.; Matulis, J. T.**

1963. Deep well disposal: Ground Water, v. 1, no. 2, p. 15-17, 33.

Details concerning the drilling and successful completion of a deep waste-disposal well at Newport, Indiana, are described. The well is 6,160 feet deep and penetrates about 900 feet into the Mount Simon Sandstone which is the reservoir for disposal of inorganic waste. Under natural conditions, the Mount Simon is saturated with essentially stagnant brine. The Eau Claire Sandstone overlying the Mount Simon has a near zero permeability, thus preventing upward migration of waste. To date, millions of gallons of waste effluent have been pumped into the well at an average injection rate of approximately 70 gallons per minute.–Authors' abstract, NAB.

Descriptors: Waste disposal, deep wells, chemical wastes, Indiana, geologic formations, construction.

0283 **Hundley, C. L.; Matulis, J. T.**
1962. Deep-well disposal, *in* Industrial Waste Conference 17th, Lafayette, Ind., 1962, Proc.: Purdue Univ. Eng. Ext. Ser. 112 (Purdue Univ. Eng. Bull., v. 47, no. 2), p. 175-180.

This paper describes the steps that were followed in the construction and operation of a deep-well system for underground injection of wastes from the U.S. Army Chemical Corps facility being operated by the Food Machinery Corporation at Newport, Ind. Having found suitable geologic conditions to exist at the site, a test well was drilled to a total depth of 6,160 feet or about 900 feet into the Mount Simon Sandstone, the proposed reservoir zone. Cores were obtained intermittently beginning at a depth of 4,500 feet to obtain sufficient samples of the Eau Claire Sandstone which acts as a roof to the Mount Simon reservoir. Samples of the native fluid in the Mount Simon were also obtained. The fluid had a specific gravity of 1.148, a low pH, and a static level 360 feet below grade. Pump-in tests made with water buffered to a pH of 2 to 4 required a maximum pressure of 1,100 psig to obtain an injection rate of 900 gpm. The shut-in pressure after pumping was 600 psig and bled off to 150 psig after three weeks. Since the well went into operation, millions of gallons of waste effluent have been pumped into it. The pump pressure which is logged regularly and plotted against time shows a constant slope. These data corrected for specific gravity are used to estimate the useful life of the pump and also supply information on well and reservoir conditions. Thus far, the injection rate has averaged 70 gpm with no apparent clogging of the reservoir. The latest calculations show that the injection pressure will not exceed the capacity of the pump for 4,100,000 years.

Descriptors: Chemical wastes, Indiana, injection wells, deep wells, construction, operation and maintenance, geologic formations.

0205 **Ihrig, H. K.**
1936. Stream pollution hazards minimized by improved salt water disposal: Oil and Gas Jour., v. 34, no. 49, p. 51.

A brief review is given of the methods of salt-water disposal in Kansas. A statement is made to the effect that if there had been statutes in Oklahoma at the time the Greater Seminole area was opened up, prohibiting the use of natural drainage as a means of disposing of large volumes of salt water produced with the oil, the ultimate amount of oil recovered would have been only a very small amount of that which will be recovered. A large revenue in the form of taxes would have been lost to the State, and royalties, interest and dividends would have been lost by the citizens. In addition, thousands of men would not have been employed.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, Kansas, Oklahoma, legal aspects, economics, pollution abatement.

0206 **Ihrig, H. K.**
1949. Oil producers making rapid progress in salt water disposal programs: Oil and Gas Jour., v., 34, no. 50, p. 36, 38.

The trend in methods for salt-water disposal is toward underground storage in barren formations and returning it to the low side of producing formations as an artificial water flood. The use of input wells and the forming of a community disposal project are the best ways of handling the problem It may, however, be necessary to chemically analyze the brines to avoid plugging the holes of the formation with precipitated salts. This may be prevented in some instances by aeration or chemical treatment. It is claimed by some, however, that the "closed system" of handling the water, in which the water is prevented from coming into contact with the air, so that it is returned to the formation without being changed in any manner whatsoever, is the best way to prevent such precipitation. Among the different types of plants used is one which consists of a gathering system of asbestos cement pipe, a large concrete-lined pit equipped with a series of baffles which cause a slow even flow of water thru the pit to permit the settling of any substances causing turbidity, and at the same time aerating the water. Another type involves the use of an aerator and a stabilizing filter. Salt water disposal in Kansas is discussed briefly.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, injection wells, Kansas, waste treatment, piping systems (mechanical).

0208 **Inoue, Yoriteru; Kaufman, W. J.**
1961. Dispersion relations in injection disposal of radioactive wastes, *in* Kaufman, W. J., ed., Ground disposal of radioactive wastes conference, Berkeley, Calif., Aug. 25-27 1959, Proc.: U.S. Atomic Energy Comm. Div. Tech. Inf. [Rept.] TID-7621, p. 131-139.

An analysis is presented of underground movement of radioisotopes comprising a radioactive waste. Injection geometries chosen for consideration include one-dimensional flow systems, as typified by columns, radial flow systems, and two well systems in which one well serves for injection of the waste and the second serves to remove the treated waste from the formation.–NSA 15-30326.

Descriptors: Radioisotopes, ion transport, injection, dispersion, radioactive wastes.

0209 **Inoue, Yoriteru; Kaufman, W. J.**
1962. Studies of injection disposal, *in* Morgan, J. M., Jr., Jamison, D. K., Stevenson, J. D., eds., Ground disposal of radioactive wastes conference, 2d, Atomic Energy of Canada Limited and U.S. Atomic Energy Comm. Div. Reactor Devel., Chalk River, Canada, 1961, Proc., Book 2: U.S. Atomic Energy Comm. Div. Tech. Inf. [Rept.] TID-7628, p. 303-321.

A theory for the prediction of radioisotope transport through porous media is presented that is applicable to complex flow systems such as may be encountered in the injection of radioactive wastes into deep sandstone formations. The application of the theory requires that the distribution of solvent residence times in the region of interest be ascertained by a suitable tracer test. If certain conditions prevail and if it is possible to obtain sufficiently accurate measures of the formation porosity and ion exchange properties, the radioisotope breakthrough curve may be computed by a simple transformation of the solvent breakthrough curve. Laboratory column studies and a two-well field test were completed and are considered to support the theory. A five-spot arrangement of injection and relief wells is under study and is expected to provide further substantiation. The inherent weakness of the method stems from the difficulty in determining the formation porosity and from the problem of characterizing a relatively nonhomogeneous natural creation by an inconsequentially small sample. The field studies described herein were conducted on a water-deposited sand- and gravel-confined aquifer of demonstrated nonhomogeneous character. It is felt that the extensive, deep sandstone formations considered suitable for waste injection will exhibit a greater homogeneity and will also permit more precise predictions of radiocontaminant transport.–Authors' abstract, NSA 16-25055.

Descriptors: Injection, radioisotopes, hydrodynamics, radioactive waste disposal, ion transport, research and development.

0210 **Inoue, Yoriteru; Kaufman, W. J.**
1963. Prediction of movement of radionuclides in solution through porous media: Health Physics, v. 9, no. 7, p. 705-715.

The transport of a cationic radionuclide through the earth was determined by hydrodynamic convection, hydraulic dispersion, and ion-exchange sorption. If the manner of water movement is first ascertained by tritiated water tracer measurements and the exchange properties are determined by laboratory tests, it is possible to predict the arrival of individual radioisotopes at some distant point of concern. For the prediction theory to be fully applicable, the formation should be reasonably homogeneous, the isotope distribution factor should remain constant, and exchange equilibria should prevail at all points. It is also desirable that the hydraulic flow net remain unchanged. The validity of the prediction theory was tested with laboratory columns and with a field investigation. The field test involved several arrays of injections and relief wells and twenty-three observation wells penetrating a confined aquifer 100 ft below the earth's surface. The results demonstrated the theoretical validity and practical utility of the theory.—NSA 17-37000.

Descriptors: Radioisotopes, hydrodynamics, dispersion, ion exchange, laboratory tests, tracers.

0829 **Inoue, Yoriteru.**
1967. Prediction of radionuclide migration in ground water at the Japan Atomic Energy Research Institute (SM-93/15), *in* Disposal of radioactive wastes into the ground—International Atomic Energy Agency and European Nuclear Energy Agency, Vienna, 1967, Symposium Proc.: Vienna, Internat. Atomic Energy Agency (STI/PUB/156), p. 199-213.

The velocity of a radionuclide in ground water is related to the velocity of ground water, and the dispersion of radionuclides may be predicted from the dispersion of ground water. The application of the theory for the prediction of radionuclide movement at the Japan Atomic Energy Research Institute (JAERI) at Tokai-mura is described. JAERI is situated at Tokai-mura, where the formation consists of stratified and loam layers, sloping about 10 deg toward the Pacific Ocean. This sand layer holds the ground water. To determine the direction and velocity of ground-water flow, two methods were applied. One was to estimate ground-water flow by Darcy's law with the aid of permeability and equi-water level through measurements of ground-water levels at 53 observation wells throughout the area. The other method was a direct measurement of ground-water flow by the point dilution method, the results of which were used for the correction of data above. The distribution coefficient k_d may be obtained by measuring the mass-action constant of the sand or by direct comparison of water and radionuclide travel by passing a radionuclide in ground water through a soil column. The value of k_d for strontium-90, for example, was 3.6. As the ground-water flow at Tokai-mura has a maximum speed of 16.7 m/day at the JRR-2 reactor site, ^{90}Sr travel is estimated to be 1.13 m/day at that location. The study is only applicable to the continuous pollution of ground water by radioactive material, and, in the case of an abrupt dose of radionuclides in ground water, the concentration is expected to be much less due to dispersion. To investigate this, water tracer was injected at one monitoring well and samples collected periodically at observation wells. Because of the slow movement of ground water (average 30 cm/day), this observation will need two to three more years before it is completed.—Author's abstract, NSA-22-16803.

Descriptors: Radioisotopes, migration, groundwater movement, hydrodynamics, flow measurement, dispersion, foreign countries.

Inoue, Yoriteru. *See* Iwai, Shigehisa. 0682.

Inoue, Yoriteru. *See* Kaufman, W. J. 0541.

0552 **International Atomic Energy Agency.**
1965. Radioactive waste disposal into the ground: Vienna, Austria, Internat. Atomic Energy Agency (Safety Ser. no. 15), 111 p.

Information is given on: site characteristics affecting ground disposal; chemical reactions and physical behavior of wastes in the ground; modes of release; evaluation of sites and methods for ground disposal; and standards and control techniques. 138 references are cited.–NSA 20-10443.

Descriptors: Radioactive waste disposal, hydrogeology, hydrodynamics, design criteria, chemical reactions.

0649 **Irish, E. R.**
1962. A comparison of ground waste disposal status at Hanford [Wash.], *in* Morgan, J. M., Jr., Jamison, D. K., Stevenson, J. D., eds., Ground disposal of radioactive wastes conference, 2d, Atomic Energy Comm. Div. Reactor Devel., Chalk River, Canada, 1961, Proc., Book 2: U.S. Atomic Energy Comm. Div. Tech. Inf. [Rept.] TID-7628, p. 491-505.

The status of ground disposal of radioactive wastes at Hanford is summarized. Emphasis is placed on the period from July 1959 through June 1961. Data are tabulated on the volumes of wastes discharged to cribs and trenches and the annual and accumulated fission product curies. The activity in the ground after decay was calculated. It was concluded that the discharge of large volumes of low- and intermediate-level wastes to the ground at Hanford has been done safely, and it is planned to continue ground disposal in the future.–NSA 16-25069.

Descriptors: Radioactive waste disposal, underground storage, safety, Washington, data collections.

0744 **Irwin, J. H.; Morton, R. B.**
1969. Hydrogeologic information on the Glorieta Sandstone and the Ogallala Formation in the Oklahoma Panhandle and adjoining areas as related to the underground waste disposal: U.S. Geol. Survey Circ. 630, 29 p.

In the report area, the Glorieta Sandstone lies at depths ranging from about 500 to 1,600 ft below the base of the Ogallala Formation. The rocks between those 2 formations are of relatively impermeable types, but solution and removal of salt has resulted in collapse of the rocks in some places. Collapse and fracturing of the rocks could result in increased vertical permeability. This might result in movement of brine under hydrostatic head from the Glorieta Sandstone into overlying fresh-water aquifers in places where an upward hydraulic gradient exists or is created by an increase in pressure within the Glorieta. Abandoned or inadequately sealed boreholes also are possible conduits for such fluids. The mixing of water in the fresh-water aquifers with brines injected into the Glorieta is not known to have occurred anywhere in the report area. [43 refs.] –Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, Oklahoma, injection wells, geohydrologic units, water pollution, geologic formations.

0650 Isaacson, R. E.
1969. The Hanford exploratory deep well: Richland, Wash., Atlantic Richfield Hanford Co. [Rept.] ARH-SA-47, 18 p. [Available from CFSTI.]

A deep well was drilled in the Hanford area to obtain rock and water samples for evaluating the geologic and hydrologic characteristics of the underlying rock strata, which in turn can be used to determine whether the deep basalt flows are thick enough and impermeable enough to store radioactive wastes for hundreds to thousands of years in mined out caverns isolated from the biosphere. As of July 12, 1969, the well was 4,282 feet deep. Geophysical logs to that depth have been obtained. Hydrologic tests are being conducted, and core drilling is proceeding. Information obtained so far indicates that several layers of basalt are thick enough to mine out and appear to be impermeable enough to assure that wastes will not migrate through the rock into more permeable zones and hence into the biosphere. The specific depths of these zones are given.—NSA 23-40855.

Descriptors: Radioactive waste disposal, deep wells, hydrogeology, rock properties, basalts, Washington.

0212 Ives, R. E.; Eddy, G. E.
1968. Subsurface disposal of industrial wastes: Oklahoma City, Interstate Oil Compact Comm. Study, 109 p.

Underground waste disposal policies and practices in the U.S. are compiled and reviewed. A questionnaire was compiled and sent out to establish information on the nature, seriousness, legal aspects, and method of handling these problems as they exist in each of the states. Another questionnaire was sent out that dealt specifically with individual subsurface waste disposal wells. A short discussion of pollution problems includes information on the nature and seriousness of the pollutants and the treatment methods currently being used. Physical considerations of use of underground reservoirs may affect other values and other uses of these reservoirs for reasonable purposes. Legal considerations and resulting complications are discussed. A summary coverage of disposal systems and disposal wells now in use in the various states includes comments on state policies, regulations and enforcement. Recommended practices and procedures in the establishment of guidelines concerning initial processing of applications, drilling, monitoring and final abandonment of disposal wells are given.—W70-05181.

Descriptors: Waste water disposal, industrial wastes, injection wells, legal aspects, water pollution, data collections.

0682 Iwai, Shigehisa; Inoue, Yoriteru; Nishimaki, Kenzo.
1968. Movement through soil of radioactive nuclides contained in chemical processing waste: Nippon Genshiryoku Gakkaishi, v. 10, no. 8, p. 435-440. [In Japanese.]

The movement through soil of radioactive nuclides contained in chemical processing waste was investigated. Theories governing this movement were reviewed. Experiments were carried out with ^{90}Sr and ^{137}Cs in 1N-HNO_3 to simulate waste. This simulated waste was passed through a column packed with sand and the behavior of these radionuclides in the column was observed. The breakthrough curve of ^{90}Sr was very similar to the curve of the waste, while ^{137}Cs showed a curve about 60 times slower than the waste. It can thus be concluded that ^{90}Sr in actual wastes travels with the ground water, while ^{137}Cs moves about 60 times slower.—Authors' abstract, NSA 22-51208.

Descriptors: Radioisotopes, migration, chemical wastes, laboratory tests, soil environment, ion transport.

0213 **Jacobs, D. G.**
1967. Behavior of radioactive gases discharged into the ground: Nuclear Safety, v. 8, no. 2, p. 175-178.

The feasibility of discharging radioactive gases and aerosols from a reactor containment vessel into the ground following a fuel-meltdown incident has been discussed by an AEC working group. This review incorporates much of the information discussed. The behavior of various radionuclides in the ground depends on the physical properties affecting the movement of fluids in the ground as modified by reactions between the radionuclides and the geologic formation. When injection is completed the subsequent movement of the radionuclides results from natural convective transport of the formation fluids and from molecular diffusion. The extent of movement of most of the gaseous radionuclides is limited by their radioactive decay.—Author's abstract, NSA 21-14410.

Descriptors: Radioactive waste disposal, gases, radioisotopes, migration, feasibility studies, soil environment.

0553 **Jacobs, D. G.**
1963. Ion exchange in the deep-well disposal of radioactive wastes [with French abs.], *in* La retention et la migration des ions radioactifs dans les sols—Colloque international, Saclay, France, 1962: Paris, Presses Universitaires de France, p. 43-54.

In order to evaluate the safety of injection of radioactive wastes into deep wells it is necessary to be able to predict the movement of the more hazardous radionuclides. Exchange of monovalent and divalent cations on numerous reference clay minerals and sandstone showed that the exchange potentials of the divalent alkaline earth cations are quite similar. Strontium is selectively sorbed over calcium by a factor of 1.25. Divalent cations are sorbed in preference to sodium by the clay minerals and the exchange is adequately described by the laws of mass action when the divalent cations occupy more than 10% of the total exchange sites. The sorption of trace quantities of strontium from a calcium-free sodium salt solution is greater than predicted for simple ion exchange, suggesting the presence of small quantities of sorption sites highly selective for divalent cations. Normalized strontium breakthrough curves coincide with normalized chloride breakthrough curves and show that radionuclide migration can be predicted by observing the dispersion of water in the disposal formation and correcting for the sorptive behavior of specific radionuclides. Exchange studies with Richfield sand, a typical deep-well disposal formation, suggest that in the disposal of ORNL [Oak Ridge National Laboratory] low-level and intermediate-level wastes strontium will move only 1% and 10% as fast, respectively, as the transporting water due to ion exchange; calcium-strontium precipitation reactions will provide additional restrictions to radiostrontium movement. Cesium would move much more slowly than strontium because of highly selective exchange reactions. Ruthenium may move rapidly but is not likely to be hazard controlling.—Author's abstract, NSA 18-17342.

Descriptors: Radioisotopes, ion exchange, clay minerals, radioactive waste disposal, ion transport, geologic formations.

0554 **Jacobs, D. G.; Sealand, O. M.; Myers, O. H.**
1963. Liquid injection into deep permeable formations, sec. 1 *of* Radioactive waste disposal, *in* Health Physics Division annual progress report for period ending January 30, 1963: U.S. Atomic Energy Comm. Oak Ridge Natl. Lab. [Rept.] ORNL-3492, p. 3-12.

The Ca-Sr exchange properties of numerous minerals show that these two cations behave quite similarly in ion exchange reactions. In cases where precipitation of slightly soluble salts occurs, the relative behavior may differ appreciably; strontium is

less likely to be removed from solution than calcium by calcium carbonate but more likely to be removed by phosphatic minerals. Solution dispersion due to formation heterogeneities is likely to lead to radionuclide dispersion a few orders of magnitude greater than that observed in laboratory columns. As a result, the factors affecting dispersion in laboratory columns are likely to be of little influence in affecting radionuclide dispersion in the environment. In order to study geometric effects of dispersion of radionuclides by porous media and to test the effectiveness of physical and chemical barriers on a laboratory scale, a sandstone model was constructed. The kinetics of ion exchange reactions observed in linear-flow columns will be extropolated to the two-dimensional flow system, and the calculated response compared to measured values.–Authors' abstract, NSA 17-39296.

Descriptors: Radioisotopes, migration, porous media, laboratory tests, ion exchange, dispersion.

0651 **Jacobs, D. G.**
1963. Movement of radionuclides through the ground: Nuclear Safety, v. 5, no. 1, p. 109-114.

Four general approaches for comparing the migration of radionuclides in the ground with the movement and dispersion of the transporting water involve its correlation with a qualitative description of water movement, a classical hydrodynamic description of the receiving formation, direct measurement of the hydraulic dispersion using an appropriate water tracer to obtain the solution velocity distribution, and a quantitative description of the various factors affecting radionuclide movement and dispersion. The primary concern is to describe the variation of activity in the solution phase with time and distance.–NSA 18-00422.

Descriptors: Radioisotopes, dispersion, hydrodynamics, tracers, ion transport, migration.

0695 **Jacobs, D. G.; Shaikh, M. U.**
1964. Liquid injection into deep permeable formations, *in* Health Physics Division annual progress report for period ending July 31, 1964: U.S. Atomic Energy Comm. Oak Ridge Natl. Lab. [Rept.] ORNL-3697, p. 3-10.

Movement of radionuclides through porous media is due to movement of the transporting water, but is also affected by the ion exchange properties of the medium. Calculations were made for the movement of the solution and radiostrontium through a slab of Berea sandstone and were confirmed by experimental data. The behavior of chloride as a water tracer is complicated by its repulsion of negatively charged soil colloids. The relative exclusion of chloride is especially complicated when clay minerals are present and restricted in their degree of lattice expansion. However, these effects would be decreased as the concentration of electrolyte is increased and would probably be rather insignificant in clean sandstones having low specific surface and high porosity, especially if most of the surfaces were sufficiently separated to permit full development of an electric double layer. Anion exclusion gives a good measure of lattice expansion and collapse of hydrobiotite systems, thereby providing a rather accurate method of measuring the distribution of surface charge density of these interstratified materials.–Authors' abstract, NSA 19-08673.

Descriptors: Porous media, injection, ion exchange, strontium radioisotopes, groundwater movement, theoretical analysis.

0697 **Jacobs, D. G.; Kim, Y. E.; Sealand, O. M.**
1966. Application of mineral exchange to reactor technology, sec. 4 *of* Radioactive

waste disposal, *in* Health Physics Division annual progress report for period ending July 31, 1966: U.S. Atomic Energy Comm. Oak Ridge Natl. Lab. [Rept.] ORNL-4007, p. 27-33.

In the event of a nuclear incident involving fuel element meltdown, ^{131}I appears to present the most serious short-term hazard. If the radioactive gases could be pumped underground, the delay time afforded by adsorption and by physical movement through the porous medium and dilution would cause a reduction in the relative hazard by a few orders of magnitude. Strontium-90 would present the most serious potential for contaminating groundwater near the site of discharge. Laboratory studies conducted on the sorption of iodine by clays suggest that the iodine consists of condensed I_2 and chemisorbed I_2. Samples leached with water retain a finite quantity of I_2, also suggesting a fixed capacity for the chemisorption of iodine. A computer program has been written to describe the transient behavior of radionuclides in the ground when the transporting solution is a different concentration than the original groundwater. Experimental data, obtained on a Berea sandstone for different sets of conditions, confirm the suitability of Glueckauf's model for the passage of a wide band of solute through a chromatographic column, modified for changes in the adsorptive capacity due to changes in the total electrolyte concentration and for nonequilibrium sorption conditions. Preliminary data on curium behavior suggest that mechanisms other than ion exchange may play dominant roles in its behavior in the ground.–Authors' abstract.

Descriptors: Radioisotopes, sorption, porous media, computer programs, migration, laboratory tests.

0830 **Jacobs, D. G.**

1963. Mineral exchange work at Oak Ridge National Laboratory, *in* The use of inorganic exchange material for radioactive waste treatment–a working meeting held in Washington, D.C., Aug. 133-14, 1962: U.S. Atomic Energy Comm. Div. Tech. Inf. [Rept.] TID-7644, p. 187-189.

Work on exchange parameters of deep-well disposal of low and intermediate-level radioactive wastes is reported. Data are included on Ca-Sr exchange by sand-calcium carbonate mixtures and Cs sorption from NaCl solutions.–NSA 17-19711.

Descriptors: Radioactive waste disposal, injection wells, ion exchange, sorption, theoretical analysis.

Jacobs, D. G. *See* Boegly, W. J., Jr. 0600.

Jacobs, Martin. *See* Bear, Jacob. 0561.

Jamison, D. K. *See* Morgan, J. M., Jr. 0666.

0652 **Jansen, G., Jr.**

1964. Thermal consequences of leaks in radioactive waste storage tanks: Richland, Wash., General Electric Company, Hanford Atomic Products Operation [Rept.] HW-80848, 12 p.

An analytical solution for determining the consequences of the leak of radioactive heat-generating solutions from storage tanks into soil was developed. As an example problem the case of a leak of Purex 241-A supernate containing $5 \times 10^{-4} M$ cesium (0.18 Btu/hr/gal) was considered. The calculations indicated that for a leak of 5000

gallons the maximum steady-state rises encountered are 14 and 62°F at the concrete-soil interface and in the soil at a point 4.2 feet from the concrete liner, respectively. For a 50,000 gallon leak comparable temperature rises are 29 and 301°F, the latter at a point 10 feet from the concrete. It was concluded that even relatively large supernate leaks from the Purex waste storage tanks do not constitute a thermal hazard. A correlation is presented, which allows the calculation of maximum steady state temperatures for hemispherical leaks of solutions containing fission products of varying activity and adsorbability on the soil. The method of solving this problem is presented and it may be useful in determining temperature distributions near tanks, pipes, and other radioactive waste solution sources in the ground.—Author's abstract, NSA 18-26976.

Descriptors: Radioactive wastes, thermal properties, hazards, underground storage.

Jargon, J. R. *See* van Poollen, H. K. 0820.

Jennings, A. Ray. *See* Schroeder, Melvin C. 0534.

Jensen, R. G. *See* Barraclough, J. T. 0618.

0508 **Jessen, F. W.; Battle, J. L.**
1943. Brine stabilization with sodium hexametaphosphate: Indus. Eng. Chemistry, v. 35, no. 6, p. 650-654.

The results of a study on the use of sodium hexametaphosphate for stabilizing the condition called "calcium carbonate supersaturation" of an oil field brine prior to injection into subsurface formations indicate that brines treated with 2 to 5 parts per million are stable with respect to precipitation of calcium carbonate for 7-14 days. This period permits sufficient time for surface storage and subsequent disposal into the formation without plugging of the interstices of the disposal sand body. A modified carbonate stability test is described based on pretreatment of the solid calcium carbonate with a concentrated solution of sodium hexametaphosphate to saturate the surface area of the solid particles prior to its use for stabilizing brines.—Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, injection, waste treatment, chemical reactions.

0527 **Jessen, F. W.**
1945. Technical problems of salt water injection: Am. Petroleum Inst. Drilling and Production Practice, 1944, p. 112-121.

Salt water injection is now common practice throughout oil producing areas. Many problems remain, however, in design and operation of salt water disposal systems. Chemical composition of brines determine whether open or closed systems will be installed. Advantages of the closed system are reduction of corrosive properties of the fluid, making possible use of ordinary steel pipe, and part elimination of chemical treatment to cause precipitation. A disadvantage is that it is more complex, requiring facilities for trapping oil, treatment, sedimentation, and filtration in the absence of air. Development of more satisfactory methods of separating oil from the brine without exposure to air would be highly beneficial. Ideal conditions for disposal plants in open systems requires absolute separation of oil before aeration begins. Present methods are not entirely adequate. Important considerations in the injection well are a clean sand surface and use of tubing and other fittings treated or coated to resist corrosion. Recent developments include use of tubing coated with thermo-setting

resin. High pressure pumps of either reciprocating or centrifugal type are widely used, with principal trouble that of corrosion. Recently glass or porcelain-lined pumps are gaining favor.–Author's abstract.

Descriptors: Brine disposal, injection wells, design criteria, waste treatment.

0589 **Jessen, F. W.**
1949. Subsurface disposal of oil field brines: Chem. Eng. Prog., v. 45, no. 1, p. 11-16.

Injection of oil well brines into the subsurface of the East Texas oil fields disposes of the brines and at the same time increases oil production. The water is injected at depths varying from a few hundred to 6,000 or 7,000 ft. A half million bbl/day are returned, which represents about 90 percent of all the water produced. Average surface treating installations in the East Texas area cost approx. $60,000 plus an additional well cost of $30,000. Such an installation can handle 15,000 bbl/day of salt water. The overall injection cost varies from 2 to 3 mills to 1-1/2 to 2 cents per bbl.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, injection, Texas, waste treatment, operating costs.

Jessen, F. W. *See* Brown, K. E. 0084.

0216 **Joers, J. C.; Smith, R. V.**
1954. Determination of effective formation permeabilities and operation efficiencies of water input wells: Producers Monthly, v. 18, no. 12, p. 21-28. [Also in Petroleum Engineer, v. 26, no. 11, 7 p.]

Useful knowledge of formation and well characteristics has been derived by the analysis of pressure-buildup and pressure-decline curves from oil-production wells. As similar information about water-input wells is equally useful in operating water-flooding and pressure-maintenance projects, the pressure-buildup method of testing oil wells has been studied to determine its applicability to testing input wells. The pressure-buildup analysis has been shown to be applicable, with a few additional assumptions, to water-input wells. Skin factors and values of effective formation permeability have been calculated. They are useful in describing the operation efficiency of input wells in terms of pressure required for injection caused by zones of either higher or lower than average permeability near the well bore. Results from a single well test indicate, by the magnitude of the skin factor, whether the intake capacity of a well is satisfactory. If it is not, the possible improvement of acidizing, shooting, or fracturing can be estimated. The analysis is particularly useful in evaluating the effects of well workovers. The analysis of data from periodic well tests reveals changes in intake performance. Gradual plugging of a sandface by impurities in the injected water is apparent as values of the skin factor increase. Conversely, loss of the injected water through fractured zones near a well are indicated by decreasing values of the skin factor. Values of the effective formation permeability, after fillup, should increase gradually, reflecting the increased water saturation of the formation.–Authors' introduction and conclusions.

Descriptors: Test procedures, injection wells, subsurface investigations, pressure head, permeability.

John, Edward C. *See* Purtymun, William D. 0526.

0218 **Johnson, D. W.**
1905. Relation of the law to underground waters: U.S. Geol. Survey Water-Supply Paper 122, 55 p.

This report summarizes the main features of the laws respecting underground waters in the early 1900's. Two classes of ground water are recognized: underground waters flowing in defined and known channels and water passing through the ground below the surface, either without a definite channel or in courses which are unknown. Legislative acts affecting underground waters are reviewed for 15 States.

Descriptors: Groundwater, legal aspects, underground streams, percolating water.

0105 **Johnson Drillers Journal.**
1969. Well technology serves the mining industry: Johnson Drillers Jour., v. 41, no. 2, p. 1-4.

Four kinds of situations are described where ground-water technology serves the mining industry, as follows: (1) dewatering for open pit mining; (2) solution mining; (3) wells for extracting mineralized water as a raw material; and (4) disposal wells for difficult-to-handle waste fluids. Lowering the water table over an area to be excavated as an open pit involves creating a composite cone of depression by pumping from a series of properly spaced wells. Solution mining of underground uranium ore in formations below the water table was tested in 1964 in Wyoming's Shirley Basin by Utah Construction and Mining Co. Use of wells for bringing salt and sulfur to the surface from deep deposits is relatively commonplace. In an operation in Texas, the mineralized ground water itself is pumped as a raw material from which magnesium metal is extracted. Petroleum and related industries have disposed of salt water underground through unused oil wells for many years. In addition to meticulous studies of the geologic section at a proposed site and the orientation of permeable and confining strata in the general area, the design details of disposal wells themselves are important.—Tulsa Univ., Inf. Services Dept.

Descriptors: Groundwater, technology, waste water disposal, deep wells, injection, design criteria, dewatering.

Johnson, George L. *See* Purtymun, William D. 0526.

0219 **Johnson, Norris; Beeson, Carrol M.**
1945. Water permeability of reservoir sands: Am. Inst. Mining Metall. Engineers Trans., v. 160, Tech. Paper 1871, p. 43-55.

For many years the permeability of reservoir sands has been measured by flowing air through a cleaned and dried core sample. This differs from the true reservoir permeability in one important respect: the rock particles in the reservoir are surrounded by interstitial water, not air, and their physical shape and condition of hydration are greatly dependent thereon. Permeability as defined must be measured with a single-phase fluid. Since no means exist for removing the oil and gas from a core sample by simply flowing water through it, the sample must be cleaned and then resaturated with water before testing. The present discussion attempts to show that after the cleaning process a considerably different permeability is determined with salt or fresh water than is obtained with air. The postulate is made that the salt-water permeability is probably closer to the true reservoir permeability than is the measurement with air. This is discussed in relation to both physically possible and economically feasible measurements. Data on more than 1200 core samples are given to show the nature of the effects observed, and a plea is made for others to consider water permeability measurements as a routine necessity, eventually replacing air permeability in regions where the differences are great.–Authors' abstract.

Descriptors: Permeability, porous media, test procedures, Darcys law.

Johnston, O. C. *See* Perkins, T. K. 0821.

0222 **Jones, O. S.**
1945. Disposition of oil field brines: Lawrence, Kans., Kansas Univ. Publications, 192 p.

The brine disposal problem is discussed, oil field brine is defined, and material is given on surface water, ground water and water movement, farm and municipal water supplies, early brine disposal, brine ponds, subsurface brine disposal, brine disposal associations, brine used in secondary recovery, inadequately plugged wells, the ultimate purpose of salt water, and the importance of conserving ground-water supplies. Appended are data on the rules of the State Corporation Commission of Kansas in relation to brine disposal, salt water disposal systems, articles of agreement for disposal associations, technical problems of salt water injection, the Interstate Oil Compact, the national stripper well survey, chemical analyses, fish and livestock tolerance to brine consumption, state water laws, and Kansas water pollution statutes.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, injection wells, Kansas, operation and maintenance, legal aspects, pollution abatement.

0223 **Jones, O. S.**
1947. Subsurface disposal of inland oil field brines conserves fresh water supply: Civil Eng., v. 17, no. 2, p. 60-63.

Oil fields in the interior of the country are confronted with the problem of disposing of highly concentrated brine solutions in areas where fresh water supplies are at a premium to keep these solutions from contaminating potable water supplies. Early attempts to dispose of brine in small ponds caused several incidents of deterioration of ground-water supplies. Modern methods involve the use of injection wells to avoid such damage and at the same time provide a means of "water flooding" or repressurizing played-out fields. Although this requires a constant battle with corrosion of brine-handling equipment, it accomplishes the objective of true conservation by not stopping the use of any resource. How well this problem is solved will be the controlling factor in future economic growth.

Descriptors: Brine disposal, Kansas, pollution abatement, injection wells, conservation.

0745 **Jones, O. S.**
1946. Salt water disposal problems: Oil Weekly, v. 120, no. 9, p. 34-36, 38.

The problem of brine disposal together with recognized practices to make disposal adequate are discussed. Tables are given showing the composition of miscellaneous Kansas waters compared to sea water and drinking water, and brines typical of several producing formations and areas in Kansas.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, Kansas, chemical analysis.

0746 Jones, O. S.
1946. Subsurface brine disposal: Oil Weekly, v. 120, no. 10, p. 27-29.

Deep disposal of oilfield brines in disposal wells of 4500 ft. or more is favorable to both conservation of oil and gas in the field, and the protection of fresh water and farm lands in the area. After suitable treating, the water may be useful in the flooding of stripper wells, greatly aiding secondary recovery. In a field, a number of operators may use a community input well, thus reducing the cost to less than one cent per bbl. of brine. The cooperation of operators and landowners to aid this system of waste disposal is urged.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, injection wells, pollution abatement, operation and maintenance, methodology.

0747 Jones, O. S.
1950. Fresh water protection from pollution arising in the oil fields: Lawrence, Kans., Kansas Univ. Press, 132 p.

The problem of pollution from brines originating in the oil fields in Kansas is discussed. Kansas water pollution statutes pertaining to oil-field waters, the subsurface disposal of brines and tabulated data of various stream analyses are also included.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, Kansas, water pollution control, legal aspects, injection, chemical analysis.

0221 Jones, Paul H.
1961. Hydrology of radioactive-waste disposal at the Idaho Chemical Processing Plant, National Reactor Testing Station, Idaho, Art. 420, *in* Short papers in the geologic and hydrologic sciences: U.S. Geol. Survey Prof. Paper 424-D, p. D374-D376.

Low-level aqueous radioactive waste (less than 10^{-4} microcuries per milliliter, gross beta-gamma) is pumped directly into the ground-water reservoir at the Idaho Chemical Processing Plant (ICPP) through a drilled, cased, gravel-packed well 598 feet deep. This well penetrates several thin basalt flows and a single bed of silt, sand, and gravel below the water table. Radioactive waste is diluted with warm nonradioactive water from plant wastes, including large amounts of sodium chloride brine from water-softening units. Since 1952, a total of 757 curies of activity have been disposed to this well in 2.5 billion gallons of water. The hydrology of the basalt aquifers is difficult to interpret because of the sheet-conduit nature of the aquifers, the very low gradients in head, and the difficulty of establishing local stratigraphic and hydraulic continuity. Geophysical logging has resulted in correlation of aquifers, and well-packing equipment has enabled isolation and testing of aquifers.

Descriptors: Radioactive waste disposal, Idaho, injection wells, basalts, water pollution effects, borehole geophysics.

0224 Jones, Paul H.
1961. Application of bore-hole geophysics in hydrologic investigations in volcanic terrane [abs.]: Geol. Soc. America Spec. Paper 68, p. 33-34.

Investigation of the hydrology of disposal of low-level radioactive wastes in southeastern Idaho has included gamma-ray, electric, temperature, water-resistivity, and hole-diameter (caliper) logging. During 1960 more than 80,000 ft of hole was logged with excellent results in wells penetrating a sequence of beds of volcanic, eolian, lacustrine, and alluvial origin. The wells were drilled by percussion methods.

Lithologic characteristics of beds in the Snake River plain are best shown by the gamma-ray log, and aquifers are indentified by the hole-diameter (caliper) log. Temperature and water-resistivity logs indicate the depths at which waste water from the plants enters and leaves the wells. Retrievable straddle packers were used during measurements. A newly developed electronic flow meter will soon be employed to measure the direction and rate of vertical flow within the open hole, and a borehole magnetometer of the flux-gate type is now under development for use in correlating the dense basalt layers between water-bearing zones. All the dense basalt contains some magnetite.–Tulsa Univ., Inf. Services Dept.

Descriptors: Radioactive waste disposal, Idaho, hydrogeology, test procedures, subsurface investigations, equipment, borehole, geophysics.

0556 **Jones, Paul H.; Shuter, Eugene.**
1962. Hydrology of radioactive waste disposal in the MTR-ETR area, National Reactor Testing Station, Idaho, Art. 106, *in* Short papers in geology and hydrology: U.S. Geol. Survey Prof. Paper 450-C, p. C113-C116.

Since 1952, aqueous low-level radioactive waste from the National Reactor Testing Station has been discharged to a leaching pond. By 1955, the annual rate reached about 1,000 curies (excluding tritium) in 100 million gallons of water, and since 1957 has averaged about 3,700 curies in 220 million gallons of water. The discharged wastes have included as many as 40 to 60 isotopes, about 90 percent of which have a half life of less than 100 days. Seepage from the pond has moved downward through the alluvium of the Big Lost River, entered the underlying basalt, and become perched on an extensive sedimentary bed that lies 110 to 160 feet below the land surface. The tritium content of the perched water (in 1961) ranged from about 10×10^{-6} μc per ml (microcuries per milliliter) to 100×10^{-6} μ c per ml. The natural tritium content of the perched water was probably less than 1.6×10^{-7} μ c per ml. If the tritium content of the water has been relatively uniform since discharge began in 1952, which seems likely, and if the water at the outer edge of the perched water body is indeed water discharged in 1952, the tritium content now observed is much too low.

Descriptors: Radioactive waste disposal, Idaho, groundwater movement, radioisotopes, water pollution effects, tritium.

0557 **Jones, Paul H.; Schmalz, B. L.**
1962. Distribution of radionuclides in groundwater at the National Reactor Testing Station, with particular reference to tritium [abs.]: Jour. Geophys. Research, v. 67, no. 9, p. 3570-3571.

Investigations involving tritium concentration in groundwater beneath the Snake River plain were conducted in 1956 by the Atomic Energy Commission. Results were conclusive only to the extent that concentrations at that time were less than 50 tritium units (TU). (Tritium Unit: One tritium atom per 10^{18} hydrogen atoms.) A second study was conducted by the U.S. Geological Survey in 1960. Both investigations were directed toward determing the rate of travel of the water. A sample taken from an observation well near the materials testing reactor (MTR) by the U.S.G.S. in connection with the above study was found to contain 20,7000 TU. In the vicinity of the chemical processing plant (CPP), concentration levels as high as 1,000,000 TU were discovered at distances of 700 feet from the CPP disposal well, and as high as 61,000 TU at 9000 feet, and 1200 TU at distances of 3 miles. Chemically contaminated waste has been traced to distances of 6000 feet. Tritium was also detected in perched groundwater in the vicinity of the MTR pond in magnitudes ranging from 3×10^4 to 3×10^5 TU for a distance as great as 2400 feet from the disposal pond. The concentration decreases as distance from the pond increases. As the water in the vicinity accrues only from discharge to the pond, the attenuation cannot be explained on the basis of dilution. Concentrations of waste streams from the MTR were found in the order of magnitude of 10^5 TU. (One tritium unit is equal to 3.26×10^{-9} μc/ml.) Evaporator condensates at the CPP were found to contain 120,000,000 TU. Service waste streams and storage canal water at the CPP were found to contain concentrations in the order of magnitude of 10^6 TU. The average rate of tritium discharge from the CPP during December 1961 was 18.6 curies per day. Concentrations in observation wells in the vicinity reflect changes in discharge and on the basis of first arrival indicate a rate of movement of approximately 100 ft/day.—Authors' abstract.

Descriptors: Radioactive waste disposal, Idaho, groundwater movement, monitoring.

0653 **Jones, Paul H.**
1962. Geophysical research at the National Reactor Testing Station, *in* Morgan, J. M., Jr., Jamison, D. K., Stevenson, J. D., eds., Ground disposal of radioactive wastes conference, 2d, Atomic Energy of Canada Limited and U.S. Atomic Energy Comm. Div. Reactor Devel., Chalk River, Canada, 1961, Proc., Book 1: U.S. Atomic Energy Comm. Div. Tech. Inf. [Rept.] TID-7628, p. 99-114.

Both surface reconnaissance and borehole geophysical methods are described that have been used in geologic and hydrologic investigations in the eastern Snake River Plain, in which the National Reactor Testing Station is located. Airborne magnetometer and scintillometer surveys and gravity surveys were also made. Six logging methods are described that have yielded information necessary for quantitative study of waste disposal hydrology. These methods include electric, gamma ray, hole-diameter, flow-meter, temperature, and water resistivity logging. The equipment used consisted of a WIDCO logger with multiconductor steel cable on a power driven reel. A magnetometer was developed to detect differences in mineral content between basalt flows. The borehole-geophysical-logging methods described were used for hydraulic and tracer studies employing a network of wells that top a single aquifer. The data formed a basis for waste disposal hydrology at the National Reactor Testing Station.—NSA 16-25043.

Descriptors: Idaho, geophysics, radioactive waste disposal, basalts, logging (recording).

0748 **Kansas-Oklahoma Oil Reporter.**
1963. Tested scale control unit shows promise in SWD [salt-water disposal] wells: Kansas-Oklahoma Oil Reporter, v. 6, no. 5, p. 58, 59.

One producing company's experience with a scale-control unit used in brine disposal wells is being watched by many Panhandle operators who have begun returning produced water to underground formations. One of the chief causes of trouble has been scale buildup on the interior wall of disposal lines. The device, called the Nero-tron is a simple cylindrical steel casing through which the water flows at a calculated rate through an electrostatic field. A positively charged electronic capacitor is suspended in the steel casing; the casing itself is negatively charged. Action of the field polarizes particles so that they become softer and larger, and lose their affinity for the wall of the pipe. The particles suspended in the flow while it is inside the piping are discharged with the water when it leaves the piping. It is reported that there has been no scale-buildup problem in the disposal well since the device was installed. Power demands for operation are extremely low.—Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, Oklahoma, injection wells, scaling, control systems.

Kaplan, M. *See* Lewelling, H. 0757.

0749 **Kastrop, J. E.**
1952. Brine disposed at small cost: World Oil, v. 134, no. 6, p. 162-164.

Two automatic control systems on a closed-type salt water disposal plant, one hydraulic and the other gas pressure, control the flow of 1700-2000 bbl/d salt water gathered from nine tank batteries through water conditioning and accumulator tanks into a disposal well.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, control systems, injection wells, equipment.

0576 **Katz, Donald L.; Coats, K. H.**
1968. Underground storage of fluids: Ann Arbor, Mich., Ulrich's Books, Inc., 575 p.

The book is written primarily for engineers, geologists, and managers, who are engaged in studies preparatory to developing storage projects, for those who have responsibilities in designing the facilities, and for personnel who operate facilities for storing fluids, either liquids or gases. Many ideas or concepts involved in storage operations are presented at the layman's level prior to engaging in the more technical material. The book brings together many pieces of information needed for those who wish to understand the development, design, and operation of storage projects. The book does not pretend to be a treatise on the subject, but rather a representation of the experiences and interests of the authors.–*from* Authors' preface, WSP 1990.

Descriptors: Underground storage, facilities, design criteria, construction, operation and maintenance.

0654 **Katz, Donald L.**
1962. Liquid-waste storage in abnormal-pressure reservoirs: Nucleonics, v. 20, no. 4, p. 71.

Extremely high pressures in certain underground reservoirs in strata along the Gulf Coast prove the reservoirs are leak-tight. This tightness makes these reservoirs ideal for storing radioactive liquid wastes without fear of leakage. Fluid pressures in these sands are 2000 to 7000 psi higher than in adjacent aquifers. The process which caused the shale compaction around the sands is discussed along with methods for using the reservoirs for storage purposes.–NSA 16-16028.

Descriptors: Hydrostatic pressure, radioactive waste disposal, liquid wastes, underground storage coastal plains.

0227 **Kaufman, W. J.**
1960. The containment of radioactive wastes in deep geologic formations, *in* Disposal of radioactive wastes, v. 2–International Atomic Energy Agency and United Nations Educational, Scientific and Cultural Organization, Monaco, Nov. 16-21, 1959, Sci. Conf., Proc.: Vienna, Internat. Atomic Energy Agency (STI/PUB/18), p. 533-546. [In English with French, Russian, and Spanish abs.]

When adequate decontamination requires that excessively large volumes of semisolid radioactive wastes must be permanently stored, the deep underlying formations of the earth may, with favorable hydrogeologic conditions, constitute a safe and economic waste-disposal resource. In sandstone, large volumes of waste may be stored with a high degree of containment integrity. Both the interstitial voids and ion-exchange properties serve to make available a great storage capacity. The disposal system can consist of a pattern of injection wells and of relief wells which serve to reduce well-head pressures, permit monitoring, and direct the flow. Design data include dis-

persion or short-circuiting properties of the formations, ion-exchange characteristics of the media, and the chemical and radiochemical properties of the wastes.

Descriptors: Injection wells, radioactive waste disposal, hydrogeology, hydrodynamics, ion exchange.

0229 **Kaufman, W. J.; Orcutt, R. G.; Klein, Gerhard.**
1955. Underground movement of radioactive wastes: U.S. Atomic Energy Comm. Oak Ridge Natl. Lab.[Rept.] AECU-3115, 92 p.

A preliminary investigation was made of several physical and chemical factors influencing the feasibility of high-level radioactive waste disposal by injection into isolated geological formations. The report includes a review of the injection disposal practices of the petroleum and chemical industries and considers the problems likely to be encountered in using similar techniques for the disposal of fission product wastes of the nuclear energy industry. Laboratory model and field studies were made to determine the influence of hydraulic parameters on velocity variations during the flow of liquids through porous media. The contribution of longitudinal mixing in laminar flow to the development of concentration fronts has been considered. It was observed that even in homogeneous isotropic media, portions of the injected waste may travel at velocities exceeding six times the average. A Hele-Shaw parallel plate viscous flow model was employed to investigate density displacements resulting from the injection of a liquid differing in density from the formation water. Column studies of clays and a typical oil sand have shown that exchange reactions may retard the advance of radiostrontium concentration fronts to as much as one-fortieth of that of the liquid fronts. Ion exchange may thus make a significant contribution to the waste storage capacity of connate formations.—Authors' abstract.

Descriptors: Radioactive waste disposal, feasibility studies, injection, porous media, model studies, ion exchange.

0541 **Kaufman, W. J.; Ewing, B. B.; Kerrigan, J. V.; Inoue, Yoriteru.**
1961. Disposal of radioactive wastes into deep geologic formations: Water Pollution Control Federation Jour., v. 33, no. 1, p. 73-84.

Injection of radioactive wastes into deep geologic formations is considered a feasible and economic approach to handling low- and intermediate-level wastes. Deep injection is a possible solution to be arrived at only after considering all factors peculiar to a given situation. Disposal by dilution into rivers and oceans is often a more satisfactory alternative and should only be rejected on the basis of a careful analysis of hazard and economic factors. The deep formations of the earth potentially offer far more permanent retention than can be achieved by surface storage systems. The technology of wastewater injection illustrates the necessity of pretreatment of wastes to insure compatibility with the receiving formation. Where the composition of wastes from nuclear sites varies widely, holdup and blending, followed by chemical precipitation, filtration, pH adjustment, and chlorination, will no doubt be required to meet the compatibility criterion.—Tulsa Univ., Inf. Services Dept.

Descriptors: Radioactive waste disposal, injection, deep wells, technology, environmental engineering, pre-treatment (water).

0577 **Kaufman, W. J. (editor).**
1961. Ground disposal of radioactive wastes conference, Berkeley, Calif., Aug. 25-27, 1959, Proc.: U.S. Atomic Energy Comm. Div. Tech. Inf. [Rept.] TID-7621, 168 p.

443-542 O - 71 - 9

This series of papers reviews progress made in research and development studies related to ground disposal of radioactive wastes over the past few years, both in the United States and abroad. Major subjects include: (1) operating practices, experiences, and problems at Hanford; Oak Ridge; National Reactor Testing Station; the Savannah River Plant; Chalk River, Ontario, Canada; Saclay, France; and Mol, Belgium; (2) research on ion exchange and adsorption in natural media; and (3) current investigations of hydrodynamic problems of flow through porous media. Methods of waste disposal discussed include spreading, well injection, and the use of pits, trenches and cribs. Disposal rates are tabulated.–WSP 1990.

Descriptors: Radioactive waste disposal, hydrodynamics, ion exchange, adsorption, United States, foreign countries.

Kaufman, W. J. *See* Inoue, Yoriteru. 0208.

Kaufman, W. J. *See* Inoue, Yoriteru. 0209.

Kaufman, W. J. *See* Inoue, Yoriteru. 0210.

Kaufman, W. J. *See* Orcutt, R. G. 0304.

Kaufman, W. J. *See* Rifai, M. N. E. 0855.

0230 **Kehle, R. O.**
1964. The determination of tectonic stresses through analysis of hydraulic well fracturing: Jour. Geophys. Research, v. 69, no. 2, p. 259-273.

The well-fracturing operation is modeled by a band of uniform pressure and two bands of uniform shear stress acting in a cylindrical cavity in an infinite body. Two interesting regions of induced stress are: either end of the pressurized interval where the tangential stress is zero (the vertical stress is approximately 95 percent of the pressure) and the center of the packed-off interval where the tangential stress equals the pressure (the vertical stress is zero). The tectonic stresses are the overburden load and two unknown principal horizontal stresses that cause easily determined stress concentrations at the well bore. All calculated stresses are modified to account for the interstitial pore-fluid pressure. It is found that three situations are of interest: (1) the induced vertical stress is less than the overburden pressure; (2) the induced vertical stress and the instantaneous shut-in pressure are greater than the overburden pressure; (3) the induced vertical stress is greater than the overburden pressure but the instantaneous shut-in pressure is less than the overburden pressure. In (1) the fracture is vertical and the stresses are determinable. In (2) the fracture is horizontal and the stresses are indeterminate. In (3) the fracture is initially horizontal but becomes vertical as it propagates away from the well, the vertical and minimum horizontal compressions are determinable, and the other principal stress is bounded by a set of inequalities. Several examples are presented in which the tectonic stress states appear to be relaxed–approximately equivalent to the 'hydrostatic' pressure.–Author's abstract.

Descriptors: Model studies, rock properties, stress analysis, mathematical models fractures (geology).

0750 **Kemler, E. M.**
1944. Reservoir data and production problems: Oil Weekly, v. 113, no. 8, p. 72, and v. 113, no. 9, p. 34, 36.

Data on bottom hole pressures are valuable to supplement short-time pumping tests with temporary equipment to indicate whether a well should be acidized or shot, drilled deeper, pumped at a higher speed, or plugged to shut off water. Each of these points is discussed with the aid of specific examples. Bottom hole pressure data can be used to follow the course of injection of water into the formation in salt water disposal or water flooding wells, because plotting the bottom hole pressure against the injection rate gives curves whose slopes and origins vary according as the formation becomes plugged or saturated–in the first case acidizing or swabbing may be beneficial. These bottom hole pressure data when correlated with production history indicate any abnormal changes in production caused by plugging of the producing formation or by increases in viscosity of the fluid produced, and help one decide what remedial measures should be taken.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, injection wells, hydrodynamics, pressure head, monitoring.

Kerrigan, J. V. *See* Kaufman, W. J. 0541.

Kevi, L. *See* Ellis, W. R. 0015.

Khomchik, L. M. *See* Sobolev, I. A. 0841.

Kim, Y.E. *See* Jacobs, D. G. 0697.

Kimbler, Oscar K. *See* Esmail, Omar J. 0017.

0751 **King, H. H.**
1936. Water disposal plan–East Texas operators start experiment as volume increases: Oil Weekly, v. 80, no. 10, p. 14.

East Texas operators are collecting and impounding salt water brines accompanying crude production, pending the solving of the problem of their disposal. Initial efforts will involve pumping into the Woodbine horizon thru a key well to be drilled about three miles west of the oil production zone. It will be drilled thru the Woodbine section and casing cemented on top of the sand. A battery of boilers and heavy duty pumps will be engaged to force the water into the original reservoir. A filter trap will be utilized in preventing mud or vegetation from accompanying the brine into the hole.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, injection, Texas, feasibility studies, geologic formations.

0752 **King, H. H.**
1938. Feasibility of returning salt water: Oil Weekly, v. 91, no. 12, p. 23-24, 26, 28.

The feasibility of returning salt water to the formation by special in-put wells is shown on the basis of the example of Sun Oil Co. operating in the East Texas fields. Data are

cited on input wells and other equipment, with emphasis on cost account, and illustrated by diagrams and graphs.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, Texas, injection, feasibility studies, operating costs, equipment.

0232 **King, L. G.**
1967. Mathematical model for underground discharge of radioactive gases: Richland, Wash., Battelle Memorial Inst. Pacific Northwest Lab. [Rept.] BNWL-SA-1152, 21 p. [Available from CFSTI.]

Injection of radioactive gas into the partially saturated section above the water table was investigated with mathematical models. One model was used during injection and another after cessation of injection. Assumptions made were: The gas obeys the Darcy equation, soil moisture is immobile, flow is isothermal and steady, soil is homogeneous and isotropic, soil moisture content is uniform, equation of state for dry air is sufficient to describe the gas, the gas is compressible, and the system is symmetric about the axis of the injection well. Calculated and measured values were found to be in satisfactory agreement.–W69-02813.

Descriptors: Mathematical models, radioactive waste disposal, gases, methodology, hydrodynamics.

0655 **King, L. G.**
1968. Mathematical models for underground injection of gaseous wastes into the vadose zone: Richland, Wash., Battelle Memorial Inst. Pacific Northwest Lab. [Rept.] BNWL-945, 149 p. [Available from CFSTI.]

Mathematical models which describe the flow of compressible gas through porous media were developed as part of a research program investigating the feasibility of underground disposal of gaseous wastes following a nuclear reactor incident. The models describe gas movement through ground during injection via a single well above the regional water table. With respect to permeability, the porous media can be treated as homogeneous and isotropic, heterogeneous and isotropic, or homogeneous and anisotropic. Solutions for the two homogeneous cases are presented in dimensionless graphical form for a wide range of conditions. The models were applied to two different types of tracer studies conducted in the field at the National Reactor Testing Station. For helium tracer tests conducted in shallow alluvium, the homogeneous, isotropic model resulted in satisfactory comparison of calculated and measured conditions. For xenon tracer tests in the fractured basalt, the homogeneous, anisotropic model was needed for satisfactory agreement.–Author's abstract, NSA 23-11738.

Descriptors: Mathematical models, injection, porous media, waste disposal, nuclear wastes.

0753 **Klassen, C. W.; Black, H. H.; Troemper, A. P.; and others.**
1938. Suggestions for prevention of pollution of waters by oil field wastes: Springfield, Illinois Dept. Public Health, 22 p. [Revised 1940]

Petroleum wastes from oil well drilling, completion, operation, and from leaking lead lines, pipe lines, or tank batteries should be disposed of in a burnpit having a capacity exceeding that of the largest tank tributary to it and constructed in such a manner as

to exclude surface drainage. Oil field brine should be disposed of by injection into subsurface geological strata, solar evaporation in lagoons, or disposal by controlled dilution. Each of these topics is briefly discussed.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, pollution abatement, injection, evaporation, waste dilution.

Klein, Gerhard. *See* Kaufman, W. J. 0229.

Klein, Gerhard. *See* Orcutt, R. G. 0304.

Klein, Gerhard. *See* Orcutt, R. G. 0593.

0233 **Klotzman, Melvin; Ven, Byron.**
1966. Celanese Chemical [Co.] pumps wastes into disposal wells: Oil and Gas Jour., v. 64, no. 15, p. 84-87.

This paper describes the planning and research that were needed to design and install a waste-injection-well treatment system to handle the increased amount of wastes at the Celanese Chemical Co.'s plant in Bay City, Tex. The waste, which consists of 0.3 percent acetic acid and chlorinated derivatives, even though in a relatively weak solution, can eat through 3 inches of steel per year. All waste-handling equipment, therefore, had to be made of materials that could withstand the corrosive actions of the wastes. Hastealloy"C" was used for all metallic components, and baked-on, holiday-free, epoxy-coated, fiber-cast casing was used to line the well. The well was perforated between depths of 3,395 and 3,608 feet. Although initial injection rates were low, the well was backwashed with gas for several days, after which the injection rate showed a tenfold increase. After a few months operation, the well was taking 7,000 barrels of waste per day at a pressure of 200 psi. The injection-well system has proven to be a profitable and trouble-free method of disposing of highly corrosive and undesirable wastes.

Descriptors: Chemical wastes, injection wells, Texas, corrosion control, operation and maintenance, design.

Knoll, K. C. *See* Nelson, J. L. 0521.

Knoll, K. C. *See* Nelson, J. L. 0671.

0558 **Knowles, D. B.**
1965. Hydrologic aspects of the disposal of oil-field brines in Alabama: Ground Water, v. 3, no. 2, p. 22-27.

Contamination of fresh-water supplies associated with the disposal of brines occurs in all Alabama's oil fields, of which the Pollard oil field is typical. Water supplies for the field come from wells tapping permeable sand and gravel beds of Tertiary and Quaternary age having an average thickness of 50 feet and underlain by relatively impermeable clay beds that serve as a confining bed for artesian water. Natural water in the aquifers is of good quality except for local areas. Disposal of brines and other

waste in the Pollard field occurs by injection into disposal pits or discharge into evaporation pits. Further contamination could be prevented by proper lining of pits and maintenance to prevent brine and oil leaks.–NAB.

Descriptors: Groundwater, Alabama, water pollution, oil fields, brine disposal, hydrogeology.

0543 **Knox, J. A.; Brogdon, B. R.; Carlile, W. C.**
1968. Preparation and stimulation of water injection and disposal wells, *in* Southwestern petroleum short course, 15th Ann., 1968, Proc.: Lubbock, Tex., Texas Technol. Univ., p. 1-7.

There are 3 types of wells which can be considered for stimulation in injection systems: (1) new wells, drilled just for the purpose of injecting water; (2) old producing wells, being converted to injection wells; and (3) injection wells currently in use. The new injection wells should be treated in much the same manner as a new producing well. Mud damage should be removed and a stimulation treatment designed to provide the desired injectivity. Some type of acidizing or fracturing treatment is generally utilized. In converting old producing wells to injection wells, samples of deposits should be obtained from the open hole or perforated interval and analyzed to aid in determining what solvents should be used. Some typical stimulation treatments are listed. In utilizing old injection wells, a sample from the perforated interval or open hole is preferred. The types of scales and solutions for their removal are discussed in detail. A number of treating techniques are listed. A combination of several treating techniques may be necessary, as it is rarely possible to obtain a completely satisfactory stimulation treatment with only one.–Tulsa Univ., Inf. Services Dept.

Descriptors: Injection wells, construction, maintenance, rehabilitation.

Knudsen, C. N. *See* Reisenauer, A. E. 0659.

0551 **Koger, W. C.**
1968. Planning a water injection system, *in* Corrosion control short course, 1968, Proc.: Norman, Okla., Oklahoma Univ., p. R1-R10.

The success of a secondary recovery project depends on a number of variables, many of which the corrosion engineer has little or no control over. However, failure to protect a system from corrosion can cause an otherwise successful project to be an economic failure. This places a great deal of responsibility on the shoulders of the corrosion engineer and the purpose of this discussion will be to point out ways that corrosion damage can be minimized in these projects. Since many of the corrosion control measures employed in water injection systems must be selected before the system is installed, the corrosion engineer should be in on the planning of a secondary recovery project from the very beginning. He should familiarize himself with the characteristics of the water supply, the produced water. the type plant to be used, the pressure involved, and all other items that can influence the selection or performance of mitigation procedures.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, injection, corrosion control, design criteria.

0754 **Kominek, E. G.**
1949. Accelerated waste treatment methods: Chem. Eng. Prog., v. 45, no. 7, p. 417-420.

Some examples of the use of "Accelator" and "Cyclator" units manufactured by Infilco., Inc., for treating refinery, oil field and other trade waste waters and sewage are described. In two pilot plant tests, oil and acid were successfully removed from A.P.I. separator effluent by treating it in an "Accelator" unit with recirculated calcium carbonate sludge from water softening. The method is also successful for removing iron and suspended matter from oil field brines prior to reinjection in flooding operations. The "Cyclator" has been used to remove emulsions formed from soluble and insoluble oils. The slurry recirculating feature of these units makes for reduction of equipment size and treating time.–Tulsa Univ., Inf. Services Dept.

Descriptors: Waste water treatment, brine disposal, injection, equipment.

0755 **Kornfeld, J. A.**
1951. Salt water disposal system: Petroleo Interamericano, v. 9, no. 8, p. 22.

An installation in Louisiana is described in which the salt water produced in the field is separated and passed to a central skimmer from which it is pumped into a 9,200 ft. dry hole.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, Louisiana, injection wells, waste treatment.

0560 **Korver, John A.**
1966. Fluid flow from nuclear chimneys: Water Resources Research, v. 2, no. 2, p. 297-310.

To assess the feasibility of using nuclear explosives to create large underground rubble chimneys into which liquid wastes can be ejected, a predictive capability has been developed by matching laboratory model studies with mathematical analogs. The effects of varying permeability, porosity, input flow rates, and chimney dimensions were examined. Variations between laboratory and mathematical model results were less than 10 percent. This paper describes the laboratory model studies of two hydrologic environments, the development of the mathematical models, and the numerical solutions obtained with the latter. Also summarized are two examples of potential applications of nuclear explosives to the field of waste disposal. Results indicate that for many selected hydrologic conditions it is feasible to use the rubble chimneys in permeable but unsaturated formations.–NAB.

Descriptors: Engineering geology, waste disposal, nuclear explosions, hydrogeology, model studies, groundwater movement.

0235 **Kramer, James R.**
1969. Subsurface brines and mineral equilibria: Chem. Geology, v. 4, no. 1-2, p. 37-50.

About 2,500 brine chemical analyses were classified according to lithology of their source aquifers. Factor analysis was used to determine possible mineral equilibria. Conclusions from factor analysis are used to calculate ion products which are compared with thermodynamically derived equilibrium values. In most analyses, Cl, sulfate, Na, Ca, Mg, bicarbonate, Sr, and Ba are reported. Most waters are Na-Ca-chloride types saturated in calcium carbonate. Sulfate is an independent variable in most waters but has a weak inverse relationship to bicarbonate, a positive correlation to Mg, and sometimes is weakly inverse to Sr and Ba, suggesting an Sr-Ba-sulfate equilibrium. Ca and Mg show a stronger inverse correlation to bicarbonate in dolomite than in other rocks. Ca shows a stronger correlation with Mg in dolomite than in limestone, suggesting Ba-Sr-carbonate equilibrium. Equilibrium involving K-Mg-H-Si is suggested by data from a smaller population of more complete analyses.–W69-06952.

Descriptors: Water chemistry, groundwater, brines, chemical properties, geochemistry.

0683 **Krause, H.**
1969. Disposal of radioactive wastes into deep geological formations: Atomic Energy Rev., v. 7, no. 1, p. 47-70.

With the continuous development of nuclear technology, the need for the ultimate disposal of radioactive wastes into underground storage sites is increasingly important, because this procedure can be applied on a large scale and completely excludes from the biosphere the radionuclides contained in the waste. According to the quality and activity of the wastes and the local geological conditions, different methods can be used. Low- and intermediate-level effluents can be introduced under pressure into deep underground porous or fissured formations to the extent that these are completely isolated by impermeable strata from the water horizons that play their part in the biocycle. This method has been applied for some years quite successfully in the United States of America and the Soviet Union. If cleavable rock formations, especially shales, are available, radioactive liquids can be introduced into these under high pressure after having been mixed with cement and other aggregates. In this process, cleavages and fissures are formed along which the mixture can spread and in which it finally hardens. The fixation of radionuclides by cement and aggregates, and the necessary insulation of the container rock from water-carrying strata guarantee the safety of the method. Solid rock is particularly suitable for storing solid waste. Since cavities in the rock are difficult to seal artificially, a natural insulation of the rock from groundwater by watertight strata is desirable. Radioactive liquids can be stored in caverns in rock only under particularly favorable geological conditions. In practice, vaults formed in rocks are used for storing low-level solid radioactive waste in Czechoslovakia and Spain. Up till now, no liquids have been disposed of in this way. Saline rock is particularly well suited to the storage of radioactive wastes of all kinds and classes of activity. The impermeability of saline rock to liquids safeguards absolute impermeability to the biosphere. The relatively good thermal conductivity of the salt even permits the storage of solid heat-generating wastes. Since saline rock of considerable depth exists in many countries and since it is possible to produce huge cavities in salt without any artificial support, this rock is excellently suited to the ultimate storage of radioactive wastes. Solid low- and intermediate-level wastes can simply be stacked in chambers of mines. High-level, heat-generating wastes are best introduced into individual boreholes in the bottom of the chambers for better heat removal and covered with salt. Solid, liquid, and gaseous radioactive wastes can also be stored in caverns formed by solution mining. Comprehensive laboratory and field tests have been carried out, especially in the United States of America and the Federal Republic of Germany, with respect to the ultimate storage of radioactive wastes in salt. In the Federal Republic the first low-level wastes have already been introduced into a disused salt mine.–Author's abstract, NSA 23-33368.

Descriptors: Radioactive waste disposal, underground storage, liquid wastes, solid wastes, methodology, salts, United States, foreign countries.

0831 **Krause, H.; Ramdohr, H.; Schuchardt, M. C.**
1967. Project for storing radioactive wastes in a salt cavity (SM-93/35), *in* Disposal of radioactive wastes into the ground–International Atomic Energy Agency and European Nuclear Energy Agency, Vienna, 1967, Symposium Proc.: Vienna, Internat. Atomic Energy Agency (STI/PUB/156), p. 479-494.

The solution method of creating a cavity in a salt dome is described. The mechanism for introduction of the radioactive waste into the cavity and the problems involved are explained (borehole diameter, method of introduction, etc.). Economic considerations are presented for a cavity of 10,000 m^3 and the influence on the cost of parameters such as depth and diameter of the borehole and size of the cavity is investigated.–Authors' abstract, NSA 22-16817.

Descriptors: Radioactive wastes, waste storage, excavation, economics, salts.

0832 **Krause, H.; Ramdohr, H.; Boehme, G.; Albrecht, E.**

1967. Experimental storage of radioactive wastes in the Asse II salt mine [Lower Saxony, Germany] (SM-93/38), *in* Disposal of radioactive wastes into the ground–International Atomic Energy Agency and European Nuclear Energy Agency, Vienna, 1967, Symposium, Proc.: Vienna, Internat. Atomic Energy Agency (STI/PUB/156), p. 519-531.

The storage of radioactive wastes in salt formations seems to be one of the most promising methods of ultimate disposal in the Federal Republic of Germany. To carry out experiments on this method and to store actual wastes, the abandoned Asse II salt mine near Braunschweig (Lower Saxony) was purchased. After termination of the present repair work the first low- to intermediate-level wastes will be introduced. In addition, preparations are being made for storage of solidified high-level wastes and spent nuclear fuels within an experimental program. The Asse II salt mine, the installations for the storage of low-level wastes and the plans for storing high-level wastes are described.–Authors' abstract, NSA 22-16820.

Descriptors: Radioactive wastes, waste storage, feasibility studies, salts, mining, foreign countries.

0236 **Kreidler, W. L.**

1968. Preliminary study of underground disposal of industrial liquid waste in New York State, App. III *of* Ives, R. E., and Eddy, G. E., Subsurface disposal of industrial wastes: Oklahoma City, Okla., Interstate Oil Compact Comm. Study, p. 100-109.

This report describes systematically the major geologic rock units that occur in the Appalachian Synclinorium section of New York State. Data are given on the character, depth, thickness, extent, and hydrologic properties of each major rock unit. The report contains a generalized geologic map of the State and an east-west cross section of Devonian strata along the New York-Pennsylvania State line. The author concludes that one formation, the Theresa of Cambrian and Ordovician age, stands out as having all of the desirable qualifications needed for underground disposal of liquid wastes.

Descriptors: Waste disposal, New York, geologic formations, rock properties, underground structures.

0469 **Kreiger, James H.**

1964. The law of the underground: Civil Eng., v. 34, no. 3, p. 52-53.

This paper outlines the legal and engineering problems concerning subsurface water. Basically, there are three functions of the underground–water supply, storage, and waste disposal. All three functions must be considered as part of a single circulating system, and therefore, regulation of all three must necessarily come under one agency. The present law is inadequate because it contains no protection against abuse of the subsurface. Only after the damage has been done do the parties come into court and seek relief. The legal way should be prepared before the problem arises. The challenge is very clear: engineers and attorneys working side by side must effectively utilize all the means available to achieve coordination of the three functions of the underground.

Descriptors: Legal aspects, environmental engineering, waste disposal, underground storage, water supply.

Kriz, George J. *See* Lewis, David C. 0029.

0578 **Krone, R. B.; McGauhey, P. H.; Gotaas, H. B.**
1957. Direct recharge of ground water with sewage effluents: Am. Soc. Civil Engineers Proc. Paper 1335, Jour. Sanitary Eng. Div., v. 83, no. SA 4, 25 p.

Mixtures of settled raw sewage and water were used to recharge a 5-foot thick confined aquifer located 95 feet underground [San Francisco Bay area, California]. Observations of pressure and of pollution travel were made in 23 sampling wells surrounding the recharge well. The bacterial pollutants traveled a maximum of 100 feet in the direction of normal ground-water movement even though steep gradients were imposed. The maximum distance of travel was quickly reached, but intensity of pollution regressed as the aquifer face in the recharge well became increasingly clogged. An injection rate (8.4 gpm per foot of aquifer) equal to the best reported for fresh-water recharge was found to be practical. With mixtures of fresh water and 20 or 27 percent primary sewage, recharge well redevelopment was necessary after 7 to 9 days of recharge. About half a day was required for redevelopment and a maximum of 4 percent of the recharged water was returned to the surface in the process. After a brief settling period this water was suitable for reinjection.–WSP 1990.

Descriptors: Sewage effluents, injection wells, water pollution, migration patterns, California.

Kryukov, I. I. *See* Verigin, N. N. 0846.

0684 **Kubota, Hisashi.**
1964. Problems in disposal of radioactive liquid wastes in salt: Chem. Eng. Prog., Symposium Ser., v. 60, no. 53, p. 68-73.

The disposal of radioactive liquid wastes in salt, and its problems are discussed. Laboratory studies on the cold chemistry of the system, the role of radiation, alteration of cavity geometry, and results of field experiments using simulated waste solution in salt models and in 3000-gal. cavities are considered.–NSA 19-40272.

Descriptors: Radioactive waste disposal, salts, chemical engineering, laboratory tests, test procedures, underground storage.

0833 **Kuehn, K.**
1967. Geo-scientific investigations in the Asse II salt mine [Lower Saxony, Germany] (SM-93/37), *in* Disposal of radioactive wastes into the ground–International Atomic Energy Agency and European Nuclear Energy Agency, Vienna, 1967, Symposium Proc.: Vienna, Internat. Atomic Energy Agency (STI/PUB/156), p. 509-518.

In the radioactive waste disposal program of the Federal Republic of Germany, the abandoned salt mine at Asse, near Wolfenbüttel in Lower Saxony, is to be used for storage of the wastes. This mine now belongs to the Gesellschaft für Strahlenforschung München. The Asse salt appears in an elongated salt dome about 8 km long. The country rock is formed by Triassic sandstone and limestone. Rock mechanical investigations were performed by hydraulic press on series of test models in the form of cubes and on room and pillar models. The cube compressive strength of Asse rock salt is about 400 kp/cm². The load-bearing capacity of the different pillars varies from 350 to 420 kp/cm². To compare the laboratory results with the conditions in the mine, investigations are being carried out in the mine. In addition to the rock mechanical investigations, detailed mine-surveying measurements have been carried out to detect possible movement of the salt. Since most of the rooms were excavated ten to fifty years ago, no significant movements have been observed. In general, the movements of the walls are relatively large immediately after the driving of the rooms, but they soon die down asymptotically. The mine-surveying measurements are done not only in the rooms but also in the drifts. The results are the same here. To study the behavior of the salt at high temperatures, a temperature test field was installed in the mine. The rock salt was electrically heated to a temperature of about 400°C. Due to the specific thermal conductivity of the salt, the temperatures decrease rapidly from the heaters to the borders of the test field. At this test field, precise mine surveying is also done to check floor lifting. Other tests have just been started to examine the compressive strength of rock salt by triaxial hydraulic press at high temperatures.–Author's abstract.

Descriptors: Radioactive wastes, waste storage, salts, mining, underground structures, foreign countries.

LaMoreaux, Philip E. *See* DeBuchananne, George D. 0680.

0239 Lang, Alexander.
1933. Pollution of water supplies, especially of underground streams, by chemical wastes and by garbage [abs.]: Am. Water Works Assoc. Jour., v. 25, no. 8, p. 1181.

Three cases are reported in which it became necessary to abandon ground-water supplies because of chemical contamination of wells caused by (1) residues of wood tar stored at a distance of 197 feet, (2) wastes of picric acid works at several miles distance, and (3) waste pickling liquors. A fourth case is reported wherein an old garbage dump located 1,476 feet upstream from a ground water supply increased total solids in ground water from 360 to 552 ppm and hardness from 190 to 272 ppm because of lixiviation and percolation by rainwater.

Descriptors: Groundwater, water pollution, foreign countries, environmental sanitation, pollutant identification.

0240 **Lang, Alexander; Bruns, Hayo.**
1941. On pollution of ground water by chemicals: Gas, Wasser, Warne, v. 83, p. 6, Jan. 6. [abs. published in Am. Water Works Assoc. Jour., v. 33, no. 11, p. 2075-2076, 1941.]

Examples of pollution in Rhine and Ruhr valleys are described. Five or 6 years after wastes of a picric acid plant leaked into a ground-water body, picric acid could be found in wells located about 3 miles downstream and about 1/2 mile from the Rhine River. A plant to granulate slag from blast furnaces by chilling molten slag in a water stream and settling in basins caused a rise in temperature in wells located 2000 ft downstream. Hardness and iron and manganese content also increased. Fluorescin and *Bacillus prodigiosus* were used to prove direct connection from the basins to the affected wells. Velocity of ground water in the gravel was determined to be about 33 ft per hour. About 25 to 30 years ago, ashes and garbage were dumped in an old sand pit reaching below ground-water level. After several years pollution was found in wells located 2000 ft away from the pit by an increase in hardness, iron and manganese content, and appearance and taste. Although the pit has not been used as a dumping ground for 15 years and has been transformed into a park, pollution still exists. A waste pile from a coal mine caused an increase in sulfate hardness and in iron and manganese in water from wells which are located within 100 ft from the Ruhr River and which are pumping mainly bank filtered water. A leaky tile effluent line of a sewage treatment plant using chlorination caused phenol tastes and fungi growth in wells located 300 ft upstream from the plant. Fluorescin put into this effluent line showed up in wells in 24 hours.–AWWA.

Descriptors: Groundwater, water pollution, foreign countries, environmental sanitation, pollutant identification.

Langhaar, Henry L. *See* Deere, Don U. 0113.

0242 Lansing, A. C.; Hewett, P. S.
1955. Disposal of phenolic waste to underground formations, *in* Industrial Waste Conference, 9th, Lafayette, Ind., 1954, Proc.: Purdue Univ. Eng. Ext. Ser. 87 (Purdue Univ. Eng. Bull., v. 39, no. 2), p. 184-194.

This paper describes the investigative and other procedures that were followed in the design and construction of a deep-well system to inject phenolic wastes from the manufacture of synthetic resins into the underground in the Detroit, Mich., area. The injection well was completed in the brine-saturated Sylvania Formation between depths of 912 to 1,064 feet below grade. Pretreatment of the waste was found to be necessary after tests were made of the compatibility of the phenolic wastes with the natural brine. Although initial injection tests proved that the well was inadequate for the purpose intended, acid treatment of the well increased the rate of injection from a few gpm at a pressure of 400 psi to 131 gpm at a pressure of 100 psi. In actual operation as much as 5,000 gallons of pretreated waste have been injected in a 24-hour period. After six months the injection pressure increased to 135 psi. It is expected that when the pressure has increased to 600 psi an acid treatment will rejuvenate the well. Deep-well injection can be a practical solution to some industrial waste problems, but it is not a sure-fire cure-all to be applied indiscriminately or irresponsibly.

Descriptors: Chemical wastes, injection wells, test procedures, Michigan, geologic formations, design data.

0712 Lasater, R. M.; Gardner, T. R.; Glasscock, F. M.
1968. Scale deposits are controlled now with liquid inhibitors: Oil and Gas Jour., v. 66, no. 3, p. 88-89, 92-93.

The use of liquid inhibitors to control scale deposition in fractured formations is discussed. Laboratory tests were conducted in order to observe the precipitation of calcium sulfate and calcium carbonate upon addition of calcium chloride, sodium sulfate, or sodium carbonate to sodium chloride solutions Following these precipitation tests, the effects of chemical inhibitors were then determined. Other tests were used to measure the adsorption of an organic phosphate and a polyorganic acid on silica. The results of these tests are tabulated. Methods are then discussed for placing liquid inhibitors in fractured formations surrounding producing, injection, or disposal wells. Several methods for detecting inhibitors have been investigated, both in the laboratory and in the field. Case histories involving chemical fracture-squeeze treatments in 3 wells are also discussed.–Tulsa Univ., Inf. Services Dept.

Descriptors: Chemical reactions, laboratory tests, inhibitors, fractures (geology), injection wells.

0465 Lazarescu, M.; Papadopol, Cornel.
1966. Operatia de epurare si injectie in strat, metoda de evacuare a apelor sarate diu exploatarile petroliere [Bed treatment and injection as a method of salt brine evacuation from petroleum-mining operations]: Hidrotehnica, Gospodarirea Apelor, Meteorologia, v. 11, no. 8, p. 422-426, 450. [In Romanian.]

After reviewing the principal sources of residual waters in petroleum mining operations as well as the general water purification methods, the authors discuss in some detail the method of partial purification and bed injection. The technological, construction and economic features of an installation of this type constructed in Romania are described, and some suggestions are offered for improving the installation and constructing even more efficient ones in the future.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, foreign countries, technology construction, economics, design criteria.

0756 Leahy, M. J.
1940. Disposal of oil field brines: Oil Weekly, v. 96, no. 5, p. 19-20, 22, 24.

Current methods of disposing of oil field brines in East Texas, where the problem is becoming very acute due to the dry weather during the past few years, consists of (1) drilling brine input wells on the edge of a field where no oil is being produced or (2) abandoning a well incapable of producing its allowance and using it as a brine input well. In the first case, equipment cost is very high due to the high corrosiveness of the brine; in the second case, the brine must be aerated before being forced back into the oil sands and the cost of the aerating system is high. The author made a study of other methods and offers several suggestions for solving the problem –Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, Texas, methodology, costs.

0559 Lebedev, G. I.
1958. Printsipial'nye resheniya po kanalizovaniyu neftepromyslov Tatarii i zapadnoi chasti Bashkirii i primenie v etix raionax fiziko-khimicheskogo metoda doochistki promyslovyx stochnyx vod [Principle decisions relating to drainage in the oil fields of Tatar and western Bashkir, and application in these regions of a physicochemical method of secondary purification of industrial waste waters], *in* Konferentsia po bor'ba zagryazneniem vodoemov, Moscow, 1956 [Conference on struggle with pollution of reservoirs by waste water]: Moscow, Gosudarstvennoe Nauchno-Tekhnicheskoe Izdatel'stvo Neftyanoi i Gorno Toplivnoi Literatury [State Scientific-Technical Publishing House of Petroleum and Mining Industry], p. 26-33.

The waste-water disposal problem in Tatarian and western Bashkirian oilfields [Russia] may be solved by discharging the waters into either absorbent cavernous formations or (for flooding purposes) into oil-bearing beds. Neither the saccharoidal dolomites of the Lower Carboniferous nor the Upper Devonian carbonates have any communication with surface waters. Boreholes 1100-1600 m deep take up about 2,000 cu m/day of water without appreciable increase in resistance. The waters are allowed to settle in pits before being pumped into the formation. When used for flooding purposes, they are subjected to preliminary treatment with 70-150 mg of lime per liter to remove iron.–Tulsa Univ., Inf. Services Dept

Descriptors: Brine disposal, foreign countries, injection wells, geohydrologic units, waste treatment, pollution abatement.

0244 **Lee, J. A.**
1950. Throw your wastes down a well: Chem. Eng., v. 57, no. 9, p. 137-139.

Experience of oil companies in disposing of wastes by injection into permeable formations in wells is described, and it is suggested that other wastes–many in some cases–be disposed of in the same way.–Tulsa Univ., Inf. Services Dept.

Descriptors: Waste water disposal, hydrogeology, injection wells.

0245 **Lee, Marvin.**
1936. Underground disposal of salt water: Oil and Gas Jour., v. 34, no. 44, p. 41-44.

This paper describes the measures taken by oil companies in Kansas to dispose of salt water and production wastes in such a way as to avoid damages to others and losses to the producers. Legislation enabling the producers to inject their wastes underground has opened the way to avoid damage to fresh water resources and to increase oil production by water-flooding techniques. The regulations, procedures, costs, and benefits are briefly described.

Descriptors: Brine disposal, Kansas, methodology injection wells, pollution abatement, operating costs.

Legge, M. S. *See* Mecham, O. E. 0272.

0028 **LeGrand, Harry E.**
1967. Role of ground water contamination in water management: Am. Water Works Assoc. Jour., v. 59, no. 5, p. 557-565.

Ground-water contamination should not be excluded in long-range integrated community plans, especially in urban areas and suburbs. It includes any deterioration of quality by waste disposal practices, artificial recharge of aquifers, accident, or salt water at shallow or underlying depths. Its problems will increase under current practices of contamination control. Maintaining good health practices while minimizing costs calls for coordinated efforts from several disciplines. Technically trained personnel, capable of determining best use of land for water supply and waste disposal, are rarely a part of water-resources administrative machinery. Specific problems are more often dealt with than long-range planning. Complex hydrogeologic conditions must be evaluated before decisions are made and policies established.–NAB.

Descriptors: Groundwater, water pollution, water supply, waste disposal, water policy, water management (applied).

0246 **LeGrand, Harry E.**
1962. Geology and ground-water hydrology of the Atlantic and Gulf Coastal Plain as related to disposal of radioactive wastes: U.S. Geol. Survey Trace Elements Investigation Rept. TEI-805, 169 p.

Results of a study are presented concerning hydrologic and geologic aspects of radioactive waste disposal in the Atlantic and Gulf Coastal Plains. The purpose of the study was to gather sufficient geologic and hydrologic data to aid in selection of disposal sites or sites for installations which produce or use radionuclides. The area includes a broad belt which extends from Long Island southward along the Atlantic Coast, and

westward along the Gulf to the Rio Grande. It includes Florida, and a broad arm extends up the Mississippi River to southern Illinois.–NSA 16-16024.

Descriptors: Radioactive waste disposal, hydrogeology, coastal plains, data collections.

0247 **LeGrand, Harry E.**
1967. A broad view of waste disposal in the ground: Water and Sewage Works, v. 114, 1967 Reference Number, p. R167-170, R179-180, Nov. 30.

Disposal of wastes and the inherent problem of pollution or contamination from these wastes in the natural environment–above and below the ground–are receiving increased attention. Management of these wastes has been centered chiefly around separate problem areas, and expediency generally has been the keynote. Although one may argue that a technological solution is available for any specific pollution problem, full advantage has not been taken of all known technology that might be pertinent to the control of pollution. Ramifications of waste disposal to the ground are extremely important, but seldom are they evaluated adequately in relation to overall water supply and waste management.–*from* Author's introduction.

Descriptors: Waste disposal, water pollution, underground.

0511 **LeGrand, Harry E.**
1964. System for evaluation of contamination potential of some waste·disposal sites: Am. Water Works Assoc. Jour., v. 56, no. 8, p. 959-974.

The method for evaluating the contamination potential of a given site is based on three categories of site geology: (1) unconsolidated granular materials extending 100 feet or more below ground surface, (2) unconsolidated granular materials at the ground surface underlain at shallow depths by dense rocks with linear openings, and (3) dense rocks at the ground surface with the movement of fluids only through interconnecting joints or solution channels. The proposed system for evaluating sites is based on weighted values of water table, sorption, permeability, water table gradient, and distance to point of use. The relative significance of these factors can be evaluated from measurements or estimates made at the sites. Examples are given and alternative proposals are offered.–NAB.

Descriptors: Groundwater, water pollution, waste disposal, sites.

0512 **LeGrand, Harry E.**
1965. Patterns of contaminated zones of water in the ground: Water Resources Research, v. 1, no. 1, p. 83- 95.

Contaminants moving from waste sites into the subsurface water circulation system produce zones or enclaves in uncontaminated ground water. Prediction of areal extent of such zones is made difficult by many factors. Before such zones are evaluated, consideration must be given to the tendency of contaminants to be entrained in ground-water flow and to be attenuated to varying degrees by water dilution, decay with time or some other mechanism, and sorption on earth materials. Depending on attenuation conditions in stabilized zones, increased concentration may keep zones the same size or enlarge them.–NAB.

Descriptors: Engineering geology, waste disposal, water pollution, groundwater, sites.

0514 **LeGrand, Harry E.**
1965. Environmental framework of ground-water contamination: Ground Water, v. 3, no. 2, p. 11-15.

Contamination is causing the volume of ground water to shrink in many areas. Management of the problem requires that hydrogeologic environments be classified along lines of interdependence of factors such as permeability, sorption, hydraulic gradient, position of water table, and distance from contamination source. Effective evaluation relates the dynamics of hydrogeologic environment to contingencies involving contamination as water-development and waste-disposal practices change. Evaluation of the problem requires attention to the tendency of waste to move with ground water or to be attenuated near disposal sites by sorption or other factors.–NAB.

Descriptors: Geology, waste disposal, groundwater, water pollution, evaluation.

0656 **LeGrand, Harry E.**
1962. Graphic evaluation of hydrologic factors in management of radioactive wastes, *in* Morgan, J. M., Jr., Jamison, D. K., Stevenson, J. D., eds., Ground disposal of radioactive wastes conference, 2d, Atomic Energy of Canada Limited and U.S. Atomic Energy Comm. Div. Reactor Devel., Chalk River Canada, 1961, Proc., Book 1: U.S. Atomic Energy Comm. Div. Tech. Inf. [Rept.] TID-7628, p. 67-76.

Favorable geologic and hydrologic conditions for handling radioactive wastes are those that prevent hazardous amounts of radioactivity from entering the present or future water and mineral supplies and from entering populated parts of the biosphere. The tendency of certain earth materials to absorb and retain radioactive ions in relation to the opposing tendency of ions to move and disperse in naturally occurring water are discussed. Hydrologic factors affecting the retention potential of various soils for wastes are reviewed.–NSA 16-25041.

Descriptors: Radioactive wastes, adsorption, dispersion, radioisotopes, hydrogeology, theoretical analysis.

Lemoine, J. *See* Archambault, J. 0612.

Leveque, P. *See* Capitant, B. 0826.

0834 **Levi, H. W.; Miekeley, N.**
1967. Studies on ion diffusion in vermiculite (SM-93/12), *in* Disposal of radioactive wastes into the ground–International Atomic Energy Agency and European Nuclear Energy Agency, Vienna, 1967, Symposium Proc.: Vienna, Internat. Atomic Energy Agency (STI/PUB/156), p. 161-168.

Clay minerals are an essential part of many soils, and diffusion of radionuclide ions in the crystal lattices of those minerals consequently plays a role in radioactivity migration through soils. Ion mobilities in vermiculite as affected by the phenomenon of fixation are studied mainly by isotopic exchange. Among the radioactive ions showing fixation in vermiculite, cesium is the most important. It is shown that in a Cs saturated vermiculite only the fraction of Cs ions adsorbed at crystal imperfections is exchangeable. For the bulk of Cs no diffusion could be observed even at 100°C over a period of months. In a vermiculite loaded with traces of Cs, however, these ions do not lose their mobility to this high degree. The behavior of vermiculite loaded with two ions, one of which was Cs, has been examined. In the case of Cs/alkaline earth, the latter was found to remain mobile but to become much slower. This finding shows that the presence of a nonhydrated and, consequently, fixed ion does not inhibit the migration of other ions in the vermiculite lattice. The conclusion is that it is not lattice-contraction associated with cesium uptake but rather the state of the particular ion in the lattice that is responsible for the fixation phenomenon. Cesium fixed with respect to isotopic exchange was shown to become mobile by exchange with many other ions. These experiments give evidence of two different defixation mechanisms. Defixation may be caused by strongly hydrated ions as well as by relatively small nonhydrated ions. It is an interesting feature that fixed cesium ions may be exchanged against potassium, but potassium ions remain fixed against cesium. The results presented are discussed with respect to radionuclide migration in soils.–Authors' abstract.

Descriptors: Diffusion, radioisotopes, ion exchange, cesium, clay minerals.

0757 **Lewelling, H.; Kaplan, M.**
1959. What to do about salt water: Petroleum Engineer v. 31, no. 7, p. B19-B24.

The handling and disposal of salt water by the oil industry is one of the biggest nonprofit businesses in the world. The salt water is disposed of in natural streams, by evaporation, by dumping in salt-water bodies, by underground injection, and in salt-water flooding. These brines contain soluble mineral salts and suspended solids and present a number of disposal problems. The oil must be efficiently separated from the water. The equipment must be protected against corrosion and excessive deposition of scale. Oil-water emulsions and the oil carried over by mechanical entrainment provide additional difficulty in the operation of water-disposal plants. Bacteria also occasionally give trouble in disposal. Many of the problems are being solved by corrosion inhibitors, polyphosphates (for scale control), de-ionization, bactericides, and automation.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, methodology, waste treatment.

0029 **Lewis, David C.; Kriz, George J.; Burgy, Robert H.**
1966. Tracer dilution sampling technique to determine hydraulic conductivity of fractured rock: Water Resources Research, v. 2, no. 3, p. 533-542.

Groundwater in foothill and mountain watershed areas commonly occurs in fractured rock. The small well diameters and apparent low groundwater velocities in fractured rock require modification of normal techniques for the investigation of unconfined groundwater movement. The determination of hydraulic conductivity by the tracer dilution method normally employs injected radioisotope tracers. The dilution is determined by monitoring the isotope activity in the well with a scintillation probe. A modification of this method, using fluorescent dye tracers and physical sampling and analysis to determine dilution, has been applied in small wells with consistent results. Hydraulic conductivities of 0.02 to 0.5 ft per day have been determined in 16 wells. Where comparison is possible, the values agree favorably with hydraulic conductivities determined by pumping tests.–AWRA 08-0016.

Descriptors: Groundwater movement, fractures (geology), tracers, test procedures, flow characteristics, aquifer characteristics.

0248 **Li, Wen-Hsiung; Yeh, Gour-Tayh.**
1968. Dispersion at the interface of miscible liquids in a soil: Water Resources Research, v. 4, no. 2, p. 369-377.

When two miscible liquids flow through a porous medium (e.g., fresh water and salt water in an aquifer), the dispersion at the interface is described by Fick's law with a velocity-dependent coefficient. In the first part of this paper, the horizontal flow of two liquids is used to demonstrate that the influence of gravity and the effects of the differences in density and viscosity are usually negligible. Then solutions are presented for the dispersion at the interface of liquids in two-dimensional flow.–AWRA 08-0113.

Descriptors: Groundwater movement, porous media, dispersion, hydrodynamics.

0475 **Lieber, Maxim; Welsch, W. F.**
1954. Contamination of ground water by cadmium: Am. Water Works Assoc. Jour., v. 46, no. 6, p. 541-547.

The discharge of plating wastes from numerous aircraft production plants on Long Island, N.Y., into recharge basins or diffusion wells has contaminated large segments of the ground-water reservoirs. Previous studies disclosed the presence of hexavalent chromium in some deep public wells and shallow private wells. Additional work has revealed the presence of cadmium (a heavier and presumably more toxic metal than chromium) in the ground water. Test wells were constructed and sampled to determine the extent and degree of contamination. The measurable concentrations of cadmium that were observed ranged from 0.01 to 3.2 parts per million. It was also learned that the indicated path of the contaminant coincided with the direction of ground-water flow. This appearance of cadmium as a ground-water contaminant is believed to be unique. It has created the need to ascertain a safe and reasonable limit for cadmium in potable waters, based on the physiological effects of the continuous injestion of minute particles of the substance.

Descriptors: New York, industrial wastes, groundwater, test procedures, water pollution.

Lieber, Maxim. *See* Davids, H. W. 0110.

0298 **Lieberman, J. A.**
1955. Disposal of high-level radioactive waste products: Natl. Research Council Div. Earth Sci. Ann. Rept. 1954-55, p. 65-66.

A problem confronts the country with the advent of electric power from nuclear reactors. The fission products from reactors have a combination of undesirable properties that precludes their handling by conventional methods of waste disposal. To date, no satisfactory method of disposal has been found, and virtually all the fission products that have been produced have been sequestered in stainless steel tanks. Storage in tanks is not disposal; we need to find some way of returning them safely to nature so that we won't have to maintain control over them. And if power from nuclear sources is ever to compete economically with power from hydrocarbon and hydroelectric plants, this disposal must be cheaper than the current storage costs. Disposal in the oceans seems unfeasible because of (a) high cost and danger of transportation, and (b) our knowledge of the oceans is not good enough to insure that ocean disposal would be entirely safe. Safe disposal into the ground would be the most desirable solution, and quite a lot of research has been done along these lines. However, we need further work and evaluation of the ideas before we are ready to get rid of the waste material with confidence that it "won't backfire."–*from* Author's summary.

Descriptors: Radioactive waste disposal, methodology, pollution abatement, research and development, feasibility studies, United States.

Lippok, W. *See* Schwille, F. 0840.

0249 **List, E. J.; Brooks, N. H.**
1967. Lateral dispersion in saturated porous media: Jour. Geophys. Research, v. 72, no. 10, p. 2531.

An analysis of experimental results from a series of lateral dispersion experiments is presented. It is shown that lateral dispersion for low molecular Peclet numbers is adequately described by Saffman's capillary model but that velocity power laws are limited in their application. The dynamic Peclet number is shown to obtain a maximum at molecular Peclet numbers of $O(10^4)$.–AWRA 08-0006.

Descriptors: Hydrodynamics, dispersion, mathematical models.

0252 **Lockett, D. E.**
1967. Subsurface disposal of industrial waste water, *in* Industrial Water and Waste Conference, 7th, Texas Water Pollution Control Assoc., Austin, Tex., June 1-2, 1967, Proc.: Austin, Texas Univ., p. III-48–III-57.

This paper describes the deep-well system that is used for the disposal of excess industrial waste water at the Petro-Chemical Complex near Odessa, Tex. The injection well is 5,802 feet deep. It is cased to a depth of 4,900 feet and finished in the brine-saturated San Andres Limestone. Upon completion, the well was acidized to improve its injection capacity. Cores and brine samples from the San Andres were used to evaluate the compatibility of the waste stream with the injection zone. Disposal of industrial waste-water alternates from small daily injections to maximum rates of 33,000 barrels per day at 1,100 psig, depending on demand. Although the system is successful, it has proven to be expensive–equivalent to 2 cents per barrel.

Descriptors: Industrial wastes, Texas, injection wells, design criteria, geologic formations, operating costs.

0660 **Loewenstein, H.**
1965. An injection probe for rapid placement of radioisotopes in soil: Soil Sci. Soc. America Proc., v. 29, no. 3, p. 328-329.

Numerous time-consuming injections of radioisotopes in soil were required in certain studies utilizing tracer techniques. The injection probe described retained desirable features of earlier models, but allowed placement of the tracer to proceed at a greatly accelerated rate.–Author's abstract, NSA 19-38870.

Descriptors: Radioisotopes, tracers, instrumentation, subsurface investigations.

Loleit, Allen J. *See* Peterson, James A. 0316.

Lomenick, T. F. *See* Boegly, W. J., Jr. 0600.

Lomenick, T. F. *See* Bradshaw, R. L. 0492.

0758 **Louisiana State Department of Conservation.**
1940. Activities of the Division of Research and Statistics, *in* Fourteenth Biennial report (1938-1939): New Orleans, Louisiana State Dept. Conserv., p. 282-313.

Among the topics dealt with in the 14th Biennial Report for 1938-39 of the Louisiana Dept. of Conservation are: the activities of the Division of Research and Statistics in petroleum and chemical engineering. The oil refinery pollution problem is narrowed down now to the task of separating waste oil from waste water and disposing the oil matter by burning. Oil field brine pollution is second in importance only to pulp wastes. The most satisfactory method of abatement is the use of drilled waste disposal wells. This method requires a greater initial expenditure due to cost of drilling, pumping equipment, and gathering systems. It requires careful supervision to prevent contamination of fresh water sands, and it usually requires complete separation of oil and water before disposal. One refinery has adapted this method to the requirements of refinery waste disposal. At present, the 47 disposal wells in Louisiana handle about 140,000 bbls. daily.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, injection wells, Louisiana, operating costs, pollution abatement, waste treatment.

0759 **Ludwig, G. K.**

1969. Gas engine power for salt water disposal maintains oil production: Diesel Gas Turbine Prog., v. 35, no. 7, p. 46-47.

The Onshore District of Tenneco Oil Co. was faced with the problem of disposing of 25,000 bbl of salt water with an ultimate of 45,000 bpd to keep up oil production and to prevent soil and stream contamination. Tenneco had been assigned a subterranean strata by the Louisiana Conservation Commission into which this water could be injected at 3 sites. The problem then resolved itself into securing pump units capable of injecting the salt water automatically and continuously into the assigned strata with maximum safeguards against interruption and with minimum personnel attention. Wilson Supply Co. was called upon to design and build the pumping equipment with all controls and safety appliances in collaboration with Tenneco engineers. This was accomplished with design of 3 automatically controlled pumping stations, two with 3 pumping units, the third currently with 1. The pumps deliver the salt water at a discharge pressure of 800 psig. All of the pumping units were unitized into a completely self-contained package. All components, consisting of the engine, pump, auxiliary equipment and accessories, are mounted on a rigid skid to preclude the need for a heavy foundation. These pumping stations are designed to operate unattended. These pump units have proved that they can provide continuous salt water disposal with fully automated operation.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, pollution abatement, pumps, injection, equipment, Louisiana.

0255 **Luff, G. S.**

1960. Underground waste disposal for American Airlines, Inc., *in* Oklahoma Industrial Wastes Conference, 11th, Pt. 1 *of* Graves, Q. B., ed., Oklahoma Water, Sewage, and Industrial Wastes Association, 1960 Proc.: Stillwater, Oklahoma State Univ., Civil Eng. School and Eng. and Indus. Ext., p. 71-80.

Wastes from American Airlines maintenance facilities at the Tulsa, Okla., airport are being pumped into the limestone of the Arbuckle Group using a procedure similar to that employed by the petroleum industry in secondary recovery operations. These wastes in the amount of 350,000 gallons per day include rinse and batch waters from electroplating operations, cleaning fluids and compounds from plane washing facilities, and oils from repair and maintenance shops. Injection well tests proved that 300 gallons per minute of the composite wastes could be injected into the Arbuckle without treatment other than the gravity separation of the oil. Details are given on the design, construction, operation and maintenance of the injection system. The disposal

well is satisfactory and is easy to operate. Present indications are that it will operate several years before the injection pressure reaches the maximum design pressure of 600 psig.

Descriptors: Industrial wastes, injection wells, Oklahoma, limestones, design criteria, geologic formations.

0661 **Lynch, Edward J.**
1964. Transport of radionuclides by groundwater–Some theoretical aspects: Hazleton-Nuclear Science Corp., Palo Alto, Calif., and Carroll E. Bradberry and Associates, Los Altos, Calif., Rept. HNS-1229-61, 56 p. Nov. [Available from CFSTI.]

Radionuclides may be transported by flowing ground water from the site of a nuclear detonation to points of potential water use. To aid in evaluating the hazard from this condition, an analysis of water transport and contaminant movement was made. Equations are presented for predicting transport time and dispersion in uniform systems. The equations indicate that dispersion should have a negligible effect on transport time, except for flow through a single set of parallel fractures. This is at variance with observed cases of dispersion in granular rocks, and suggests that geologic inhomogeneities may play an important role.–Author's abstract, NSA 20-11010.

Descriptors: Radioisotopes, groundwater movement, theoretical analysis, dispersion, ion transport.

0257 **Lynn, R. D.; Arlin, Z. E.**
1962. Anaconda successfully disposes of uranium mill waste water by deep well injection: Mining Eng., v. 14, no. 7, p. 49-52.

Disposal of mildly acidic excess mill waste water containing a low level of radioactivity due to small amounts of natural U, Th^{230}, and Ra^{226} by deep well injection was investigated. A study of the regional geology and hydrology of Grants, New Mexico, indicated that a disposal well was feasible, and a test well to basement rock was planned. It was also determined that, after the process waste water was discharged to a tailing pond and subjected to partial loss by evaporation, there would still be about 400 gpm available for injection into the disposal well. The selected location was on the northeast flank of the Zuni Uplift, within the extreme southern limits of the San Juan Basin in northwest New Mexico. Construction of the well, surface installations, behavior of injected waste water, and monitor program are discussed.–NSA 17-02648.

Descriptors: Radioactive waste disposal, New Mexico, deep wells, injection, hydrodynamics.

0258 **Lynn, R. D.; Arlin, Z. E.**
1962. Deep well construction for the disposal of uranium mill tailing water by The Anaconda Co. at Grants, N. M.: Soc. Mining Engineers Trans., v. 223, no. 3, p. 230-237.

A deep well injection system is used by The Anaconda Co. for the disposal of uranium mill tailing water near Grants, N. M. A 2511-ft hole was cored and tested through Triassic, Permian, and Pennsylvanian(?) sediments and bottomed in Precambrian granite gneiss. The disposal well was plugged back to 1830 ft and completed in 536 ft of sandstones in the Yeso Formation. The reservoir sandstones contain water similar to the injected waste water, and are isolated from overlying fresh-water aquifers by an evaporite barrier zone. Mill tailing water is decanted, filtered, and introduced into the

well by gravity at an average rate of 400 gpm. The reservoir has a life expectancy of 10 years.–Authors' abstract.

Descriptors: New Mexico, engineering geology, radioactive waste disposal, injection wells.

0850 **Mackrle, Vladimir; Dracka, Oldrich; Svec, Jan.**
1965. Hydrodynamics of the disposal of low-level liquid radioactive wastes in soil: Internat. Atomic Energy Agency (NP-15859), Contract No. 98. 142 p. [Report submitted to the Internat. Atomic Energy Agency of Vienna by the Czechoslovak Academy of Sciences, Inst. of Hydrodynamics, Prague, 1965.]

The general aspects of liquid flow carrying suspension through a porous medium was studied in order to obtain data that might serve in evaluating the applicability of injection for the disposal of the radioactive sludge. Theoretical and laboratory studies were made on: injection of diluted suspension; injection of concentrated sludge; and two-dimensional filling of geological formations. The results offer a theoretical basis for the formulation of the requirements for a suitable geological structure as well as for the technology of injection.–NSA 21-18163.

Descriptors: Hydrodynamics, porous media, injection, radioactive waste disposal, theoretical analysis, technology.

0260 **MacLeod, I. C.**
1961. Disposal of spent caustic and phenolic water in deep wells, *in* Ontario Industrial Waste Conference, 8th, 1961, Proc.: Honey Harbour, Ont., Ontario Water Resources Comm., Water and Pollution Advisory Comm., p. 49-58.

This paper discusses the factors that must be considered when waste disposal in deep wells is proposed and summarizes the disposal well project at the Imperial Oil Limited's refinery and chemical plant at Sarnia, Ont. [Canada]. To avoid contamination of the St. Clair River, five injection wells were drilled to inject the wastes into the Detroit River Group, a sequence of porous dolomites and anhydrites between depths of 500 and 1,000 feet below the refinery site. Injection pressures are restricted to self-imposed limits of 400 psig. At this pressure, rates of injection ranged from 10 barrels per hour to 130 barrels per hour. After well stimulation techniques were used, the total injection capacity of four of the wells was increased from 200 barrels per hour to 250 barrels per hour. The total cost of the entire project including surface facilities was about $190,000. In all probability, several more wells will be drilled to handle the anticipated volume of wastes.

Descriptors: Chemical wastes, design criteria, injection wells, geologic formations, foreign countries, costs.

0760 **Maehler, C. Z.; Greenberg, A. E.**
1962. Identification of petroleum industry wastes in groundwaters: Water Pollution Control Federation Jour., v. 34, no. 12, p. 1262-1267.

A special study, undertaken to evaluate organic pollutants in groundwaters, is described. Oil well brines, termed "formation waste-waters," are brought to the surface with crude oil. In 1959, about 8.4 million bbl of such waste was produced, and disposed of as follows: 8% was diluted with well water and used for irrigation of cotton and alfalfa, 30% was injected through wells below the usable groundwater, and 62% was discharged to unlined sumps for percolation to the groundwater. Production of refinery waste waters amounted to about 2.7 million bbl in 1959. This waste consisted of cooling tower return, boiler blowdown-waters, zeolite regeneration wastes, and, most important, process wastes; 95% of these wastes were discharged to sumps. The following conclusions were reached: (1) The wells sampled were grossly polluted with organic compounds; (2) the organic compounds found in the wells were clearly related to the compounds in the oil field wastes. The value of organic analyses in pollution studies is clearly indicated.–Tulsa Univ., Inf. Services Dept.

Descriptors: Waste water disposal, oil wastes, pollutants, groundwater, chemical analysis, organic wastes.

Maes, W. F. *See* Baetsle, L. H. 0040.

Maes, W. F. *See* Baetsle, L. H. 0677.

Maes, W. F. *See* de Jonghe, P. 0636.

Mairhofer, J. *See* Borowczyk, M. 0004.

0320 Major, Maurice W.; Simon, Ruth B.
1968. A seismic study of the Denver (Derby) earthquakes, *in* Geophysical and geological studies of the realationships between the Denver earthquakes and the Rocky Mountain Arsenal well, Pt. A: Colorado School Mines Quart., v. 63, no. 1, p. 9-55.

This report discusses the Denver earthquakes which occurred during the period January 1, 1962, to September 1, 1967, and their relationship to the Rocky Mountain Arsenal disposal well. Conclusions reached are: (1) The quality of the original correlation between fluid injection and earthquake occurrence has been reduced by the seismic events of the past 18 months when no injection has taken place. (2) The Denver earthquakes have a normal frequency versus magnitude distribution. The past occurrence of many small shocks cannot be considered to have reduced the probability of the occurrence of a larger event. (3) The zone of earthquake hypocenters has a sharply defined southern limit and more diffuse northwestern limit and no symmetry about the disposal well. (4) The two largest quakes resulted from strain release via rupture which began at 2 to 2-3/4 km north and 4-1/2 to 6-1/2 km west of the disposal well and traveled N. 70 degrees W. for about 10 km.–Geophys. Abs. 266-094.

Descriptors: Earthquakes, Colorado, injection wells, waste disposal.

Malina, Joseph F., Jr. *See* Moseley, Joe C., II. 0524.

0685 Mal'tsev, E. D.; Yudin, F. P.; Shamin, V. S.; Dolgikh, P. F.
1962. The thermal factor in the problem of inserting radioactive wastes into mineral deposits: Soviet Jour. Atomic Energy, v. 12, no. 1, p. 32-36. [Translated from Atomnaya Energiya, v. 12, no. 1, p. 36-39, 1962.]

In disposing or storing liquid radioactive waste materials in deep wells, salt mines, and similar deep geological formations, the heating of the medium presents a serious problem. This question was examined by calculating the heat generated in the layer, assuming a continuous flow of the waste effluents into it. A direct correlation was established between the temperature reached and the activity of the liquid; the porosity and the width of the vein also affect the top temperature. The activity of the waste liquids thus depends primarily on the permissible maximum temperature. An obvious upper limit is presented by the volatilization temperature of the liquid under the prevailing field conditions; another is determined by the physicochemical changes of the stratum which may affect the waste disposal process. In the calculations, the temperature of the incoming waste stream, heat transfer by convection, sorption and desorption of the radioactive materials on the mineral deposits, and radiolysis under evolution of gas were not taken into consideration.–NSA 16-11346.

Descriptors: Radioactive waste disposal, liquid wastes, underground storage, thermal stress, salts, theoretical analysis.

Manneschmidt, J. F. *See* Witkowski, E. J. 0710.

0262 **Manning, John C.**
1969. Deep well injection of industrial wastes, *in* Industrial Waste Conference, 23d, Lafayette, Ind., 1968, Proc., Pt. 2: Purdue Univ. Eng. Ext. Ser. 132 (Purdue Univ. Eng. Bull., v. 53, no. 2), p. 655-666.

When water is injected into a confined subsurface formation, the pressure in the formation is increased, and the formation tends to dilate. There is ample space in the subsurface reservoir for injection of large quantities of fluid so long as an areally extensive injection formation is available. Almost any area underlain by sedimentary rocks could have potential disposal reservoirs. Igneous or metamorphic rocks might have favorably situated subsurface zones, but generally these will not be as favorable as will the sedimentary rocks. Any waste fluid that is free of particulate matter and that, after reasonable treatment, will not cause undesirable reactions with the solid matrix of the disposal formation or its original fluid should be suitable for injection disposal. However, injection disposal is expensive and is best suited for relatively small quantities of particularly noxious wastes. All types of water desalination schemes have the problem of concentrated brine disposal, and where there is no convenient ocean, an injection well might provide a safe and convenient disposal.–W69-07117.

Descriptors: Injection wells, waste disposal, industrial wastes, geohydrologic units, chemical reactions, technical feasibility.

Mardock, E. S. *See* Watkins, J. Wade. 0430.

0517 **Marine, I. W.**
1967. The use of a tracer test to verify an estimate of the groundwater velocity in fractured crystalline rock at the Savannah River plant near Aiken, S. C., *in* Isotope techniques in the hydrologic cycle–Symposium, Univ. Illinois, 1965: Am. Geophys. Union Geophys. Mon. Ser., no. 11, p. 171-179.

A recent investigation at the Savannah River plant indicated the technical feasibility of and the safety afforded by storage of high-level radioactive wastes in unlined chambers excavated in crystalline rock about 1,500 feet beneath the ground surface. To test the validity of hydraulic estimates, a between-holes tracer test using tritium was designed. Water is pumped from one rock well and piped to another 1,760 feet away. In August 1964, 300 curies of tritium were injected; the tritium was first detected 73 days later and since then the concentration has increased steadily. It appears that the peak concentration of tritium was reached in about a year, making the average ground-water velocity 1,760 feet/yr. The predicted average velocity for the tracer test was 320 feet/yr, making this estimate too low by a factor of 5.5.–*from* Author's abstract, NAB.

Descriptors: Radioisotopes, tracers, tritium, groundwater movement, South Carolina, test procedures.

Marine, I. W. *See* Proctor, J. F. 0328.

Marine, I. W. *See* Webster, D. S. 0455.

0263 **Marsh, John H.**
1968. Design of waste disposal wells: Ground Water, v. 6, no. 2, p. 4-8.

Basic design principles for disposal wells are presented and 2 recently constructed wells for disposal of very corrosive refinery waste are described. Many disposal wells are constructed using oil well completion techniques, which are greatly inferior to modern water-well techniques, for disposal-well purposes. Oil well drilling with bentonite mud tends to plug pores, and the common practice of cementing casing and gun perforating the selected disposal interval results in insufficient area for efficient outflow. Drilling with organic mud which breaks down after use and the setting of screen instead of perforated casing greatly enhances the access of fluids to the injection zone. Design requirements for disposal wells are the same as for water wells with the additional considerations of aquifer protection by selection of a zone bounded by aquicludes, positive sealing of casing through the aquiclude, protection of casing from the fluid in the injection string, preventing clogging by precipitates or sediment, and use of screen with enough opening area to keep flow rate under 0.05 ft per sec.–W68-00659.

Descriptors: Injection wells, waste disposal, industrial wastes, water pollution control, design criteria.

0261 **Marshall, G. E.; Stephens, J. R.**
1968. Observations of earth-tilt and earthquake correlation, Denver area, Colorado: Earthquake Notes, v. 39, nos. 1- 2, p. 23-36.

Evidence for correlation between earth surface tilt and subsequent local earthquakes has been observed at the Inertial Test Facility of the Marietta Corporation, Waterton, Colo. The facility is located about 30 miles southwest of the apparent epicenters of the "Derby earthquakes" in the Denver area. During the period April-November 1967, 18 local earthquakes were recorded at Waterton. Fifteen of these earthquakes were preceded by a measurable unidirectional tilt from 7 to 48 hours before the earthquakes occurred. Magnitude of the earthquakes ranged from less than 1.0 to 5.4 on the Richter scale. Highest rate of tilt was 0.05 arc sec per hr and greatest amount of tilt was 1.15 arc sec. With one exception, each instance of sustained tilt for periods of more than 10 to 15 hours was followed by an earthquake. The exception was for a period of 62 hours following an earthquake of 5.4 magnitude. Instrumentation consists of tiltmeters, bubble levels, and short-period seismometers. It appears that correlation of earthquakes in the Derby area is sufficient to warrant the establishment of additional tilt-measuring stations here.–Authors' abstract, Geophys. Abs. 264-093.

Descriptors: Earthquakes, Colorado, seismic studies.

0182 **Martensen, V. N.**

1968. Primeneniye skorykh keramzitovykh fil'trov dlya ochistki promyshlennykh stochnykh vod ot vzveshennykh veshchestv i nefti [Use of rapid clay filters for purifying produced waters by removing suspended particles and crude oil]: Vyssh. Ucheb. Zavedeniy Izv., Neft i Gaz, no. 11, p. 111-114. [In Russian.]

Rapid filters containing porous clay filler were tested in the field for preparation of produced water for underground injection. These filters removed suspended solids and crude oil from water without use of coagulants or flocculants. In a series of tests under identical conditions, the clay filters were 1.5 to 2.0 times more effective than sand filters. Under the same conditions, the clay filters produced clearer water and had 2 to 3 times longer filter runs than the sand filters. Water and steam were used to regenerate clay filters. Clay filters were cleaned and regenerated more readily than sand filters. The clay had a density of 0.35 to 0.40 tons/cu m, porosity of 75%, and a large surface area.–Tulsa Univ., Inf. Services Dept.

Descriptors: Injection, waste treatment, methodology, filters, brine disposal.

0835 **Marter, W. L.**

1967. Ground waste disposal practices at the Savannah River Plant (SM-93/7), *in* Disposal of radioactive wastes into the ground–International Atomic Energy Agency and European Nuclear Energy Agency, Vienna, 1967, Symposium Proc.: Vienna, Internat. Atomic Energy Agency (STI/PUB/156), p. 95-106.

Solid radioactive waste has been buried at the Savannah River Plant since 1953. The waste, consisting of equipment and material contaminated with fission products, activation products, and transuranic isotopes, has been buried in unlined earthen trenches above the water table. A total of 1,500,000 Ci of fission and activation products and 9000 Ci of transuranic elements have been buried through 1966. Materials containing long-lived transuranic isotopes such as ^{239}Pu are encapsulated in concrete to permit retrieval for more permanent storage. The average cost of all land burial is $35.00/m^3 but burial of transuranic isotopes is higher because of concrete encapsulation. Disposal of high-activity gamma waste is also more costly because of increased handling problems. In thirteen years, no radioactive materials have been detected in ground water underlying the burial trenches, and no significant amounts are expected to outcrop at the surface on the flood plain of a Savannah River tributary. Low-level wastes, mainly from chemical separation areas, are discharged to connected earthen seepage basins. Water levels in these basins remain essentially constant because seepage and evaporation are about equal to the volume of rainfall and the influent liquid waste. Liquid wastes are analysed both before and after disposal in seepage basins. Procedural release guides limit the amount of each isotope discharged because certain long-lived isotopes, such as ^{90}Sr and ^{137}Cs, could eventually outcrop at a Savannah River tributary. A total of 1500 Ci of fission products (exclusive of tritium) and 13 Ci of transuranic elements have been committed to seepage basins. Only tritium oxide (a ternary fission product) has been detected in a surface stream. This occurred where the seepage basins were close to a stream. The soil surrounding the basins has an ion-exchange capacity that delays the movement of radioactive materials other than tritium oxide. The long travel time to reach a stream, and limits on amounts discharged to the basins, limit the amount of radioactive material in the off-site environment to levels that will result in exposures far below those set by the Federal Radiation Council. Seepage basins cost about $0.25/m^3 to construct, and experience indicates that the useful life of a basin is greater than 10 years.–Author's abstract.

Descriptors: Radioactive waste disposal, solid wastes, liquid wastes, South Carolina, environmental effects, costs.

0264 **Matson, G. C.**
1911. Pollution of underground waters in limestone, *in* Fuller, M. L., and others, Underground water papers: U.S. Geol. Survey Water-Supply Paper 258, p. 48-56.

In limestone regions where country rock is covered by a thin mantle of residual materials, the dangers of pollution are very great because water that flows in channels in limestone probably receives less natural filtration and purification than a surface stream. For this reason, the practice of putting rubbish, sewage, and garbage into sinkholes should be prohibited by legislation.

Descriptors: Limestones, groundwater, underground streams, water pollution control.

Matulis, J. T. *See* Hundley, C. L. 0204.

Matulis, J. T. *See* Hundley, C. L. 0283.

0518 **Mawson, C. A.**
1965. Management of radioactive wastes: Princeton, N. J., D. Van Nostrand Co., 196 p.

Principles and problems of radioactive waste management are reviewed. Eleven chapters cover principles of waste management; sources and nature of radioactive wastes; management in uranium industry; treatment of gaseous effluent; storage, fixation and treatment of liquid wastes; processing of solid wastes; storage in geological formation; ground disposal; disposal in sea, lakes, and rivers; management of small amounts of waste; monitoring and control; and political and legal considerations, with appendixes on atmospheric dispersion, selected references, and availability of special reports. Geological formations recommended for waste disposal are salt formations, deep wells in fractures produced between bedded strata by injection at high pressure, and deep caverns in original caves or mined cavities where there is no danger of contamination of ground water.–NAB.

Descriptors: Radioactive waste disposal, methodology, injection wells, legal aspects, waste treatment, underground storage, United States.

Mawson, C. A. *See* Merritt, W. F. 0836.

0519 **Maxey, G. B.; Farvolden, R. N.**
1965. Hydrogeological factors in problems of contamination in arid lands: Ground Water, v. 3, no. 4, p. 29-32.

The ideal hydrogeologic system in arid lands includes a recharge area in the mountains and a discharge area in lowlands, a system modified in nature by geologic and physiographic factors. The concentration of population and agricultural activity in valleys presents water-supply contamination and disposal problems. The suitability of hydrogeologic units for any function of these operations depends primarily on their position within the hydrologic system, and secondarily on physical properties. For example, at the Nevada Test Site nuclear contaminants must travel through considerable thicknesses of valley fill alluvium which fixes them before they reach the carbonate water level, in direct contrast to the conventional means of sewage disposal at Las Vegas, 70 miles to the south.–NAB.

Descriptors: Nevada, hydrogeology, arid lands, waste disposal, groundwater, water pollution.

Maxey, G. B. *See* Bredehoeft, John D. 0083.

0265 **McCann, Thomas P.; Privrasky, Norman C.; Stead, Frederick L; Wilson, James E.**
1968. Possibilities for disposal of industrial wastes in subsurface rocks of north flank of Appalachian basin in New York, *in* Subsurface disposal in geologic basins—A study of reservoir strata: Am. Assoc. Petroleum Geologists Mem. 10, p. 43-92.

The north flank of the Appalachian basin in New York was studied to determine the suitability of the region for subsurface disposal of industrial wastes, particularly liquid wastes. Permeable sandstone, salt beds that can provide leak-proof manmade caverns, and shale that can contain fluids in artificially produced fractures are especially significant. Subsurface strata dip southward at rates between 50 and 160 ft/mi. Local deformations such as low-relief anticlines and small displacement faults are few. Potential reservoirs for injection of liquids are the Cambrian Potsdam Sandstone, with 100 ft and the Cambrian Theresa Sandstone with a thickness range from 0 to 1,500 ft. Drilling depths to the Potsdam Sandstone, the lowest potential reservoir, range from 1,000 to 12,600 ft. Other possible sandstone reservoirs are present in the Silurian and Devonian Systems, but have less potential because of vagaries in porosity and permeability and because of the possibility of leakage from numerous unrecorded borings in the shallower strata. Salt beds in Silurian rocks at depths between 500 and 4,000 ft offer sites for construction of storage cavities. Shale sections that appear to be suitable for storage of grouted wastes in hydraulically produced fractures are present in Upper Devonian and Upper Ordovician strata. There are thinner sections of possible interest for the same use in Silurian and Middle Ordovician rocks.—W69-04943.

Descriptors: Injection wells, waste disposal, New York, geohydrologic units, groundwater basins.

0266 McClain, W. C.
1968. Rock mechanics in the disposal of radioactive wastes by hydraulic fracturing: Felsmechanik u. Ingenieurgeologie [International Society of Rock Mechanics Jour.], v. 6, no. 3, p. 139-161.

The ultimate capacity of a hydraulic-fracturing waste disposal facility is governed primarily by the integrity of the rocks overlying the injected wastes. The objective of the study was to analyze theoretically the stresses and strains generated by the injected wastes so that the failure mechanism could be predicted and the capacity of the injection well estimated. The surface uplifts at Oak Ridge National Laboratory's fracturing site were compared with theoretical curves obtained by assuming the uplifts to be inversely analogous to the subsidence which occurs over mining excavations. The most probable mechanism of failure of the rock appears to be by the formation of a vertical instead of a horizontal fracture. Fracture is controlled primarily by the orientation of the principal stress field in the rock. Each successive waste injection slightly modifies this stress field toward a condition more favorable to the formation of a vertical fracture. The effect of repeated injections was evaluated for various assumed original stresses and the minimum ultimate capacity of the formation was estimated as 4 million gal. It is also possible to make recommendations to avoid, as far as possible, the conditions leading to failure and in this way increase the formation capacity.—W69-03522.

Descriptors: Radioactive waste disposal, injection wells, rock mechanics, fractures (geology), permeability, stress, Tennessee.

0460 **McClain, W. C.; Tamura, Tsuneo; Brinkley, F. S.**
1966. Disposal by hydraulic fracturing, sec. 2 *of* Radioactive waste disposal, *in* Health Physics Division annual progress report for period ending July 31, 1966: U.S. Atomic Energy Comm. Oak Ridge Natl. Lab. [Rept.] ORNL-4007, p. 10-14.

The most probable failure mechanisms limiting the ultimate capacity of the shale formation in the hydraulic-fracturing waste-disposal method appear to be related to the stresses induced in the rocks surrounding the injection by the injection itself. The problem of defining the number and size of injections required to produce a failure condition is under investigation using elastic analysis. Examination of the nuclide retention properties of the set grouts, especially those containing low-cost fly ash, continued.–Authors' abstract.

Descriptors: Radioactive waste disposal, hydraulic properties, injection, shales, fractures (geology).

0657 **McClain, W. C.; Bradshaw, R. L.; Empson, F. M.**
1967. Disposal of high level solidified wastes in salt mines: U.S. Atomic Energy Comm. Oak Ridge Natl. Lab. [Rept.] ORNL-P-3053, 22 p.[Available from CFSTI.]

Project Salt Vault, an experiment demonstrating the disposal of high-level radioactive solid wastes in an inactive salt mine 1000 ft below ground, at Lyons, Kansas is described. The objectives of the experiment were: confirmation of the feasibility and safety of waste disposal in salt mines; demonstration of waste handling equipment and techniques; determination of the stability of salt under the influence of heat and radiation; and collection of information on creep and plastic flow of salt. Of the six experimental rooms in the mine, the main radioactive array contains seven 12-ft deep holes with electrical heaters and a canister with two ETR fuel assemblies for waste simulation. To note the effects of radioactivity, an identical array without the ETR fuel assemblies was constructed in another experimental room. Experimental data and conclusions are presented along with solutions to structural problems encountered in the experiment. The desirability of establishing an actual disposal facility is now being examined based on the results derived from Project Salt Vault.–NSA 21-28184.

Descriptors: Radioactive waste disposal, solid wastes, Kansas, underground storage, thermal properties, design data, salts.

0663 McClain, W. C.
1967. Hydraulic fracturing as a waste disposal method: U.S. Atomic Energy Comm. Oak Ridge Natl. Lab. [Rept.] ORNL-P-3054, 20 p. [Available from CFSTI.]

A method is described for the subterranean disposal of radioactive waste. The method which is based on hydraulic fracturing consists of pumping a mixture of aqueous waste and cements into a nearly horizontal fracture located in a deep shale formation. After injection of the mixture, the cements serve as a confining seal for the radioactive waste. The most economic cement solution was found to consist of Portland cement (Type II), fly ash, attapulgite clay to prevent phase separation, illite (Grundite) to serve as retention of radiocesium, and a retarder (Delta Gluconolactone). Analysis of the stresses and deformations induced around the injected mixtures indicates that any failure of the rock barrier will cause a vertical fracture rather than an extended horizontal fracture. A method of calculating the maximum capacity of a fracture facility in terms of allowable stresses is presented. Data on cost analysis and evaluation procedures for possible sites are also presented.–NSA 21-28185.

Descriptors: Radioactive waste disposal, injection, hydrostatic pressure, fractures (geology), grouting.

0664 **McClain, W. C.**
1969. Site evaluations, pt. V *of* Disposal of radioactive wastes by hydraulic fracturing: Nuclear Eng. Design, v. 9, no. 3, p. 315-326.

Although hydraulic fracturing has been shown to be a safe and economical method of waste disposal at the Oak Ridge National Laboratory, it will be necessary to carry out an extensive site examination program before the technique can be used at any other location. The most difficult part of this site examination is proving that the hydraulically induced fractures in the underground rocks are horizontal or nearly so. A site-testing program which utilizes several methods of remote determination of fracture orientation is discussed, but confirmatory core holes from the surface intersecting the test grout sheets will be required.–Author's abstract, NSA 23-31512.

Descriptors: Tennessee, radioactive waste disposal, hydrostatic pressure, fractures (geology), injection.

McClain, W. C. *See* Boegly, W. J., Jr. 0625.

McClain, W. C. *See* Bradshaw, R. L. 0492.

McConiga, M. W. *See* Brown, R. E. 0088.

McGauhey, P. H. *See* Butler, R. G. 0091.

McGauhey, P. H. *See* Krone, R. B. 0578.

McGhan, V. L. *See* Raymond, J. R. 0691.

0268 **McLean, D. D.**
1969. Subsurface disposal–precautionary measures: Indus. Water Eng., v. 6, no. 8, p. 20-22.

Rules for the dependable construction, installation, and operation of waste injection wells are outlined. One of the most important and least understood considerations is the history and effect of the liquid waste after it is injected into its receiving formation. Ideally, the sedimentary formation should be uniform sandstone, limestone, dolomite, or fractured shale of large areal extent with sufficient thickness, porosity, and permeability. Injection horizons should have adequate overlying and underlying aquicludes, low pressure, and be separated from freshwater horizons. Formation fluids should be compatible with injected fluids and no unplugged wells should penetrate the injection formation near the disposal well. The size and weight of the casing is important, depending on the pressures and depths encountered and the volume of fluid to be injected. Larger injection-strings reduce well-head injection pressures, but oversize holes are more costly to drill. Injection rates can be increased via chemical or mechanical stimulation. Such methods not only effectively increase the porosity of the critical region of the well bore but also reduce the chance of plugging. To accurately evaluate the hydrologic properties of the disposal formation, injectivity tests should be made. A disposal operation must include a properly designed monitor program to detect failure of various components.–W69-09234.

Descriptors: Waste disposal, injection wells, design criteria, installation, operation and maintenance, monitoring.

0270 **McLean, D. D.**
1968. Subsurface disposal of liquid wastes in Ontario [Canada]: Toronto, Ontario Dept. Energy and Resources Management, Petroleum Resources Section, Paper 68-2, 91 p.

All over North America pollution of our streams and lakes with industrial wastes has become a matter of grave concern to all levels of government, to industry, and to the general public. While many industries in Ontario have requested permission to dispose of liquid wastes in the subsurface, there are many others with similar disposal problems, completely unaware of the concept. With the expected population increase in Ontario and the growth of industry that will accompany it, the use of the limited water resources as a means of disposing of industrial effluent will have to cease or be rigidly controlled. Subsurface disposal as an alternative, where favorable conditions exist, is discussed with regard to the advantages and disadvantages of such an operation. The concept of subsurface disposal is not new. The oil and gas industry has made use of wells for the disposal of its collected oil field brine for many years, with an estimated 40,000 such wells in existence today. However, the concept of using the subsurface for industrial waste disposal was not adopted by other industries until about 1950, and today only 120 of these wells exist in 18 states in the U.S., 16 in Ontario (of which 11 are operating), and 4 in Saskatchewan.–Tulsa Univ., Inf. Services Dept.

Descriptors: Waste water disposal, injection wells, industrial wastes, foreign countries, technology, pollution abatement.

0665 **McMaster, W. M.; Waller, H. D.**
1965. Geology and soils of Whiteoak Creek Basin, Tennessee: U.S. Atomic Energy Comm. Oak Ridge Natl. Lab [Rept.] ORNL-TM-1108, 36 p. [Available from CFSTI.]

Since Oak Ridge National Laboratory began operation in 1943, radioactive wastes have been released on a continuous basis to the environment of Whiteoak Creek Basin. The natural factors affecting movement or retention of the radionuclides released are the water moving in and through the basin and the materials over and through which the water and its associated radionuclide load pass in transit. Because the geology and soils of Whiteoak Creek Basin are the principal modifying agents in water movement and the soil selectively fixes radionuclides, a knowledge of their characteristics is necessary for an understanding of the manner in which radionuclides move through or are stored in the basin. The geologic setting, the characteristic soils, and the general hydrologic characteristics of the geology and soils of the basin are described.–NSA 19-27835.

Descriptors: Tennessee, radioactive waste disposal, geology, soils radioisotopes, migration.

0269 **McMillion, L. G.**
1965. Hydrologic aspects of disposal of oil-field brines in Texas: Ground Water, v. 3, no. 4, p. 36-42.

In Texas, where 35 percent of the nation's crude oil is produced, brine production and disposal figures for 1961 showed that a total of 2,236,599,746 bbl of salt water were produced from approximately 67,000 oil and gas leases throughout the State. In that year 460,892,427 bbl of salt water were reportedly disposed of into unlined earthen pits, from which they seeped or overflowed to pollute fresh water, and 1,536,543,715 bbl were injected into the subsurface where inadequate well-completion methods may constitute a longer range problem than surface disposal. Brine-pollution control programs, to safeguard usable water supplies, must regulate standards for the whole range of oil-field operation, equating them with the objective of maximum oil and gas conservation and development.—NAB.

Descriptors: Texas, hydrogeology, oil fields, brine disposal, water pollution, injection wells.

McSpadden, T. W. *See* Halloway, H. D. 0170.

0271 **Mecham, O. E.; Garrett, J. H.**
1963. Deep injection disposal well for liquid toxic wastes: Am. Soc. Civil Engineers Proc. Paper 3650, Jour. Construction Div., v. 89, no. CO 2, p. 111-121.

On November 30, 1961, the deepest known pressure injection disposal well for liquid toxic waste was completed on the Rocky Mountain Arsenal near Denver, Colorado. Total depth of the well was 12,045 ft. with the injection interval being 11,975 ft. to 12,045 ft. in the fractured granite. With this example in mind, the feasibility of subsurface industrial waste water disposal is examined. For a number of years the oil industry has used subterranean waste disposal methods. An ideal subterranean waste disposal reservoir would provide the following requisites: (1) An accumulation of rocks with sufficient pore volume to contain desired or commercial quantities of waste water under pressure available from injection facilities; (2) sufficient permeability to accept waste water at commercial rates with available injection pressures; (3) natural barriers at horizontal and vertical extremities of the pore volume to assure confinement of waste water; and (4) no natural resources of commercial or domestic value within the pore volume. Because of the essential reservoir evaluation, the simple drilling of a hole in the ground to dispose of waste fluids is far short of the requirements of a disposal well.—Authors' abstract.

Descriptors: Injection wells, waste water disposal, Colorado, design criteria.

0272 **Mecham, O. E.; Legge, M. S.**
1960. How to forecast accurate drilling costs: World Oil, v. 151, no. 5, p. 112-116.

Drilling contractors are finding it imperative to determine, with the greatest accuracy possible, cost factors on which drilling bids will be based. Experience has shown that under normal drilling conditions, net drilling days and drill bit needs can be forecast consistently with an accuracy of 95 to 97 percent, using the profile method of estimating drilling penetration rates and drill bit requirements. This method makes use of drilling analysis charts on which are plotted profiles of (1) overall drilling progress, (2) net drilling progress, and (3) rotating progress, as well as other drilling data on previously drilled wells. From this information a reasonably accurate estimate can be made of the drilling time and bits that will be needed to complete the proposed well. The profile method of forecasting drilling costs has been time-tested in many areas and found to be very accurate when properly applied.

Descriptors: Drilling, cost analysis, methodology, data collections, economics, deep wells.

Mehlhorn, P. F. *See* Harleman, D. R. F. 0171.

0273 **Mercado, A.; Halevy, E.**
1966. Determining the average porosity and permeability of a stratified aquifer with the aid of radioactive tracers: Water Resources Research, v. 2, no. 3, p. 525-531.

A tracing technique for determining the average porosity and the permeability of the various layers of a stratified aquifer is presented. The average porosity and the different permeabilities of the four layers of a shallow sandstone aquifer were determined by tracing a pulse of $K_3Co^{60}(CN)_6$ between two wells located 15 meters apart, as well as by using standard pumping-test techniques. The results were confirmed by the salinity balance of the aquifer. The experiment has indicated the usefulness of radiotracer techniques combined with standard pumping techniques and chemical analyses for the study of microstructural properties of sandstone aquifers.–AWRA 08-0015.

Descriptors: Radioactivity techniques, aquifer characteristics, permeability, porosity.

0579 **Mercado, A.**
1966. Underground water storage study, recharge and mixing experiments in the Haifa Bay field: Tel Aviv, Tahal–Water Planning for Israel, Ltd., Tech. Rept. 18, Pub. 495, 37 p.

The investigation was to determine: (1) the spreading pattern of injected water bodies in two different flow nets, (2) the breakthrough curves at the pumping wells, and (3) the transition zone between injected and local water, the zone being caused by the dispersivity and the permeability distribution in the aquifer. The results of the test measurements were related to theoretical models. The experimental results are applicable to large-scale recharge and mixing operations.–WSP 1990.

Descriptors: Underground storage, mixing, injection, migration patterns, foreign countries.

0580 **Mercado, A.**
1967. The spreading pattern of injected water in a permeability stratified aquifer [with French abs.]: Internat. Assoc. Sci. Hydrology Pub. 72, p. 23-36.

The paper describes an explanation of the existence of a transition zone between the injected and the aquifer's waters, the explanation being developed on the assumption of a flow through an aquifer with horizontally stratified permeability, in which it is assumed that the frequency of permeabilities follows approximately the normal distribution function. The resulting transition zone is S-shaped and similar to that caused by dispersion. Its shape depends on the permeability distribution factor. The width of the transition zone caused by the horizontally stratified flow is directly proportional to the distance traveled while the width of the transition zone caused by dispersion is proportional to the square root of the distance traveled. In the latter case, the width of the transition zone increases also during the return flow, whereas it decreases in the case of horizontally stratified return flow. It is believed that in nature the dispersion and the horizontally stratified flow occur simultaneously, and thus the shape and width of the transition zone is a resultant of the two processes. A field experiment of the "injection-pumping pair" type carried out at the Haifa Bay Experimental Field is described and interpreted. The values of the permeability distribution factor as determined from the experimental breakthrough curves lie within the limits of 0.1 and 0.2. The results of the investigations in the experimental field are applicable to large-scale underground recharge and mixing operations.–*from* Author's abstract, WSP 1990.

Descriptors: Migration patterns, injection, permeability, dispersion, foreign countries.

Merkt, E. E., Jr. *See* Plummer, F. B. 0323.

0836 **Merritt, W. F.; Mawson, C. A.**
1967. Experiences with ground disposal at Chalk River [Canada] (SM-93/6), *in* Disposal of radioactive wastes into the ground–International Atomic Energy Agency and European Nuclear Energy Agency, Vienna, 1967, Symposium Proc.: Vienna, Internat. Atomic Energy Agency (STI/PUB/156), p. 79-92.

The soil at Chalk River is quite shallow and consists mainly of sand. It has a low exchange capacity, but is very permeable. Large disposals of radioactive wastes have been made into this soil, in solid and liquid form, both experimentally and as part of the normal waste management program. The experiments included the pumping of kilocurie amounts of mixed fission products, dissolved in nitric acid, into soil pits. An emergency disposal of mixed fission products suspended and dissolved in water, resulting from a reactor accident, was also made directly into the sand. The geology and soil structure are known in considerable detail, and the hydrology of the region around the waste management areas has been studied intensively. A description is given of the rate and direction of movement of radionuclides through the soil, and particularly in the ground water. It will be shown that, even under the difficult conditions at Chalk River, direct disposal into the ground has been both convenient and safe. The amount of ground used has been small, and movement of radionuclides through the soil has been extremely limited. Decay of radionuclides during their slow movement makes ground disposal a safe operation if ground conditions are adequately known.–Authors' abstract.

Descriptors: Radioactive waste disposal, hydrogeology, environmental effects, groundwater movement, foreign countries.

0761 **Metzler, D. F.; Hilton, W. O.**
1952. Oil industry wastes–their threat to fresh water: North Dakota Water Works Conf. Bull., v. 20, no. 4, p. 14-15. [Available from State Library Commission, Bismarck, N. Dak.]

Pollution of ground and surface waters by brine from oil fields in Kansas is discussed in relation to the future development of oil fields in North Dakota and to the measures that should be taken to protect unpolluted water. The most satisfactory method of disposal of brine is considered to be injection into subsurface formations.–Tulsa Univ., Inf. Services Dept.

Descriptors: Pollution abatement, North Dakota, brine disposal, injection.

Miekeley, N. *See* Levi, H. W. 0834.

0157 **Miklyutin, V. N.**
1958. Sbros stochnykh vod neftepromyslov v pogloshchayushchie skvazhiny [Disposal of waste waters in oilfields into absorbing wells]: Kuybyshev, Gosudarstvennyi Institut po Proektirovaniiu i Issledovatel'skim Rabatam v Neftedobyvaiushchei Promyshlennosti Trudy, no. 1, p. 455-467. [In Russian.]

Experimental work in various oilfields in the Volga region [Russia] indicates the possibility of pumping away oilfield waste waters, which contain substantial amounts of oil as well as dissolved salts and coarse solid particles, into absorbing horizons that contain saline water and also into oilbearing strata via oil wells that have been invaded by water. These wells may also be utilized for dumping waste waters of other industrial operations. Dumping water into reception wells is more economical than building special plants for their thorough purification.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, foreign countries, injection wells, feasibility studies.

Miller, E. B., Jr. *See* Rhea, A. S. 0342.

0762 **Mills, B.**
1940. Injection method for salt water disposal: Oil Weekly, v. 97, no. 8, p. 15-18, 20, 22-25. [Additional installments in v. 97, no. 9, p. 19-26, and v. 97, no. 10, p. 19-27.]

Salt water disposal by injection into converted or specially drilled wells in the East Texas field is discussed with detailed descriptions and plans of various injection projects in the field. Other disposal methods have proved inadequate to handle the daily 200,000 bbls. produced in the field. Nine companies have completed 13 disposal projects in the field. Simple aerating and settling plants are the most popular type and treating has been limited to an occasional coagulating agent and a small amount of chlorine to prevent bacteria formation. All plants use filters of some type for final trapping of solids ahead of injection. Sand filters are used almost entirely. Flow is usually by gravity, and cement-lined tubing and casing is used to prevent corrosion and the formation of iron compounds which tend to plug the formation. In the concluding article, descriptions are given with photographs and flow diagrams of the following injection systems: Humble Oil & Refg. Co.'s (N.C. Thompson lease), Sinclair Prairie's (Bunch Wilson lease and Amanda Wiley lease), Gulf Oil Corp.'s (Grissom lease), and Texas Co.'s (A. W. Kersh lease).–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, injection, Texas, waste treatment.

Mitchell, R. *See* Nevo, Z. 0582.

0763 **Mitchell, R. C.**
1936. Water pollution in Kansas: Oil and Gas Jour., v. 34, no. 43, p. 49-50, 52.

Since it is illegal in Kansas to dump brines into streams, the Board of Health and the Bureau of Mines are cooperating in an attempt to overcome the troubles encountered when brines are returned to the formation. It is recommended that careful records be kept of the depth, amount, analysis, etc., of fresh and mineralized water when drilling wildcat wells, and that adequate protection be made to prevent the escape of waste oil. Curves are included for determining the amount of fresh water necessary to dilute brines to water carrying nonpolluting quantities of solids.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, Kansas, data collections, pollution abatement, injection.

0158 **Mitry, E.; Gawad, A.; Emara, S.; Farah, M. Y.**
1966. Further studies on the uptake of long-lived fission products on some clays from the United Arab Republic with a view to eventual ground disposal (SM-71/63C), *in* Practices in the treatment of low- and intermediate-level radioactive wastes–International Atomic Energy Agency and European Nuclear Energy Agency, Vienna, 1965, Symposium Proc.: Vienna, Internat. Atomic Energy Agency (STI/PUB/116), p. 921-930.

Further studies in the UAR program on the feasibility of ground disposal of radioactive wastes are reported. New clays from the Nile and Meadi have been studied as well as those of Mokattam and Ainai. Their eventual domestication was demonstrated for long-lived isotopes as exemplified by ^{90}Sr. The effects of competing ions and heat treatment of clays was particularly emphasized, and an interpretation is proposed for the reported behavior. Further studies are being carried out for cesium on some deep mineralizations at Inshas and Borg el Arab reactor sites.–NSA 21-20350.

Descriptors: Radioactive waste disposal, foreign countries, clays, physicochemical properties, strontium radioisotopes, sorption.

0278 Moffett, J. G., Jr.
1960. Underground disposal of industrial wastes, *in* Short course for superintendents and operators of water and sewerage systems, 23d, Ann., General Extension Division and College of Engineering of Louisiana State Univ., Baton Rouge, 1960, Proc.: Louisiana State Univ. Eng. Expt. Sta. Bull. 64, p. 155-162.

Shell Chemical Company's first development venture with underground disposal of industrial waste utilizing a minimum capital installation has been a successful one. A second disposal well has been drilled for continuation of development studies and to dispose of all the waste water from new Acrolein and Glycerine Units to be completed at Norco [La.] in 1960. For those who are considering underground disposal, it must be emphasized that success in underground disposal of industrial waste will be expensive and will depend on a suitable installation, facilities, and ability to prepare properly the waste stream to be compatible with underground formations and waters.–Author's summary.

Descriptors: Industrial wastes, Louisiana, injection, waste water disposal, facilities, waste treatment.

Moore, B. H. *See* Samuelson, G. J. 0349.

0280 Moore, W. D.
1952. The pressure performance of 5 fields completed in a common aquifer: Am. Inst. Mining Metall. Petroleum Engineers Trans., v. 195, Tech. Paper 3460, p. 297-302.

This paper presents the results obtained after calculating matches of the observed pressure performance of five fields completed in a common aquifer. A general description of the Central Basin Platform area in west Texas in which the five fields, Andector, Embar, Martin, TXL, and Wheeler, are located is contained in the paper. The method of utilizing the electric analyzer to calculate simultaneously matches of the observed pressure performance of the five fields is outlined. The determination of boundaries of pressure communication is discussed and the extent of pressure interference between fields consistent with the configuration of the area aquifer is shown graphically.–Arad, USGS.

Descriptors: Hydrostatic pressure, aquifers, Texas, hydrodynamics, analog models.

0281 Moran, J. H.; Finklea, E. E.
1962. Theoretical analysis of pressure phenomena associated with the wireline formation tester: Jour. Petroleum Technology, v. 14, no. 8, p. 899-908.

The pressure build-up technique is a recognized method of determining permeability from conventional drill stem tests. In this paper an effort is made to extend such techniques to the interpretation of data obtained from the wireline formation tester, a formation testing device that operates on logging cable. Such a study is necessary because of the differences, for this case, in the magnitude of the flow parameters (rate of flow, amount of recovered fluids) and in the flow geometry (flow through a perforation vs. flow across the face of the wellbore, etc.) involved in the solution of the equations of flow for compressible fluids. The perforation is replaced by a spherical hole, and the effect of the borehole is neglected, so that the flow can be considered to be radial in a spherical co-ordinate system. Arguments are presented to justify this idealization. Assuming single-phase flow, general relations between pressure and flow rate are developed for a homogeneous medium. The study is then extended to permeable beds of finite thickness. It is shown that the early stages of pressure build-up tend towards spherical flow, while the later stages tend towards cylindrical flow. The thinner the bed, the more quickly flow approaches the

cylindrical model. The prevalence of thin beds in practical work makes this analysis quite important. Cases involving permeability anisotropy are treated.–Authors' abstract.

Descriptors: Hydrodynamics, theoretical analysis, subsurface investigations, flow characteristics, methodology.

0666 **Morgan, J. M., Jr.; Jamison, D. K.; Stevenson, J. D. (editors).**
1962. Ground disposal of radioactive wastes conference, 2d, Atomic Energy of Canada Limited and U.S. Atomic Energy Comm. Div. Reactor Devel., Chalk River, Canada, 1961, Proc.: U.S. Atomic Energy Comm. Div. Tech. Inf. [Rept.] TID-7628, Book 1, p. 1-300; Book 2, p. 301-644.

A conference on the *Ground Disposal of Radioactive Wastes* was held at Chalk River, Canada, in September 1961. Technical aspects of the ground disposal of various types of radioactive wastes in the United States and other countries were discussed. Separate abstracts have been prepared on many of the papers presented at this meeting.

Descriptors: Radioactive waste disposal, technology, United States, foreign countries.

0667 **Morgan, J. M., Jr.; Geyer, J. C.; Costello, D. C.; and others.**
1962. Land burial of solid packaged low hazard potential radioactive wastes in the United States, *in* Morgan, J. M., Jr., Jamison, D. K., Stevenson, J. D., eds., Ground disposal of radioactive wastes conference, 2d, Atomic Energy of Canada Limited and U.S. Atomic Energy Comm. Div. Reactor Devel., Chalk River, Canada, 1961, Proc., Book 2: U.S. Atomic Energy Comm. Div. Tech. Inf. [Rept.] TID-7628, p. 396-427.

More than 7,000,000 cubic feet of low hazard potential solid radioactive waste from the 15-year old nuclear energy industry have been buried in the continental United States in shallow trenches at government-controlled Atomic Energy Commission installations. Throughout the atomic industry today, there are over four thousand establishments, ranging in size from the largest Commission production sites through modest commercial and industrial isotope users to small hospital and university research laboratories, performing operations that result in the generation of increasingly large amounts of solid radioactive materials that must be painstakingly handled, safely packaged, and often transported long distances. The wastes are characterized by a wide variety of chemical content and toxic types, and generally by low concentrations of activity. The management and disposal of this large volume of useless material, of varying activity, from the nation-wide nuclear energy and radioisotope program are described. The problems vary widely depending upon the nature, concentration, and quantity of radioactivity involved, and on the specific environment in which the material will ultimately repose. Safety factors and hazards must be carefully considered at each step in the disposal system which involves packaging, shipping, handling, monitoring, and burial.–Authors' abstract, NSA 16-25062.

Descriptors: Radioactive waste disposal, United States, solid wastes.

Morris, Billy P. *See* Cocanower, R. D. 0010.

0282 **Morris, D. A.; Barraclough, J. T.; Chase, G. H.; and others.**
1965. Hydrology of subsurface waste disposal, National Reactor Testing Station, Idaho–Annual progress report, 1964: U.S. Geol. Survey open-file rept. (IDO-22047), 304 p. [Available from CFSTI.]

Research was conducted on the hydrologic aspects of the disposal of low-level aqueous waste to the NRTS environment. Geologic and geohydrologic data were analyzed, and some new data are reported. Studies were made of the TRA [Test Reactor Area] waste-disposal pond area. The effects of the Alaskan earthquake on the water levels are described.–NSA 19-40269.

Descriptors: Radioactive waste disposal, hydrogeology, Idaho.

0520 **Morris, D. A.**

1967. Use of chemical and radioactive tracers at the National Reactor Testing Station, Idaho, *in* Isotope techniques in the hydrologic cycle–Symposium, Univ. Illinois, 1965: Am. Geophys. Union Geophys. Mon. Ser., no. 11, p. 130-142.

Chemical and radioactive tracers were used in studies of geology and hydrology of basalt terrane at the National Reactor Testing Station. A salt tracer used near waste disposal from a processing plant indicated rates of flow ranging from 15-50 feet/day in the regional groundwater reservoir, and a sodium fluorescein dye an average rate of about 23 feet/day. Recent studies using tritium indicated average rates of flow of about 54 feet/day based on 'first arrival' and from 10-13 feet/day based on arrival of the 'center of mass' or maximum tritium concentration. Studies of water perched in alluvium and basalt underlying the area indicated a rate of flow of about 2-10 feet/day. Long-range tritium studies in the regional groundwater reservoir in the Central Facilitiės area indicated rates of flow of 6-8 feet/day under normal hydraulic gradients of 5 feet/mile and distances of 4-5 miles from points of injection.–*from* Author's abstract, NAB.

Descriptors: Radioisotopes, tracers, flow rates, groundwater movement, basalts, hydrogeology, Idaho.

0658 **Morris, D. A.; Teasdale, W. E.; and others.**

1964. Hydrology of subsurface waste disposal, National Reactor Testing Station, Idaho–Annual progress report, 1963: U.S. Geol. Survey open-file rept. (IDO-22046), 228 p. [Available from CFSTI.]

Results of investigations of the NRTS geological area are presented. Special studies are reported concerning waste disposal. It was found that ground water underlying NRTS is part of the larger ground-water body underlying the entire Snake River plain. NRTS is underlain by basalt and unconsolidated sediments. Study during 1963 was devoted to determining chemical or radiometric changes that occurred as ground water containing radioactive waste moved through the geologic environments underlying the NRTS area. Results of water level studies and test hole sample analyses are included.–NSA 19-22529.

Descriptors: Radioactive waste disposal, hydrodynamics, basalts, Idaho, hydrogeology, research and development.

0284 **Morris, W. S.**

1943. Subsurface disposal of salt water in the East Texas field: Petroleum Engineer, v. 14, no. 11, p. 41-49, 53.

In discussing the subsurface disposal of salt water in the East Texas field by injecting it into the Woodbine sand, the author traces the history of these disposal projects, both those owned by individual companies and by the East Texas Salt Water Disposal Co., which is owned by 249 companies; maps the encroachment of water in the field; graphs and tabulates the salt water and oil production since 1931, the reservoir pressure, the number of injection systems, the amount of salt water injected, and the

cost of injection as a function of the injection rate; lists the ownership and operating data of the 56 injection wells; and describes the method of drilling injection wells, the treatments given the water to oxidize the iron, kill the bacteria, and remove foreign matter, the salt water gathering systems of cement-lined asbestos or wood fiber coal tar-impregnated pipe, and the salt water pits, usually made of gunite. Although the costs of injection vary greatly throughout the field, they are always reasonable. The author's company charges 1.8 cents per bbl., a cost that is offset by the Texas Railroad Commission's allowing the production of an additional barrel of oil for each 50 bbl. salt water returned to the formation.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, injection, Texas, data collections, methodology, operating costs, geologic formations.

0285 **Morris, W. S.; Dial, L. H.**
1943. Salt water disposal program in the East Texas field [abs.]: Oil and Gas Jour., v. 42, no. 29, p. 56.

The operators in the East Texas field have 61 salt water disposal wells, 22 of which are operated by the East Texas Salt Water Disposal Co. The wells are completed in the Woodbine sand below the depth of the original oil-water interface (3,320 ft. below sea level). The procedures that have been adopted by the Company for the construction of disposal wells are described. Corrosion is an ever-present problem. Pipe lines, pumps, etc., must be designed to withstand it. Asbestos cement pipe is particularly suitable, because it is not only corrosion resistant, but offers immunity to tuberculation and electrolysis. A wood-fiber coal-tar product has been used successfully, too, in a limited field of application on gravity lines and then only where the pressure does not exceed 15 lb. per sq.in. Where high pressures are required, cement-lined pipe (steel) is most satisfactory. This type of pipe is, of course, subject to external corrosion from the soil and lasts a very short time in soil impregnated with salt water.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, Texas, injection wells, installation, operation and maintenance, geologic formations.

0286 Morris, W. S.
1945. Methods of salt-water disposal in oil fields, East Texas oil field: Am. Water Works Assoc. Jour., v. 37, no. 6, p. 569-573.

General article describing organization of East Texas Salt Water Disposal Company, giving statistics on salt water returned to Woodbine Sand through wells.–Arad, USGS.

Descriptors: Brine disposal, Texas, injection wells.

0287 **Morris, W. S.**
1946. How the world's largest brine injection project is handled, pt. 1 *of* Salt water disposal in East Texas field: Oil and Gas Jour., v. 45, no. 14, p. 72-82, 86, 91.

The problem of salt water disposal in the East Texas field, the organization of the East Texas Salt Water Disposal Co., and its operations are described. The plan has worked smoothly and there have been very few past due accounts. Injection has increased from more than 50,000 bbl./day in March 1943 to an average of 300,000 bbl./day in May 1946.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, Texas, injection wells, operation and maintenance.

0288 **Morris, W. S.**
1946. Engineering factors and operating problems in the East Texas field, pt. 2 *of* Salt water disposal: Oil and Gas Jour., v. 45, no. 15, p. 89-91, 93-94.

In this second installment of the description of the Texas Salt Water Disposal Co. system, the asbestos cement pipe "open" type gathering system and treating plant are described. The company has about 200 miles of gathering lines and two crews are required constantly for cleaning these lines. Treatment includes aeration, both at the collection centers and at the treating plant, chlorination, treatment with alum, and settling before injection of the treated water into the wells. The chemistry of East Texas salt water is discussed briefly.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, Texas, injection wells, piping systems (mechanical), waste treatment.

0289 **Morris, W. S.**
1946. Engineering factors for pressure filters, pits, injection wells, and other items used in the East Texas field, pt. 3 *of* Salt water disposal: Oil and Gas Jour., v. 45, no. 16, p. 86-90, 124.

Engineering factors are given for pressure filters, pits, injection wells, and other items used in the East Texas field.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, Texas, injection wells, design data, equipment.

0293 **Morris, W. S.**
1946. East Texas field has record of outstanding results from its four-year program of salt water disposal, pt. 4 *of* Salt water disposal: Oil and Gas Jour., v. 45, no. 17, p. 92, 95, 97.

This fourth and concluding article of a series completes the treatment of many items of design, equipment and operation involved in the huge East Texas salt water disposal project. Subjects discussed include bottom-hole pressure maintenance, its relation to oil production, and legal requirements for a 10 to 1 and later a 5 to 1 production water/oil ratio as a conservation measure.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, Texas, injection wells, legal aspects, effects.

0403 **Morris, W. S.**
1946. Salt water injection and maintenance in the East Texas field [abs.]: Oil Weekly, v. 124, no. 4, p. 66.

The field-wide program in the East Texas field for the disposal of subsurface salt water and the reduction in the net withdrawal of fluids is described. By October 1946, 79 injection wells were in use. Approximately 530 million bbl. of water have been returned to the Woodbine sand. During November 1946, 91.6% of the total water produced was returned to the sand. The bottom-hole pressure in the field showed an increase of 14.91 lbs./sq. in. during 1945, and in the first ten months of 1946 the pressure has increased 1.63 lbs./sq.in. Since the Salt Water Disposal Co. became active in October 1942, the pressure of the reservoir has declined only 2.93 lbs./sq.in. notwithstanding the production of over 528 million bbl. of oil during that period, which is at the rate of more than 180 million bbl. of oil per lb. pressure drop. It is estimated that the recoverable reserves have been increased by more than 600 million bbl. of oil as a direct result of the project.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, Texas, injection wells, effects, oil fields.

0463 Morris, W. S.
1947. Results of water injection in Woodbine reservoir of the East Texas field: Am. Petroleum Inst. Proc., v. 27, no. 4, p. 36-45.

The disposal of salt water produced with the oil in the East Texas oil field, which is a water-drive type reservoir, by the return of salt water into subsurface formations has been successful not only in eliminating pollution and contamination of fresh-water streams and increasing the recovery of oil but also in maintaining the bottom-hole pressure to the extent that the use of artificial lift has been greatly reduced. Data on the volume of salt-water produced, growth of salt-water disposal systems, and oil pressure relationships are tabulated.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, injection wells, Texas, pollution abatement, data collections.

0476 Morris, W. S.
1960. Subsurface disposal of salt water from oil wells: Water Pollution Control Federation Jour., v. 32, no. 1, p. 41-51.

The organization and execution of the salt water disposal project to return salt water, from all operators in the [East Texas] oil field, to the Woodbine sand reservoir on a field-wide basis, is a significant and outstanding conservation and water pollution control measure. The oil operators in the East Texas field and the Railroad Commission of Texas have shown excellent cooperation in working out a successful answer to a most difficult problem. In addition to the benefits derived by the elimination of pollution of the streams, the return of salt water to the reservoir has maintained the bottom-hole pressure to the extent that many wells have continued to flow that otherwise would have required mechanical lifting. It is estimated that as a direct result of the salt water disposal program, more than 600 million barrels of additional oil will be recovered from the reservoir. An oil field with 100 million barrels recovery is considered a major field in the oil industry. The additional oil to be recovered from East Texas is therefore equal to the equivalent of six major oil fields.–Author's summary.

Descriptors: Texas, brine disposal, injection wells, effects, geologic formations.

0494 Morris, W. S.
1967. Fighting scale in salt water lines: Petroleum Engineer, v. 39, no. 2, p. 55-56, 58.

A summary is presented of methods employed to eliminate scale in the mammoth East Texas Salt Water Disposal Co.'s system. This complex system has disposed of nearly 3 billion bbl. of salt water and currently handles over 417,000 bbl. daily throughout 455 miles of gathering and distribution lines. The current program to control and remove scale deposition is a combination of best experiences to date and the use of new materials including the development of an epoxy-lined asbestos cement pipe and use of 14% hydrochloric acid flushes. The lining of the asbestos cement pipe is a hard, permeable and smooth epoxy that discourages scale deposition.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, Texas, piping systems (mechanical), scaling, control.

Morton, R. B. *See* Irwin, J. H. 0744.

Morton, R. J. *See* Struxness, E. G. 0845.

0524 **Moseley, Joe C., II; Malina, Joseph F., Jr.**
1968. Relation between selected physical parameters and cost responses for the deep well disposal of aqueous industrial wastes: Austin, Univ. Texas Center for Research in Water Resources Rept. CR WR 28, 276 p. [Technical rept. to U.S. Public Health Service EHE 07-6801.]

The objectives of this investigation were: (a) to develop the equations and the systems of equations governing the performance of an injection well, (b) to collect economic data on the components of such a system, (c) to develop a computerized design and cost model giving the cost responses to the input variables, (d) to test this model on many feasible input data combinations, and (e) to develop generalized relationships between physical conditions and the costs of injection. Physical relationships in common usage in the petroleum industry were modified where necessary and used to describe the behavior of the injection system. Knowledge and information from other disciplines, including geology, chemical engineering, and civil engineering were utilized where applicable. Cost data were collected from a variety of sources, especially the petroleum and chemical engineering fields. The resulting model was tested on data collected from published sources and other selected values. The resulting information was analyzed and relationships between input variables and cost responses were developed. The results of this preliminary study indicate that deep-well injection of aqueous wastes is both technically and economically feasible under certain conditions. The cost of this operation may run upward from a minimum of 25 cents to 40 cents per thousand gallons, including minimal preinjection treatment and amortization of the initial capital investment. Certain aspects of this operation differ sufficiently from those of the oil industry to merit further investigation. These include (a) the evaluation of certain common petroleum practices in the light of constraints placed on injection operations, (b) the development of a method to better predict fluid incompatibility, (c) the evaluation of various formations and wastes to determine if they are suitable for this type of disposal, and (d) a detailed study of possible long-term effects.

Descriptors: Injection wells, equations, computer models, economics, design data, cost analysis.

0290 **Mudra, P. J.; Schmalz, B. L.**
1965. An appraisal of gaseous waste disposal into the lithosphere at the National Reactor Testing Station, Idaho: U.S. Atomic Energy Comm. Idaho Operations Office [Rept.] IDO-12024, 141 p. [Available from CFSTI.]

A series of gas-injection field tests were performed at the National Reactor Testing Station, Idaho, during the summer of 1964, to determine the feasibility of discharging radioactive gaseous waste to the lithosphere. Specific objectives included the determination of the: (a) storage capacity of the lithosphere, (b) direction and velocity of migration of the injected gas, (c) dilution and dispersion effects on the initial concentration of the injected gas, and (d) pressures required for injection. A cost estimate using this concept under hypothetical circumstances was also developed. Helium was used as a tracer gas to identify approximately 33 million standard cubic feet of air injected into porous zones both above and below the regional water table within the subsurface basalts underlying the station and into the unconsolidated sandy regolith materials. The maximum depth of injection was 400 feet below land surface. A mean pressure of 15 psig was required to maintain an injection rate of 1000 cubic feet per minute into the unsaturated basalt zones. Observations indicated that no finite geological reservoir existed in the subsurface and that the regolith materials offered the most restrictive barrier to vertical movement. Although injected gas could eventually arrive at land surface, the amount of dispersion and dilution observed indicates that lithospheric gas disposal is feasible at the NRTS for single injection volumes of up to 6 million standard cubic feet. The cost for a lithospheric disposal system is estimated at a maximum of $250,000.—Authors' abstract, NSA 19-48077.

Descriptors: Idaho, injection, radioactive wastes, basalts, feasibility studies, gases.

0291 **Murata, K. J.**
1943. Internal structure of silicate minerals that gelatinize with acid: Am. Mineralogist, v. 28, no. 11/12, p. 545-562.

A list of silicate minerals that are reported to gelatinize on being treated with acid was compiled and arranged according to a classification based on the internal structures of the minerals. From an examination of this data it is concluded that the following classes of minerals will gelatinize, if they are vulnerable to acid attack.

1. Those minerals containing silicate radicals of small molecular weight, namely orthosilicates, pyrosilicates, and possibly silicates containing ring structures of three silicon atoms.
2. Those minerals with large continuous silicon-oxygen networks that will disintegrate into units of low molecular weight.
   (a) Disilicates containing appreciable ferric iron in the silicon-oxygen sheets.
   (b) Minerals of the silica type with three-dimensional networks that contain aluminum in the ratio of at least two aluminum atoms to three silicon atoms.

Minerals that separate insoluble silica, instead of gelatinizing, upon being treated with acid, are characterized by silicon-oxygen structures of large dimensions that do not disintegrate into small units under acid attack. These are SiO_3 chains, Si_4O_{11} double chains, Si_2O_5 sheets not containing large amounts of ferric iron replacing silicon, and three-dimensional networks having an aluminum content less than the ratio of two aluminum atoms to three silicon atoms. The exceptions to these rules are briefly discussed.—Author's abstract.

Descriptors: Chemical reactions, silicates, gels, mineralogy, acids.

0292 **Murata, K. J.**
1946. The significance of internal structure in gelatinizing silicate minerals, *in* Wells, R. C., and others, Contributions to geochemistry, 1942-45: U.S. Geol. Survey Bull. 950, p. 25-33.

Silicate minerals that dissolve in hydrochloric or nitric acid to give gelatinous silica fall into two classes, based on their internal atomic structure:

1. Minerals containing silicate radicals of small molecular weight, namely orthosilicates, pyrosilicates, possibly silicates with the ring structure of three silicon atoms, and possibly silicates with the ring structure of six silicon atoms.
2. Minerals with large continuous silicon-oxygen frameworks that will disintegrate into units of low molecular weight under acid attack.
   (a) Disilicates, sheet structures, containing large amounts of ferric iron in the silicon-oxygen sheets.
   (b) Minerals with three-dimensional structures that contain aluminum in the ratio of at least two alumimum atoms to three silicon atoms.

Minerals that separate insoluble silica, instead of gelatinizing, upon being treated with acid are characterized by silicon-oxygen structures of large dimensions that do not disintegrate into small units under acid attack. These structures are SiO_3 chains, Si_4O_{11} double chains, Si_2O_5 sheets not containing large amounts of ferric iron replacing silicon, and three-dimensional frameworks having an aluminum content less than the ratio of two aluminum atoms to three silicon atoms. These relationships may be interpreted through the qualitative hypothesis that small silicon-oxygen units or radicals dissolve in acid to yield gelatinous silica, whereas large units will yield insoluble separated silica. The maximum size of the soluble units is as yet undetermined.–Author's abstract.

Descriptors: Chemical reactions, silicates, mineralogy, gels, acids.

0581 Muravev, I. M.
1967. Determining the permissible amount of impurities in injection water: Neftyanoye Khozyaystvo [Russia], v. 45, no. 3, p. 47-49.

Injectivity data from 12 wells were analyzed in an effort to determine the maximum amount of suspended matter which can be tolerated in injection water. Some wells were found to be unaffected by injection of 70,000 kilograms of suspended solids, while other wells were affected by injection of 15,000-30,000 kg of solids. The data indicate that water injection rates did not decrease, as long as specific suspended-solids load was in the range 0.0035-0.0040 mg/l per square centimeter. Analysis of suspended-particle size and of pore size showed that particles 1-30 microns in diameter can readily pass through reservoir rocks. From field data, the authors developed the following equation for calculating maximum permissible suspended-matter content in injection water:

$$b = nKF$$

where b is maximum suspended matter in milligrams per liter, n is permissible amount of suspended matter per unit of formation permeability in milligrams per liter per square centimeter per millidarcy, K is average permeability in millidarcies, and F is average formation well bore surface in square centimeters. For river water, n is about 0.00001, while for produced water, n is about 0.000025.–WSP 1990.

Descriptors: Injection, suspended load, equations, water quality, water treatment, design criteria.

Myers, O. H. *See* Jacobs, D. G. 0554.

0220 Nace, Raymond L.
1960. Contributions of geology to the problem of radioactive waste disposal, *in* Disposal of radioactive wastes, v. 2–International Atomic Energy Agency and United Nations Educational, Scientific and Cultural Organization, Monaco, Nov. 16-21, 1959, Sci. Conf., Proc.: Vienna, Internat. Atomic Energy Agency (STI/PUB/18), p. 457-480. [In English with French, Russian, and Spanish abs.]

Accumulated geologic knowledge and established principles have been applied widely in the United States to problems of radioactive-waste disposal, and the unique nature of these problems has led to research and significant advancements of knowledge in specialized aspects of geology. A common activity has been appraisal of sites for nuclear-energy facilities. This includes analysis and evaluation of geologic, topographic, hydrologic, geochemical and seismic factors. Special studies include actual and potential behavior of intermediate- and low-level wastes in specific geologic environments such as volcanic, limestone, shale, and coarse-clastic terranes. Other studies concern possible use of structural basins, stratigraphic traps, and salt beds and salt domes for storage and containment of high-level waste. Water is the critical factor in waste disposal because (1) water is the ubiquitous and universal solvent which dilutes and disperses released waste, and (2) water is a basic natural resource whose usefulness should not be impaired. Certain natural processes by which water may be

purified, or chemically altered have been investigated. Examples are ion exchange and adsorption, chemical precipitation, biological concentration, evaporation, diffusion, dispersion, turbulent mixing, and isotopic dilution. Significant results have been achieved in studies of dispersion and diffusion processes in ground water and surface water; the rate of travel of contaminants in streams; the mechanics of ground-water flow in granular materials; ground-water flow in cavernous rocks; and the behavior of water and chemical solutions in the zone of aeration. Thermal and chemical-stability problems that would develop if high-level waste were injected in geologic formations also have been investigated. Geologic, petrologic and geophysical studies have been made of specific areas, and research in clay mineralogy, ion exchange, and geochemistry has been aimed directly at waste disposal problems.–*from* Author's abstract.

Descriptors: Radioactive waste disposal, United States, geology, methodology.

0294 Nace, Raymond L.
1961. Underground storage of radioactive wastes: Interstate Oil Compact Comm. Comm. Bull., v. 3, no. 1, 15 p.

Overall prospects for safe storage of radioactive waste liquid within the United States seem reasonably favorable. No single method or kind of environment can be universally applicable for all kinds of wastes. However, several methods may be used simultaneously at a single locality. Storage in salt mines or salt domes looks favorable. The most serious problem appears to be to control heat and off-gases. Injection of high-level waste in permeable formations seems less promising. Pilot injection with simulated waste and later with medium- and low-level wastes can be planned to test a formation for suitability. Several hazards should be considered beyond those of the storage site itself. One is that of transporting radioactive materials, where sources of waste may not be near suitable storage areas.–Randolph, USGS.

Descriptors: Radioactive wastes, underground storage, liquid wastes, injection, United States.

0318 Nace, Raymond L.
1962. Management of radioactive waste in a basalt terrane, Idaho [abs.]: Geol. Soc. America Spec. Paper 68, p. 315.

Problems arising from the storage, discharge, or escape of radioactive waste on or in the ground are basically problems of physical geology, hydrology, and geochemistry. The NRTS (National Reactor Testing Station) of the U.S. Atomic Energy Commission operates in the unique setting of the Snake River Plain, southern Idaho. There the principal aquifer is basalt, whose permeability ranges up to 10^7 gallons per day per foot. About 25 reactors and critical assemblies on the Station were operable at the end of 1960. There is also a large chemical plant for reclaiming uranium from used fuel. Atomic Energy Commission policy and practice are to manage all radioactive wastes in such a way that they will cause no undue exposure of operating personnel or the general public to ionizing radiation. Principal radioactive wastes generated on the Station are liquid solutions that contain fission products. After treatment, these fall into two categories: high level (intensely radioactive) and low level (slightly radioactive). About 1.5 million gallons of high-level waste is stored on the NRTS in durable steel tanks. Solutions discharged to the geologic environment consist of low-level waste diluted with nonactive service waste. Solid waste is consigned to a sequestered burial ground and interred in alluvial gravel. The U.S. Geological Survey has collaborated with the Atomic Energy Commission since 1949 in comprehensive and special studies of geology, hydrology, and geochemistry on the NRTS in relation to construction, operations, and environmental safety. Waste management at the NRTS has been influenced greatly by earth-science data and principles, and no definable hazard to water supplies has developed. Although no one can say with

absolute assurance that no hazard will ever occur, knowledge and means are available to continue operation of the NRTS as a safe facility for an indefinite period.–Author's abstract.

Descriptors: Radioactive waste disposal, basalts, Idaho, environmental engineering, methodology, management.

0668 Naeser, C. R.
1962. Geochemical studies pertaining to ground studies of radioactive wastes, *in* Morgan, J. M., Jr., Jamison, D. K., Stevenson, J. D., eds., Ground disposal of radioactive wastes conference, 2d, Atomic Energy of Canada Limited and U.S. Atomic Energy Comm. Div. Reactor Devel., Chalk River, Canada, 1961, Proc., Book 1: U.S. Atomic Energy Comm. Div. Tech. Inf. [Rept.] TID-7628, p. 237-247.

Results are reported from geochemical studies pertaining to waste disposal. Both empirical and fundamental approaches to the problem were considered. The behavior of vermiculite, glauconite, crandallite, and anhydrite as scavengers for radio-cesium and/or radio-strontium and the effectiveness of the scavenging process as a function of the pH were investigated.–NSA 16-25053.

Descriptors: Radioactive waste disposal, geochemistry, scavengers, radioisotopes, sorption.

Naor, I. *See* Orcutt, R. G. 0593.

0764 National Petroleum News.
1929. Salt water disposal: Natl. Petroleum News, v. 21, no. 37, p. 67.

Disposal of brine in the oil fields of Texas is carried out by four methods: 1) cavity wells, 2) direct run-off to streams and the sea, 3) seepage into the ground and evaporation, 4) storage in dry periods and run-off to streams during floods. Evaporation pits must be shallow and as level as possible. Brine which is run into streams or directly into the sea, must be carefully freed from waste oil by passing thru a skimming plant.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, Texas, methodology, water pollution control.

0765 National Petroleum News.
1937. Joint disposal plant for salt oil well water: Natl. Petroleum News, v. 29, no. 47, p. 23.

Five companies in the Edmond pool, Oklahoma are disposing of about 2000 barrels of water daily from 36 wells, by returning it to a dry hole. Equipment installed to put the water into the sand under pressure up to 750 pounds has not been necessary. Water from the five companies is brought from inside coated pipe into a 200-barrel wrought iron separator tank which has an inside coating of bitumistic enamel. The waste oil is cleared from the salt water and is burned when enough has accumulated. Water from the separator goes to an open type aerator 8 X 8 X 12 feet high, containing eight trays made of lath with about two inches of coke between the lath. This filters the water and frees it of material which might clog the sand of the disposal well. This material is chiefly iron products of corrosion of casing and tubing in the oil wells. Water from the aerator falls into the concrete accumulator pit of 5000 barrels capacity, divided into three compartments in order to retard the flow of water and secure the precipitation of iron oxide or other solids that will settle. Water moves from the filter into a clear water pit from which it goes by gravity to the disposal well.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, Oklahoma, injection wells, waste water treatment.

0766 **National Petroleum News.**
1945. University scientists study East Texas oil field salt water disposal system: Natl. Petroleum News, v. 37, no. 36A, p. R726-R728.

A report by the University of Texas on the system of salt water disposal in the East Texas field summarizes the defects in the present system as (1) corrosion inside the concrete pits and filters; (2) excessive consumption of chemicals; (3) imperfect separation of waste oil from the water; (4) ineffectual elimination of a fine black precipitate of iron sulfide in some of the water; (5) insufficient stabilization of the bicarbonate which causes hardening of the filter sand. Recommendations for future design improvements to correct these defects include (1) aerators, strainers and partial filters; (2) design and construction of nonmetallic filter tanks; (3) installing the initial aeration and chemical treatments on some of the 30 systems in the field close to the wells where the water is hottest; (4) improving the design of the settling pits; and (5) coating the inside of the filters and concrete pits with asphalt paint or the like.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, Texas, injection wells, treatment facilities, design data.

Nazarov, A. I. *See* Yudin, F. P. 0450.

0521 **Nelson, J. L.; Haney, W. A.; Knoll, K. C.; Bensen, D. W.**
1963. Laboratory, pilot and field scale studies of fission product migration rates in soils [with French abs.], *in* La retention et la migration des ions radioactifs dans les sols–Colloque international, Saclay, France, 1962: Paris, Presses Universitaires de France, p. 107-115.

Results of laboratory, pilot, and actual waste-disposal studies relating to the migration rates of fission products in soils are presented. Work planned to obtain a more accurate definition of the radioisotope capacity of specific disposal sites is also described. The variables that influence the rate of movement of trace concentrations of radio-cations in soil were determined. Methods were investigated for extrapolating laboratory results to field disposals, and model waste-disposal facilities were constructed.–NSA 17-01159.

Descriptors: Geochemistry, waste disposal, Washington, radioisotopes, migration, soil dynamics.

0533 **Nelson, J. L.; Ames, L. L., Jr.; and others.**
1962. Chemical effluents technology: Richland, Wash., General Electric Co., Hanford Atomic Products Operation [Rept.] HW-73337, p. 158-237.

Results are reported from recent studies on geologic features and groundwater flow at the Hanford area [Wash.]. The disposal of decontamination wastes from the new production reactor to ground at an inlet site is discussed. A logging system for well water temperature measurements, and a flowmeter for measuring vertical currents in wells are described. Equations for the prediction of ion exchange column break-through curves were modified to insure more consistent results for soil columns of different lengths. The efficiency of aluminum turnings for the decontamination of reactor effluent was investigated on pilot-scale beds. A scheme is described for over-coming the computational problem in field permeability measurements on soil. An approximate method is presented of computation for in-place permeability measurement, and basic equations are presented to describe steady, partially saturated flow in porous media.–Tulsa Univ., Inf. Services Dept.

Descriptors: Radioactive waste disposal, Washington, geology, test procedures, chemical reactions, equations.

0671 **Nelson, J. L.; Bensen, D. W.; Knoll, K. C.**
1962. Hanford [Wash.], studies in geochemistry, *in* Morgan, J. M., Jr., Jamison, D. K., Stevenson, J. D., eds., Ground disposal of radioactive wastes conference, 2d, Atomic Energy of Canada Limited and U.S. Atomic Energy Comm. Div. Reactor Devel., Chalk River, Canada, 1961, Proc., Book 1: U.S. Atomic Energy Comm. Tech. Inf. [Rept.] TID-7628, p. 214-236.

In 1957, a research program was initiated at Hanford to quantitatively define the variables that effect the retention of radionuclides by soils. Chromatographic equations from the literature were applied to soil column breakthrough data, thus permitting a prediction of breakthrough of radionuclides from ground disposal facilities. A study was made of the effects of temperature, species of accompanying ion, concentration of accompanying ion, concentration of trace ion, pH, column diameter, column length, and flow rate on strontium breakthrough curves. Although initial attempts to fit the column length data to chromatographic equations were not successful, some adjustment methods were found which bring the equations into better agreement with laboratory results. The adjustments also tended to provide an improved understanding of the mechanisms involved. In addition to these findings, the results of research on the reactions of rare earths with soils, a study of the effect of hydrodynamic unsaturation on ion exchange, further results from a model crib, and a brief description of the mineral reactions studied at Hanford are presented.–NSA 16-25052.

Descriptors: Radioisotopes, geochemistry, soils, radioactive waste disposal, laboratory tests, sorption, Washington.

0522 **Nelson, R. W.; Haney, W. A.**
1963. Analog simulation of Hanford ground water flow [with French abs.], *in* La retention et la migration des ions radioactifs dans les sols–Colloque international, Saclay, France, 1962: Paris, Presses Universitaires de France, p. 131-138.

Development of an electrical analog of the Hanford [Wash.] ground water flow system is described. It is noted that the independent causations which must be considered in an analysis of ground water flow include hydrodynamic dispersion, exchange reactions, and the macroscopic flow pattern. The last-mentioned causation is considered in some detail.–NAB.

Descriptors: Washington, groundwater movement, hydrodynamics, analog models, radioactive waste disposal, dispersion.

0523 **Nelson, R. W.**
1965. A sequence for predicting waste transport by ground water, *in* American Water Resources Assoc. Mtg., 1st Ann., Chicago, Ill., 1965: Am. Water Resources Assoc. Proc. Ser., no. 1, p. 80-87C.

An analysis sequence is presented to enable rational predictions of contaminant concentrations entering potable waters in the area of study, by ground-water transport. Steps in this analysis involve several types of basic data and computer programs. The three major ones are discussed: in-place permeability measurement, setup and solution of the boundary value problem, and waste-transport analysis.—NAB.

Descriptors: Hydrodynamics, groundwater movement, data processing, waste water (pollution), computer programs, mass transfer.

0669 **Nelson, R. W.**

1962. Mathematical and numerical formulation, pt. 1 *of* Steady Darcian transport of fluids in heterogeneous partially saturated porous media: Richland, Wash., General Electric Co., Hanford Atomic Products Operation [Rept.] HW-72335, 36 p.

The equations describing macroscopically a rather general class of problems on flow in porous media are presented. The expressions extend beyond the classical saturated flow equations to include partially saturated flow in heterogeneous media and the associated reduced forms. The reduced forms include partially saturated flow in homogeneous media, saturated flow in heterogeneous media, and, finally, classical saturated flow in homogeneous soils. In all cases the equations were reduced to nondimensional parameters for optimum computational effectiveness. The assumptions involved in deriving the macroscopic general equations were considered in more detail than is often used. The equations presented are nonlinear and usually are complex if not impossible to solve in closed form. Accordingly, a finite difference formulation was developed preparatory to writing a rather general computer program to solve this class of problems. An iterative solution method of the Gauss-Sidel type is presented for solving the difference equation system. The several boundary condition types to be found in practical flow problems are tabulated for all combinations. An effective coding and abbreviated designation for the boundary types was prepared. The various boundary conditions peculiar to a specific flow problem can be designated rapidly from the mathematical boundary conditions through utilization of these calculation types. The computer program, which utilizes the formulation presented, exceeded the original expectations with respect to usefulness. It is possible to solve numerically steady one-dimensional, two-dimensional and axially symmetrical problems very satisfactorily. Moderate size three-dimensional problems can also be treated within size limitations imposed by the 8000 grid point capacity. Such ability in analyses may contribute appreciably to the solution of waste disposal problems through detailed study and prediction of many practical flow systems which occur in nature.—Author's abstract, NSA 16-34139.

Descriptors: Mathematical studies, porous media, equations, unsaturated flow, saturated flow, computer programs.

0670 **Nelson, R. W.; Reisenauer, A. E.**

1962. Hanford [Wash.] studies on flow in porous media, *in* Morgan, J. M., Jr., Jamison, D. K., Stevenson, J. D., eds., Ground disposal of radioactive wastes conference, 2d, Atomic Energy of Canada Limited and U.S. Atomic Energy Comm. Div. Reactor Devel., Chalk River, Canada, 1961, Proc., Book 1: U.S. Atomic Energy Comm. Div. Tech. Inf. [Rept.] TID-7528, p. 130-144.

Methods are described for use in studies on the behavior of ground water in both homogeneous and heterogeneous soils. Basic equations are presented for use in hydrodynamic descriptions. A computer program is described for use in solving problems of unsaturated flow, saturated flow problems with either heterogeneous or homogeneous soils, and problems involving combined partially saturated and saturated flow. Typical applications are included.—NSA 16-25045.

Descriptors: Porous media, groundwater movement, hydrodynamics, computer programs, equations, saturated flow, unsaturated flow.

443-542 O - 71 - 12

Nelson, R. W. *See* Reisenauer, A. E. 0659.

0582 Nevo, Z.; Mitchell, R.
1967. Factors affecting biological clogging of sand associated with ground-water recharge: Water Research [Great Britain], v. 1, no. 3, p. 231-236.

Clogging of sand beds by microbial polysaccharides during ground-water recharge of waste water appears to be correlated with a decline in measured potential in the sand, which inhibits degradation of the polysaccharides. Growth of paddy rice was found to be an effective alternative to periodic resting as a means of keeping the sand bed oxidized. Adjustment of pH could also be used to prevent polysaccharide accumulation. A correlation between water temperature and clogging was observed. Preliminary evidence that sandy soils might be used for infiltration of waste water is presented.–Authors' abstract, WSP 1990.

Descriptors: Groundwater recharge, microbiology, water temperature, infiltration.

0767 Nicholson, G. B.
1941. Backwash by gas lift increases efficiency of salt water injection: Oil Weekly, v. 104, no. 4, p. 19-21.

The efficiency of salt water injection is increased by the Shell Oil Co. in the Roanoke Field of Coastal Louisiana by installing a tubing string equipped with flow collars to permit backwashing by gas lift. Infiltration is augmented by applying pressure from a nearby gas well into the tubing and flushing water through the casing to the salt water pit, thus carrying accumulated sand and residue from the formation face. The washing action "expurgates" the receiving formation, a shallow salt-water sand, opening the pores and removing materials which deter the movement of input water into the sand. The equipment for carrying out this procedure is illustrated and described in detail.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, Louisiana, injection wells, equipment.

0768 Nicholson, G. B.
1946. Separator pressure used for salt water disposal: Oil Weekly, v. 121, no. 13, p. 36-37.

The Shell Oil Co. uses converted separators as water knockouts to remove the large volumes of salt water from the oil produced at the Gibson and Northeast Gibson fields, Louisiana. These fields produce 21,000 and 25,000 bbl. of salt water daily, most of which is removed by the specially modified knockouts; the oil-water emulsion is then sent to a gun barrel-treating unit where the remainder is removed. The freed water is returned to the formations by input wells. Details of this practically closed system are presented.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, Louisiana, injection wells, waste treatment, piping systems (mechanical).

Niskimaki, Kenzo. *See* Iwai, Shigehisa. 0682.

0300 Nowak, T. J.
1952. The estimation of water-injection profiles from temperature surveys: Am. Inst. Mining Metall. Petroleum Engineers Trans., v. 198, Tech. Paper 3637, p. 203-212.

The heat-flow processes determining the injection and shut-in temperature logs in a water-injection well have been analyzed and the theoretical basis for determining the water-injectivity profiles from the temperature logs has been presented. Both the injection and the subsequent shut-in logs are necessary to resolve the injection interval into relative water-intake strata; the former, to provide an accurate estimation of the thicknesses of the strata, and the latter to indicate the major and minor intake rates into the strata. A procedure is described for estimating the injectivity profile from the temperature logs and is applied to several temperature logs. For a water-injection well, a comparison is made of the injectivity profiles obtained from the core analysis, the spinner survey, and the temperature logs.—Arad, USGS.

Descriptors: Injection wells, methodology, test procedures, temperature, logging (recording), thermodynamics.

0302 **Nutting, P. G.**
1943. The action of some aqueous solutions on clays of the montmorillonite group: U.S. Geol. Survey Prof. Paper 197-F, p. 219-235.

This experimental investigation of the solubility of several types of montmorillonite clay covers the range of acid and alkali concentration from 0 to 4 percent, using two liters of solvent and excess clay. Each solubility-concentration curve changes slope in its central portion (0.2 to 0.6 percent), the variation being characteristic of the type of montmorillonite. Silica dissolved exceeds the saturation limit (about 0.4 gram per liter) over a range of concentration probably due to partial recombination as silicate micellae. Dissolved sesquioxides are partly water insoluble silicates and partly soluble salts. The results are discussed and their interpretation suggested.—Author's abstract.

Descriptors: Montmorillonite, solubility, aqueous solutions, chemical reactions.

0583 **Ogata, Akio.**
1963. Effect of the injection scheme on the spread of tracers in a ground-water reservoir, *in* Short papers in geology and hydrology: U.S. Geol. Survey Prof. Paper 475-B, p. B199-B202.

Commonly, the dispersion of a tracer or contaminant injected into an isotropic granular medium, in which the regional flow is unidirectional, is attributed principally to microscopic velocity variations and ionic diffusion. This is true provided the injection scheme neither disturbs nor alters the preexisting flow regime. The effect on the spread of tracers, caused by injection disturbance, is discussed using two examples. The first example concerns injection from an elliptic source and the second concerns injection from a point source. These examples demonstrate that the spread of tracers caused by these methods of injection may be much larger than the spread due to diffusion.—Author's abstract, WSP 1990.

Descriptors: Injection, dispersion, porous media, tracers, diffusion.

0769 **Oil and Gas Journal.**
1938. East Texas water disposal: Oil and Gas Jour., v. 37, no. 30, p. 50, 52.

Return of the salt water to the Woodbine sand will solve the problem of water disposal and effectively check reservoir pressure decline. Experiments in this direction are being carried out by the Sun Oil Co. in Smith County, Texas. The salt water produced is stored in 2 gun barrels, passes through 2 baffle towers for initial aeration, thence down flumes to the first of 4 large redwood tanks which provide further contact with air. From the receiving tank the water passes through a take-off near the top, through transit pipe to the center of the bottom of No. 2 tank, thence to tank 3,

where it is allowed to settle further. It is finally stored in tank 4, from where it moves downhill to the well site. There it is filtered, metered, and conducted to the well through a 3-inch duroline string extending to the bottom of the cemented liner in the well, which takes the salt water at a vacuum. During the 45-day period of experimentation 70,805 bbls. of salt water were returned to the Woodbine sand. No detrimental effects were noted in the neighboring wells. The arrangement of the water disposal plant is shown in a diagram; the record of a 45-day experimental injection period is reproduced in a graph.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, Texas, injection, waste treatment, equipment, design data, geologic formations.

0770 **Oil and Gas Journal.**
1951. Automatic system at Rio Bravo features salt-water injection: Oil and Gas Jour., v. 50, no. 25, p. 133, 135.

Success in disposing of oil field brine in Rio Bravo field, California, without any pretreatment, is due primarily to two factors: (a) the water is separated from the oil, in a wash tank, as quickly as practicable; (b) the water is never exposed to the atmosphere so that no change in composition and characteristics is possible. The clean water is injected into a nonproducing well, both to prevent contamination of adjacent land and to assist in maintaining flowing pressures on the producing wells. Maximum automatic operation is obtained through electric motor-driven reciprocating pumps controlled by liquid-level instruments.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, California, injection, equipment, methodology.

0771 **Oil and Gas Journal.**
1957. California acts to cut water pollution: Oil and Gas Jour., v. 55, no. 28, p. 66-67.

Oil operators in the San Joaquin Valley, Calif., are faced with the problem of water disposal. The oldest fields offer the biggest problems since they are large water producers. Although the worst potential pollution spots are under control through injection and percolation, some operators find it necessary to change the method of handling the water output or to correct the present disposal methods. Waste water must be returned underground or moved to areas where it can seep into formations already containing brackish water, thus preventing crop destruction. The cost to oil operators in the San Joaquin Valley for water disposal was $3 million in four years, not counting water-flood projects.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, California, injection, pollution abatement, operating costs.

0772 **Oil in Canada.**
1957. Salt water disposal at Midale–Shell lays 92,000 feet of field gathering lines: Oil in Canada, v. 9, no. 51, p. 13-14.

Over 92,000 ft. of four- and six-inch salt water gathering lines serve 89 wells in Shell Oil Co.'s Midale field (Saskatchewan). The water is chemically treated in a skimmer tank and filtered free of solids at central facilities before disposal in 3400-3600 ft. wells. The disposal wells will take about 2500 bbl./day of water under gravity.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, injection, piping systems (mechanical), waste treatment, foreign countries.

0773 **Oil Weekly.**
1940. Salt water disposal system: Oil Weekly, v. 99, no. 11, p. 23, 26.

In a salt water disposal system developed in the Tomball, Texas, field by the Humble Oil & Refg. Co., the salt water is stored, prior to injection, in 2000 bbl. reservoirs 10 ft. deep by 100 ft. in diameter lined with stabilized soil composed of asphalt base oil and native sand, costing $1600 each. The flow to all reservoirs is by gravity from producing wells, as is the injection into the injection wells. Each injection well consists of a 13-inch hole to 1000 ft., in which a string of 9-5/8 inch casing is cemented, and an 8-5/8 inch hole drilled to bottom at about 3800 ft. with a 5-1/2 inch casing cemented through the injection zone. The casing is perforated opposite the disposal sand with about 100 shots and injection is through these perforations. Chemical treatment of water prior to injection is not necessary, although the water is caused to flow through a small concrete pit equipped with baffles and excelsior traps for the removal of oil particles and foreign matter. The combined capacity of two of these wells is about 3000 bbls. daily.—Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, Texas, injection wells, design data, flow rates.

0774 **Oil Weekly.**
1946. Cooperative salt water disposal system serves Erath operators: Oil Weekly, v. 123, no. 6, p. 28-29.

The cooperative salt water disposal plant recently placed in service in the Erath field, La., and operated by the Texas Co. with Phillips Petroleum Co., Humble Oil & Refg. Co. and Tide Water Associated Oil Co., is described. The system now permits riddance of all water produced in the field by means of a single disposal well. Its capacity is about 6000 bbl. of salt water daily.—Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, Louisiana, injection wells, equipment, design, flow rates.

Okun, Daniel Alexander. *See* Fair, Gordon Maskew. 0144.

Olson, E. A. *See* Smith, E. R. 0800.

0304 **Orcutt, R. G.; Rifai, M. N. E.; Klein, Gerhard; Kaufman, W. J.**
1957. Underground movement of radioactive wastes: Sewage and Indus. Wastes, v. 29, no. 7, p. 791-804.

Several theories are presented for describing quantitatively hydraulic dispersion, ion-exchange equilibria, and ion-exchange kinetics as they apply to the movement of radioisotopes through natural porous media. Laboratory studies were conducted with radiostrontium and several natural exchangers to determine the applicability and limitations of these theories. The laboratory results do not conclusively establish that the maximum rate of strontium movement can be readily predicted under all circumstances. However, it is believed that the theories of dispersion and ion exchange, when used in conjunction with field-scale tests, will serve to reduce greatly the uncertainties of ground disposal operations. The salient experimental results are summarized.—Authors' abstract.

Descriptors: Radioisotopes, ion transport, porous media, hydraulics, ion exchange.

0593 **Orcutt, R. G.; Naor, I.; Klein, Gerhard.**
1956. Hydraulic and ion-exchange phenomena in the underground movement of radiostrontium, *in* Seminar on sanitary engineering aspects of the Atomic Energy Industry, U.S. Atomic Energy Comm. and U.S. Public Health Service, [held at] Robert A. Taft Engineering Center, Cincinnati, Ohio, 1955, Proc.: U.S. Atomic Energy Comm. Div. Tech. Inf. [Rept.] TID-7517, pt. 1a, p. 191-211.

The design of underground disposal facilities for radioactive wastes requires a knowledge of the hydrodynamics and chemistry controlling the movement of exchangeable cations through natural porous media. Darcy's law is not entirely adequate for delineating the velocity distribution of various portions of a liquid moving through a porous medium. Ion exchange is shown to greatly increase the storage capacity of geological formations and to retard the rate of movement of radioisotopes through the ground. This paper reviews the physical and chemical factors influencing the rate of travel of radiostrontium and considers the application of certain principles of chemical engineering and soil chemistry to the ground disposal of radioactive wastes.–Authors' abstract.

Descriptors: Radioactive waste disposal, hydrodynamics, geochemistry, ion exchange, hydraulics, strontium radioisotopes.

Orcutt, R. G. *See* Kaufman, W. J. 0229.

0305 **Orlob, G. T.; Radhakrishna, G. N.**
1958. The effects of entrapped gases on the hydraulic characteristics of porous media: Am. Geophys. Union Trans., v. 39, no. 4, p. 648-659.

Investigation of the hydraulic characteristics of prepared porous media indicates that a 10 percent increase in air content of media voids is capable of producing a 15 percent reduction in effective porosity, a 35 percent decrease in permeability, and about 50 percent reduction in hydraulic dispersion. The location of bubbles in large or small pores affects the uniformity of pore sizes and determines the amount of water-saturated void volume which is isolated by air bubbles. The shape of the chloride tracer breakthrough curve is greatly modified by changes in uniformity of pore size. An appreciation of the effects of gas accumulation is essential to a proper interpretation of the hydraulic behavior of natural formations.–Arad, USGS.

Descriptors: Hydrodynamics, aquifer characteristics, air entrainment.

0585 **Orlob, G. T.**
1956. Effect of water reclamation practices on quality of ground water, *in* Conference on California ground-water situation, Proc.: California Univ. Water Resources Center Contr. 2, p. 146-156.

The feasibility of waste-water reclamation by artficial recharge is largely dependent on the economics of source development. Water quality problems, although they may be formidable, particularly in the field of public health, do not appear as serious limitations on the use of either surface spreading or direct injection.–*from* Author's conclusions, WSP 1990.

Descriptors: Reclaimed water, waste water disposal, water reuse, water quality, water spreading, injection.

0586 **Orlob, G. T.**
1957. Assimilative capacity of receiving waters in relation to the pulp and paper industry, *in* Waste treatment and disposal aspects: California State Water Pollution Control Board Pub. 17, p. 73-100.

The author examines the particular wastes of typical pulping processes together with the characteristics of potential receiving waters with a view toward determining the general requirements for disposal of pulpmill wastes. The author discusses the underground disposal of these wastes which involves the artificial comingling of waters of widely variant quality and the resulting problems.—WSP 1990.

Descriptors: Industrial wastes, waste water disposal, mixing, injection, underground, pulp wastes.

Orlob, G. T. *See* Butler, R. G. 0091.

Orlova, E. I. *See* Belitskii, A. S. 0678.

0306 **O'Rourke, E. V.**
1962. The uses of water injection to the subsurface through boreholes, *in* Morgan, J. M., Jr., Jamison, D. K., Stevenson, J. D., eds., Ground disposal of radioactive wastes conference, 2d, Atomic Energy of Canada Limited and U.S. Atomic Energy Comm. Div. Reactor Devel., Chalk River, Canada, 1961, Proc., Book 2: U.S. Atomic Energy Comm. Div. Tech. Inf. [Rept.] TID-7628, p. 374-379.

The use of water injection to the subsurface through boreholes for the disposal of salt water produced by oil wells, and the use of sedimentary rocks for the storage of natural gas, are discussed. The possibility of using old oil and gas fields for the disposal of radioactive wastes is considered.—NSA 16-25060.

Descriptors: Injection wells, brine disposal, underground storage natural gas, radioactive waste disposal.

Owens, E. O. *See* Taylor, S. S. 0393.

0713 **Page, R. D.**
1967. Pollution control for oil field brines: Drill Bit, v. 15, no. 9, p. 32-36.

The increase in production of salt water in the State of Texas has created the necessity of strict control over salt water disposal. Some of the regulations placed on operators by the Texas Railroad Commission are discussed. The seriousness of using unlined pits and the resultant water pollution problems are considered. The most desirable means of disposal is by controlled subsurface injection. The Railroad Commission is promoting underground disposal by approving a larger percentage of secondary recovery projects. A number of recommendations are discussed which are intended to serve as guidelines for effective and economical subsurface fluid injection and disposal.—Tulsa Univ., Inf. Services Dept.

Descriptors: Texas, brine disposal, regulation, injection, water pollution control.

Papadopol, Cornel. *See* Lazarescu, M. 0465.

Papadopulos, Istavros S. *See* Cooper, Hilton H. 0011.

0307 Paradiso, S. J.
1956. Disposal of fine chemical wastes, *in* Industrial Waste Conference, 10th, Lafayette, Ind., 1955, Proc.: Purdue Univ. Eng. Ext. Ser. 89 (Purdue Univ. Eng. Bull., v. 40, no. 1), p. 49-60.

Composite wastes from the production of synthetic cortical steroids at the Upjohn Co. Plant in Kalamazoo, Mich., are being injected into the Traverse and Dundee Formations at depths of 1,300 and 1,400 feet beneath the plant site. Prior to injection, the wastes are treated by adjusting the pH to 5.5 minimum with high calcium lime followed by flocculation, sedimentation and filtration operations. The treated waste is injected by means of plunger pumps at the rate of about 80,000 gallons per day under injection pressures that vary between 500 and 900 psi. The details of well construction and waste treatment and handling equipment are discussed.

Descriptors: Chemical wastes, injection wells, Michigan, waste treatment, construction, deep wells, geologic formations.

0310 Parker, F. L.
1969. Status of radioactive waste disposal in U.S.A.: Am. Soc. Civil Engineers Proc. Paper 6597, Jour. Sanitary Eng. Div., v. 95, no. SA 3, p. 439-464.

The main emphasis in research studies of liquid radioactive management has been: (1) Demonstration of the effectiveness and economic feasibility of conversion to solids of the higher level liquid wastes; (2) conversion to solids in place and in the ground for low and intermediate level waste; and (3) determination of the fate and hazard of the minor quantities of liquid waste discharged to the environment. For gaseous wastes, the emphasis has been on the removal of the various forms of iodine in the off-gas systems and the development of new methods for noble gas removal. For solid waste disposal, better containment has been sought, and private burial operations have been transferred to commercial burial grounds. The management of radioactive wastes has not proven to be a deterrent to a nuclear power economy. The major problems remaining are methods of the removal of noble gases and tritium, development of methods of fuel reprocessing, and understanding of the movements of radionuclides in the environment.—Author's abstract.

Descriptors: Radioactive waste disposal, environmental engineering, injection, feasibility studies, effects, United States.

0672 Parker, F. L.; Blanco, R. E.
1963. Waste treatment and disposal progress report for November-December 1962, and January 1963: U.S. Atomic Energy Comm. Oak Ridge Natl. Lab. [Rept.] ORNL-TM-516, 134 p.

Progress is reported on developments in waste treatment and disposal in terms of: high-level-waste calcination; low-level-waste treatment; engineering, economics, and safety evaluation; disposal in deep wells; disposal in natural salt formations; Clinch River study; fundamental studies of minerals; White Oak Creek Basin study; and foam separation.—NSA 17-26932.

Descriptors: Radioactive waste disposal, waste treatment, engineering, economics, Tennessee.

0686 Parker, F. L.
1965. Radioactive waste disposal, *in* Health Physics Division annual progress report for period ending July 31, 1965: U.S. Atomic Energy Comm. Oak Ridge Natl. Lab. [Rept.] ORNL-3849, p. 1-42.

Studies of sorption and desorption of iodine on mineral surfaces indicate that some species of iodine, probably I_2, can be actively adsorbed onto such surfaces. The sixth radioactive waste injection of a series was started using a mix containing Kingston fly ash as a substitute for some of the portland cement. After approximately 64,000 gal of waste had been injected, a leak developed in the high-pressure piping in the wellhead cell. The injection well was kept open to determine the bleed-back characteristics of the grout. Preparations are nearly complete for the startup of Project Salt Vault, a demonstration of the disposal of high-level waste solids in salt mines. Operation of the prototype test proved the procedures for measurement of salt flow, temperature, etc., in the demonstration. The field and laboratory work of the co-operative study of the Clinch River was terminated. Sorption tests of three soils from the southeastern United States showed that ion exchange capacity was not the controlling factor in radiocesium sorption by these soils. Desorption with sodium acetate revealed a maximum in the time-desorption relationship, particularly in the subsurface horizons. Solution-dispersion coefficients were measured in Berea sandstone as a function of flow rate. The experimental values of the dispersion coefficients varied as the 1.21 power of the solution velocity. Analysis of the critical pathways of radiation exposure to man resulting from the discharge of radioactive materials to the Clinch River has shown that fish and water consumption are most important. The U.S. Geological Survey cooperated in the preparation of a report on the soils and geology of White Oak Creek Basin. The work of the multiagency steering committee for the Clinch River Study has continued.–NSA 20-08479.

Descriptors: Radioactive waste disposal injection, test procedures, research and development, sorption, ion exchange, Tennessee, Kansas.

0837 Parker, F. L.
1966. Radioactive waste disposal, *in* Health Physics Division annual progress report for period ending July 31, 1966: U.S. Atomic Energy Comm. Oak Ridge Natl. Lab. [Rept.] ORNL-4007, p. 1-41.

Continuing studies of the field plots show a reduced rate of loss of ^{137}Cs in the fall and winter months of the second year. There is a logarithmic relationship between ^{137}Cs loss and the soil loss. Mass balance analyses do not provide a satisfactory accounting of the total ^{137}Cs applied to the clipped meadow plot. Studies of the selective adsorption of cobalt by layer lattice silicates show that adsorption is influenced by the method of sample preparation. With identical sample preparation techniques, trioctahedral lattices sorb more cobalt than comparable minerals with dioctahedral lattices. The most probable failure mechanisms limiting the ultimate capacity of the shale formation in the hydraulic-fracturing product are also being studied. The major effort in the disposal of high-level wastes into geologic formations to date has been the field investigations in salt formations. The exploratory drilling program to determine feasibility of storage in impermeable underground caverns was initiated at the Savannah River Plant. Hydrofracturing work at Oak Ridge National Laboratory is proceeding toward the design of a pilot plant facility with actual Oak Ridge wastes. The fraction of nuclear power costs allowable for waste disposal has not been established, and because of the preliminary status of the development program, no realistic cost estimate for these ultimate disposal methods is now available. However, the cost of storing wastes in tanks of present design on a perpetual care basis has been estimated to lie between 0.1 and 0.15 mill/Kw-hr of electricity produced. This cost approximates only 1 to 2% of the cost of nuclear power in an 8 to 10 mill/Kw-hr economy. Cost estimates for ultimate disposal methods fall within this range, and, if engineering development work substantiates these expectations, waste disposal should not constitute a major obstacle to the development of economic nuclear power.–NSA 21-08565.

Descriptors: Radioactive waste disposal, Tennessee, feasibility studies, economics, sorption, South Carolina.

Parker, F. L. *See* Blanco, R. E. 0622.

Parker, F. L. *See* Boegly, W. J., Jr. 0624.

Parker, F. L. *See* Boegly, W. J., Jr. 0625.

Parker, F. L. *See* Schaffer, W. F., Jr. 0698.

Parker, F. L. *See* Struxness, E. G. 0845.

0808 Parker, R. G.
1968. Environmental factors related to deep well fluid injection [Preprint of paper presented to Petroleum Industry Technical Conference, Urbana, Ill., 1968]: Urbana, Illinois Geol. Survey, 23 p.

Deep well injection of fluids may be used for several purposes: (1) to permanently dispose of wastes (chemical, atomic, or solid) that cannot be treated; (2) to add gas or water to a reservoir to increase its energy and ability to drive out valuable mineral substances; (3) to break up the formation adjacent to the well bore so that the fluids may be produced at a higher than natural rate; and (4) in solution mining to wash out valuable mineral substances, or to create storage cavities to store hydrocarbon products during periods of low demand. Each of these processes has been used for many years. When they are properly engineered they can be operated at minimum cost with little danger of contaminating our natural resources. The end result of each is the permanent disposal of untreatable wastes that would otherwise degrade our water resources, the recovery of mineral resources that would not be recoverable, and the conservation of our hydrocarbon resources, thus making them more available at times when needed and at less cost.–Tulsa Univ., Inf. Services Dept.

Descriptors: Injection wells, waste disposal, environmental effects, resource development.

0687 Parsons, P. J.
1962. Migration from a single source of liquid waste deposited in porous media, pt. 4 *of* Movement of radioactive waste through soil: Chalk River, Ont., Atomic Energy of Canada Ltd. [Rept.] CRER-1077, 25 p. [Also available as Rept. AECL-1485.]

A soil survey was carried out in a wooded region surrounding a disused plant where waste liquid fission products were concentrated. During operations in 1954 acid waste containing complexing agents and more than 1000 nominal curies of mixed fission products was poured into a pit excavated in dry sand and lined with limestone. Radionuclides migrated in the groundwater away from the disposal pit and the pattern of this movement was investigated by intensive sampling with a multiple soil sampler. Ru^{106} migrated rapidly soon after the disposal. This was followed by slower moving Sr^{90} that developed into a continuous tongue 650 ft long, containing 800 curies. No other radionuclides were found in the tongue. It is estimated that Sr^{90} will escape into surface waters in about 130 years. However, the rate of release will not cause the concentration in a nearby drainage stream to rise above the maximum permissible concentration for occupation workers.–Author's abstract. NSA 16-18703.

Descriptors: Radioactive wastes, migration patterns, groundwater movement, porous media.

0688 **Parsons, P. J.**
1962. The liquid disposal area, pt. 5 *of* Movement of radioactive waste through soil: Chalk River, Ont., Atomic Energy of Canada Ltd. [Rept.] CRER-1089, 19 p. [Also available as Rept. AECL-1561.]

Two seepage pits, used for the routine disposal of water containing low-level radioactive wastes, were examined by a soil and groundwater survey. Reactor Pit 2 received 1.75×10^8 gallons and absorbed 11000 curies of soluble beta-emitting radionuclides with 90 g Pu. Of these, 87 curies migrated as cations and the weak front of this movement, containing Sr^{90}, Co^{60}, Cs^{137}, and Ce^{144}, is expected to be released into the runoff of a nearby swamp in 4 years. The Chemical Pit, used for the disposal of low-level moderately acid waste accumulated 500°C of total beta and 50 g Pu. It recently released Sr^{90} and Co^{60} into a nearby swamp three months after receiving a disposal containing high concentrations of complexing agents. Soil and groundwater sampling showed that the ion-exchange capacity of the soil was greatly reduced and that the escape of Co^{60} will increase to roughly three times its present value. The escape of Sr^{90} is not expected to increase.–Author's abstract, NSA 16-28634.

Descriptors: Radioactive waste disposal, porous media, liquid wastes, migration.

0775 **Payne, B. W.**
1942. Production and disposal of salt water in the East Texas oil field: Oil Weekly, v. 105, no. 11, p. 21-38,

A detailed discussion of the salt water problem in the East Texas oil field and the attempts to dispose of it by return to the sand is well illustrated with tables, maps and charts showing the amounts of salt water produced and injected over a period of about four years.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, Texas, injection wells, design data.

0776 **Pearce, W. A.**
1944. Water flow chart for designing salt-water-disposal system: Oil Weekly, v. 113, no. 1, p. 16-17.

A chart based on the Hazen-Williams formula is reproduced for use in calculating the loss of head in pipe for disposing of salt water, the pipe varying in size from 2.5 to 12 inches in internal diameter and carrying between 0 and 32,000 bbl. water/day. Although it is based on a "c" factor of 120, the values read from the chart can be corrected to factors from 100 to 140 by multiplication by values given.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, piping systems (mechanical), design data.

Pearsall, S. G. *See* Gemmel, L. 0548.

0314 **Peckham, A. E.**
1961. Underground waste disposal studies–Chemical processing plant area [Idaho], *in* Kaufman, W. J., ed., Ground disposal of radioactive wastes conference, Berkeley, Calif., Aug. 25-27, 1959, Proc.: U.S. Atomic Energy Comm. Div. Tech. Inf. [Rept.] TID-7621, p. 157-166.

Information collected in studies of saline liquid waste movement in the disposal area at NRTS [National Reactor Testing Site] is presented. Data are discussed and it is concluded that the solutions are moving down the regional slope defined by the generalized regional water level contours. Data indicate that the saline water is moving with the normal water in the area in one or more horizons to form a band that widens an unidentified amount down-gradient. Data also indicate straight-line average rates of ground-water movement of 15 to 50 ft per day.—NSA 15-30327.

Descriptors: Radioactive waste disposal, ion transport, hydraulics, dispersion, Idaho.

Peckham, A. E. *See* Clebsch, Alfred, Jr. 0505.

0315 **Pecsock, D. A.**
1954. Disposal of nuclear power reactor wastes by injection into deep wells: U.S. Atomic Energy Comm. Oak Ridge Natl. Lab. [Rept.] CF-54-10-64, 24 p.

Experience in the deep well disposal of various chemical wastes has demonstrated certain inherent advantages of this mode of disposal, namely, the comparative low cost of installation, maintenance, and operation and the elimination of the waste from surface waters. To ensure the feasibility of this disposal method for a particular waste, experience in the chemical industry has indicated that the geological area under question must be properly surveyed and found satisfactory and that the chemical compatibility of the waste and underground media must be aptly demonstrated. One of the inherent disadvantages of the method is the loss of contact with the waste material, and, consequently, the possibility of contamination of some underground strata of value to mankind. As to the feasibility of disposing of nuclear power reactor wastes into deep wells, geographical locations must be sought which provide sufficient physical capacity for containment of the waste and which ensure the prevention of health hazard resulting from migration of radioactive materials from the disposal site. Geological and ground water conditions appear most suitable for such disposal areas in the central states, bound by the Appalachian Mountains on the east and the Great Plains region on the west.—Author's abstract.

Descriptors: Chemical wastes, waste disposal, injection wells, economics, chemical reactions, effects, design criteria.

0821 **Perkins, T. K.; Johnston, O. C.**
1969. A study of immiscible fingering in linear models: Soc. Petroleum Engineers Jour., v. 9, no. 1, p. 39-46.

Recent improvements in processes for recovering viscous reserves has renewed interest in the phenomenon of immiscible fingering. This paper describes studies of immiscible fingering in linear Hele-Shaw and bead-packed models. Immiscible fingers were readily initiated in all models. The fingers, however, were damped out before traveling very far in the uniform bead packs that contained connate water. The damping mechanism is believed due to the movement of the two phases in a direction transverse to the direction of gross flow. To study the transverse flow phenomenon under controlled conditions, oil and water were injected simultaneously and side by side in linear models. Transition zones were formed that grew broader as the distance from the inlet increased. The saturation distribution in the transition zones could be described mathematically by an "immiscible dispersion coefficient" and the well-known error function solution of the dispersion equation. The immiscible dispersion coefficients were found to be proportional to the interstitial velocity and proportional to the product of the bead diameter and packing inhomogeneity factor.—Authors' abstract.

Descriptors: Injection, porous media, model studies, immiscibility, dispersion.

0674 Perona, J. J.; Bradshaw, R. L.; Blomeke, J. O.
1963. Comparative costs for final disposal of radioactive solids in concrete vaults, granite, and salt formations: U.S. Atomic Energy Comm. Oak Ridge Natl. Lab. [Rept.] ORNL-TM-664, 22 p.

Costs were estimated for permanent storage of calcined radioactive wastes in concrete vaults and in rooms mined out of granite formations. In comparison with previously estimated costs for storage in salt mines, costs for concrete vaults were five to seven times as much and for storage in granite about twice as much. This economic advantage, as well as the greater safety it is believed to offer, makes salt the preferred choice. Vaults for storage of calcined solid wastes would be similar in their gross features to many of the tanks built for storage of liquid radioactive wastes, in that they would be underground structures of reinforced concrete with about 10 ft of earth cover and a floor-to-ceiling height of about 15 ft. To make storage in vaults as safe as possible, they were sealed completely from the surface, and space requirements were calculated assuming dissipation of the heat of radioactive decay by conduction through the earth cover. Vaults of two types of concrete were considered: ordinary concrete, capable of withstanding 400 to 500°F. and "high-temperature concrete," capable of 1000°F. Space requirements for storage of calcined wastes in rooms mined out of granite formations are about the same as for storage in salt formations. However, mining costs are higher for granite because heavier equipment is required, drilling is more difficult and slower, and costs of explosives are higher.—Authors' abstract, NSA 17-42417.

Descriptors: Radioactive waste disposal, solid wastes, geologic formations, waste storage, salts, thermal properties.

Perona, J. J. *See* Bradshaw, R. L. 0629.

0316 Peterson, James A.; Loleit, Allen J.; Spencer, Charles W.; Ullrich, Richard A.
1968. Sedimentary history and economic geology of San Juan basin, New Mexico and Colorado, *in* Subsurface disposal in geologic basins—A study of reservoir strata: Am. Assoc. Petroleum Geologists Mem. 10, p. 186-231.

The stratigraphy of the San Juan basin of Colorado and New Mexico is discussed in detail and the properties of the rocks are reviewed for suitability as waste injection reservoirs. The basin contains up to 15,000 ft of sedimentary rocks from Cambrian to Recent. Development of the area as a sedimentary basin apparently took place in Pennsylvanian time; the basin was maintained with changing rates of subsidence and filling through the remainder of geologic time. Dominantly cyclic marine carbonate deposition during the early phases preceded the infilling of the trough with coarse clastics. The early Mesozoic is characterized by fluvial and eolian environments, interrupted periodically by thin marine transgressive deposits of nearshore redbeds, with a final widespread Late Cretaceous marine thick cyclic sequence of gray shale and sandstone, interbedded with coal. Major reserves of petroleum are in Cretaceous and Pennsylvanian rocks, coal in Cretaceous, and uranium in Jurassic and Cretaceous. Much of the San Juan basin is considered potentially suitable for waste disposal, contingent upon such factors as depth, volume of waste, petroleum and mining activities, present and future groundwater needs, and other industrial and cultural considerations. The Chaco slope probably is the most favorable area for waste disposal.—W69-04948.

Descriptors: Colorado, New Mexico, injection wells, waste disposal, geohydrologic units.

0317 **Peterson, S. F.**
1945. Methods of salt-water disposal in oil fields, Illinois oil fields: Am. Water Works Assoc. Jour., v. 37, no. 6, p. 573-576.

General article pointing out benefits of returning salt water to producing formations. Of 126 permits issued since July 1941 for salt-water disposal wells, only 17 were issued for returning to the producing formation. Shallow formations are generally used. The need is pointed out for cooperative organization within an oil field to obtain maximum efficiency of return.—Arad, USGS.

Descriptors: Illinois, geohydrologic units, brine disposal.

0777 **Peterson, S. F.**
1945. Utilization of salt water in Illinois oil fields: Oil and Gas Jour., v. 43, no. 36, p. 69, 71-72.

The disadvantages of ineffective and expensive salt water disposal by individual operators are contrasted with the advantages to be derived from disposal for the entire pool as a unit. Cooperative action should have the following aims: (1) To dispose of salt water into a common source, namely the producing stratum. (2) To utilize salt water as an agent to recover the maximum ultimate yield of oil in the reservoir. Valid objections, i.e., from edge-well operators, should be met and compensated equitably. Successful cases of cooperative action under the Illinois Division of Oil and Gas Conservation are reported.—Tulsa Univ., Inf. Service Dept.

Descriptors: Brine disposal, Illinois, injection wells, coordination.

0714 **Petroleum Engineer.**
1967. Crack down on oil field pollution: Petroleum Engineer, v. 39, no. 7, p. 33-36.

U.S. Federal and local governments and other regulatory agencies have become seriously concerned with water pollution resulting from mishandling of oil field brine. This concern has generated a number of regulations that will control the production and disposition of saline solutions. This article includes some statistics which reveal that nearly 24 million bbl of salt water are produced daily. Of this amount, approximately 72% is reinjected and another 8% is disposed of in a manner acceptable and approved by 8 regulatory agencies. The largest mishandling of salt water is disposal to unlined pits. Sizeable quantities are also disposed into the nation's streams and rivers. A number of states have already passed or are considering passing, regulations that outlaw the use of unlined pits.—Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, oil fields, regulation, injection, water pollution control.

0715 **Petroleum Equipment and Services.**
1967. Salt water disposal and oilfield water conservation: Petroleum Equipment and Services, v. 30, no. 4, p. 22, 24-26, 28.

State authorities—via stringent disposal well rules, open pit bans, and lined reservoir orders—are moving the oil industry to a new era in the conservation of natural resources, and new expenses. In addition to the steps being taken by the Federal Government to control pollution, it was reported in April that more than 700 water measures were being considered by State legislatures of the 44 States then in session. Control of pollution will very soon become a way of life in the U.S. The control and the disposal of wastes will be a major concern of many plants. The imposed rules and regulations vary considerably from State to State, and in impact upon the oil community, usually in proportion to the importance of its oil production and trans-

mission. In the Mid-Continent and Southwest–where oil and water are so intertwined–the new water rules are having the most pronounced effect on the oil man. By far the most favored disposal method is the disposal well technique. Wells or a lease that produces in excess of 300 bbl of salt water monthly normally requires an excessively large evaporative pit to handle the water. A disposal well then usually becomes necessary. Other disposal techniques are being developed which show promise in the whole field of waste water disposal.–Tulsa Univ., Inf. Services Dept.

Descriptors: Waste water disposal, regulation, water pollution control, injection wells, conservation.

0778 Petroleum Equipment and Services.
1966. There's a new 'brine line' for East Texas field disposal: Petroleum Equipment and Services, v. 29, no. 5, p. 8-10.

Since the discovery of the East Texas oil field, the operators have been striving to dispose of the mammoth salt water production as efficiently and economically as possible. The large companies have been returning the salt water to the reservoir which has helped to maintain the rapidly declining pressure. There were many small companies who were unable to undertake a project of this magnitude. A group of farsighted operators formed a corporation that is now called the East Texas Salt Water Disposal Co. This company operates similar to a utilities firm and provides the specific service of disposal of salt water to the East Texas operators. The salt water is collected from the various leases through a complex series of pipelines that terminate at a central collecting system. Scale deposits have been a serious problem in recent years. In most instances, the removal of this scale has been costly and results in permanent damage to the pipelines. To solve this problem trial strings of epoxy lined asbestos-cement pipe have been installed into the 400-mile system.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, Texas, pipelines, scaling.

0779 Petroleum Equipment and Services.
1967. Fiberglass reinforced epoxy tubing rising in downhole use: Petroleum Equipment and Services, v. 30, no. 1, p. 20-21.

A new oil country tubing made of fiberglass reinforced epoxy has been developed. The new tubing is being used in water injection wells, salt water disposal wells, water supply wells, and multiple completions. The new product is fiberglass reinforced epoxy tubing. This recently developed plastic pipe is a nonconductor of electricity and thus not subject to electrolysis. It is a low conductor of heat. Its linear expansion characteristics are impressive. It has excellent abrasion resistance to the extent that (according to one manufacturer) sucker rods may be run in it. Its low friction loss and high impact strength are also to its advantage. Reinforced plastic pipe is offered in most popular tubing sizes and is fitted with integral joints or threaded and coupled joints with API threads. This tubing can be used with conventional slips and elevators and with normal wellhead equipment.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, pipelines, equipment, plastic pipes, well casings.

0780 Petroleum Weekly.
1961. Unique triple completion made: Petroleum Weekly, v. 12, no. 18, p. 30.

Amerada Petroleum Corp.'s unique salt-water disposal-oil-oil triple completion in the Justis pool, Lea Co., N. Mex., is described and illustrated. This is believed to be the first triple completion of its kind, because it incorporates a salt water disposal zone

into a formation above the two oil pays. Salt water disposal is through perforations at 4,070-90 ft and 4,145-65 ft, with 3-1/2 in. tubing, plastic coated internally, set at 4,241 ft. Oil production is through 2-7/8 in. tubing oil strings, one set at 5,341 ft, the other at 5,318 ft. The three tubing strings are cased from 1,805 ft to the top of the open hole at 5,318 ft. The oil producing strings are externally plastic coated above the salt water injection points.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, New Mexico, injection wells, design data.

0587 **Pickett, Arthur.**
1957. Industrial wastes and their relation to the re-use of water, *in* Industrial uses of water in California: California Univ. Water Resources Center Contr. 3, p. 31-36.

Artificial recharge of pretreated connate water, derived from oil-field production, is accomplished through injection wells and replaced in the oil sands from which it came. These wells are injecting more than 5,600,000 gpd under a casing head pressure in some wells of more than 2,000 psi. In some oil fields, controlled injection is being used to increase total production of oil-producing zones by 50 percent or more.–WSP 1990.

Descriptors: Water reuse, industrial wastes, artificial recharge, connate water, injection, California.

0319 **Pickett, G. R.**
1968. Properties of the Rocky Mountain Arsenal disposal reservoir and their relation to Derby earthquakes, *in* Geophysical and geological studies of the relationships between the Denver earthquakes and the Rocky Mountain Arsenal well, Pt. A: Colorado School Mines Quart., v. 63, no. 1, p. 73-100.

Injection pressure and volume data of the Rocky Mountain Arsenal disposal well were studied to learn the physical properties of the reservoir and to correlate reservoir properties with the earthquake history of the area. The Rocky Mountain disposal reservoir contains a total fluid volume between 0.6 and 1.9 X 10 billion barrels. The total reservoir consists of several parts which have significantly different fluid permeabilities. The reservoir pressure before start of injection in 1962 was between 300 and 1400 psi subhydrostatic. After cessation of injection in 1966, the different parts of the reservoir were at different pressures, the most permeable part having the highest pressure (about 100 psi subhydrostatic). An empirical correlation exists for the injection history of the Arsenal well between cumulative number of earthquakes and calculated static reservoir pressure. A means for predicting the total number of earthquakes to be anticipated before the reservoir comes to pressure equilibrium is suggested. Empirical comparison of injection energy with earthquake magnitude shows that if injection energy is returned as earthquake energy, it is stored for significant lengths of time before release. If it is assumed that all injection energy has now been returned as earthquake energy, then the total energy magnitude is consistent with energy-earthquake magnitude relations proposed by Richter.–W69-07411.

Descriptors: Earthquakes, injection wells, waste disposal, Colorado, fractures (geology).

0781 **Pierce, R. L.**
1969. Reducing land subsidence in the Wilmington oil field by the use of saline waters [abs.]: Am. Geophys. Union Trans., v. 50, no. 4, p. 152.

The subsidence at Long Beach attributed to the Wilmington oil field development encompassed an area of 22 sq miles where subsidence ranged from 2 ft to 30 ft. Fifteen years of experience in injecting saline water into the oil producing zones has developed a technology in waterflooding that has successfully stopped the Long Beach Harbor area subsidence and has made an economic project out of disaster by increasing oil recovery. Historically, brines resulting from oil production were disposed of into the harbor waters, where oil and fines, and a deficiency of oxygen in the water, were harmful to fish life. Over 2.1 billion bbl of saline water have been injected into the oil field through Dec. 1968. The bulk of this was seawater produced from source wells open to sands 200 to 400 ft deep. The current injection rate of the field is 1.1 million bbl (46 million gal) per day. The expanded use of the oil field brine for injection is apparent, however, in that 550,000 bbl of this brine will have replaced seawater during 1969. The methods used to clean the brine include: (1) filtration, (2) blending with fresh or other saline waters, and (3) re-cycling through the shallow aquifers.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, California, injection wells, subsidence, pollution abatement, waste water treatment.

0321 **Pierce, W. G.; Rich, E. I.**
1962. Summary of rock salt deposits in the United States as possible storage sites for radioactive waste materials: U.S. Geol. Survey Bull. 1148, 91 p.

Cavities in salt beds offer an attractive means of disposal of radioactive wastes. For reference purposes, information on the geology of salt and the distribution, thickness, and depth below the surface of all the known rock salt deposits of the U.S. are assembled. Salt reserves and production, and the development of underground cavities for storing liquefied petroleum gas are discussed briefly.–NAB.

Descriptors: Salts, excavation, radioactive waste disposal, United States, sites.

0689 **Pilgrim, D. H.; Watson, K. K.**
1965. The application of radioisotope techniques to water engineering investigations: Australian Inst. Eng. Jour., v. 37, no. 7/8, p. 175-184.

The value of radioisotope techniques in water engineering investigations in the hydrologic and hydraulic fields is discussed and reference made to the nature of radioisotopes, detecting equipment, and radionuclear methods. Four areas of application of the techniques (surface water, ground water, soil moisture, and sediment and littoral deposit transport) are reviewed with particular reference to recent overseas and Australian work. A number of miscellaneous applications are considered.–Authors' abstract, NSA 20-00548.

Descriptors: Radioisotopes, radioactivity techniques, investigations, foreign countries.

Pimenov, M. K. *See* Spitsyn, V. I. 0383.

Pimenov, M. K. *See* Yudin, F. P. 0450.

Pimenov, M. K. *See* Zakharov, S. I. 0848.

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0468 **Piper, A. M.**
1969. Disposal of liquid wastes by injection underground–Neither myth nor millenium: U.S. Geol. Survey Circ. 631, 15 p.

Injecting liquid wastes deep underground is an attractive but not necessarily practical means for disposing of them. For decades, large volumes of unwanted oil-field brine have been injected. Currently the injection rate is about 10,000 acre-feet yearly, and the rate is increasing rapidly with time. Effects of deep injection are complex and not all are understood clearly, but in a responsible society, injection cannot be allowed to put wastes out of mind. Injection is no more than storage in underground space of which little is attainable in some areas and which is exhaustible in most areas. Liquid wastes range widely in character and concentration–some are incompatible one with another or with materials of the prospective injection zone; some which are reactive or chemically unstable would require pretreatment or could not be injected. Standards by which to categorize the wastes are urgently desirable. Few, if any, State agencies currently have the staff skills, centralized authority, and financial resources to regulate deep injection. Therefore, some new institutional arrangement with hierarchal structure appears to be essential to assure a unified policy nationwide.–*from* Author's abstract.

Descriptors: Liquid wastes, injection, underground storage, legal aspects, regulation.

0478 **Piper, A. M.; Garrett, A. A.; and others.**
1953. Native and contaminated ground water in the Long Beach–Santa Ana area, California: U.S. Geol. Survey Water-Supply Paper 1136, 320 p.

This report examines the chemical aspects of salt-water contamination along and near the Long Beach–Santa Ana coastline. It describes (1) the chemical character of the ground waters native to the area, both those widely utilized and those of inferior quality; (2) the chemical features of the potential sources of salt-water contamination (the ocean, native bodies of saline connate water, works for the disposal of waste fluids from the several oil fields, and the reaches of streams that carry fluid industrial wastes); (3) the lateral extent of present salt-water contamination in each of the several water-bearing zones of the area; and (4) the tendency, if any, for depreciation in water quality to become more intense or more widespread. Many of the contaminated waters have been profoundly modified in chemical character after admixture of the contaminant, especially by base-exchange substitution of calcium and magnesium for sodium. Thus, the slightly contaminated or moderately contaminated waters commonly contain calcium and chloride as their dominant constituents; from their ordinary constituents it is usually impossible to discriminate between contamination by ocean water and that by oil-field brine or connate water. Determinations of iodide or borate are seldom reported, and thus only to a limited extent aid in discriminating the source of contamination. It is suggested that these two minor constituents, together with barium, be determined in future analyses of contaminated waters. Areas in which the fresh ground water has been contaminated are described in detail–the Santa Ana Gap, Huntington Beach Mesa, in and near the Alamitos Gap, and the northeast part of the Newport Mesa, all in Orange County; also, the Dominguez Gap, a part of the Torrance Plain, and the southwest flank of Signal Hill, all in Los Angeles County.–*from* Authors' introduction and abstract.

Descriptors: California, chemical reactions, saline water intrusion, chemical analysis, water pollution effects.

0323 **Plummer, F. B.; Merkt, E. E., Jr.; Power, H. H.; and others.**
1944. Effect of certain microorganisms on the injection of water into sand: Petroleum Technology, v. 7, no. 1, 13 p.

Some of the common microorganisms that occur in waters obtained from tanks in the Luling and East Texas oil fields are described. The effect of the organisms on the chemical content of the waters is discussed. The bioproducts and precipitates resulting from the growth of bacteria and algae are described. Experiments show the effect of these organisms and their precipitates on the permeability of oil sands into which contaminated water is introduced. The experiments and discussion are designed with special reference to water-flooding and water-disposal problems in oil fields.

Descriptors: Brine disposal, water quality, microorganisms, injection wells, permeability, effects.

0782 **Plummer, F. B.**
1945. Methods of testing salt water for injection into oil sands: Oil and Gas Jour., v. 44, no. 16, p. 145-146.

A rapid electrometric method for determining soluble iron in salt water for injection into oil sands is described. Also described is the use of the electrophotometer for measuring color intensity, from which iron content and turbidity of the water can be quickly determined.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, injection wells, equipment, chemical analysis, instrumentation.

0783 **Plummer, F. B.**
1945. Calcium carbonate precipitates in water-disposal systems: Oil and Gas Jour., v. 44, no. 17, p. 83-84.

Methods of removing calcium carbonate precipitates from water-disposal systems have been suggested as follows: (1) Adopting the closed system of salt-water disposal. (2) Adding about 3 p.p.m. of sodium hexametaphosphate to the water. (3) Adopting heat treatment and large efficient aeration towers. (4) Practically disregarding the presence of calcium and its cement properties, but using injections of hydrochloric acid into the subsurface areas of the injection wells.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, injection wells, waste water treatment, descaling.

Pohl, Herbert A. *See* Clark, Joseph R. 0098.

0324 **Pollard, P.**
1959. Evaluation of acid treatments from pressure build-up analysis: Am. Inst. Mining Metall. Petroleum Engineers Trans., v. 216, Tech. Paper 8053, p. 38-43.

A method has been developed for evaluating acid treatments in fractured limestone fields by breaking down pressure drawdown into three component parts: (1) pressure differential across "skin" near the borehole face, (2) pressure differential due to flow resistance in the coarse communicating fissures and (3) pressure differential between the fine voids and the coarse fissures. It is apparent that in most successful acid treatments the first term, skin resistance, has been reduced or eliminated. Further, it is often possible to estimate the volume of coarse fissures associated with the second term, coarse fissure flow resistance. In cases where this volume is comparable with practical acid volumes it seems likely that this resistance also may be attacked with a suitably retarded acid.–Author's abstract.

Descriptors: Methodology, fractures (geology), limestones, acids, treatment, testing.

Power, H. H. *See* Plummer, F. B. 0323.

0327 Powers, T. J.; Querio, C. W.
1961. Check on deep-well disposal for specially troublesome wastes: Power, v. 105, no. 8, p. 94-95.

Since the early 1930's it has been common practice to dispose of oil-field brines by pumping them into deep wells and allowing them to diffuse into deep-seated rock formations. However, this technique is not widely used elsewhere in industry. Nonetheless, it is worth studying where concentrated, toxic, or odorous wastes (radioactive wastes, ammonia-still liquor, and brine) are produced in an area of limited stream flows or strict regulation. As today's advancing process industries must cope with more and more liquid wastes of this type, the use of deep wells for water disposal will surely become more widespread. The basic factors that must be considered are superficially discussed.

Descriptors: Waste disposal, industrial wastes, injection, deep wells, geologic formations, underground storage.

Powers, T. J. *See* Querio, C. W. 0333.

0525 Price, Don.
1967. Rate and extent of migration of a "one-shot" contaminant in an alluvial aquifer in Keizer, Oregon, *in* Geological Survey Research 1967, Chapter B: U.S. Geol. Survey Prof. Paper 575-B, p. B217-B220.

Late in 1946, ground water in a shallow aquifer tapped by numerous domestic wells in Keizer, Oreg., was contaminated by industrial waste dumped into a borrow pit at an experimental aluminum-reduction plant. The concentration of sulfate (the principal constituent of the contaminant) at one time exceeded 1,000 parts per million locally. Samples of water from selected wells in the contaminated area were collected periodically and were analyzed for hardness, which was used as the principal indicator of contamination. At times the samples were analyzed for other constituents also. The contaminant, while becoming naturally diluted in the immediate vicinity of the borrow pit, spread into the aquifer downgradient for a distance of a little more than a mile during the period 1947-64.—Author's abstract, NAB.

Descriptors: Oregon, hydrogeology, groundwater movement, migration, water pollution.

Privrasky, Norman C. *See* McCann, Thomas P. 0265.

0328 Proctor, J. F.; Marine, I. W.
1965. Geologic, hydrologic, and safety considerations in the storage of radioactive wastes in a vault excavated in crystalline rock: Nuclear Sci. Eng., v. 22, no. 3, p. 350-365.

A recent investigation established the technical feasibility and indicated the high degree of safety that could be afforded by the storage of high-level radioactive wastes in unlined vaults excavated in crystalline rock 1500 ft beneath the surface of the Savannah River Plant near Aiken, S.C. The crystalline rock at the proposed site is covered by 1000 ft of unconsolidated sediments consisting predominantly of sand and clay. A virtually impermeable layer of clay separates the rock from the overlying sediments in which several prolific water-bearing zones occur. The separation of the

waters above and below this clay layer is confirmed by their different chemical composition and by the presence of dissolved helium-bearing gas only in the water in the rocks beneath the clay. Based on geologic and hydrologic information obtained in an intensive drilling and testing program, upper limits on the rates of water movement through the crystalline rock are calculated to be 1.5 to 7 ft/year, depending upon the degree of fracturing of the rock. Comparable data on the unconsolidated sediments lead to a calculated maximum rate of water movement of 350 ft/year. The most significant driving force for the migration of radionuclides from the storage site is derived from the natural water movement, coupled with effects due to dispersion and ion exchange. Characteristics of the waste, heat generation, and radiolysis have, by contrast, only small effects on migration. Three barriers prevent migration of the radionuclides: the very low permeability of the rock in which the storage vault is located, the virtually impermeable clay layer separating the rock and sediments, and the ion exchange properties of the sediments. Any one of these barriers is capable of confining the radionuclides well within the plant boundaries for a time much greater than the 600-year period required to render the wastes innocuous.–Authors' abstract, NSA 19-33681.

Descriptors: Radioactive wastes, South Carolina, waste storage, crystalline rocks, test procedures.

Proctor, J. F. *See* Webster, D. S. 0455.

0675 Prout, W. E.

1962. Studies of the containment of radioactive wastes in underground mined caverns at the Savannah River Plant, *in* Morgan, J. M., Jr., Jamison, D. K., Stevenson, J. D., eds., Ground disposal of radioactive wastes conference, 2d, Atomic Energy of Canada Limited and U.S. Atomic Energy Comm. Div. Reactor Devel., Chalk River, Canada, 1961, Proc., Book 2: U.S. Atomic Energy Comm. Div. Tech. Inf. [Rept.] TID-7628, p. 380-395.

The du Pont Company is coordinating an exploratory drilling program to determine the feasibility of mining caverns for the storage of radioactive wastes in the basement rock underlying the Savannah River Plant. Other groups participating in the study include the U.S. Corps of Engineers and the U.S. Geological Survey. The results obtained from tests made in conjunction with the first deep rock boring reinforce the initial indication that the geology of the basement rock is favorable for storage of radioactive wastes. From the results of the chemical and physical tests of the rock core, and from packer tests made in the boring, the quality of the 500-foot section of rock below about 400 feet is favorable for waste storage. The physical tests, such as unconfined compressive strength, show that the rock is adequate to preclude any unusual design restrictions on the size and shape of storage caverns. The less-than-average unconfined compressive strength values (below 16,000 psi) of some of the core samples do not necessarily affect the design and stability of underground openings.–Author's abstract, NSA 16-25061.

Descriptors: Radioactive waste disposal, solid wastes underground storage, mining, feasibility studies, granites, South Carolina.

0330 Prusick, H.

1960. Chemical treatment of injection wells, *in* Forty-second Texas water works short school, Proc.: College Station, Tex., Texas Water and Sewage Works Assoc., p. 165-174.

The purpose of water treatment before subsurface disposal is to eliminate dangers of plugging input wells and to prevent corrosion, which also might cause plugging. Proper

treatment should be devised for each individual case on a basis of water analysis, bacteriological evaluation, reservoir rock characteristics, and character of the formation fluids. Laboratory flooding tests should be made on core samples. Products consisting of a combination of nonionic chemicals, cationic chemicals, and citric acid show promise of being useful in treatment of injection water. The chemical agents are used for (1) controlling the degree of clay rehydration after acid pretreatment by the use of the absorptive and exchange capacity of the large organic cationic molecule; (2) sequestration of dissolved iron to avoid physical plugging, and maintenance of lower pH; and (3) improvement to water injection efficiency by increasing the input rate.

Descriptors: Injection wells, waste water disposal, water treatment, operation and maintenance.

Pryor, M. F. *See* Wilhelm, C. J. 0816.

0076 **Purdue University.**
1968. Industrial waste conference, 22d, Lafayette, Ind., May 2-4, 1967, Proc.: Purdue Univ. Eng. Ext. Ser. 129 (Purdue Univ. Eng. Bull., v. 52, no. 3), pt. 1, p. 1-552; pt. 2, p. 553-1122.

The 22nd annual Industrial Waste Conference, Purdue University, 1967, discussed means of treating industrial wastes, industrial reuse of municipal and industrial waste water, and water pollution treatment in streams. Recovery of materials from wastes and identification of waste materials were also discussed. Contains 85 papers.—W69-06821.

Descriptors: Industrial wastes, water reuse, waste identification, reaeration, waste disposal, injection wells, waste treatment.

0077 **Purdue University.**
1969. Industrial waste conference, 23d, Lafayette, Ind., May 7-9, 1968, Proc.: Purdue Univ. Eng. Ext. Ser. 132 (Purdue Univ. Eng. Bull., v. 53, no. 2), pt. 1, p. 1-618; pt. 2, p. 619-1255.

The 23rd annual Industrial Waste Conference, Purdue University, 1968, discussed means of treating industrial waste, industrial reuse of municipal waste water, and water pollution treatment in streams. Recovery of materials from wastes and identification of waste materials were also discussed.—W69-07110.

Descriptors: Industrial wastes, waste treatment, waste identification, reaeration, waste disposal, injection wells, water reuse.

0526 **Purtymun, William D.; Johnson, George L.; John, Edward C.**
1966. Distribution of radioactivity in the alluvium of a disposal area at Los Alamos, New Mexico, *in* Geological Survey Research 1966, Chapter D.: U.S. Geol. Survey Prof. Paper 550-D, p. D250-D252.

Fine particles in alluvial material in a disposal area for liquid radioactive wastes at Los Alamos have greater affinity for radionuclides than coarse particles. However, most of the radioactivity is in the coarse material, which is more abundant. The radioactivity in the alluvium is dispersed by waste water and storm runoff and decreases with distance from the point of effluent outfall. Most of the radionuclides are retained in

the upper 3 feet of the deposits, resulting in very little change in the quality of the ground water perched in the alluvium.–Authors' abstract, NAB.

Descriptors: New Mexico, radioactive waste disposal, hydrogeology, water pollution, alluvium.

0333 **Querio, C. W.; Powers, T. J.**
1962. Deepwell disposal of industrial wastewater: Water Pollution Control Federation Jour., v. 34, no. 2, p. 136-144.

Subsurface disposal may provide the only method of disposal where toxic or odoriferous wastes are involved. Where wastes are concentrated and have high specific gravities it may be the most economical method. The method should be considered and evaluated early in wastes treatment planning along with other treatment methods. It must be pointed out that the method has limitations and responsibilities. The limitations can be evaluated through detailed study and reservoir testing. Because it is of vital concern in protecting sources of water, surface and subsurface, these responsibilities must be accepted.–Authors' summary.

Descriptors: Waste water disposal, injection, industrial wastes, evaluation.

Querio, C. W. *See* Powers, T. J. 0327.

Radhakrishna, G. N. *See* Orlob, G. T. 0305.

0334 **Rady, J. J.**
1940. Treatment and disposal of oil field brines: Oil and Gas Jour., v. 38, no. 44, p. 48-49, 51.

Evaporation, diversion into surface streams, and return to subsurface formations are general methods of disposing of oil field brines. The first method is too slow to be effective; the second requires adequate storage facilities and careful control of brine discharge for satisfactory operation. The third method requires careful conditioning of the brine, either by the closed system, which allows for complete removal of suspended matter, but permits the retention of other components in permanent solution with the brine, or by the open-type system wherein all suspended matter as well as all components that might become suspended are removed before subsurface injection of the brine. Disadvantages of the closed-type system are high operating costs and expensive chemicals. The open-type system is operated in five steps: separation of oil from brine, aeration for removal of carbon dioxide and hydrogen sulfide, if present; stabilization of carbonate components by intimate contact of the brines with calcium carbonate sludge; reduction of the dissolved oxygen in the brine; and filtration of suspended matter. The equipment used in this process is discussed briefly.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, oil fields, pre-treatment (water), injection, chemical engineering.

Raifsnider, P. J. *See* Dunlop, A. K. 0726.

Raleigh, C. B. *See* Healy, J. H. 0022.

0198 **Ramdohr, H.**
1965. Untersuchaungen zur standortwahl einer versuchskaverne zur einlagerung radioaktiver rueckstaende [Siting investigations for a prototype cavity for radioactive waste storage]: U.S. Atomic Energy Comm. [Rept.] BMwF-FBK-65-06, 40 p. [In German with English abs.]

Saline formations in the subsoil of the Federal Republic of Germany offer many possibilities for ultimate storage of radioactive wastes. These types of rock, especially the pure halite-rock, are practically impermeable, have a good thermal conductivity and permit the excavation of large underground rooms at low cost. The storage of radioactive residues is possible either in accessible excavations (as in mines) or in inaccessible rooms (as in storage caverns), which are formed by the solution method. Caverns can be washed out especially in the salt domes of Northern Germany, because these deposits show all necessary criteria (purity, thickness, depth, disposal possibilities for brine). Seven salt domes are investigated and compared both geologically and topographically. It is shown that the deposits of Bunde, Lesum and Harsefeld are good, the deposits Heide and Geesthacht to a limited extent and the deposits of Krummendeich and Leutesheim are not suited for the installation of a disposal cavern.—Author's abstract, NSA-21-22113.

Descriptors: Radioactive waste disposal, foreign countries, underground storage, salts, rock excavation, geologic formations.

Ramdohr, H. *See* Krause, H. 0831.

Ramdohr, H. *See* Krause, H. 0832.

0784 **Ramey, B. J.**
1968. Deep-down waste disposal: Mech. Eng., v. 90, no. 8, p. 28-31.

Deep-well injection—the disposal of large volumes of liquid waste underground—is gaining acceptance among chemical and petrochemical processors because it has proved over the years to be safe and economically sound. A recent report notes that, as of the end of 1966, 78 industrial injection disposal wells were in operation; of this number 67 were being operated by chemical and petrochemical processors. Current forecasts predict that the number of injection disposal wells will triple in the next 3 years. For a deep-injection disposal system certain conditions are critical. Principal among these is a subsurface disposal horizon that meets the following requirements: (1) It must be porous, permeable, and of sufficient areal extent to act as a liquid storage reservoir at safe injection pressures for an indefinite period of time; (2) it must be sealed above and below by horizons impermeable to the waste effluent to prevent migration and contamination of potable ground waters and other natural resources; and (3) interstitial formation fluids must be compatible with waste effluent.—Tulsa Univ., Inf. Services Dept.

Descriptors: Waste water disposal, injection wells, design criteria.

0838 **Rancon, D.**
1967. Mecanisme de la contamination radioactive des roches consolidees impermeables ou tres peu permeables (SM-93/14) [Mechanism of radioactive contamination in consolidated impermeable rocks or rocks of very low permeability], *in* Disposal of radioactive wastes into the ground—International Atomic Energy Agency and European Nuclear Energy Agency, Vienna, 1967, Symposium Proc.: Vienna, Internat. Atomic Energy Agency (STI/PUB/156), p. 179-197. [In French with English abs.]

The geochemical studies of radioactive contamination carried out so far have been mainly concerned with granular rocks (clay and soil) in which, owing to the infiltration of water, the radioisotopes are retained by micrograins or microcrystals of clay. But a circulation of radioactive effluents can also affect consolidated rocks which are impermeable or of very low permeability. The retention phenomena are then different, since they occur mainly on the surface. In order to determine the capacity of a body to retain a given radioisotope, use is made of the distribution coefficient or Kd. This value, which is characteristic of a granular rock for a given radioisotope, is not characteristic of a consolidated rock. We have, however, devised a law expressing the variation of this Kd measured as a function of the thickness of penetration (e) of the liquid and of the dimension of the rock, which was experimentally verified by measuring the Kd as a function of the diameter x of the grains in the rock. Similarly it has been found that this measured Kd increases linearly with the specific surface of the rock. Thus, the Kd does not represent a physico-chemical characteristic when applied to rocks of very low permeability, since it is dependent upon grain size and the specific surface. Accordingly, an alternative concept has been defined for uptake by rocks of this nature, i.e. the surface distribution coefficient, or Kd (S). Experience has shown that this value of Kd (S) was constant and characteristic of a rock and a radioisotope for a specific contact time. The author describes the methods used to ascertain the retention stability of the radioisotope on the rock and the kinetic study of its diffusion.–Author's abstract.

Descriptors: Radioactive waste disposal, geochemistry, radioisotopes, sorption, hydrogeology, rock properties.

0690 **Rawson, Donald E.**
1966. Industrial applications of contained nuclear explosions: Livermore, California Univ., Lawrence Radiation Lab. [Rept.] UCRL-14756, 59 p. [Available from CFSTI.]

The phenomena and technology of contained (nonexcavation) nuclear explosions as they relate to potential industrial uses are summarized. The results of nuclear explosions of a given yield, at a given depth, and in a known geologic setting are understood sufficiently that further explosions can be conducted safely and, within limits, the characteristics of the resulting environment can be predicted. The features of contained nuclear explosions that should be of most interest to industry are (1) the creation of a large void underground in the form of a cavity generated by the explosion. This void becomes distributed between rubble fragments when the roof of the unstable cavity collapses; (2) the creation of a large amount of fragmented rock distributed within a chimney that develops as a result of the collapse of the roof of the cavity; (3) the fracturing of rock surrounding the cavity-chimney region and associated increased permeability in most rock types. To illustrate the magnitudes of these effects, a 100-kiloton explosion at a depth of 900 meters (3000 feet) will produce a cavity with radius of about 45 meters (148 feet) or a void volume of 1.23 million cubic meters (43.5 million cubic feet). Cavity roof collapse will extend about 194 meters (635 feet) above the explosion center and will contain 1.61 million tons of rubble. About ten times this tonnage may be cracked and become more permeable. The environment resulting from a contained nuclear explosion has applications leading to the recovery of oil, natural gas, minerals, water, and geothermal energy; to the underground storage of oil, natural gas, water, and compressed air; and to the disposal of fluid waste.–Author's abstract, NSA 20-43463.

Descriptors: Nuclear explosions, underground storage, waste disposal.

0598 **Raymond, J. R.; Bierschenk, W. H.**
1957. Hydrologic investigations at Hanford [Washington]: Am. Geophys. Union Trans., v. 38, no. 5, p. 724-729.

During the twelve-year history of the Hanford Plant, several hundred wells were drilled throughout the area in order to obtain hydrologic, geologic, and radiologic monitoring data. Hydrologic data obtained throughout the Hanford site show that due to discharge to ground of about 28 billion gallons of nonradioactive process cooling water, the water table has locally been raised approximately 80 feet and that 20 miles southeast of the disposal sites it has been raised 0.5 foot. Pumping-test data indicate that locally the underlying aquifers may transmit as little as 30,000 gpd/ft and as much as 3,000,000 gpd/ft. Such hydrologic and hydraulic data are used to assist evaluation of safe radioactive waste disposal practices and to estimate effects of large volume nonradioactive process cooling water disposal.—Authors' abstract.

Descriptors: Washington, data collections, aquifer characteristics, flow rates, hydrogeology, subsurface investigations, radioactive waste disposal.

0691 **Raymond, J. R.; McGhan, V. L.**
1964. Scintillation probe results on 200 area waste disposal site monitoring wells: Richland, Wash., General Electric Company, Hanford Atomic Products Operation [Rept.] HW-84577, 62 p. [Available from CFSTI.]

Scintillation well probes were used to monitor the subsoil contamination below radioactive liquid waste ground disposal facilities. Results are discussed for the 200-East and 200-West facilities. The results indicate that significant lateral spread of wastes occurs in the sediments beneath the 200 areas, and that the downward migration rates of gross gamma emitters is relatively slow.—NSA 19-25773.

Descriptors: Radioactive wastes, monitoring, Washington, water pollution, radioactive well logging.

0692 **Raymond, J. R.; Tillson, D. D.**
1968. Evaluation of a thick basalt sequence in south-central Washington—Geophysical and hydrological exploration of the Rattlesnake Hills deep stratigraphic test well: Richland, Wash., Battelle Memorial Inst. Pacific Northwest Lab. [Rept.] BNWL-776, 127 p. [Available from CFSTI.]

The Rattlesnake Hills 10,655-foot deep stratigraphic test well located in south-central Washington State was re-entered, cleaned-out, and drilling fluid conditioned for in-hole geophysical examination and drill-stem testing. The objectives of the work were to evaluate the practicability of deep, subsurface disposal of radioactive wastes and to determine the physical properties of a portion of the Columbia River Basalt sequence that is not exposed for examination at other locations. Fossil dust assemblages recovered from coal cuttings between 2100 and 4800 feet offer evidence to support regional time-stratigraphic correlations proposed on the basis of chemical variations found. All the pollen evidence suggests a late Oligocene to early Miocene age (about 30 million years) which is generally considered as the beginning of the Columbia River Basalt. It was concluded that waste disposal by cavern or tunnel methods might be possible in some of the relatively unfractured basalt flows. Typical upper and mid-depth zones potentially suitable for such disposal occur at 1520, 2140, 2720, and 3200 feet below ground surface at the well site.—NSA 22-35920.

Descriptors: Washington, deep-well pumping, radioactive waste disposal, electrical well logging, basalts, rock properties, geologic formations.

Raymond, J. R. *See* Brown, D. J. 0495.

Raymond, J. R. *See* Brown, D. J. 0630.

Raymond, J. R. *See* Brown, R. E. 0497.

Raymond, J. R. *See* Brown, R. E. 0631.

0479 **Reck, C. W.; Simmons, E. J.**
1952. Water resources of the Buffalo-Niagara Falls region: U.S. Geol. Survey Circ. 173, 26 p.

Although the ground water in the Buffalo-Niagara Falls region is generally of good quality, in some areas, especially those underlain by the Onondaga Limestone, wells have been drilled by individuals and industries for the discharge of waste material. This has resulted in the pollution of large sections of this aquifer. Many of the wells soon become clogged, losing their efficiency to absorb waste. The practice of drilling drainage wells, however, is discouraged by health officials.

Descriptors: New York, injection wells, industrial wastes, water pollution effects, groundwater.

0335 **Reed, Paul.**
1938. Water-flooding and brine disposal methods used in the mid-Continent: Oil and Gas Jour., v. 36, no. 44, p. 84-85, 88.

Water-flooding and brine disposal methods used in mid-Continent are discussed. Consideration is first given to water-flooding with particular reference to the following aspects: (1) what has been accomplished in recent years, (2) the extent of present operations, (3) some of the methods for dealing with conditions in the producing formations, and (4) water supply and treatment. Water disposal practices are outlined as they are followed in western Kansas. Water-flooding and brine disposal methods have a common problem in the treatment of water or brine so that no deposits will form in the injection wells to plug the limestone and sandstone formations.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, injection wells, methodology, Kansas, pre-treatment (water).

0785 **Reed, Paul.**
1938. Brine disposal plant: Oil and Gas Jour., v. 37, no. 5, p. 44-46.

Operators in the Fitts pool of Oklahoma have united under the name of Fitts Salt Water Disposal Association to build a large brine disposal plant. A brief description of the project is as follows: A gathering system using pipe made of materials not subject to corrosion takes brine from the tank batteries of the companies and conducts it by gravity to a large concrete pit, from which it is pumped by centrifugal pumps to a filter plant and then by reciprocating pumps through cement-lined steel pipe to two disposal wells drilled to the Wilcox sand especially for this purpose. Further details of the construction of the reservoir and pipe lines are given. Diagrams of the inverted siphons used in crossing streams with rock beds and streams with earth beds are given.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, Oklahoma, injection wells, equipment, pipelines, construction, geologic formations.

0786 **Reed, Paul.**
1938. Magnolia Petroleum Company's water disposal project: Oil and Gas Jour., v. 37, no. 32, p. 30-32, 34, 37.

The water disposal project installed by Magnolia Petroleum Co. in the Fitts pool, Okla., is described and illustrated. The physical and chemical properties of the brine, disposed of in specially drilled wells, are given. The brine requires treatment in a special treating plant. Before reaching the treating tank, the oil admixtures are trapped in concrete sumps. Other notable features are: interior connections within the sumps which permit connecting and cleaning of lines by scrapers while operating under pressure, flexibility in the capacity both of the gathering lines and the plant, and reduction of reservoir storage to a minimum. All pipes are made of noncorrosive duroline steel. A high percentage of the equipment may be salvaged when the work is discontinued.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, Oklahoma, injection wells, chemical analysis, waste water treatment.

0787 **Reed, Paul.**
1939. Disposal of oil field brines: Oil and Gas Jour., v. 37, no. 46, p. 174-175.

A continuous system for the disposal of oil field brines by pressure injection in connection with a closed system has been designed by the Ryan Consolidated Petroleum Corp. and installed in the Bemis pool in Kansas to handle a daily salt water production of 1,877 bbl. which is encroaching at the rate of 8% monthly. In operation, the brine flows by gravity from tank batteries to a vacuum-resistant tank equipped with a vacuum gauge, baffled inlets and outlets, gauge glasses, drains, and a separator switch to control the pump. From the tank the brine is injected into the Cheyenne sandstone at 235 lbs. pressure at the pump at a rate of 186 bbl./hour. Operations are judged by a recording pressure gauge which is changed daily and from curves which may be computed showing the quantity of salt water injected into the disposal well. Analyses of brine samples taken at an oil well bleeder and at the head of the salt water disposal well are tabulated. The costs of the pumping station, lead lines, and of drilling and equipping the disposal well are given.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, injection wells, Kansas, operations, flow rates, equipment, geologic formations.

0788 **Reed, Paul.**
1941. Water injection in southeast Kansas: Oil and Gas Jour., v. 39, no. 36, p. 54-56.

A description of water injection to increase production and for water disposal as practiced in some southeast Kansas fields is briefly described. In one pool, five-spot spacing of 660 ft. has been used, the water being injected by gravity flow after leaving treating equipment consisting of a settling tank, two conventional sand-and-gravel filters and chemical mixing equipment. About 8 bbl. of water has been injected for each barrel of oil recovered. The clogging of pores by algae has been treated by backwashing wells over a period of several days. Other injection projects are briefly treated.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, Kansas, injection, equipment, operations.

0336 **Reichert, S. O.**
1962. Radionuclides in groundwater at the Savannah River [South Carolina] plant waste disposal facilities: Jour. Geophys. Research, v. 67, no. 11, p. 4363-4374.

Disposal of radioactive waste to the ground at the Savannah River plant has been limited to the burial of solid waste and the discharge of very-low-level liquid waste to seepage basins. Although the solid wastes are subjected to leaching by an annual rainfall of 45 to 50 inches, no radionuclides have been detected in the ground water from this source. Retention of radionuclides in the seepage basins [excavated in the Hawthorn formation (Miocene)] has not been as good.–*from* Author's abstract.

Descriptors: Radioisotopes, South Carolina, radioactive waste disposal, solid wastes, underground, geologic formations.

0528 **Reichert, S. O.; Fenimore, J. W.**

1964. Lithology and hydrology of radioactive waste-disposal sites, Savannah River plant, South Carolina: Geol. Soc. America Eng. Geology Case Histories, no. 5, p. 53-69.

As is the case at many other locations, the hydrologic, geologic, climatic, and demographic characteristics of the Savannah River Plant do not encourage the disposal of radioactive waste to the environment. Disposal to the ground has been limited to the burial of solid waste and the discharge of very low-level liquid waste to seepage basins. Although solid wastes are subjected to leaching by an annual rainfall of 45 to 50 inches, no radionuclides have been detected in ground water from this source. Seepage-basin retention of radionuclides has been less satisfactory, since liquid waste is usually acidic (pH 3-4), and strontium^{90} is poorly adsorbed on local soil under these conditions. Strontium^{90} is detectable in sand layers (at concentrations less than the Radioactivity Concentration Guide) as far as 500 feet from the basins. Fission product tritium, present as water, is not adsorbed and thus serves as a useful ground-water tracer. The path of radionuclide migration from seepage basins excavated in the Hawthorn Formation (Miocene) is determined by the geology and hydrology of each disposal area. Most of the radionuclide migration has been through sandy strata or sand-filled clastic dikes. Wherever the soils do not contain these imperfections, migration has been slow. Maps, diagrams, and photographs are used to portray the areal and detailed hydrology, lithology, and structure of waste-disposal areas and to show migration patterns of radioactive ground water from the seepage basins during the period February through September 1962.–Authors' abstract.

Descriptors: South Carolina, radioactive waste disposal, water table, hydrogeology, groundwater, geologic formations.

0693 **Reichert, S. O.**

1962. Disposal of radioactive waste to the ground at the Savannah River plant [South Carolina], *in* Morgan, J. M., Jr., Jamison, D. K., Stevenson, J. D., eds., Ground disposal of radioactive wastes conference, 2d, Atomic Energy of Canada Limited and U.S. Atomic Energy Comm Div. Reactor Devel., Chalk River, Canada, 1961, Proc., Book 1: U.S. Atomic Energy Comm. Div. Tech. Inf. [Rept.] TID-7628, p. 115-129.

Results are presented from geological and hydrological studies in the area of the Savannah River Plant. The hydrologic, geologic, climatic, and demographic characteristics of the region do not encourage the disposal of radioactivity to the environment except under the most conservative conditions. Therefore, total containment of radioactive waste is the basic principle of operation. Waste management practices are described.–NSA 16-25044.

Descriptors: Radioactive waste disposal, South Carolina, geologic investigations, hydrologic aspects.

0659 **Reisenauer, A. E.; Nelson, R. W.; Knudsen, C. N.**
1963. The computer program, pt. 2 *of* Steady Darcian transport of fluids in heterogeneous partially saturated porous media: Richland, Wash.,General Electric Company, Hanford Atomic Products Operation [Rept.] HW-72335, 84 p.

The computer program, "Steady Darcian Flow in Soils," provides a means of obtaining numerical solutions to problems in the general class involving steady flow through porous media. Based on the mathematical and numerical treatment presented previously, the program was designed to handle the widest possible variety of boundary conditions. Potential distributions in saturated and partially saturated, homogeneous or heterogeneous soils may be obtained. Combined saturated and partially saturated flow cases may also be solved, since the equations used for one part are reducible to solve the other. Such a solution proceeds smoothly with little concern for the water table position which can be located easily in the problem solution. Moisture contents may be obtained from the results. The program was written for the IBM 7090 in Fortran and FAP languages. It can solve one-, two-, and three-dimensional and axisymmetrical problems with up to 8000 grid points. As many as 15 different soils may be included in a heterogeneous, partially saturated flow problem. Optimum underrelaxation and overrelaxation techniques are used to increase the speed of convergence and to maintain stability. Other methods of maintaining stability are also discussed.–Authors' abstract, NSA 18-26975.

Descriptors: Computer programs, steady flow, porous media, groundwater movement.

Reisenauer, A. E. *See* Nelson, R. W. 0670.

0694 **Reist, Parker C.**
1967. Disposal of waste radioactive gases in porous underground media: Nuclear Applications, v. 3, no. 8, p. 474-480.

Underground storage as a disposal method for long-lived radioactive gases is an attractive possibility. It is estimated that radioactive gases could be disposed of underground for about \$2/1000 ft^3 (atm) of waste gas. Possible problems which might arise with this type of disposal are discussed.–Author's abstract, NSA 21-32352.

Descriptors: Radioactive waste disposal, underground, feasibility studies, gases.

0337 **Repenning, Charles A.**
1959. Geologic summary of the San Juan basin, New Mexico, with reference to disposal of liquid radioactive waste: U.S. Geol. Survey Trace Elements Inv. Rept. TEI-603, 57 p.

The San Juan basin occupies about 20,000 square miles of northwestern New Mexico and adjacent parts of Colorado. Parts of the area contain over 13,000 feet of sedimentary rock. The Paleozoic rocks are approximately 55 percent siltstone, 30 percent limestone, and 14 percent sandstone with some evaporite deposits. The Mesozoic rocks of the San Juan basin are about half sandstone and half siltstone and claystone. Four types of reservoirs in the San Juan basin appear to deserve consideration for possible storage of high-level liquid radioactive waste. These are in gypsum, limestone, shale, and sandstone. Gypsum appears more useful for the storage of sintered waste. Storage of liquid waste in limestone is possible but it is uncertain whether the stored waste could be controlled. The construction of artificial reservoirs in shale units by hydraulic fracturing or deep-seated explosion has several advantages, the most significant of which is the relative certainty of confinement. Storage in permeable sandstone units is favorable from the standpoint of heat control.–*from* Author's abstract.

Descriptors: Injection wells, waste disposal, New Mexico, hydrogeology, sedimentary rocks, rock properties.

0338 **Repenning, Charles A.**
1960. Geologic summary of the Central Valley of California, with reference to disposal of liquid radioactive waste: U.S. Geol. Survey Trace Elements Inv. Rept. TEI-769, 69 p.

The Central Valley of California lies west of the Sierra Nevada and east of the Pacific Coast Ranges. It is about 450 miles long and has an average width of about 40 miles. The northern part is drained by the Sacramento River and is called the Sacramento Valley. Much of the southern part is drained by the San Joaquin River and the remainder has an interior drainage; the southern part is called the San Joaquin Valley. As much as 6 miles of sedimentary rocks fill the San Joaquin Valley and as much as 10 miles fill the Sacramento Valley. Most deposits in the Sacramento Valley are composed of Cretaceous sandstone and siltstone with little regional variation. The deposits in the San Joaquin Valley, by contrast, are largely Tertiary sandstone, siltstone, and claystone with great regional variation in rock types. Stratigraphic traps of several types are present, and many could be used to store liquid waste. Selection of more favorable areas for waste disposal is influenced by areas of favorable geologic structure.–*from* Author's abstract.

Descriptors: Injection wells, waste disposal, California, hydrogeology, sedimentary rocks, underground structures.

0341 **Reynolds, T. D.; Gloyna, E. F.**
1960. Reactor fuel waste disposal project–Permeability of rock salt and creep of underground salt cavities–Final report: U.S. Atomic Energy Comm. Div. Tech. Inf. [Rept.] TID-12383, 121 p.

A study was made of two problems of salt-cavity storage, namely, seepage of wastes out of formations and closure of cavities due to plastic flow of salt. The results indicate that both problems are negligible; bedded salt is more impermeable than dome salt. Kerosene was found to be nonreactive with dome salt, whereas brine solution showed some interaction. It is concluded that storage of radioactive wastes in salt cavities is feasible.–NSA 15-33052.

Descriptors: Radioactive wastes, waste storage, salts, engineering geology.

0342 **Rhea, A. S.; Miller, E. B., Jr.**
1940. Disposal of salt water in the East Texas field: Petroleum Technology, v. 3, no. 1, Tech. Paper 1151, p. 1-10.

Because of the gradual increase in the amount of salt water produced in the East Texas field, the present production amounting to 200,000 bbl. per day, experiments were conducted to attempt subsurface injection of salt water into the Woodbine sands, thereby disposing of the water and simultaneously increasing the oil reservoir pressure, enabling a greater recovery of oil. It was found that the closed system type of disposal was impracticable because of plugging, apparently due to precipitation of the iron in the water. The open system worked satisfactorily, but it was necessary to keep the aerated water, which is very corrosive, from touching any metal surfaces by lining the pipes with cement or cement-asbestos. Copper sulfate is added to prevent growth of algae and calcium hypochlorite and chlorine are added to stop bacterial action. Using the open system type, injection was carried on for about 10 months, with a decrease in effective permeability being noticed after the 8th month. At the 10th month, the well was still taking about 2200 bbl. water/day with a surface pressure of 40 lb. A chart of performance during injection is presented. It was found that (1) the open system is the best method of disposal, but that plugging causes a decline in injection rate, due to the iron and suspended matter, and other unknown causes; (2) the disposal well must be carefully cleaned to remove all foreign matter from the sand surfaces; and (3) completing the well by setting a noncorrosive perforated liner and gravel packing or by setting a noncorrosive blank liner and perforating opposite the sand zones for injection may be necessary. The cost of a salt water disposal plant is between $20,000 and $30,000; costs per barrel have not been computed since figures on the life of the plant are not yet available. A plant for the chemical treatment of water, to remove interfering substances, is under consideration.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, Texas, injection, factilites, geologic formations, operation and maintenance.

Rhodes, D. W. *See* Wilding, M. W. 0709.

0606 **Rice, Ivan M.**
1968. Salt water disposal in the Permian basin: Producers Monthly, v. 32, no. 3, p. 28-30.

In order to prevent contamination of fresh water a great deal of attention is being directed to reinjecting produced water into brine-bearing formations. Various factors to properly design, install and operate field-wide systems must be considered to provide trouble free and economical disposal.–Author's abstract.

Descriptors: Water pollution control, oil fields, brine disposal, injection wells, Texas, New Mexico.

0789 **Rice, Ivan M.**
1952. New plastic tubing tried in oil field service: Oil and Gas Jour., v. 51, no. 14, p. 106-107.

Installation of glass-fiber-reinforced plastic tubing in a Superior Oil Co.'s salt water disposal well in Acadia Parish, Louisiana, indicated the following: (1) Plastic tubing is easy to handle–the 20 ft. lengths weigh only 40 lbs. each. (2) 3,476 ft. can be run in and the well connected within 7 hrs. (3) Stretch is negligible, about 0.3 ft. in 3,476 ft. (4) Application is limited by physical conditions existing in the well. (5) The tubing appears entirely corrosion resistant and unaffected by common well fluids and acid treatment. (6) Extreme care should be taken in entering threads into the collar while making up the pipe, and while making up the joint.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, Louisiana, injection wells, plastic pipes.

0790 **Rice, Ivan M.**
1967. Guidelines for disposal systems: Petroleum Engineer, v. 39, no. 7, p. 36-38.

In designing a disposal system, one of the first requirements is an analysis of producing formations, types of reservoirs involved, and the quantity of water they are capable of producing. While surface and subsurface mechanical producing equipment may have some bearing on anticipated volumes, the equipment can be changed. When the total volume of water has been determined, the disposal well formations and location must be selected. If no history is available, the probable capacity may be estimated by correlation of logs, sample analyses, and drill stem tests. The number and general distribution of disposal wells can then be related to anticipated water production.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, subsurface investigations, geohydrologic units, transmissivity.

Rich, E. I. *See* Pierce, W. G. 0321.

0529 **Richardson, R. M.**
1963. Significance of climate in relation to the disposal of radioactive waste at shallow depth below ground [with French abs.], *in* La retention et la migration des ions radioactifs dans les sols–Colloque international, Saclay, France, 1962: Paris, Presses Universitaires de France, p. 207-211.

Climate is of supreme importance in evaluating the suitability of sites for the disposal of radioactive waste at shallow depth below ground. To illustrate the profound importance of climate in relation to ground disposal operations, a number of sites in humid eastern United States where radioactive wastes are disposed at shallow depth below ground are described and compared with each other, and with two sites in arid parts of western conterminous United States. Consideration of conditions prevailing in these sites indicates that from the standpoint of results consequent to disposal or release, either deliberate or accidental, of radioactive waste to shallow depth below ground, sites in arid regions are, in general, infinitely more satisfactory than those in humid regions. In humid regions where radioactive waste is disposed at shallow depth below ground, the sorptive action of certain minerals in the soil is the only mechanism that prevents the rapid reappearance of radioactive ions in nearby surface water courses. Where the local soils do not immobilize the hazardous ions, structures of some sort must be provided for containment.–NSA 18-17347.

Descriptors: Radioactive waste disposal, climates, hydrogeology, sites.

Richardson, R. M. *See* Warde, John M. 0415.

0855 **Rifai, M. N. E.; Kaufman, W. J.**; Todd, D. K.
1956. Dispersion phenomena in laminar flow through porous media–Progress report no. 2, Canal seepage research, July 1, 1955 to June 30, 1956: Berkeley, California Univ., Sanitary Eng. Research Lab. and Div. Civil Eng., I.E.R. Ser. no. 93, Issue no. 2, 157 p.

Seepage from an earth canal involves a mixing of the intruding and displaced liquids with the formation of a dispersed front or zone between the two water masses. In the underground disposal of chemical and radioactive wastes, dispersion may be a determining consideration in estimating the utility of a formation for waste storage. Two theoretical approaches were studied for comparision with experimental data concerning the dispersion phenomena of laminar flow through porous media. In the first approach, porous media were reduced to bundles of capillary tubes and the longitudinal dispersion in one tube was investigated. The second approach assumed that the statistical characteristics of porous media play the same role as molecular diffusion does in a stationary fluid. A statistical method based on Galton's probability distribution was applied. It was found that the distribution of a tracer particle will be a normal probability distribution after a long distance of flow.

Descriptors: Canal seepage, laminar flow, porous media, dispersion, waste disposal, theoretical analysis.

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Rifai, M. N. E. *See* Orcutt, R. G. 0304.

0202 **Rima, D. R.**
1969. Some factors to be considered in the design of waste disposal wells, *in* Sanitary and Water Resources Eng. Conf., 8th Ann., 1969, Proc.: Nashville, Tenn., Vanderbilt Univ., Dept. Civil Eng., p. 119-127.

The hydrologic phenomena most commonly overlooked in the design of waste disposal systems are natural hydraulic gradients and hydrodynamic dispersion. This paper examines these two factors as they relate to the post-injection movement of waste-bearing waters. Techniques are given for estimating the possible spread of contaminants from a proposed injection well. The author concludes that assessments of contaminant spread in injection zones are questionable unless these factors are considered.

Descriptors: Injection wells, hydrodynamics, equations, groundwater movement, porous media, dispersion.

Robeck, G. G. *See* Warner, D. L. 0417.

Roberts, I. C. *See* Beranek, J. 0621.

0699 **Robertson, J. B.**
1969. Behavior of xenon-133 gas after injection underground–Molecular diffusion, materials balance, and barometric pressure effects: U.S. Geol. Survey open-file rept. (IDO-22051), 37 p. [Also available as U.S. Atomic Energy Comm. Rept. TID-4500; available from CFSTI.]

Nine hundred eighty-seven curies (Ci) of radioactive Xe-133 gas were injected rapidly under pressures of 1.5 to 1.65 psig with one million cubic feet of air into permeable basalt strata at the National Reactor Testing Station, Idaho. A capping layer of semipermeable fine-grained playa sediments confined the gas underground. The subsurface Xe-133 was monitored by Geiger–Mueller detectors and by air samples from observation wells surrounding the injection well. Underground distribution patterns after injection pressures had dissipated were evaluated by materials-balance analyses. The results indicated that most of the Xe-133 remained underground and decayed radioactively, and that the underground air-sample analysis data were erroneously low by a factor of approximately 10. Molecular diffusion rates of Xe-133 from the ground were estimated using a simplified numerical model. It was concluded that molecular diffusion and barometric effects could produce the flux rates measured; however, the rates were too low to remove a significant portion of the 987 Ci of Xe-133, nearly all of which remained underground and decayed, radioactively. Although they are only approximate, the general methods and techniques used for the diffusion, materials balance, and barometric analyses were generally satisfactory and could be applied to future underground gas-injection problems.–*from* Author's abstract, NSA 23-47722.

Descriptors: Injection, Idaho, radioisotopes, gases, diffusion, basalts.

Robertson, J. B. *See* Barraclough, J. T. 0618.

0530 **Robinson, B. P.**
1962. Ion-exchange minerals and disposal of radioactive wastes–A survey of literature: U.S. Geol. Survey Water-Supply Paper 1616, 132 p.

A review of the literature on ion-exchange theory, naturally occurring ion-exchange minerals and the role of ion exchange in the disposal of radioactive wastes is presented and discussed in terms of colloid science, thermodynamics, reaction kinetics, reaction mechanisms and adsorption equations. Clay minerals and other ion-exchange minerals including glauconite, ultramarines, and zeolites are discussed in terms of origin, nomenclature, composition, structure and exchange capacities. It appears that practical means for the permanent disposal of high-level radioactive wastes remain to be discovered.–*from* Author's abstract.

Descriptors: Radioactive waste disposal, sorption, ion exchange, clay minerals, mineralogy, geochemistry, thermodynamics.

0791 **Roedder, Edwin.**
1959. Problems in the disposal of acid aluminum nitrate high-level radioactive waste solutions by injection into deep-lying permeable formations: U.S. Geol. Survey Bull. 1088, 65 p.

The problems of injection and the possibility of chemical reactions occurring upon contact between earth materials and typical high-level acid aluminum nitrate wastes, from atomic reactor fuel processing, are discussed in connection with proposed methods of disposal of such wastes by injection into deep-lying, brine-saturated permeable beds (salaquifers). To discuss the mechanics of the interaction of moving waste with salaquifer minerals, the concept of a "zone of equilibration" is developed and the factors modifying it are considered; it is shown that the width of the zone of equilibration controls the usable storage capacity of the salaquifer, per well. Although the known variables include physical effects, chemical effects, and rate processes, most of which cannot be calculated rigorously but can be truly evaluated only by large-scale tests, it is shown experimentally that reactions with carbonates, limonite, clays, and other typical salaquifer materials will occur. These reactions can reasonably be expected to cause the precipitation of aluminum and ferric hydroxide gels, effectively blocking further injection. Whether this stoppage will occur before the amount of waste pumped into the well is sufficient to make the procedure economically feasible depends upon various factors that cannot be evaluated precisely without a number of simplifying assumptions and further experimental work, but the procedure would appear to be feasible only under certain very special conditions. A few extrapolations of the data to other types of wastes and salaquifers are made, remedial procedures to avoid precipitation are discussed, and suggestions are offered for future studies, based on the pertinent literature.–*from* Author's abstract.

Descriptors: Radioactive waste disposal, injection wells, geohydrologic units, chemical reactions, evaluation.

Rogowski, A. S. *See* Tamura, Tsuneo. 0704.

0346 **Rorabaugh, Matthew I.**
1960. Problems of waste disposal and ground water quality: Am. Water Works Assoc. Jour., v. 52, no. 8, p. 979-982.

The problems associated with waste disposal and its effect on ground water are many and complex. The risks, however, can be reduced where careful studies of the geology and hydrology are made as a basis for selecting disposal sites and where provision is made for containment or control of waste movement after release. For example, the concept that an injection well behaves in the same manner as a pumped well, except that there is a buildup of head instead of drawdown, is approximately true for computing the quantities that might be injected, but is grossly inadequate in predicting where the waste will go and its rates of travel after injection. For this purpose, it is necessary to consider what happens underground when a fluid of different pressure, temperatures, density, or dissolved chemicals is injected into an aquifer. The influence of each of these factors is discussed in the light of theory and field observations. The report concludes that future growth and technological advances will produce vastly greater quantities and many new types of waste. To meet this challenge successfully, a substantial amount of research and field investigation will be needed in the geologic, hydrologic, chemical, physical and geophysical phases of the problem to provide the tools to do the job.

Descriptors: Waste disposal, underground storage, injection wells, hydrodynamics, theoretical analysis.

Rowe, P. P. *See* Brown, R. E. 0088.

Ruby, W. W. *See* Healy, J. H. 0022.

Rummer, R. R. *See* Harleman, D. R. F. 0171.

Rummer, R. R. *See* Harleman, D. R. F. 0172.

0792 **Runyan, E. E.**
1965. Cement lining, modern technology put an old tool to work in battle against corrosion: Drill Bit, v. 12, no. 10, p. 4-7.

Modern cement lining is a low-lime, high-silica material that is chemically inert to any substance normally found in oilfield waters or crude oils. This chemical inertness is due to the dense, compact nature of the lining and the extensive use of pozzolan in the mix. Handling of acid waters such as those containing H_2S and CO_2 present no problem. Due to its smooth surface, flow of liquids under a given pressure is greater than that of unlined pipe of comparable inside diameter. This smoothness does not deteriorate with age. The excellent mechanical, chemical, and flow properties of cement-lined pipe coupled with its low cost and almost indefinite operating life have made it standard operating practice for surface lines in Permian Basin waterfloods and salt-water disposal projects. In recent years, these same properties have been winning much support for the cement lining of downhole injection strings. The effectiveness of cement in protecting steel from corrosion in marine structures has been recognized for many years. This same protective mechanism will protect steel pipe with a lining of cement. Basically this protective mechanism results from moisture in the cement absorbing calcium hydroxide and maintaining the pH in the steel contact area above 12.0.–Tulsa Univ., Inf. Services Dept.

Descriptors: Pipes, corrosion control, chemical properties, equipment.

Ryan, V. H. *See* Engquist, M. A. 0555.

0347 **Sadow, R. D.**
1963. How Monsanto handles its petrochemical wastes: Wastes Eng., v. 34, no. 12, p. 640-644, 664.

Wastes originating from the cracking of light crude oils, separation and handling of hydrocarbon streams, phenol-acetone production, and minor amounts of cooling waters and domestic wash waters are effectively being handled by two completely different processes at Monsanto Chemical Co.'s new chemical complex near Alvin, Tex. The strong or high-level phenol wastes are successfully being handled by high-pressure deep well injection whereas the medium- and low-level wastes are subjected to a trickling filter-activated sludge treatment process prior to their release into Chocolate Bayou, a tidal estuary. The injection well, completed in July 1961, is 6,302 feet deep and is finished in highly permeable, brine-saturated Miocene sands between depths of 6,045 and 6,294 feet. Laboratory tests with cored samples provided the necessary data to identify treatment requirements needed to prevent precipitation, clogging, and undue swelling of clays in the injection zone. Pumping tests showed that the strata could receive up to 400 gpm with back pressures of less than 600 psi. Preinjection treatment includes paddle mixing, lowering the pH, increasing the salinity, and filtering to make the wastes compatible with the connate waters and to prevent clogging of the subsurface formation. Deep well injection has been quite successful with over 45 million gallons already disposed of. Back pressures have been steady with only slight formation clogging; the entire well strata represents a total acceptance life of at least 40 years.

Descriptors: Chemical wastes, injection wells, Texas, design data, waste treatment, equipment.

0348 **Sadow, R. D.**
1966. Waste treatment at a large petrochemical plant: Water Pollution Control Federation Jour., v. 38, no. 3, p. 428-441.

Treatment of petrochemical wastes at the Chocolate Bayou plant [Texas] of the Monsanto Company is carried out by several processes. Phenolic wastes are pretreated by coagulation and sedimentation before injection into a deep well. High-level nitrile wastes undergo sedimentation and gravity sand filtration before injection. Oily water is skimmed, coagulated, and oxidized biologically in ponds equipped with mechanical aerators, and sour water is skimmed, subjected to trickling filtration, and treated by an activated sludge process. Toxic wastes from acrylonitrile manufacturing are incinerated.—Author's abstract.

Descriptors: Waste water disposal, chemical wastes, phenols, Texas, pre-treatment (water), injection wells.

0349 **Samuelson, G. J.; Moore, B. H.**
1958. Chemical compatibility problems in water injection systems: Oil and Gas Jour., v. 56, no. 9, p. 113, 115, 118, 120.

In petroleum production, water may be injected into subsurface strata for either of two major purposes: (1) to stimulate production, as in secondary recovery; or (2) to dispose of the water (brine) where so much is produced with the oil that it cannot, because of salt or other contamination, be disposed of by surface drainage. In each of these injection situations certain problems exist. The underground formations may act as extremely effective filters and thus the waters must be free of suspended or dissolved matter which might block the fluids by deposition of solids, either existing in the fluids or produced by chemical reaction with the formations. Various chemicals and processes may be used in pretreating such injection waters to improve injectability. These are designed to remove existing or potential causes of formation plugging. Simple sedimentation, with or without chemical flocculating agents, followed perhaps by filtration, removes suspended matter. Bactericides or algicides may be required to control sulfate-reducing or other bacteria and algae. Inhibitors

may be used to prevent the formation of corrosion products. Surface-tension reducers may be added to overcome the normally high resistance of the formation interstices to passage of water. Chemicals with dispersant or sequestering characteristics may minimize scale deposition. When additives are used—especially if different ones are to be used simultaneously or successively in the same injection system—these must be compatible with each other and with the subject water. Indeed, where the injection water is compounded, perhaps of produced brine and fresh surface water, the compatibility of these waters themselves must be considered.—Authors' summary.

Descriptors: Brine disposal, injection wells, design criteria, waste treatment, methodology.

0325 **Sand, Francis M.**

1967. Waste disposal, *in* Cohen, Gerald D., and Sand, Francis M., Water resources applications, underground storage of natural gas, and waste disposal using underground nuclear explosions: U.S. Atomic Energy Comm. Peaceful Nuclear Explosions [Rept.] PNE-3008, p. 64-71.

Although many alternative methods exist dealing effectively with waste disposal problems, the report concludes that the application of nuclear explosives for creating underground storage for harmful wastes is an alternative to the existing methods which at present do not appear to demand substantive investment of resources, but which could prove to be a valuable addition to the Federal anti-pollution program, particularly if used in conjunction with a regional resource management scheme.—*from* Author's summary.

Descriptors: Nuclear explosions, underground storage, waste disposal.

0350 **Sandberg, C. A.**

1962. Geology of the Williston basin, North Dakota, Montana, and South Dakota, with reference to subsurface disposal of radioactive wastes: U.S. Geol. Survey Trace Elements Inv. Rept. TEI-809, 156 p.

The southern Williston basin, which underlies about 110,000 square miles in North Dakota, South Dakota, and eastern Montana, is part of a large structural and sedimentary basin. The sedimentary sequence that fills the basin has a maximum thickness of about 16,700 feet and rests on Precambrian metamorphic rocks at depths of 500 to 13,900 feet below sea level. It contains rocks of every geologic system from Cambrian to Quaternary. Rocks of the Williston basin are gently folded, and regional dips are 1° or less from the margins to the basin center. The most important mineral resource of the area is oil, which is produced predominantly from the Paleozoic carbonate sequence and largely on three of the major anticlinal folds, and lignite, which is present near the surface in Paleocene rocks. The subsurface disposal of radioactive wastes at some places in the Williston basin appears to be geographically and geologically feasible. Many sites, at which large quantities of wastes might be injected with minimal danger of contamination of fresh-water aquifers with oil-producing strata, are available. The strata and types of reservoirs that deserve primary consideration for waste disposal are the Winnipeg Formation of Middle Ordovician age as a deep salaquifer, the Permian to Jurassic salt beds as moderately deep units in which solution cavities might be created for storage, the thick Upper Cretaceous shale beds as shallow hydraulically fractured shale reservoirs, and the Newcastle Sandstone of Early Cretaceous age as a shallow shale-enclosed sandstone reservoir.—Author's abstract, NSA 16-27419.

Descriptors: Radioactive waste disposal, geology, injection, sedimentary rocks, geologic formations, Montana, North Dakota, South Dakota.

0351 **Sanders, T. P.**
1937. Salt water disposal in Michigan: Oil and Gas Jour., v. 35, no. 34, p. 47, 49.

A discussion is given of specific instances of the use of deep wells for the disposal of brine in Michigan fields by the Cryden Oil Co. and the Gulf Oil Co. In some cases abandoned wells are used, but much opposition is met from the royalty owners. All methods used in Michigan call for putting the brine back into the ground except for that used in the Porter field. There it is taken to the Dow Chemical Co. plant to be manufactured into chemicals. The Pure Oil Co. has provided for a gathering line to pump brine into the line leading to the Dow plant. Other operators in this field have formed the Porter Brine Disposal Co. which has constructed a similar gathering system.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, deep wells, Michigan.

0793 **Sanford, R. M.**
1942. Closed siphon system for water disposal: Oil and Gas Jour., v. 40, no. 42, p. 57-58.

A description is given of Union Producing Co.'s closed injection system which disposes of 3,360 bbl. of salt water daily in the Tinsley, Miss., field by siphoning into a 2,880 ft. well, the salt water being siphoned by suction down through the casing while formation water flows out through the tubing. The closed-type system was chosen because of the high iron content of the water which makes exclusion of air essential.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, Mississippi, injection wells.

0603 **Sceva, Jack E.**
1968. Liquid waste disposal in the lava terrane of central Oregon: Corvallis, Oreg., Federal Water Pollution Control Adm., Pacific Northwest Water Lab. Tech. Proj. Br. [Rept.] FR-4.

A large part of the Middle Deschutes Basin in Central Oregon is underlain by basaltic lava flows that restrict the construction of conventional drain fields for liquid waste disposal. Drilled disposal wells in the lava serve as the chief method of liquid waste disposal. The disposal wells are concentrated in the Bend, Redmond, and Madras areas. They range from a few feet to over 400 feet in depth. Large quantities of ground water underlie these areas and are being developed for domestic water supplies. The injection of liquid waste into disposal wells and the construction of deep, uncased water wells create a threat to water quality. The prevention of further drain well construction and the casing of all deep water wells are recommended.–Author's abstract.

Descriptors: Oregon, drainage wells, basalts, liquid wastes, water quality, groundwater.

0698 **Schaffer, W. F., Jr.; Boegly, W. J., Jr.; Parker, F. L.; and others.**
1964. Project Salt Vault [Kansas]–Design and demonstration of equipment: U.S. Atomic Energy Comm. Oak Ridge Natl. Lab. [Rept.] ORNL-P-1987, 36 p. [Available from CFSTI.]

Handling, transfer, and storage techniques applicable to high-level solid waste disposal operations were successfully demonstrated with short-cooled ETR fuel assemblies. The design of Project Salt Vault equipment for the encapsulation of the fuel assemblies, cross country shipment, transfer from the surface to the mine level, movement within the mine, and transfer into storage is described. The operations are

unique in that high-level radioactive materials are transferred from a shipping cask on the surface to the mine level 1000 feet below without the use of hot cells.—Authors' abstract, NSA 20-18165.

Descriptors: Radioactive waste disposal, mining, methodology, salts, design data, equipment, Kansas.

0354 **Scheidegger, Adrian E.**
1955. General statistical hydrodynamics in porous media: Geofisica pura e applicata, v. 30, p. 17-26, Jan.—Apr.

The study of fluid flow in the ground is based upon the physics of flow through porous media. The author has recently proposed a theory of such flow based upon the statistics of disordered phenomena which, however, was applicable to a special type of flow only. In the present paper, the earlier theory is developed into a general theory applicable to any type of microscopic flow equation. It is shown that the qualitative analogy which is observed between the equations of flow through porous media and the equations of flow through capillaries can be logically explained without the assumption of capillaric models. Thus, a theorem is proven stating that the flow through porous media is described by the superposition of two effects: firstly, one corresponding to the average flow through a set of small channels, and secondly, a dispersivity effect. Finally, the results are applied to a variety of flow equations such as laminar flow, turbulent flow, and molecular streaming, all of which may occur in ground-water flow.—Author's abstract.

Descriptors: Hydrodynamics, turbulence, capillary action, dispersion, porous media.

0356 Scheidegger, Adrian E.
1960. Underground dispersion of miscible liquids: Internat. Assoc. Sci. Hydrology Pub. 52, p. 462-469.

The intrusion of salt water into coastal and estuarine aquifers represents a case of underground dispersion of miscible liquids. The theory of this dispersion is presented in a general form which makes it applicable to a calculation of the intrusion under arbitrary geometric conditions. It is shown that the proposed theory leads to a mean error not exceeding 3 percent. Some solutions of the differential equation are given for simple cases. Finally, the method which has to be followed for the calculation of a complicated case is indicated.

Descriptors: Dispersion, liquids, aquifers, saline water intrusion, equations, theoretical analysis.

0700 **Schmalz, B. L.**
1962. National Reactor Testing Station waste disposal practices and programs, *in* Morgan, J. M., Jr., Jamison, D. K., Stevenson, J. D., eds., Ground disposal of radioactive wastes conference, 2d, Atomic Energy of Canada Limited and U.S. Atomic Energy Comm. Div. Reactor Devel., Chalk River, Canada, 1961, Proc., Book 2: U.S. Atomic Energy Comm. Div. Tech. Inf. [Rept.] TID-7628, p. 536-568.

The purpose of the National Reactor Testing Station is to further the Atomic Energy Commission's reactor development program. It was established in 1949 in order to provide a place where various types of nuclear reactors and allied plants could be built and tested. Its size and relatively isolated location allow research in this field which would not be initially permissible in more populous areas. The research efforts at the station are localized in 10 separate areas. Disposal of aqueous liquid waste to the ground in these areas is accomplished by discharge into ponds, wells, cribs, cesspools, and one subirrigation sewer system. The amount of waste discharged at each area is tabulated. Results are reported from investigations of the movement of aqueous radioactive wastes through the regolith in the vicinity of waste disposal areas.–NSA 16-25073.

Descriptors: Radioactive waste disposal, testing, injection wells, subsurface flow, migration, soil environment, Idaho.

0701 **Schmalz, B. L. (compiler).**
1969. Injection of gas into the lithosphere at the National Reactor Testing Station, Idaho Falls, Idaho: U.S. Atomic Energy Comm. Idaho Operations Office [Rept.] IDO-12069, 166 p. [Also available as U.S. Atomic Energy Comm. Rept. TID-4500; available from CFSTI.]

Tests were conducted by injecting 1 million ft^3 of air, containing 1,000 Ci xenon-133, into a porous zone 120 feet below the land surface. The movement of this gas was studied by means of air samples and radiation detection equipment placed in surrounding monitoring wells. Air samples also were collected at the land surface and from strategic locations in the atmosphere. Analysis of the results using diffusion equations verified that the movement could be explained on this basis. Variation of estimated flux from that measured was explained on the basis of barometric influences. It was estimated that 0.5 [Ci] of 1,000 Ci injected escaped to the atmosphere during a 24-day period. This amount resulted in concentrations that were less than the mean concentration of xenon-133 in the injected air by a factor of 10^8. Mathematical models describing the flow by convective forces created by injection also were tested and found adequate for making engineering estimates.–Author's abstract, NSA 23-43503.

Descriptors: Injection, gases, radioisotopes, porous media, migration patterns, Idaho.

Schmalz, B. L. *See* Jones, Paul H. 0557.

Schmalz, B. L. *See* Mudra, P. J. 0290.

0358 **Schmidt, Ludwig; Devine, J. M.**
1929. The disposal of oil-field brines: U.S. Bur. Mines Rept. Inv. 2945, 17 p.

The U.S. Bureau of Mines has completed a preliminary study of the disposal of oil field brines. It was found that some harm is done to agricultural lands by allowing the brines to flow over them, but the extent was not determined. The four methods of disposal studied were: (1) Use of ponds. This is limited to small amounts of brine. Ponds are useful for temporary storage. (2) Plants for recovering the common salts from oil field brines are uneconomical except in special cases. (3) Diversion into selected streams offers possibilities. (4) Return to subsurface formations seems to be feasible in isolated cases. This method must be practiced with care, however.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, methodology, waste storage, desalination, surface runoff, injection.

0794 **Schmidt, Ludwig; Devine, J. M.**
1929. Oil field brines: Oil and Gas Jour., v. 28, no. 17, p. 39.

Investigation of the four general methods used in the disposal of oil field brines indicates that the use of ponds is limited to the evaporation of small quantities, or for temporary storage. Plants for recovering the salts are uneconomical except in special cases. The diversion of brines into selected streams offers possibilities, but a complete analysis to insure absence of poisonous salts should be made of all brines run into streams. The return of brines to subsurface formation is feasible in isolated instances. Care must be taken to determine that they cannot migrate to fresh water sands and pollute fresh water supply, and that oil production is not endangered.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, methodology, evaporation, desalination, surface runoff, injection.

0795 **Schmidt, Ludwig; Thorne, H. M.; Wilhelm, C. J.**
1935. Disposing of oil field brines: Petroleum World, v. 32, no. 415, p. 103-106.

Data are given on the analysis of water samples obtained from representative producing areas in Oklahoma and the Ritz-Canton field, Kansas. Subsurface contamination of fresh water supplies may be due to poor plugging or faulty casing. Bottom hole plugging and systematic casing programs sometimes assist in controlling contamination. Methods of disposal of surface accumulations of brines are discussed. The return of brines to subsurface formations is most satisfactory if the brine is returned to the same formation from which it was produced thru "edge" wells. It is uneconomical if pressures in excess of 250 lbs. per sq.in. are required. The possibilities and difficulties involved in using selected streams for drainage channels are discussed.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, chemical analysis, Oklahoma, Kansas, injection.

Schmidt, Ludwig. *See* Grandone, P. 0164.

Schmidt, Ludwig. *See* Wilhelm, C. J. 0436.

Schnoor, F. H. *See* Crooker, J. T. 0724.

0534 **Schroeder, Melvin C.; Jennings, A. Ray.**
1963. Laboratory studies of the radioactive contamination of aquifers: Livermore, California Univ., Lawrence Radiation Lab. [Rept.] UCRL-13074, 120 p.

Exchange column experiments and batch determinations of the distribution coefficient were utilized in studying the migration of radioactive cesium and strontium through earth materials. Distribution coefficients were determined by the batch method for cesium and strontium for the 20-30 and 50-60 mesh sizes of quartz sand, crushed quartz, and crushed microcline for several concentrations of either sodium, potassium, or calcium. Coefficients were determined for some other minerals such as calcite, soda feldspar, and limestone. Exchange column experiments were done using the previously stated two sizes of quartz sand, crushed quartz, and crushed microcline. These experiments have used various concentrations of calcium, potassium, and sodium as the competing or eluting cation. An isotope pulse was placed on the minerals in the columns and eluted at flow rates of 10 cm or 1 cm per hour. The distribution coefficient can be determined from the column elution history by the Mayer and Tompkins equations. However, this calculation was made using the position of 50 percent elution of the activity from the column instead of the peak position of the radioactivity. Discrepancies between the batch and column coefficients for the same materials and solutions are of small magnitude. Therefore, the equation

derived by Higgins in 1959 can be used to determine the rate of migration of tracer concentrations of radioisotopes.–NSA 17-39270.

Descriptors: Hydrodynamics, radioisotopes, laboratory tests, migration, sorption, physicochemical properties.

Schuchardt, M. C. *See* Krause, H. 0831.

0839 **Schwibach, J.**
1967. Research on the permanent disposal of radioactive wastes in salt formations in the Federal Republic of Germany (SM-93/34), *in* Disposal of radioactive wastes into the ground–International Atomic Energy Agency and European Nuclear Energy Agency, Vienna, 1967, Symposium Proc.: Vienna, Internat. Atomic Energy Agency (STI/PUB/156), p. 465-477.

In the Federal Republic of Germany, as well as in other densely populated European countries, the method of burying radioactive wastes in shallow ground could not be adopted because of the intensive land utilization, apprehensions on the part of the public, and the need to preserve the natural water resources. Only in exceptional cases may radioactive wastes be disposed of in the same way as conventional refuse. For the permanent disposal of the bulk of radioactive wastes, which are packaged and currently stored in private or state-owned interim storage halls, scientific bodies in the Federal Republic have recommended that such wastes be stored in deep salt formations. Research and development of this method have been entrusted by the Federal Ministry for Scientific Research to the Gesellschaft für Strahlenforschung, Munich, together with the Gesellschaft für Kernforschung, Karlsruhe, and the Bundesanstalt für Bodenforschung, Hanover, and other scientific institutes. The first step was the signing of a research contract between the Gesellschaft für Strahlenforschung and Euratom to establish a cavity for low-level radioactive wastes in a salt dome in the northwest of the Federal Republic. The abandoned Asse salt mine was then purchased by the Federal Government. The research which is under way there or planned for the near future is reviewed. In particular, questions of the inherent safety of salt storage of high-level wastes are discussed.–Author's abstract, NSA 22-16816.

Descriptors: Radioactive waste disposal, underground storage, research and development, salts, sedimentary rocks, foreign countries.

0840 **Schwille, F.; Lippok, W.; Weisflog, D.**
1967. Model experiments on fluid flow in the transition zone from unsaturated to saturated soil (SM-93/11), *in* Disposal of radioactive wastes into the ground–International Atomic Energy Agency and European Nuclear Energy Agency, Vienna, 1967, Symposium Proc.: Vienna, Internat. Atomic Energy Agency (STI/PUB/156), p. 151-160.

Since central water supply systems were established in Germany, ground water has been preferred as a water source and will undoubtedly continue to be so. More than four-fifths of the necessary drinking water is extracted from the subsoil either as genuine ground water or as bank-filtered river water. The most important aquifers in the Federal Republic of Germany are fluviatile and fluvioglacial Pleistocene sand and gravel deposits, situated in the valleys of the large rivers. The ground-water level is generally from 3 to 15 m below ground surface. Depending on the permeability of the substrata, about 100 to 300 mm of precipitation water probably infiltrates. Therefore, the possibility of ground-water contamination by dissolved products is always present. These alluvial plains are suitable locations for radionuclide-producing plants. However, because of the intensive exploitation of the aquifers, it is hard to find any locality

where such plants would not have a marked effect on the water-supply system. If ground water is to be protected effectively and at reasonable cost against radionuclide contamination, a detailed knowledge is first necessary of the migration mechanisms of radionuclide-containing solutions both into the unsaturated zone, i.e., the aerated zone, and the saturated zone, as the migration of radionuclides depends on the static and dynamic behavior of fluids in porous media. Infiltration in the unsaturated zone and spreading in the saturated zone were studied by means of sand models scaled to resemble the natural conditions as closely as possible. Large special glass lysimeters, experimental troughs with glass walls and small diameter copper and glass segment-tubes, were used as models. The liquid fronts were traced mainly with ultraviolet light. The result shows that it is not yet possible to treat the flow of liquid analytically in every case, even in homogeneous media.–Authors' abstract, NSA 22-16800.

Descriptors: Hydrogeology, model studies, hydrodynamics, pollution abatement, foreign countries, radioactive wastes, unsaturated flow.

0796 **Sclater, K. C.**
1930. Salt water disposal: Petroleum Engineer, v. 1, no. 4, p. 38.

In Texas, the problem of salt water disposal is generally solved by a special company, which does the planning on a strictly engineering basis. In small isolated pools, the small producer must provide his own facilities to suit the particular requirements. Where the rate of natural evaporation exceeds that of rainfall, and pollution of surface water is not a problem, the evaporation method is adaptable. In other cases the problem can be solved by pumping the water down a well into barren underground formations where there are suitable subsurface cavities into which water can be pumped without danger of plugging up the pores.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, Texas, injection wells, pollution abatement.

0361 **Scopel, Louis J.**
1964. Pressure injection disposal well, Rocky Mountain Arsenal, Denver, Colorado: Mtn. Geologist, v. 1, no. 1, p. 35-42. [Abs. also published in Geol. Soc. America Spec. Paper 68, p. 317, 1962.]

The pressure injection disposal well recently completed for the U.S. Corps of Engineers at the Rocky Mountain Arsenal, 10 miles northeast of Denver, Colorado, exemplifies a revolutionary concept in industrial waste disposal; however, this method is one that has been used by the oil industry for many years. This well has two major distinctions: it is the deepest well drilled in the Denver basin and it may provide a precedent for solving waste-disposal problems anticipated in the future industrial growth of the Denver area. The well was drilled on the east flank and near the axis of the Denver basin and penetrated Tertiary through pre-Pennsylvanian sedimentary rocks. Drilling was completed at a depth of 12,041 feet in Precambrian gneiss. The sedimentary rocks from Tertiary through Pennsylvanian are in normal sequence that shows only minor variations in thickness and lithology from that of adjacent areas. The occurrence in this part of the Denver basin of pre-Pennsylvanian sedimentary rocks, possibly Ordovician in age, was unexpected and may shed valuable light on the paleogeography of the Denver area. Lost circulation was a major drilling problem in the Paleozoic rocks and in the Precambrian gneiss. Slow penetration rates resulting from the induration of the Paleozoic sediments necessitated the use of special hard-formation drilling bits. Core information shows that the Permian and Pennsylvanian strata are fractured and have a rock matrix of low porosity and

permeability. Drill-stem tests indicate that the Paleozoic sediments contain low-pressure reservoirs.—Author's abstract.

Descriptors: Injection wells, Colorado, chemical wastes, construction, operation and maintenance.

Scott, Verne H. *See* Esmaili, Houshang. 0140.

Sealand, O. M. *See* Boegly, W. J., Jr. 0600.

Sealand, O. M. *See* Jacobs, D. G. 0554.

Sealand, O. M. *See* Jacobs, D. G. 0697.

Selby, J. M *See* Bowen, B. M., Jr. 0104.

0363 **Selm, R. P.; Hulse, B. T.**
1960. Deep well disposal of industrial wastes, *in* Industrial Waste Conference, 14th, Lafayette, Ind., 1959, Proc.: Purdue Univ. Eng. Ext. Ser. 104 (Purdue Univ. Eng. Bull., v. 44, no. 5), p. 566-586. [Also published in Chem. Eng. Prog., v. 56, no. 5, p. 138, 140, 142, 144; 1960.]

Deep wells can be very expensive disposal facilities. The costs depend upon the nature of pretreatment required, depth of the hole, corrosivity of the waste, state regulations, nature of the formation, and many other factors. Deep well disposal will not ordinarily compete with surface disposal processes, chemical or biological, unless high total dissolved salts concentrations are present. A very rough rule would be that a single well installed should be able to dispose of 500 million gallons of waste to be on an equal first cost basis with a biological or chemical treatment facility. In some cases, the waste may require more extensive chemical treatment for injection than may be required for surface disposal. Compatibility treatment to prevent Class 1 precipitates is seldom required of wastes for surface disposal, and such treatment can cause injection to be considerably more costly for some waste disposal projects. Waste disposal wells normally cost between $50,000 and $250,000 for completion of each wellhead. The average flow capacity to be maintained for a 4-inch well string receiving conditioned water should be estimated at about 200 gpm (286 bbl/hr), although these figures depend on so many factors that they are little more than a guide. Certainly the old rule that every waste should be treated at the process first should be investigated before deep well disposal. The presence of intolerable amounts of dissolved salts is almost mandatory before deep well disposal is definitely more economic than surface disposal techniques.—Authors' summary.

Descriptors: Injection wells, economics, design criteria, industrial wastes.

Sexton, R. C. *See* de Laguna, Wallace. 0118.

Sexton, R. C. *See* de Laguna, Wallace. 0637.

Shaikh, M. U. *See* Jacobs, D. G. 0695.

Shamin, V. S. *See* Mal'tsev, E. D. 0685.

0365 **Shamir, Uri Y.; Harleman, D. R. F.**
1967. Numerical solutions for dispersion in porous mediums: Water Resources Research, v. 3, no. 2, p. 557-581.

A numerical method is presented for the solution of problems of dispersion in steady three-dimensional potential flow fields in porous mediums, in which the miscible fluids have the same density and viscosity. The method is developed and tested for two-dimensional problems, and the extension to three dimensions is presented. Efficiency of the numerical scheme and its generality are emphasized. It is shown to be independent of the geometry of the flow field. The computer program for carrying out the computations as described is tested with simple problems for which exact or approximate analytical solutions exist. It is also used to obtain solutions to a few problems for which no other solution is known.—AWRA 08-0058.

Descriptors: Dispersion, porous media, steady flow, numerical analysis.

0366 **Shamir, Uri Y.; Harleman, D. R. F.**
1967. Dispersion in layered porous media: Am. Soc. Civil Engineers Proc. Paper 5445, Jour. Hydraulics Div., v. 93, no. HY 5, p. 237-260.

Analytical solutions have been obtained to two problems of dispersion in a layered porous medium. The solution for longitudinal dispersion in flow perpendicular to the layers is given in terms of an integral, which has to be evaluated numerically for each layer. The solution for lateral dispersion in flow along the layers is in a closed form. Experiments were conducted to verify the theoretical results.—AWRA 08-0092.

Descriptors: Dispersion, hydrodynamics, theoretical analysis, porous media.

0604 **Shannon, E. S.**
1968. Underground disposal of activated sludge: Water Pollution Control Federation Jour., v. 40, no. 12, p. 2059-2061.

Efforts are being directed toward removal of organic contaminants from liquid wastes so that these treated wastes can reenter natural watercourses with a minimum of effect on the subsequent beneficial uses of the receiving waters. One of the most widely used systems for removing organics from aqueous solutions is the activated sludge process, but the disposition of the resulting excess activated sludge is one of the most complex problems facing sanitary engineers today. A promising development of industrial pollution control is that of deep-well disposal of excess activated sludge. Generally, where the location permits the deep-well method will easily assure the most economical solution provided that the volume in a given situation is amenable to the subsurface disposal potential. Another advantage of the deep-well method is that it provides a complete and final solution to the problem of disposal of activated sludge. The Dow Chemical Company has for many years used the well technique to dispose of activated sludge at the Midland, Mich. plant. The well method was first used occasionally for getting rid of unmarketable byproduct chemicals. Later it was found that brines from which bromine and other constituents had been stripped could be returned advantageously to the producing formation. The system used at Midland should remain useful for many years to come.

Descriptors: Waste disposal, injection wells, activated sludge, Michigan, limestones.

0367 **Shannon, R. L.**
1950. Radioactive waste disposal–A bibliography of unclassified literature: U.S. Atomic Energy Comm. Div. Tech. Inf. [Rept.] TID-375, 8 p.

A bibliography of various processes and methods of radioactive waste disposal has been compiled.–NSA 04-06514.

Descriptors: Radioactive waste disposal, bibliographies.

0459 **Sheldrick, Michael G.**
1969. Deep-well disposal–Are safeguards being ignored?: Chem. Eng., v. 76, no. 7, p. 74-76, 78.

Deep-well disposal has caught many states without proper laws. Critics say that deep-well disposal, though potentially a useful tool in pollution control, has been misapplied and that materials are being disposed of without adequate understanding of what will happen to them once they are underground. It is claimed that deep-well disposers show little concern for potential underground resources, and that widely varying state regulations generally do not provide adequate protection for ground-water supplies. Though there have actually been few failures of deep wells, there has been much criticism of the geologic criteria on which the feasibility and safety of the wells depend. For example, some U.S.G.S. geologists suggest that the hydrodynamics of underground formations are not understood enough to permit injection as it has been practiced to date. Still another point of controversy is how to keep track of fluids once they have been injected.–Tulsa Univ., Inf. Services Dept.

Descriptors: Waste water disposal, deep wells, water pollution control, legal aspects, hydrogeology, hydrodynamics.

Sherzhukov, B. S. *See* Verigin, N. N. 0411.

0369 **Shindala, Adnan.**
1968. Treatment and disposal of radioactive wastes: Water and Sewage Works, v. 115, 1968 Reference Number, p. R210-R212, Nov. 29.

Radioactive wastes may be treated and disposed of by concentration and storage, dilution and dispersion, and storage for in situ decay. Liquid wastes must be fixed in inert solids to prevent contamination of water. They may be made into concrete, dissolved in nonleachable glass, calcined in aluminum nitrate, adsorbed on clay, and fused into ceramic glaze. The most commonly used process is fixation in concrete and burial. Ion exchange extraction and evaporation are used for radioactive waste concentration for more efficient handling. Deep well injection allows very long-term detention while radioactivity decays. Hydraulic fracturing allows injection into otherwise impermeable rocks such as shale, and cavities may be dissolved in salt beds for waste storage. Several examples of radioactive waste disposal systems now in operation are briefly described.–W69-04229.

Descriptors: Radioactive waste disposal, adsorption, burning, injection wells, underground storage, dispersion.

0797 **Shoeneck, W. E.**
1945. Injection of water into underground reservoirs in Michigan: Am. Petroleum Inst. Drilling and Production Practice, 1945, p. 95-116.

Water injection in Michigan has been solely for the purpose of disposal. In excess of

90 percent of the oil field water produced has been returned underground in recent years. Disposal wells are of three types: wells which inject water into the annular space between casing strings, oil and gas wells converted to water disposal wells, and those dug specifically for water injection. There is no record of any kind of water treatment in disposal plants. Corrosion of equipment occurs, and injection wells become plugged, but it is considered cheaper to treat wells after they become contaminated than to install expensive water-treating equipment. Most treatment or repair methods used in Michigan are acid treatment, application of pressure, fresh water injection, and lye-solution injection. Injection characteristics of each of the seven different formations employed for disposal are included, as well as detailed statistics on injection wells by years and by formations.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, Michigan, injection wells, geohydrologic units, data collections.

0370 **Short, E. H., Jr.**
1946. Latest improvements incorporated into Conroe salt-water disposal plant: Oil and Gas Jour., v. 44, no. 36, p. 95, 97-98.

A salt-water-disposal system, recently completed in the Conroe field, Montgomery County, Tex., which utilizes in its design all of the most recently proven engineering practices pertaining to salt-water disposal, is described. The plant is an open system and handles water from 25 tank batteries. In this type of system, salt water is collected at the plant, exposed to the air, treated, and injected into a disposal well. A special feature of the project is the use of an oil skimmer at each tank battery as an added precaution to the escape of oil to the gravity lines, thus preventing extra trouble at the disposal plant. This skimmer, consisting of a 100-barrel redwood tank 12 ft. in height, is equipped with a siphon.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, Texas, injection wells, design data, waste water treatment.

Shuter, Eugene. *See* Jones, Paul H. 0556.

Simmons, E. J. *See* Reck, C. W. 0479.

0473 **Simon, Ruth B.**
1968. The Denver earthquakes, 1962-1967: Earthquake Notes, v. 39, nos. 1-2, p. 37-40.

Studies of the Denver-Derby area earthquakes, their numbers and magnitudes, azimuthal distribution, and possible fault mechanism continues at the Colorado School of Mines. A summary of recent data is presented.–*from* Author's introduction, Geophys. Abs. 264-094.

Descriptors: Earthquakes, Colorado, faults (geology).

Simon, Ruth B. *See* Major, Maurice W. 0320.

0798 **Simons, H. F.**
1941. Salt water disposal plant in Illinois field: Oil and Gas Jour., v. 39, no. 34, p. 32-33.

To dispose of about 6,000 bbl./day of water in the Noble field, Richland Co., Ill., the Pure Oil Co. uses a closed system which consists mainly of the treating equipment at the leases (a manifold and 2 separators, heaters, and air-tight settling tanks under 2 to 4 oz./sq. in. pressure), gathering lines, and the disposal plant where the water is filtered before injection. An adjustable U-turn made of 2-1/2 in. tubing and a siphon breaker control the level of salt water in the tank and prevent the entry of air. The water in the disposal well, which requires a pressure of 550 lbs./sq. in. for injection of 5,500 bbl. of water into the Tar Spring sand, contains no iron and only a small amount of reducing compounds and bicarbonates, and has an average pH of 6.7. Photographs of the equipment and an engineering diagram of the surge tanks, filters, and other equipment used on the disposal project are given.—Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, Illinois, equipment, injection, design data, engineering structures, geologic formations.

0799 **Simons, H. F.**
1943. East Texas salt-water disposal project may set pattern for future: Oil and Gas Jour., v. 41, no. 39, p. 38-41.

The East Texas Salt-Water Disposal Co., capitalized for $2,000,000, has been formed by the 249 companies and operators in the East Texas field for operation of the cooperative project of returning the salt water produced from the Woodbine formation back to the same formation. The injection pays for itself from the bonus permitted by the Texas Railroad Commission of 1 bbl. of oil for each 50 bbl. of salt water injected. At the same time it maintains the natural water drive.—Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, Texas, injection, operations.

Simpson, E. *See* Souffriau, J. 0696.

0372 **Siple, George E.**
1964. Geohydrology of storage of radioactive waste in crystalline rocks at the AEC Savannah River plant, South Carolina, *in* Geological Survey Research 1964, Chapter C: U.S. Geol. Survey Prof. Paper 501-C, p. C180-C184.

Geologic, hydrologic, and water-quality studies indicate two distinct aquifer systems at the Savannah River plant: one in crystalline basement rock, and the other in the overlying 900 ft sequence of sedimentary strata. A confining layer of saprolite separates the two systems, preventing significant exchange of water between them and retarding circulation within the crystalline rocks. Safe storage of radioactive wastes in sound crystalline rocks appears feasible.—Author's abstract.

Descriptors: South Carolina, hydrogeology, radioactive waste disposal, groundwater, aquifers, crystalline rocks.

0373 **Skibitzke, H. E.**
1961. Temperature rise within radioactive wastes injected into deep formations: U.S. Geol. Survey Prof. Paper 368-A, 8 p.

The data and method of analysis presented here provide for an approximate determination of expected temperature rises. They show that, in general, when large masses of liquid waste are injected into an aquifer through wells, heat conduction is not very significant, and as an approximation, the temperature rise within the aquifer, since

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injection began, is equal to the total heat generated in a unit volume of aquifer divided by the product of the specific gravity of the aquifer and contained waste and its heat capacity. The generalizations outlined here should lead to an understanding of the relative importance of heat storage as compared to thermal conduction away from the region.—Author's abstract.

Descriptors: Radioactive wastes, thermal properties, injection, heat flow.

0466 **Slagle, K. A.; Stogner, J. M.**
1969. Oil fields yield new deep-well disposal technique: Water and Sewage Works, v. 116, no. 6, p. 238-244.

The predominant practice of injecting liquid wastes into permeable or naturally fractured subsurface strata is not the only method for the disposal of pollutants in deep wells. Utilizing other oil field operations and other modifications may eliminate some common objections to this procedure—lack of suitable formations, expensive pre-injection equipment and treatment, and production of a secondary waste presenting in itself a disposal problem.—Authors' summary.

Descriptors: Injection, deep wells, liquid wastes, water pollution, fractures (geology).

0108 **Slansky, C. M.; Buckham, J. A.**
1969. Ultimate management of radioactive liquid wastes: Chem. Eng. Prog., Symposium Ser., v. 65, no. 97, p. 26-31.

Ultimate disposal of high-level radioactive wastes may involve nuclear transmutation to inert isotopes or extreme isolation such as transmission to the sun, storage in deep reservoirs produced by nuclear explosives, or in the ocean depths. These approaches are discussed along with the accompanying desirability of interim storage as retrievable solids with a minimum of additives.—Tulsa Univ., Inf. Services Dept.

Descriptors: Radioactive waste disposal, methodology, waste storage.

0438 **Smirnov, A. S.**
1957. Nadezhnyi sposob ochistki stochnykh promyslovykh vod [A reliable method for purifying the waste waters in oil fields]: Neftyanoye Khozyaystvo [Russia], v. 35, no. 7, p. 66-67. [In Russian.]

The waste water from an oil dehydrating unit in the Bavlyneft field [Russia] is dumped into an underground reservoir and then pumped alternately into one of a pair of settling tanks while settling takes place in the other tank. After settling for 10-15 hours, the water layer is discharged into an input well purposely drilled to a horizon which was known to have caused catastrophic losses of mud circulation. The oil and the intermediate emulsified layer are returned periodically from the tank to the dehydrating unit.—Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, foreign countries, injection wells, waste water treatment.

0800 **Smith, E. R.; Olson, E. A.**
1959. Waste water disposal by subsurface injection—California oil fields: Dallas, Tex., Am. Petroleum Inst. Div. Production, Paper No. 801-35F, 9 p.

Primarily this paper presents factual data pertaining to disposal well and injection sands, surface facilities, chemical treatment, injection history, remedial operations, cost data (both original investment and operating), and water analysis of 44 wells and

42 systems in 5 areas of the state. The more obvious conclusions of these data are briefly discussed and tabulated, together with an estimated minimum expenditure for investment and disposal costs to date to the operators of these systems.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, California, injection wells, facilities, waste water treatment, operating costs.

0801 **Smith, L. E.**
1936. Disposal of salt water in oil fields: Natl. Petroleum News, v. 28, no. 53, p. 50-51.

The chief danger of bills introduced in Congress on the disposal of waste from oil fields is that they do not differentiate between oil industry wastes and those contributed by other industries and by municipalities through sewage disposal. Disposal of waste oil is made by burning, but the principal problem is the disposal of salt water. It is usually allowed to escape through natural drainage, and if its disposal in this way were prohibited, it would mean that a great many wells would have to stop producing. Attempts made to return the salt water to the sand from which it came have met with varying degrees of success. In some cases it contaminates fresh water streams and in other cases the precipitation of iron compounds and salts in solution seals the porous formation and prevents the salt water from settling.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, legislation, water pollution control, effects.

0443 **Smith, R. D.**
1969. Burying your pickle liquor disposal problem: Civil Eng., v. 39, no. 11, p. 37-38.

Pickle liquor is an acid, used to remove iron oxide mill scale from hot rolled steel. Being very corrosive, it is difficult to dispose of after use. At Armco Steel's new Middletown, Ohio, mill, it is being pumped through deep wells into the Mount Simon Sandstone 2,950 ft down, between the basement rock and an impervious caprock layer which prevents the waste from contaminating the ground water above. Water pumping tests through the 9-5/8 in. casing showed that wellhead pressures in well 1 ranged from 600 psig (pounds per square in gage) at 200 gallons per minute to 790 psig at 740 gpm. In well 2, water pumping tests required pressures ranging from 460 psig at 100 gpm to 595 psig at 300 gpm. The new pickling operation at Armco's Middletown plant will generate up to 100 gpm of spent liquor, which is drained into collection tanks with up to 20 min retention capacity. The liquor is pumped 1,300 ft via an overhead transmission line to storage tanks with 24-hour capacity. Before injection into the disposal wells, diatomaceous earth precoat filters are used to remove essentially all suspended solids. An in-line turbidimeter automatically diverts liquor with detectable solids in order to eliminate plugging of the sandstone pores. Periodically, service water is pumped into the well to flush out the corrosive liquor. Biocide is added to the water to inhibit biological growths in the receiving formation.

Descriptors: Industrial wastes, acids, injection wells, operation and maintenance, waste treatment, geologic formations, Ohio.

Smith, R. V. *See* Joers, J. C. 0216.

0535 Smith, R. W.; Wen, W. W.
1966. Adsorption of cationic and anionic surfactants on kaolinite, *in* Mining Symposium, 27th Ann., and AIME, Minnesota Sec., 39th Ann. Mtg., Duluth, 1966: Minneapolis, Minn., Univ. Minnesota, Nolte Center Continuing Education, p. 193-196.

Kaolinite of high grade from Lewistown, Mont., was obtained for adsorption tests. It was found that both anionic and cationic surfactants appear to adsorb strongly on kaolinite. Cationic adsorption increases with increasing pH surfactant concentration being limited by the cation exchange of the clay; for the clay studied the maximum appears to be 3 mequiv per 100 gm kaolinite at an equilibrium pH 9.5. Anionic surfactant adsorption increases with decreasing pH although there were discrepancies at near neutrality which may have resulted from heavy metal activation. The maximum anion exchange capacity for the kaolinite studied at low equilibrium pH values appears rather high, greater than 40 mequiv per 100 gm clay; however, the surfactant adsorption at near neutrality is much less than this.–NAB.

Descriptors: Geochemistry, ion exchange, adsorption, surfactants, waste disposal, clay minerals.

0536 Smith, Richard E.
1967. Petrographic properties influencing the reservoir potential of the Gatesburg Formation based on studies near State College and Tyrone, Pennsylvania: Producers Monthly, v. 31, no. 6, p. 18-23.

The Cambrian Gatesburg Formation has potential as a reservoir for untapped deep oil and gas, an important aquifer, and a reservoir for deep disposal of industrial wastes. Thickness ranges from 1,600 feet near Tyrone to 2,000 feet in central Pennsylvania. Deposition was cyclic, black alternating with buff dolomites with interbedded quartzite. Samples were collected from a section near Tyrone and from cores in the State College area. Conclusions are that intergranular porosity and permeability of the sandy dolomites are low, porosity increases as size of dolomite grains decreases and as sorting of quartz grains improves, packing is the best single predictor of porosity above 50-60 percent insoluble residue, and vugs increase porosity only slightly. Results obtained are believed to be true at depth, and thus the potential of sandy beds can be estimated by measuring the insoluble residue and degree of packing.–NAB.

Descriptors: Pennsylvania, dolomite, sedimentary rocks, waste disposal, deep wells, geologic formations.

0499 Sniegocki, R. T.
1959. Plugging by air entrapment in artificial recharge tests: Water Well Jour., v. 13, no. 6, p. 17-18, 43-44.

During experiments to determine whether untreated surface water could be used successfully to recharge the alluvial deposits of the Grand Prairie region of Arkansas, air entrainment resulting from the equipment arrangement was the most serious cause of plugging. Special redevelopment procedures, involving the use of sodium hexametaphosphate and vigorous surging and pumping, were necessary to restore the specific capacity of the well.–WSP 1990.

Descriptors: Groundwater recharge, Arkansas, air entrainment, injection wells, water treatment, hydrodynamics.

0500 Sniegocki, R. T.
1960. Ground-water recharge and conservation–Effects of viscosity and temperature: Am. Water Works Assoc. Jour., v. 52, no. 12, p. 1487-1490.

Several recharge tests through wells were described. Two tests were made in which effects of water viscosity variation due to different water temperatures were observed. One test was made with water at an average temperature of 66°F, and the other, at 43°F. Native ground-water temperature was 65°F. Recharge specific capacity was 9.4 gpm per foot higher for the warmer water; computed temperature corrections applied to permeability would predict a difference of 8.7 gpm per foot. It was indicated that differences in recharge specific capacity and ground-water mound buildup during the two tests were caused by changes in the water viscosity. The problems arising from a ground-water temperature reduction were discussed.–WSP 1990.

Descriptors: Groundwater recharge, injection wells, Arkansas, testing, hydrodynamics, viscosity, water temperature.

0515 Sniegocki, R. T.
1963. Geochemical aspects of artificial recharge in the Grand Prairie region, Arkansas: U.S. Geol. Survey Water-Supply Paper 1615-E. 41 p.

Chemical changes in the injected water and native ground water during artificial recharge through a well have an important bearing on the success or failure of recharge-well operation. In this study, the principal chemical changes observed that may cause clogging of the recharge well and aquifer were a change in calcium carbonate saturation of the injected and native water whereby the calcium carbonate precipitated, a precipitation of iron when reducing and oxidizing waters are mixed, an ion exchange and clay dispersion, and changes in water stability caused by water treatment.–*from* Author's abstract, WSP 1990.

Descriptors: Injection wells, Arkansas, groundwater recharge, geochemistry, radioactive waste disposal.

0379 Snow, David T.
1968. Hydraulic characteristics of fractured metamorphic rocks of Front Range and implications to the Rocky Mountain Arsenal well, *in* Geophysical and geological studies of the relationships between the Denver earthquakes and the Rocky Mountain Arsenal well, Pt. A: Colorado School Mines Quart., v. 63, no. 1, p. 167-199.

Hydraulic and geometrical properties of fractured metamorphic rocks of the Front Range of Colorado are determined from damsite pressure-injection tests and records of domestic water wells. Since these same rocks beneath the Denver basin comprise the reservoir into which fluid wastes have been injected at the Rocky Mountain Arsenal well, the Front Range properties are applicable to studies of the Arsenal well injection performance and the possible earthquake response. Fracture permeability may be of like origin in both cases: faulting, weathering and erosional stress release beneath a surface of erosion. At damsites in the Front Range metamorphic rocks, fracture spacing is about 5 to 10 ft. near the ground surface, increasing to about 15 to 35 ft. at the 200 ft. level. Water wells intercept even fewer significant fractures. Openings close from about 200 microns to about 70 microns between the near-surface and 200-ft. depth and porosities decrease from about 0.04% to 0.001%. The logarithm of permeability decreases linearly with the logarithm of depth. The fractured aquifer is a thin skin draped over the terrane. Test data suggest that the aquifer is bounded by vanishing permeability at about 200 ft., though open fault zones may extend to greater depths. Different lithologic units have different transmissibilities. These exceed the transmissibilities deducted from Arsenal well flow, so the pre-Pennsylvanian soils and sediments resting on the gneiss at the well site may effectively confine flow to the fractured basement.–W69-07412.

Descriptors: Earthquakes, injection wells, waste disposal, Colorado, hydraulic properties, geohydrologic units.

0380 **Snow, David T.**

1968. Fracture deformation and changes of permeability and storage upon changes of fluid pressure, *in* Geophysical and geological studies of the relationships between the Denver earthquakes and the Rocky Mountain Arsenal well, Pt. A: Colorado School Mines Quart., v. 63, no. 1, p. 201-244.

Fractures are nonrigid fluid conductors of such small size that changes of the openings with changes of pressure result in appreciable changes of permeability and account for the major portion of storage. Plane vertical strain is assumed in the derivation of an equation of transient flow, but in radial cases, such as the Rocky Mountain Arsenal well injection, the distributions of stress, permeability, and hydraulic potential are interrelated. A deformability coefficient for fractures in the Front Range metamorphic rocks at Bergen Park, Colorado, is deduced from strain measurements near a water-supply well which drains the fracture system. Effective stress changes consequent to fluid-pressure changes may have significance to the question of the earthquake mechanism, especially if geological evidence, such as faulting, points to a critical state of tectonic stress. From the time of latest faulting in the Denver basin, criticality probably may have been maintained by erosional release of confinement, suggesting that the fractured basement is prone to failure upon injection of fluids.–W69-07413.

Descriptors: Earthquakes, injection wells, waste disposal, Colorado, hydrostatic pressure, fractures (geology).

0841 **Sobolev, I. A.; Khomchik, L. M.; Bazhenov, Yu. M.; and others.**

1967. Opytnoye zakhoroneniye radioaktivnykh otkhodov nizkogo urovnya aktivnosti v glinistykh gruntakh na Moskovskoy Stantsii (SM-93/4) [The experimental disposal of low-level radioactive wastes in clay soil at the Moscow Disposal Center], *in* Disposal of radioactive wastes into the ground–International Atomic Energy Agency and European Nuclear Energy Agency, Vienna, 1967, Symposium Proc.: Vienna, Internat. Atomic Energy Agency (STI/PUB/156), p. 37-47. [In Russian with English abs.]

Studying the possibilities of burying radioactive waste directly in the soil is of great interest, since a successful solution of this problem would make it unnecessary to build expensive watertight burial chambers. With this means of waste disposal, however, there is serious danger of the radioisotopes migrating from the chamber into the surrounding soil and, what is even more serious, into water-bearing formations. Isotope migration is determined largely by such soil characteristics as the rate of filtration of aqueous solutions, the sorption capacity and the rate of advance of the saturation front. The paper gives data obtained from laboratory determinations of the above mentioned properties of the clay soils at one of the Moscow Disposal Centre's disposal areas, together with the results of the experimental burial of small quantities of low-level wastes, the wastes in question being in solid and liquid form with a specific activity of 10^{-6}-10^{-5} Ci/l. The major part of the activity in the wastes was due to cesium-137 and strontium-90. Cemented and noncemented solid wastes were studied, both radioactive and nonradioactive cement solutions being used for cementation. The paper gives data obtained from a survey of radioisotope migration, carried out by taking soil samples in the vicinity of the experimental burial chambers. Sampling was carried out a year after burial. On the basis of the results of an analysis of the samples, the authors have calculated the rate of movement of the saturation front in loam soils and their sorption capacity.–Authors' abstract.

Descriptors: Radioactive waste disposal, water pollution control, hydrogeology, laboratory tests, dispersion, ion exchange, foreign countries.

0696 **Souffriau, J.; Simpson, E.; Baetsle, L. H.; de Jonghe, P.**
1962. The copper-rod method for measuring ground-water flow, pt. 2 *of* Investigations on the movement of radioactive substances in the ground, *in* Morgan, J. M., Jr., Jamison, D. K., Stevenson, J. D., eds., Ground disposal of radioactive wastes conference, 2d., Atomic Energy of Canada Limited and U.S. Atomic Energy Comm. Div. Reactor Devel., Chalk River, Canada, 1961, Proc., Book 1: U.S. Atomic Energy Comm. Div. Tech. Inf. [Rept.] TID-7628, p. 155-165.

Preliminary tests showed the possibility of measuring the ground-water flow using a chemisorption reaction on silver-plated copper rods after injecting I^{131} as a ground-water tracer. Laboratory tests with the I^{131}-copper-rod system indicated that a reproducible relation exists between the activity in solution and that fixed on the metallic surface (copper, silver-plated copper, or mercury-coated copper). Two preliminary field tests are described in which silver-plated copper rings were fixed on a steel bar and inserted in the ground after injection of, respectively, 1 mc I^{131} in test n° 1 and 5 mc I^{131} in test n° 2. In both tests, the I^{131} solutions were introduced after freezing. Results indicate the copper-rod method is convenient for detailed measurement of the ground-water flow paths and dispersion in shallow aquifers. However, some technical aspects of the method have to be elaborated further with regard to mechanical strength of the rods and possible vertical movement of the injected source. Furthermore, it is envisaged to extend the use of the method by studying other tracing systems which could react with a metallic surface. Presently the possibility of using a tracer such as $Co(CN)_6^{4-}$ is under consideration.—Authors' abstract, NSA 16-25046.

Descriptors: Radioisotopes, injection, groundwater movement, laboratory tests, tracers.

Souffriau, J. *See* Baetsle, L. H. 0040.

Souffriau, J. *See* Baetsle, L. H. 0056.

Souffriau, J. *See* Baetsle, L. H. 0822.

0381 **Spalding, C. W.; Halko, D. L.; Carpenter, H. S., Jr.**
1965. Deep-well disposal of spent pulping liquors: TAPPI [Tech. Assoc. Pulp and Paper Industries], v. 48, no. 5, p. 68A-71A.

Deep well disposal of spent pulping liquors involves injecting suspensoid-free liquid wastes into deep, underground, permeable, brine-bearing geological formations by means of deep wells in a manner such that no underground commercially valuable materials become contaminated and such that the wastes remain in the injection formation. A disposal well completed in the limestone of the Bass Islands Dolomite at 1,600-1,700 ft was found to accept fluids at practical injection pressures. The well was equipped with injection pumps and filtration equipment. Injection of over 55 million gallons of fluid was possible without appreciable injection pressure increases. A second well was completed in the Bass Islands Dolomite at a deeper formation (5,900 ft).

Descriptors: Injection wells, waste water disposal, pulp wastes, sulfite liquors, geologic formations, limestones, Pennsylvania.

Spalding, C. W. *See* Brown, R. W. 0090.

Spencer, Charles W. *See* Peterson, James A. 0316.

0842 **Spicyn, W. J.**
1957. Problem odpadow promieniotworczych w technice wspolczesnej [Problems of radioactive wastes in modern technology]: Nukleonika [Warsaw], v. 2, no. 3, p. 451-464. [In Polish.]

Methods for separation and recovery of Cs^{137} and Sr^{90} from mixtures of fission products and the adsorptive properties of soil as a medium for waste disposal are discussed.–Translated from author's abstract, NSA 12-04784.

Descriptors: Radioactive waste disposal, environmental engineering, cesium, strontium radioisotopes, adsorption, soils.

0383 **Spitsyn, V. I.; Pimenov, M. K.; Yudin, F. P.**
1967. Scientific prerequisites for utilizing deep-lying formations for burying liquid radioactive wastes (SM-93/43), *in* Disposal of radioactive wastes into the ground–International Atomic Energy Agency and European Nuclear Energy Agency, Vienna, 1967, Symposium Proc.: Vienna, Internat. Atomic Energy Agency (STI/PUB/156), p. 563-576.

The Soviet Union is pursuing several lines of research on disposal of liquid radioactive wastes, including the injection of wastes into deep geological formations. The use of porous water-bearing strata in the earth's crust far enough below the surface and isolated above and below by thick strata of species that are impermeable to water is considered. The main features and methods of hydrogeological surveying and the various research projects that are necessary to ensure health and radiation safety are described, and a number of questions relating to the physico-chemical processes which occur in absorbing strata when radioactive waste is injected into them are considered. The processes discussed include migration, radiolysis, evolution of gas and heating of the surrounding medium. It is shown that, under particular geological conditions, deep burial of radioactive waste affords a promising means of disposal that ensures health and radiation safety and is at the same time economically advantageous. It is also demonstrated that the waste is distributed over a limited area of the stratum, which involves no serious changes in the hydrogeological pattern of the region and so does not prevent the formation from being used for other purposes.–W69-02692.

Descriptors: Injection wells, radioactive waste disposal, safety, sorption, migration, effects, foreign, countries.

0843 **Spitsyn, V. I.; Balukova, V. D.**
1967. Investigation of sorption and migration of radioactive isotopes in soils and rocks of various compositions (SM-93/13), *in* Disposal of radioactive wastes into the ground–International Atomic Energy Agency and European Nuclear Energy Agency, Vienna, 1967, Symposium Proc.: Vienna, Internat. Atomic Energy Agency (STI/PUB/156), p. 169-177.

As a rule, the sorption properties of soil and rock are assessed by investigating a number of competing physico-chemical factors which determine the state of the sorbent itself, of the radioisotope and of the medium in which it is present, and by observing the changes which may occur when liquids interact with the solid phase. The paper examines the results of investigations of the sorption and migration of individual radioisotopes in soils, rocks and minerals of various geological formations.

The authors give data on the effect of the initial concentration of isotope and the accompanying macrocomponents of the liquid phase, together with the results of a study of sorption kinetics, static and dynamic capacity and other factors. They describe the basic mechanisms which appear to govern the sorption of the individual microcomponents contained in low-level waste. Finally, they discuss methods of conducting laboratory and field studies for assessing radioisotope migration.–*from* Authors' abstract.

Descriptors: Radioisotopes, migration, sorption geologic formations, soils, foreign countries.

0844 **Spitsyn, V. I.; Balukova, V. D.; Bagretsov, V. F.**
1968. Physicochemical conditions of underground disposal of radioactive wastes: Soviet Atomic Energy, v. 24, no. 2, p. 160-163. [Translated from Atomnaya Energiya, v. 24, no. 2, p. 133-136, 1968.]

The basic complex of physical-chemical studies necessary for evaluation of the underground burial of liquid radioactive wastes was determined. The conditions for the burial of the deactivated wastes at NIIAR [Atomic Reactor Research Institute] were described. Rational technological procedures, guaranteeing the stability of the liquid phase during combination of the wastes with subterranean media, were established. The general conditions for the sorption of radioactive isotopes during burial in subterranean water in strata with high-mineral water content were examined.–*from* Authors' summary, NSA 23-33625.

Descriptors: Radioactive waste disposal, landfills, injection, hydrodynamics, chemical reactions, sorption, foreign counties.

0384 **Stahl, C. D.**
1962. Compatibility of interstitial and injection waters: Producers Monthly, v. 26, no. 11, p. 14-15.

A brief literature review is given concerning laboratory findings on the chemical character of several interstitial waters and the compatibility of injection waters with formation fluids. Some investigators have found that permeability reductions of 15 to 70 percent occurred from simultaneous injection of incompatible waters. Quality of the water to be injected should be tailored to that of the interstitial fluid for best results.

Descriptors: Injection wells, chemical reactions, water chemistry, brine disposal, effects.

Staner, P. *See* de Jonghe, P. 0636.

0142 **Stanonis, F. L.**
1969. Oil-field technology applied to subsurface disposal of industrial fluid wastes: Kentucky Geol. Survey Spec. Pub. 15, Ser. 10, p. 90-96.

Ever increasing liquid, solid, and gaseous wastes have underscored the necessity for seeking a better method of disposal than traditional outdoor dispersal into earth, water, and atmosphere. Subsurface injection offers the best possibility for disposing of large quantities of fluid wastes in most areas underlain by a wedge of sedimentary rocks more than 1,000 ft thick without contaminating surface facilities and resources. Moreover, qualified personnel and established techniques for formulating and implementing subsurface disposal systems are readily available within the petroleum industry. Essential considerations for any subsurface disposal system are: (1)

characteristics of the disposal or utility zone; (2) formation fluids; and (3) waste fluids. General conclusions have been drawn from experience with such systems: (1) each disposal problem must be evaluated separately; (2) selection of surface equipment for preinjection waste treatment is contingent on the characteristics of the disposal formation; (3) a buffer zone of water compatible with the injected waste can be created within the formation; (4) well-casing corrosion is a serious problem that must be dealt with; (5) a waste reservoir exposed to the atmosphere should be avoided, because it tends to promote harmful bacterial growth; and (6) standby disposal facilities.–Tulsa Univ., Inf. Services Dept.

Descriptors: Waste water disposal, injection, sedimentary rocks, design criteria, equipment.

0537 **Stead, Frank W.**
1964. Distribution in groundwater of radionuclides from underground nuclear explosions, *in* Engineering with nuclear explosives–Proceedings of Third Plowshare Symposium, April 1964: U.S. Atomic Energy Comm. Div. Tech. Inf. [Rept.] TID-7695, p. 127-138.

Underground nuclear explosions in the Plowshare program release and distribute radionuclides in the medium by direct explosive action, but the long-lived and biologically significant radionuclides later may enter into and move with ground water. No significant post-explosion movement of radionuclides has been demonstrated where adequate precautions have been taken as in the Nevada test site and Project Gnome area, but radioactive waste disposal operations have shown transport of radionuclides for considerable distances by ground water. Each proposed site must be evaluated individually for prediction of possible radionuclide contamination of ground water and to insure the absence of hydrologic and geologic conditions favorable to such contamination.–NAB.

Descriptors: Groundwater, water pollution, radioisotopes, nuclear explosions, migration patterns, mass transfer.

Stead, Frederick L. *See* McCann, Thomas P. 0265.

0803 **Stearns, G. M.**
1943. Disposal line cost comparison: Oil and Gas Jour., v. 42, no. 11, p. 47.

A cost comparison is made of methods to be used in handling the lease waste-water production from a central salt water pit to a disposal well. An example is given of a typical problem.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, injection wells, operating costs.

0143 **Stefanko, Robert.**
1970. Subsurface disposal of mine water–Paper presented at 98th Ann. Mtg., Am. Inst. Mining Metall. Petroleum Engineers, Washington, D.C., 1969: Soc. Mining Engineers Trans., v. 247, no. 1, p. 54-60.

The concept of disposing of liquid industrial wastes by deep-well injection is not a new one. Brines associated with crude oil long have been disposed of in this manner, with the additional benefit of aiding secondary oil recovery. More recently, with the expansion of nuclear energy, the lethal, highly radioactive wastes which are by-products of the fission process have created severe disposal problems. During the past 10 yr, a variety of industries have resorted to subsurface disposal. The list reveals wide

variations in injection rate, pumping pressure, cost, and waste disposition. Enactment of more restrictive clean water legislation in Pennsylvania recently had a great impact on the coal industry. Among its provisions was the reclassification of most mine water as industrial waste whose disposal is prohibited in any stream of the Commonwealth. This had the effect of accelerating research in a variety of areas although treatment methods still retain primary interest. When a feasibility study of deep-well disposal was proposed to the Pennsylvania Department of Mines and Mineral Industries, the Coal Research Board approved it. The efforts on this project are summarized.–Tulsa Univ., Inf. Services Dept.

Descriptors: Waste water disposal, injection wells, industrial wastes, pollution abatement, legal aspects, feasibility studies, Pennsylvania.

Stephens, J. R. *See* Marshall, G. E. 0261.

0804 **Stericker, William.**
1941. Prevention of corrosion of steel pipe lines by oil-well brines [abs.]–Paper presented at regular spring meeting of Southwestern District of American Petroleum Institute, Div. of Production, Shreveport, La., 1941: Oil and Gas Jour., v. 39, no. 42, p. 72, 74.

A 50% reduction in the number of leaks per month in a pipe line for oil-well-brine disposal has been obtained by the use of a silicate treat, consisting of 100 gal. of sodium silicate containing 8.9% sodium oxide and 28.7% silicon dioxide to each 1,000,000 gal. of salt water. These proportions are based upon preliminary tests indicating that under pipe-line conditions, 40 p.p.m. of soluble silica will give an 80% protection or better. The silicate (diluted 10 times to avoid precipitation) is added at the rate of 10.5 gal./hr. by means of a needle valve to the system comprising about 5 miles of 6-in. pipe and about 4-1/2 miles of 8-in. pipe, into which 10,500 gal./hr. of brine is pumped. It was observed that during the treat the old corrosion scale gradually disappeared, increasing the effective diameter of the pipe and reducing the pumping costs. Another effect observed was the fact that there was no precipitation of calcium and magnesium and that the brine became clear and free from suspended matter. In an attempt to explain the fact that the amount of silicate required for protection is so much smaller than that reported earlier (U. R. Evans, Jour. Soc. Chem. Industry Trans., v. 46, 1927), it is pointed out that in the earlier work the amount of surface is not specified, nor the type of silicate used, and that the tests were carried out with maximum aeration.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, injection, waste water treatment, chemical engineering.

Stevenson, J. D. *See* Morgan, J. M., Jr. 0666.

0538 **Stewart, J. W.; Callahan, J. T.; Carter, R. F.**
1964. Geologic and hydrologic investigation at the site of the Georgia Nuclear Laboratory, Dawson County, Georgia: U.S. Geol. Survey Bull. 1133-F, p. F1-F90.

This report describes the results of a study of the geology and ground-water resources and the hydrology of two sites within the Georgia Nuclear Laboratory area of the Lockheed Aircraft Corporation, near Dawsonville, Ga. The specific purpose of the study was to describe (1) the occurrence, rate and direction of movement, discharge, and recharge of the ground water, (2) the quantity and quality of water available, and (3) the effects of liquid waste disposal on the water table in the radiation effects facility and radiation effects laboratory sites.–NAB.

Descriptors: Georgia, water table, groundwater, hydrogeology, waste disposal, maps.

0539 Stewart, J. W.
1964. Infiltration and permeability of weathered crystalline rocks, Georgia Nuclear Laboratory, Dawson County, Georgia: U.S. Geol. Survey Bull. 1133-D, p. D1-D59.

An investigation was made in this area to determine the probable effect of discharging radioactive waste into a disposal pit in weathered crystalline rocks. The report describes the geology of the pit, the results of infiltration and aquifer tests, hydrologic properties of core samples, water tracer tests, and water-table contour maps and profiles.–NAB.

Descriptors: Georgia, hydrogeology, crystalline rocks, radioactive waste disposal, permeability.

Stewart, Ronald C. *See* Walker, William R. 0414.

0385 Stiff, H. A., Jr.; Davis, L. E.
1952. A method for predicting the tendency of oil field waters to deposit calcium carbonate: Jour. Petroleum Technology, v. 4, no. 9, p. 213-216. [Also published in Am. Inst. Mining Metall. Petroleum Engineers Trans., v. 195, Tech. Paper 3395, p. 213-216, 1952.]

Calcium carbonate scaling tendencies in brines have been evaluated by experimentally determining the K term in the Langelier equation. The calculated values are in good agreement with actual conditions. Its application to heat treater, producing wells and water flood and water disposal are described.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brines, scaling, calcium carbonate, chemical reactions.

Stogner, J. M. *See* Slagle, K. A. 0466.

0805 Stormont, D. H.
1941. East Texas salt-water injection plants: Oil and Gas Jour., v. 40, no. 22, p. 34-35.

A description of the various designs of salt-water injection plants by which 60,000 bbl./day of salt water is injected into the Woodbine sand in East Texas is given with charts and a table showing the trends in salt-water withdrawal and injection in this field. Most of the plants are of the open type, consisting of either gun barrels or skimming vats of some type to remove oil; aerators of various design; settling tanks of steel, wood or concrete, or open earth pits; and sand-gravel filters at the input well equipped with back-wash tanks.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, Texas, injection, engineering structures, design data.

0806 Stormont, D. H.
1941. Cost estimates for reinjecting salt water to the East Texas Woodbine Sand: Oil Weekly, v. 104, no. 2, p. 24, 26.

Cost estimates for reinjecting salt water into the East Texas Woodbine sand total $3,307,740, $3,067,169 and $2,770,873 for three plans which involve, respectively, (1) using present injection facilities, valued at $1,250,000 and drilling 28 new injection wells mostly outside the field; (2) using present facilities and drilling 37 new injection wells, mostly inside the field; and (3) leaving present injection facilities at their current rate of injection and providing facilities for the remaining injection requirements, involving the drilling of 39 new wells, mostly outside the field. The 46

injection systems now in operation handle about 72,500 bbl. of the field's 456,000 bbl. daily salt water production.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, Texas, injection wells, operating costs, facilities, geologic formations.

0807 **Stormont, D. H.**
1953. Automatic brine disposal plant small but efficient: Oil and Gas Jour., v. 51, no. 36, p. 114.

Sunray Oil Corp. has installed facilities to stabilize and purify the water-output of its Newhall-Potrero field [California] for reinjection since the brine cannot be dumped into surface sands in this agricultural district. A polyphosphate, a sulfonated lignin, and a bactericide and algicide are added to the brine and it is then filtered using a filter aid before reinjection.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, injection wells, facilities, waste water treatment, California.

0540 **Straub, Conrad P.**
1964. Discharge to the soil environment, chap. 5 *in* Low-level radioactive wastes–Their handling, treatment, and disposal: Washington, D. C., U.S. Atomic Energy Comm. Div. Tech. Inf., p. 103-128.

This chapter discusses the geological and hydrological factors that relate to the discharge of radioactive waste to the soil environment. Laboratory data and field experience gained from waste disposal operations at the major atomic energy installations in the United States are freely used to illustrate the principles involved in the movement or migration of radionuclides after release to the natural environment. Descriptions are given of the diverse geological and hydrological features indigenous to the areas being used for waste disposal, the retention capacities of the soils, and the methods being used to discharge and monitor the wastes in the subsurface environment.

Descriptors: Radioactive waste disposal, United States, soil environment, methodology, migration, radioisotopes, hydrogeology.

Street, Robert L. *See* Bruch, John C. 0006.

0845 **Struxness, E. G.; Morton, R. J.; Parker, F. L.**
1962. Radioactive waste disposal, *in* Health Physics Division annual progress report for period ending July 31,1962: U.S. Atomic Energy Comm. Oak Ridge Natl. Lab. [Rept.] ORNL-3347, p. 1-46.

It now seems likely that initial application of deep-well liquid injection techniques will be in the disposal of high-volume, low-level process waste water that will require containment for about 200 yr due to the presence of Sr^{90}. Studies on the exchange properties of Sr, Ca, Cs, and Ru with soils led to the conclusion that the restricted movement of radionuclides compared to water would make it possible to use a deep aquifer as a large ion exchange bed, rather than just as a storage basin. A study was made of the feasibility of disposing of liquid radioactive waste by mixing with cement, or some other hardening agent, and then injecting the slurry deep into bedded rock through a specially constructed well. The development and testing of suitable mixes are discussed and results are reported from a three-year field test. The feasibility of disposal of solidified high-level liquid wastes in salt formations was also investigated. Canned ETR fuel assemblies were used to simulate the solidified wastes in heat

generation and radioactivity. Laboratory studies were made on the effects of temperatures greater than 80°C on the physical properties of salt. Studies were continued on the fate of radioisotopes released to the Clinch River, the diluting capacity of the river system, and the long-term effects of radioactive contamination on the fluvial environment. A map of the Clinch River basin, showing location of sampling stations, is included. Data are included from an intensive study of sources of contamination and movement of radionuclides in the White Oak Creek drainage area. Studies were continued on ion exchange reactions of fission products with various minerals, with emphasis on the removal of Cs^{137} and Sr^{90} from waste solutions. A study was undertaken to evaluate the economics and hazards associated with alternative methods for ultimate disposal of highly radioactive liquid and solid wastes. Preliminary data are presented.—NSA 17-02785.

Descriptors: Radioactive waste disposal, underground storage, ion exchange, feasibility studies, laboratory tests, economics, Tennessee.

Struxness, E. G. *See* Boegly, W. J., Jr. 0624.

Struxness, E. G. *See* de Laguna, Wallace. 0118.

0388 **Subrahmanyan, K.; Bhaskaran, T. R.**
1950. The risk of pollution of ground water from borehole latrines: Indian [Calcutta] Med. Gaz., v. 85, p. 418-420, Sept.

The results of detailed experiments by several workers on the extent of pollution diffusing from borehole latrines are summarized in a table and plotted in a graph. The graph suggests that the extent of travel of pollution from a borehole (or a leaching cesspit) into the ground water seems to depend mainly on the velocity of flow of ground water. This velocity will depend largely on the mechanical structure of the soil. The finer the soil and the smaller its effective size, the greater will be the frictional resistance to flow of water. The velocity will depend also on the gradient of the water table. From the graph it appears as if the travel of bacterial pollution in subsoil water is not more than the distance covered by the ground water in 4-7 days. Hence the safe distance between a borehole latrine or leaching cesspit and a ground-water source may be taken to be the distance represented by about 8 days travel of the ground water. If and when the gelatinous membrane of defense is formed in the soil around the borehole there will be a mechanical barrier to arrest bacteria and the factor of safety will be increased.

Descriptors: Sewage disposal, water pollution sources, groundwater movement, diffusion, effects.

0856 **Sun, R. J.**
1969. Theoretical size of hydraulically induced horizontal fractures and corresponding surface uplift in an idealized medium: Jour. Geophys. Research, v. 74, no. 25, p. 5995-6011.

For the disposal of radioactive wastes by hydraulic fracturing and grout injection, it is considered essential that the induced fractures be nearly horizontal. Bottom-hole injection pressure in excess of overburden pressure has been recognized as one indication that fracturing is horizontal. The amount of uplift of the ground surface caused by the injection can be used as another indicator. For an impervious, homogeneous, isotropic medium, a mathematical model for calculating the amount of uplift of the ground surface, the maximum separation of the horizontally induced fracture at the injection well site, and the radius of extension of the fracture was developed from the basic formulas derived by I. N. Sneddon (1946) and A. E. Green

(1949). If the bottom-hole injection pressure is greater than the overburden pressure, and the observed uplift is nearly the same as the calculated uplift, the fracture orientation probably is nearly horizontal. Uplifts from 9 injections made at the Oak Ridge National Laboratory, Tennessee, from 1960 through 1965, have been used to test the validity of the mathematical model. The calculations agree reasonably well with the observed data.–Tulsa Univ., Inf. Services Dept.

Descriptors: Radioactive waste disposal, injection wells, fractures (geology), mathematical models, rock mechanics, Tennessee

Svec, Jan. *See* Mackrle, Vladimir. 0850.

0702 **Tadmor, Jacob; Cowser, K. E.**

1967. Underground disposal of krypton-85 from nuclear fuel reprocessing plants: Nuclear Eng. Design, v. 6, no. 3, p. 243-250.

An evaluation was made of the different methods for large-scale removal of Kr-85 from the off-gas stream of a reprocessing plant and of the feasibility of underground disposal of Kr-85. Although the apparent advantages of underground disposal are its relative simplicity and effectiveness, one severe requirement is that the disposal formation must be essentially free of vertical channels. The principal mechanisms by which Kr-85 may be retarded or retained underground include adsorption and trapping (containment). In the absence of convective transport, vertical underground movement is influenced by molecular diffusion. These mechanisms are evaluated for quantities of Kr-85 and volumes of off-gas assumed to be produced at a 10 tons/day reprocessing plant.–Authors' abstract, NSA 22-02335.

Descriptors: Radioactive waste disposal, gases, injection, feasibility studies, radioisotopes, migration.

0389 **Talbot, J. S.; Beardon, P.**

1964. The deep well method of industrial waste disposal: Chem. Eng. Prog., v. 60, no. 1, p. 49-52.

The deep well method is a proven technique, and has been used for many years by oil and gas producers in disposing of oil field brines and by various process industries. It is capable of handling a great variety of wastes, and is a safe method of waste control. It is not a hazard to potable groundwaters or to commercial mineral deposits. A properly constructed disposal well should exceed the life of the plant itself, with 40 yr being a reasonable well life. Several factors must be considered in designing a disposal system: (1) Laws of states where disposal is contemplated; (2) overall legal aspects; (3) subsurface geology; (4) groundwater hydrology; (5) estimated injection pressures and volumes; (6) chemical and physical problems of injection; (7) preliminary disposal well design and estimated costs; (8) preliminary surface equipment design and estimated costs; and (9) estimated costs of operation.–Tulsa Univ., Inf. Services Dept.

Descriptors: Injection wells, industrial wastes, waste disposal, legal aspects, design criteria, economics.

0390 **Talbot, J. S.**

1967. Some basic factors in the consideration and installation of deep-well disposal systems, *in* Industrial Water and Waste Conference, 7th, Texas Water Pollution Control Assoc., Austin, Tex., June 1-2, 1967, Proc.: Austin, Texas Univ., p. III-1–III-24.

This paper discusses the basic factors—economics, public relations, and legal aspects—that are involved when deep-well or geological disposal is considered. The principal limitations of deep-well disposal are those of geology and the nature of the wastes. To be effective, disposal aquifers should cover large areas, and have practical thicknesses as well as satisfactory permeability. The wastes, on the other hand, must be virtually free of suspended solids and compatible with the fluids and skeleton of the injection aquifers. Injection should take place at the lowest possible injection pressure. Techniques to achieve this are acidizing and hydraulic fracturing. Costs vary from $20,000 to over $1,500,000. If proper care is not taken in the design and construction of the system, pollution or other damage may be caused to potable surface- or ground-water supplies. A number of examples are discussed. The author concludes that the deep-well disposal method is one that has been proven by many years of application and acceptance by processing industries and State regulatory bodies. In many cases, it is the best and the most economical technique that can be used.

Descriptors: Industrial wastes, injection wells, design criteria, economics, legal aspects.

0391 **Talbot, J. S.**

1968. Some basic factors in the consideration and installation of deep well disposal systems: Water and Sewage Works, v. 115, 1968 Reference Number, p. R210-R212, Nov. 29.

The basic disposal factors of deep injection wells and the hazards of well disposal are discussed with particular attention to prevention of damage to potable groundwater, commercial mineral deposits, and mining activities. Economic, public relations, and legal factors are also major considerations for any waste disposal techniques. Most state and Federal laws either encourage or do not discourage deep well disposal, but the legal aspects of trespass on underground property and damages to property by disposal need legal clarification. Well design and surface equipment for deep well disposal are described. A method for calculating the radius of injection and formation capacity for injection is given. Geological hazards which might cause contamination of potable water are briefly described.—W69-04228.

Descriptors: Waste disposal, injection wells, legal aspects, social aspects, hazards, geology.

0147 **Tamura, Tsuneo.**

1967. Chemical development of waste-cement mixes, pt. 4 *of* Disposal of radioactive wastes by hydraulic fracturing: Nuclear Eng. Design, v. 5, no. 4, p. 477-485.

The shale-fracturing program has been concerned with the development of a technique for the safe and economic disposal of large batches of radioactive liquid wastes by mixing the waste with cement and other additives, and injecting the slurry into bedded shale at depths of about 1,000 ft. Mixes suitable for use with ORNL's intermediate-level liquid waste have been developed. The slurries remain pumpable for the time required to complete an injection and, once in place in the disposal formation, set into a solid matrix that fixes the principal radionuclides. These mixes have a cement base with clays added to enhance the fixation of radiocesium and a pozzolan cement system to retain the radiostrontium.—Tulsa Univ., Inf. Services Dept.

Descriptors: Radioactive waste disposal, injection, fractures (geology), methodology, chemical engineering.

0703 **Tamura, Tsuneo.**
1962. Strontium reactions with minerals, *in* Morgan, J. M., Jr., Jamison, D. K., Stevenson, J. D., eds., Ground disposal of radioactive wastes conference, 2d, Atomic Energy of Canada Limited and U.S. Atomic Energy Comm. Div. Reactor Devel., Chalk River, Canada, 1961, Proc., Book 1: U.S. Atomic Energy Comm. Div. Tech. Inf. [Rept.] TID-7628, p. 187-197.

Results are reported from slurry tests of the reactions of Sr^{85} in simulated waste solutions with various absorbent minerals. Mechanisms investigated included ion exchange as an absorption process exemplified by the resins, clinoptilolite, and the clay minerals; ion exchange as an adsorption process characterized by the reaction of alumina; metasomatic replacement as characterized by the $CaCo_3$-phosphate reaction; and precipitation reactions as evidenced by natural vermiculites and clinoptilolite in contact with phosphated waste. Data are tabulated.–NSA 16-25049.

Descriptors: Strontium radioisotopes, ion exchange, sorption, clay minerals, chemical reactions.

0704 Tamura, Tsuneo; Eastwood, E. R.; Rogowski, A. S.; and others.
1966. Fate of nuclides in terrestrial environment, sec. 1 *of* Radioactive waste disposal, *in* Health Physics Division annual progress report for period ending July 31, 1966: U.S. Atomic Energy Comm. Oak Ridge Natl. Lab. [Rept.] ORNL-4007, p. 3-9.

Continuing studies of the field plots show a reduced rate of loss of ^{137}Cs in the fall and winter months of the second year. There is a logarithmic relationship between ^{137}Cs loss and the soil loss. Mass balance analyses do not provide a satisfactory accounting of the total ^{137}Cs applied to the clipped meadow plot. Studies of the selective adsorption of cobalt by layer lattice silicates show that adsorption is influenced by the method of sample preparation. With identical sample preparation techniques, trioctahedral lattices sorb more cobalt than comparable minerals with dioctahedral lattices.–Authors' abstract.

Descriptors: Radioisotopes, cesium, soil environment, sorption, migration.

Tamura, Tsuneo. *See* de Laguna, Wallace. 0637.

Tamura, Tsuneo. *See* de Laguna, Wallace. 0638.

Tamura, Tsuneo. *See* McClain, W. C. 0460.

0392 **Taylor, S. S.; Holliman, W. C.; Wilhelm, C. J.**
1940. Study of brine-disposal systems in Illinois oil fields: U.S. Bur. Mines Rept. Inv. 3534, 20 p.

A detailed survey was made of three oil field brine disposal plants in Illinois to illustrate the open, semiclosed, and closed subsurface disposal systems, the systems used in that state. The survey includes a study of the mineral content and the chemically unstable components of brine samples from 18 oil fields. The surface equipment, disposal well, corrosion and chemical tests, and application of data are discussed for the three systems. The problems of each brine-disposal system vary with the characteristics of the oil-producing formations in each particular locality, making a general system of brine conditioning and disposal impossible. Flow diagrams illustrate the types of conditioning systems, and tables present the results of (1) mineral

analyses, showing the field; producing stratum; sampling point; specific gravity at 15.6°C; amount of total solids, iron, calcium, magnesium, sodium, bicarbonate, sulfate, chloride, bromide, and iodide; and (2) of corrosion and chemical tests, showing the field, producing stratum, location, sampling point, reducing compounds as hydrogen sulfide, average alkalinity and average super-saturation in bicarbonates as calcium carbonate, average hydrogen ion concentration, average total iron, and appearance and loss in weight of specimen after corrosion test. Since the subsurface disposal of brine is a relatively new practice in Illinois, the authors think that the information in this report should be of increasing value as case histories on brine-disposal systems handling various brines by different methods are developed.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, Illinois, injection wells, equipment, methodology, chemical engineering.

0393 **Taylor, S. S.; Owens, E. O.**
1942. Subsurface disposal of oil-field brines in Oklahoma: U.S. Bur. Mines Rept. Inv. 3603, 54 p.

Methods of preparing oil field brines in open, closed and semiclosed systems for disposal in subsurface strata are discussed, particularly as they apply to Fitts Pool. For effective and economical subsurface disposal of brines, deep seated permeable strata in selected wells are desirable if large quantities of brine are to be injected into a single well. The chemical character of the brine should be such that no precipitation of solids will be caused in the strata, and there should be no suspended solids in the brine. The removal of iron compounds from the brine is usually the most important chemical change necessary in its preparation for injection into the disposal well, and the dissolved oxygen content should be minimized. For maximum efficiency brine conditioning systems should be operated under at least part-time technical supervision.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, injection, Oklahoma, chemical properties, geohydrologic units, waste water treatment.

0394 **Taylor, S. S.; Wilhelm, C. J.; Holliman, W. C.**
1939. Typical oil field brine-conditioning systems, preparing brine for subsurface injection: U.S. Bur. Mines Rept. Inv. 3434, 71 p.

Detailed descriptions are given of the construction and operation of some typical brine-conditioning and disposal systems for preparing brine for subsurface injection. Data are given on the chemical and corrosive characteristics of brines before, during and after conditioning in various types of systems for subsurface injection. Several modifications of standard methods of water analysis are described. Closed, open and semiclosed types of systems that are used to condition the sour brine as well as the stable brines containing iron are discussed. Brines from four typical formations were studied. Cost data are included for several of the systems.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, chemical engineering, methodology, injection, treatment facilities.

Teasdale, W. E. *See* Barraclough, J. T. 0618.

Teasdale, W. E. *See* Morris, D. A. 0658.

0809 Teis, K. R.
1941. Subsurface disposal of oil field brines: Oil Weekly, v. 100, no. 5, p. 16-22, 24.

A comprehensive outline of the procedure and technical details of the subsurface disposal of oil field brines by utilizing the abandoned or unprofitable oil wells as input wells includes a tabulated summary of input well data of 73 Kansas and Oklahoma wells, including a group of 18 wells averaging more than 3700 bbl./day/well daily input. Treatment of the brine in closed or open-type treating systems by aeration, chemical treatment, sedimentation or filtering is said to be usually required when large quantities of brine have to be returned to deep wells having tight or sieve formations. The use of corrosion-resistant conduits such as pitch-impregnated wood fiber conduit, salt-glazed vitrified clay sewer pipe, concrete pipe, cement-asbestos pipe, or cement-lined steel pipe is recommended. Operating expenses of the Fitts Pool disposal plant in 1938 and 1939 are tabulated and the pool agreement under which this project is operated is outlined in detail. A cooperative approach to the problems of brine disposal, on the part of government regulatory and enforcement officers, is suggested.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, Kansas, Oklahoma, injection wells, waste water treatment, equipment, operating costs.

0480 Telfair, John S., Jr.
1948. The pollution of artesian ground waters in Suwannee and Orange Counties, Florida, by artificial recharge through drainage wells: Tallahassee, Florida State Board of Health, Bur. Sanitary Eng. Interim Rept. Inv., 40 p.

Investigations were made in 1948 to evaluate the effect of diffusion of surface drainage, sewage, and trade wastes into the permeable Eocene limestone aquifers at Live Oak and Orlando, Florida. This report gives the results of the study including topography and drainage, geologic and hydrologic factors, ground-water flow, and bacteriological findings. Summaries and conclusions are made concerning pollution, the sufferers, possible remedies, and future prospects.

Descriptors: Water pollution, limestones, drainage wells, waste water disposal, Florida, effects.

0395 Theis, C. V.
1955. Geologic and hydrologic factors in ground disposal of waste, *in* Sanitary Engineering Conference, Baltimore, Maryland, April 15-16, 1954: U.S. Atomic Energy Comm. [Rept.] WASH-275, p. 261-283.

This paper indicates the features of ground-water circulation that bear on the problem of waste disposal to the ground. Some of these features are favorable to such disposal, particularly the generally low velocity of ground water and perhaps the capacity of most water-bearing materials for some ion-exchange. Some of the characteristics of radioactive wastes, such as their extremely high toxicities, their heat-generating properties, their densities, and their chemical properties raise problems regarding their movement underground, about which there is little information and which may be quite difficult to solve, especially when raised with regard to particular locations. It is apparent that waste cannot be stored underground without a rather precise knowledge of the geology and hydrology of the area.–Author's summary.

Descriptors: Radioactive waste disposal, ion exchange, groundwater movement, hydrogeology.

0397 **Theis, C. V.**

1956. A review of the ground-water geology of the major waste-producing sites, *in* Seminar on sanitary engineering aspects of the Atomic Energy Industry–U.S. Atomic Energy Comm. and U.S. Public Health Service, [held at] Robert A. Taft Engineering Center, Cincinnati, Ohio, 1955, Proc.: U.S. Atomic Energy Comm. Div. Tech. Inf. [Rept.] TID-7517, pt. 1a, p. 116-131.

The geology and ground-water conditions at the major radioactive waste-producing sites–Hanford, Wash., Idaho Falls, Idaho, Oak Ridge, Tenn., and Savannah River, S. C.–serve to illustrate the great diversity of conditions that must be considered in the design of waste disposal systems for the atomic-energy industry. The Hanford site is underlain by basalts and unconsolidated sediments, and is in a semiarid area in which the water table is generally about 350 feet below the land surface. Specific retention, ion exchange and sorption in the unsaturated zone restrict the movement of radionuclides from surface cribs. Similar conditions exist at the Idaho Falls site except that the unsaturated zone contains comparatively little material that can retain or restrict the movement of radionuclides. Hence, only low-level wastes can be released. In contrast, the Oak Ridge and Savannah River sites have humid climates and relatively shallow water tables. Oak Ridge is underlain by lowly permeable, folded and faulted sandstones, shales, and carbonate rocks in which movement of ground water is controlled by rock fractures and solution openings. The Savannah River site is underlain by highly permeable, unconsolidated coastal plain sediments. Hence, there is no good way of confining wastes at either of these sites. The only possibility of local disposal is either through ion exchange or other attenuation or delay mechanisms.

Descriptors: Hydrogeology, Washington, Idaho, Tennessee, South Carolina, radioactive waste disposal.

0399 Theis, C. V.

1959. Disposal of nuclear wastes underground [abs.], *in* Weir, James E., Jr., and Baltz, E. H., Jr., eds., Guidebook of west-central New Mexico, New Mexico Geol. Soc., 10th Field Conf., 1959: Socorro, New Mexico Bur. Mines and Mineral Resources, p. 161.

Two geologic environments seem most feasible for the disposal of high-level wastes: (1) injection into permeable beds containing salt water well below the zone of potable waters and (2) placing in salt domes or beds, preferably the latter. Injection into deep formations involves two main problems: control of the heat generated and compatibility of the chemically complex wastes with the formation. The heat problem can be solved by aging of the wastes before injection, and by dilution. An American Petroleum Institute committee that intensively studied the problem believes that the compatibility problem can be solved. Obviously the well system used must be carefully constructed and operated. Salt in the United States seems to be one natural resource that could be sacrificed for the safe disposal of these wastes. Sufficient salt is mined at present to easily take care of the wastes expected for a long time in the future. Solution cavities may be feasible. Solid wastes, not necessarily insoluble, could be placed in salt, because of the absence of ground-water circulation through it.–*from* Author's abstract.

Descriptors: Radioactive waste disposal, injection, hydrogeology, chemical reactions, heat, salts.

0705 **Theis, C. V.**

1962. Notes on dispersion in fluid flow by geologic features, *in* Morgan, J. M., Jr., Jamison, D. K., Stevenson, J. D., eds., Ground disposal of radioactive wastes conference, 2d, Atomic Energy of Canada Limited and U.S. Atomic Energy Comm. Div. Reactor Devel., Chalk River, Canada, 1961, Proc., Book 1: U.S. Atomic Energy Comm. Div. Tech. Inf. [Rept.] TID-7628, p. 166-178.

Geologic features that affect both longitudinal and lateral dispersion during the flow of fluids through a porous medium, such as soils, are discussed. The effects of sedimentary structures and other nonhomogeneities found in nearly all geologic formations are considered. It is pointed out that presence of materials of variable permeabilities in an aquifer produces a wide range of velocities in essentially horizontal flow and inhibits vertical flow and the movement of water between different horizons in an aquifer. Results are included from two tracer studies, one using uranine dye and the other tritium as tracer, of ground water dispersion in dissimilar geologic formations.–NSA 16-25047.

Descriptors: Porous media, dispersion, sedimentary structures, geologic formations, groundwater movement.

0706 **Thomas, Henry C.**
1962. Problems in sorption on clay minerals illustrated with data on the system Cs-Ba-montmorillonite, *in* Morgan, J. M., Jr., Jamison, D. K., Stevenson, J. D., eds., Ground disposal of radioactive wastes conference, 2d, Atomic Energy of Canada Limited and U.S. Atomic Energy Comm. Div. Reactor Devel., Chalk River, Canada, 1961, Proc., Book 1: U.S. Atomic Energy Comm. Div. Tech. Inf. [Rept.] TID-7628, p. 179-186.

Problems encountered in studies on the sorption of radionuclides on soil minerals are discussed. Tentative results are included from investigations on the characteristics of the exchange sorption of Cs-Ba on heated montmorillonite clay. Data are tabulated.–NSA 16-25048.

Descriptors: Clay minerals, sorption, radioisotopes, soils.

Thomas, R. D. *See* Champlin, J. B. F. 0503.

Thomas, R. G. *See* Christenson, C. W. 0634.

Thorne, H. M. *See* Schmidt, Ludwig. 0795.

Thorne, H. M. *See* Wilhelm, C. J. 0816.

0400 **Thurston, William R.**
1956. Summary of Princeton Conference on disposal of high-level radioactive waste products in geologic structures, *in* Seminar on sanitary engineering aspects of the Atomic Energy Industry–U.S. Atomic Energy Comm. and U.S. Public Health Service, [held at] Robert A. Taft Engineering Center, Cincinnati, Ohio, 1955, Proc.: U.S. Atomic Energy Comm. Div. Tech. Inf. [Rept.] TID-7517, pt. 1a, p. 47-52.

The geologists at the Princeton Conference [Sept. 10-12, 1955] found that many principles and methods which are common practice in the petroleum industry are applicable to the problems of waste disposal. The volume of the waste solutions is not large by oil industry standards. The preparation of artificial cavities in salt and shale for the storage of hydrocarbons may be adaptable to shallow underground disposal of wastes. It seems probable that the natural porosity of many sedimentary rocks can be utilized as reservoirs for the safe disposal of wastes at great depths.–Author's abstract.

Descriptors: Radioactive waste disposal, injection, technology, underground storage.

Tillson, D. D. *See* Raymond, J. R. 0692.

Todd, D. K. *See* Rifai, M. N. E. 0855.

0810 **Towers, L. H.**
1938. Salt water disposal plant in oil field: Petroleum Engineer, v. 9, no. 6, p. 52, 54.

A salt water disposal plant was installed on the eastern edge of the producing field at Edmond, Okla. by the Pure Oil Co. The disposal well is one which was dry in the Wilcox sand at a depth of 6700 ft., plugged back to 2700 ft. in an 8-3/4 inch hole. A Schlumberger test was made and numerous sands suitable for water return sands were found above the one selected as the most suitable one. Tests of the sand made to find relative pressures and rate of intake used fresh water. Data from these tests are given in tables. The plant for treating the saltwater before returning it to subsurface sands was constructed near the disposal well and is now treating 500 bbl. of salt water per day. The capacity of the plant is 1500 bbl. per day and the addition of another reciprocating pump engine would double it. Exclusion of air prevents corrosion and simplifies treating methods before returning the water to the sand. In the redwood skimming tank, the lease treating tanks, and the surge tank, the space above the water is kept filled at all times with gas at a pressure of 4 oz., which acts as a seal against air. A 2-1/2 inch suction box with leak-proof sides and open at top and bottom surrounds the 6-inch discharge pipe from the skimming tank. The top of the suction box extends almost to the top of the tank and far above the liquid level, making it necessary for the fluid to be sucked up from the bottom. A diagram illustrated the relative location of tanks and filter. By treating the water to remove all suspended matter before returning it to the sand, the face of the sand is kept open.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, Oklahoma, injection wells, design data, engineering structures, geologic formations.

0360 **Troemper, A. P.**
1942. Salt water disposal: Independent Monthly, v. 12, no. 9, p. 17-20, and v. 12, no. 10, p. 19-24.

Part I of a thorough review of the entire subject of salt water disposal from oil fields and stream pollution, written in terms of Illinois practice, deals with the injurious effects of oil-field brines, disposal formations, and the Illinois problem of brine disposal. Part II summarizes disposal equipment, types of brine treatment, the economics of subsurface disposal, and possibilities of further experimentation.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, Illinois, effects, pollution abatement, injection, economics.

Troemper, A. P. *See* Klassen, C. W. 0753.

Ullrich, Richard A. *See* Peterson, James A. 0316.

0402 **U.S. Army Corps of Engineers.**
1966. Injection well–earthquake relationship–––Rocky Mountain Arsenal, Denver, Colorado: Omaha, U.S. Army Corps Engineers, Omaha Dist. Rept. Inv., 54 p.

The Rocky Mountain Arsenal (RMA) well was expressly designed and constructed to dispose of chemical wastes in such a manner as to completely eliminate any possibility of contaminating underground water sources or the atmosphere in the Denver area. Shortly after waste injection into the Arsenal well began, numerous small earthquakes or tremors were recorded in the Denver area. Statistical correlations suggest that injection operations have influenced the frequency of earthquakes in the area. Studies of injection pressure and well input energy suggest that a tectonic stress exists within the reservoir rock and injection operations may possibly influence the rate of release of this stress. If so, it is conceivable that releases of this stress may be of benefit to the Denver Community in possible prevention of a very damaging earthquake. Aside from the understandable interest and concern on the part of the local populace, it is generally accepted that continued operation of the disposal well would offer little if any risk and that the Derby tremors are more of a nuisance than a danger. However, the first concern of the Army is its obligation to the public as the Government Agency responsible for the operation of the Arsenal. On the basis of what appears to be noncontestable evidence of the statistical correlations, the Army must assume that some relationship does exist between the deep well and the earthquakes, and the use of the well as a disposal facility should be discontinued.

Descriptors: Waste disposal, injection wells, Colorado, earthquakes, effects.

0407 **van Everdingen, A. F.**
1968. Fluid mechanics of deep-well disposals, *in* Subsurface disposal in geologic basins–A study of reservoir strata: Am. Assoc. Petroleum Geologists Mem. 10, p. 32-42.

The fundamental law which governs the flow of slightly compressible fluids in permeable formations was used to compute three unit functions useful in well or reservoir analysis. These unit functions give quantitative information on (1) the change of pressure in the well or formation as a result of unit rate of injection during a period of time, (2) the amount of fluid which can be disposed of per unit pressure increase in a given time, and (3) the effect of an enlarged borehole on the injection pressure. Accurate prediction of pressures and pressure changes is now possible provided sufficient information is available on the physical characteristics of the formation, the formation fluids, and the injected fluids. The numerical values of these characteristics can vary considerably. To simplify computations, conversion factors are used so that the solutions given here can be used to solve most of the problems, irrespective of the numerical values of the characteristics encountered.–W69-04928.

Descriptors: Hydrodynamics, groundwater movement, injection wells, equations, hydrostatic pressure, geohydrologic units.

0820 **van Poollen, H. K.; Jargon, J. R.**
1969. Steady-state and unsteady-state flow of non-Newtonian fluids through porous media: Soc. Petroleum Engineers Jour., v. 9, no. 1, p. 80-88.

Non-Newtonian fluids may be injected into a reservoir during secondary recovery operations. The non-Newtonian fluid used in this work is a power-law type of fluid; that is, the viscosity of the fluid decreases as the flow rate or rate of shear increases. This paper presents equations for steady-state linear and radial flow of such fluids, transient behavior results from a finite difference model of a radial system, and transient behavior results from a field test. The equations that describe the flow of a non-Newtonian fluid are nonlinear and are solved numerically. Finite difference solutions are presented as curves of dimensionless pressure drop at the wellbore vs dimensionless time for a constant injection rate. Solutions were obtained for 5 percent, 10 percent and 100 percent PV [pore volume] of a non-Newtonian fluid for injection rates of 1, 10, 100 and 1000 cc/sec and for a 5 percent PV of

non-Newtonian fluid located at $r = r_w$, 3, 10, 20, 50 and 100 ft for a flow rate of 1 cc/sec. The buildup curves do not exhibit a straight-line portion as is the case for Newtonian flow through porous media. Correlations also are shown for the productivity index vs rate for the computer model study and the field tests.—Authors' abstract.

Descriptors: Injection, steady flow, non-uniform flow, equations, flow rates.

Veal, Harry K. *See* Garbarini, George S. 0018.

0409 **Veir, B. B.**
1967. Celanese deep-well disposal practices, *in* Industrial Water and Waste Conference, 7th, Texas Water Pollution Control Assoc., Austin, Tex., June 1-2, 1967, Proc.: Austin, Texas Univ., p. III-25–III-36. [Also published in Water and Sewage Works, v. 116, no. 5, p. I/W21–I/W24, 1969.]

This paper deals primarily with the deep well disposal experience of the Celanese Chemical Co. in Bay City, Tex. An economic comparison between a biological-treatment system and a deep-well system showed that the proposed deep-well system would cost twice as much in capital outlay, but the annual operating cost would be half as much. After a State permit for the deep-well system was granted, a well was drilled to inject wastes into a brine-saturated Miocene sand between the depths of 3,350 and 3,550 feet below the plant site. Samples of native brine and cores were obtained to check the compatibility of the wastes with the injection formation. A heavy wall, baked-on, epoxy fiberglass tubing was used in the well to reduce corrosion attack of the waste to a minimum. Preinjection treatment of waste is described. The success of the initial well system has prompted the construction of a second system and plans are in progress for a third to handle wastes from other plant process areas.

Descriptors: Chemical wastes, injection wells, Texas, economics, equipment, waste treatment.

Ven, Byron. *See* Klotzman, Melvin. 0233.

0411 **Verigin, N. N.; Sherzhukov, B. S.**
1968. Some questions concerning geochemical hydrodynamics: Internat. Assoc. Sci. Hydrology Pub. 78, p. 45-53.

The migration and diffusion of solutes in moving groundwater and the mass transfer of ions between groundwater and rock minerals are discussed. Diffusion and sorption equations are derived theoretically and their solutions are compared with the results of field observations. Equations are given for 2-dimensional convective diffusion, sorption, flow of miscible fluids, solution at surfaces, and ion exchange.—W69-08919.

Descriptors: Geochemistry, diffusion, dispersion, sorption, ion transport, hydrodynamics, equations.

0846 **Verigin, N. N.; Zimakov, P. V.; Kryukov, I. I.; and others.**
1967. Problema samorazogreva pri zenslyanom zakhoronenii tverdykh radioaktivnykh otkhodov (SM-93/32) [Problem of heat generation in underground storage of solid radioactive wastes], *in* Disposal of radioactive wastes into the ground—International Atomic Energy Agency and European Nuclear Energy Agency, Vienna, 1967, Symposium Proc.: Vienna, Internat. Atomic Energy Agency (STI/PUB/156), p. 441-454. [In Russian with English abs.]

The authors consider the self-heating of solid wastes due to the heat given off in radioactive decay. This self-heating imposes restrictions on the quantities that can be buried. The paper gives the thermophysical properties of various soils and different types of material (powder, glass, basalt, bitumen) destined for burial. The authors derive formulae for calculating the self-heating temperatures of radioactive materials in burial chambers of varying shapes when there is no provision for heat removal except that which is afforded by the thermal conductivity of the soil enclosing the chamber. The formulae obtained are used to compile nomograms and examples are given of how these can be used. The paper describes experiments carried out in field conditions and gives experimental data on determination of the temperatures of solid wastes and the coefficients of soil thermoconductivity in the presence of heat sources. The paper also gives the results of a study of the effect of rainfall percolation on the storage temperature in radioactive waste burial chambers.–Authors' abstract.

Descriptors: Radioactive wastes, underground storage, heat, theoretical analysis, thermal properties, thermodynamics.

Volek, C. W. *See* Chappelear, J. E. 0819.

0412 **Voress, H. E.; Davis, Theodore F.; Hubbard, Thomas N., Jr. (compilers).**
1958. Radioactive waste processing and disposal–A bibliography of selected report literature: U.S. Atomic Energy Comm. Div. Tech, Inf. [Rept.] TID-3311, 131 p.

An annotated bibliography is presented containing 698 references to unclassified reports on current and proposed radioactive waste processing and disposal practices for solutions from radiochemical processing plants and laboratories, decontamination of surfaces, air cleaning, and other related subjects. Author, corporate author, subject and report number indexes are included.–Authors' abstract.

Descriptors: Radioactive waste disposal, bibliographies, waste disposal.

0413 **Wainerdi, R. E.**
1961. The disposal of radioactive waste: Producers Monthly, v. 25, no. 1, p. 6-7.

A depleted gas-field sand lens may be considered as a gigantic adsorption column which can produce purified water at a distance from the injection well if the magnitude of the adsorption of radioactive wastes is sufficient. The disposal of radioactive wastes is one of the fundamental problems confronting the growing nuclear industry. It is possible that many techniques of petroleum reservoir engineering may be useful in developing an economical and feasible method of safe underground waste disposal and waste water reclamation.

Descriptors: Injection wells, radioactive waste disposal, ion exchange, hydrogeology.

0482 **Walker, E. H.**
1956. Ground-water resources of the Hopkinsville quadrangle, Kentucky: U.S. Geol. Survey Water-Supply Paper 1328, 98 p.

Unusually high nitrate concentrations were found associated with high bacterial counts in water from wells tapping limestone aquifers in the Hopkinsville area of Kentucky. This condition is attributed to contamination from human and animal wastes which enter crevices and solution openings in the limestone aquifer and move long distances, not just hundreds of yards but even miles, through the subsurface. To avoid contamination new wells should be located upslope as far as possible from barnyards and houses. Wells, old and new, should be sampled and the water should be

analyzed. If contamination is found it may be possible to reduce or eliminate it by leading wastes away some distance instead of permitting them to enter the ground near the well.

Descriptors: Groundwater, Kentucky, limestones, water pollution, nitrates, coliforms.

Walker, R. A. *See* Erickson, M. D. 0639.

0544 Walker, T. R.
1961. Ground-water contamination in the Rocky Mountain Arsenal area, Denver, Colorado: Geol. Soc. America Bull., v. 72, no. 3, p. 489-494.

Improper waste-disposal practices by spreading in surface waste basins have been responsible for contamination of the underlying ground-water aquifer by unintentional artificial recharge. Contaminated ground water within the affected area is toxic to agricultural crops and unpotable for humans. Corrective measures have been taken to halt further contamination but the area of toxicity is expanding owing to migration of the body of ground water already contaminated.–WSP 1990.

Descriptors: Waste disposal, groundwater, Colorado, water pollution.

0414 Walker, William R.; Stewart, Ronald C.
1968. Deep well disposal of wastes: Am. Soc. Civil Engineers Proc. Paper 6171, Jour. Sanitary Eng. Div., v. 94, no. SA 5, p. 945-968.

Deep-well disposal as a method for pollution control in the United States is investigated to ascertain the degree of development of deep-well disposal, and the procedures evolved to control this mode of disposal are reviewed. Only 9 of the 45 states surveyed expressly prohibit or, as a matter of policy, actively discourage the method of deep-well disposal. Some type of disposal wells are presently in operation in 25 states. The two controlling conditions necessary for an operable deep-well disposal system are a suitable disposal stratum, and a waste physically and chemically compatible with the resident material in the disposal formation. Care must be taken to assure that the various benefits are balanced, and that one aspect is not protected in such a manner as to be to the complete detriment of others. State regulations are summarized and tabulated.–W69-02342.

Descriptors: Deep wells, well regulations, waste water disposal, hydrogeology, data collections, water pollution control, United States.

Waller, H. D. *See* McMaster, W. M. 0665.

Wallin, W. E. *See* Alciatore, A. F. 0035.

0415 Warde, John M.; Richardson, R. M.
1955. Waste disposal–vital to atomic power development: Mining Eng., v. 7, no. 5, p. 458-461.

Atomic wastes, unlike other waste material, cannot be destroyed and the transmutation from one physical or chemical state to another does not solve the problem of their disposition, for only time diminishes radioactivity. In the selection of a site for disposal of radioactive liquids, all available information dealing with the various aspects of geology, topography, and hydrology–including information on ground-water occurrence–should be coordinated. One phase of the problem is the rate of movement of liquid flow in subsurface media. Included in this paper are two tables, entitled respectively, "Handling of radioactive wastes in atomic energy operations" and "Removal of radioactive materials by various clays." References are cited concerning specific activities at the Hanford Atomic Products Operation, the Oak Ridge National Laboratory, and the Brookhaven National Laboratory.–Birdsall, USGS.

Descriptors: Radioactive waste disposal, waste treatment, technology, sites, environmental engineering.

0401 Warner, D. L.
1965. Deep-well disposal of industrial wastes: Chem. Eng., v. 72, no. 1, p. 73-78.

Widely used for years by the petroleum industry, deep-well injection is now attracting greater attention as a method for disposing of liquid industrial wastes. Deep wells, as considered herein, may range from a few hundred feet to over 12,000 ft in depth. Well depth at any specific location depends on the depth required to reach a porous, permeable, salt-water-bearing horizon that is overlain and underlain by impermeable beds, such as shale. In order to achieve successful results and prevent contamination of natural resources, the planning, construction, and operation of an injection well requires the services of qualified geologists or petroleum engineers, as well as consultation with the appropriate water pollution control and resource agencies. To determine the feasibility of deep-well injection as a solution to an industrial waste problem, the following factors must be considered: (1) State regulations; (2) suitability of available sites; (3) suitability of waste for injection; and (4) economics. These factors and some aspects of drilling, testing, completing and monitoring injection wells are discussed.–Tulsa Univ., Inf. Services Dept.

Descriptors: Industrial wastes, waste water disposal, injection wells, design criteria, methodology, deep wells.

0416 Warner, D. L.
1965. Deep-well injection of liquid waste–A review of existing knowledge and an evaluation of research needs: U.S. Public Health Service Pub. 999–WP-21, 55 p.

A review of the knowledge pertinent to the use of deep wells for the subsurface injection of liquid waste has been carried out to evaluate the technical and economic feasibility and desirability of this method and to outline existing research needs. This review has shown that the deep-well injection of liquid waste is technically feasible to many areas of the country and, if properly planned and implemented, is not likely to be harmful to natural resources. While most of the technical knowledge and experience necessary to carry out the deep-well injection of liquid waste is presently available, further investigation is necessary to solve specific problems that remain as barriers to the safe, efficient, and economic use of this method.–Author's abstract, WSP 1990.

Descriptors: Deep wells, injection, liquid wastes, waste disposal.

0417 Warner, D. L.; Robeck, G. G.; Hannah, S. A.
1967. Injection wells for pollution control and conservation, *in* Bienn. microbiology symposium, 3d, Anaheim, Calif., 1966, Reprints: Am. Petroleum Inst., Production Div., p. 192-200.

This paper is a discussion of the application of some recent studies at the Cincinnati Water Research Lab to the treatment, control, and monitoring of injection liquids. A discussion of the uses of multiple-media filtration systems is presented. The multiple-media is a modification of the rapid sand filtration method that utilizes 2 or more filtration steps for the flocculation and sedimentation of suspended solids. It is suggested that turbidity measurement is a convenient method of continuously evaluating the quality of filtered water, because optical turbidimeters will operate reliably with little maintenance and can be connected electrically to the hydraulic components of the water-treatment system to prevent production of a water containing an excessive amount of turbidity. Following a review of the literature, a theoretical and laboratory study of incompatibility between injected and interstitial fluids was undertaken.–Tulsa Univ., Inf. Services Dept.

Descriptors: Injection wells, instrumentation, filtration, laboratory tests, chemical reactions.

0418 Warner, D. L.
1967. Deep wells for industrial waste injection in the United States, summary of data: Federal Water Pollution Control Adm., Water Pollution Control Research Ser. Pub. WP-20-10, 45 p.

This publication contains a summary of data for deep wells used for industrial waste injection and some of their characteristics including: operation, location, well depth, depth of injection horizons, geologic formation used for injection, chemical and physical character of waste, injection rate, injection pressure, and sources of information. The data cover 110 wells from 16 States.–WSP 1990.

Descriptors: Deep wells, industrial wastes, injection, waste disposal, data collections, United States.

0419 Warner, D. L.
1966. Deep well waste injection–reaction with aquifer water: Am. Soc. Civil Engineers Proc. Paper 4881, Jour. Sanitary Eng. Div., v. 92, no. SA 4, p. 45-69.

Deep-well injection is a promising method for permanently storing some liquid wastes. The influence of reactions between injected and interstitial waters on aquifer permeability is a problem of significant interest. A theoretical and laboratory study has shown that, under specified conditions, the amount of reaction between injected and interstitial solutions can be anticipated if the dispersive character of the porous medium is known. Laboratory evidence also showed that permeability loss resulting from the formation of some precipitates may not be as great as has been suggested. Others have proposed that, where reaction between injected waste and interstitial water is undesirable, a zone of nonreactive water can be injected between the waste and the aquifer water. This buffer-zone concept was substantiated in the laboratory and equations are proposed for the design of such zones in field situations.–Author's abstract.

Descriptors: Injection wells, liquid wastes, permeability, chemical reactions.

0422 Warner, D. L.
1968. Subsurface disposal of liquid industrial wastes by deep-well injection, *in* Subsurface disposal in geologic basins–A study of reservoir strata: Am. Assoc. Petroleum Geologists Mem. 10, p. 11-20.

Deep-well injection of concentrated, relatively untreatable liquid wastes is discussed. The feasibility of deep-well injection is determined by study of site suitability, waste characteristics, economics, and legal factors. Careful geologic evaluation is necessary to determine site suitability, economics, and suitability of the waste for injection. At

least 110 deep industrial injection wells are presently in use, injecting various wastes at widely different rates and pressures into subsurface reservoirs, ranging in age from Pleistocene to Precambrian. Most of the reservoir rocks used are sandstones, limestones, and dolomites.–W69-04941.

Descriptors: Waste water disposal, injection wells, methodology, design criteria, groundwater basins, sedimentary rocks.

0542 Warner, D. L.
1967. Subsurface injection of liquid wastes, *in* Natural gas, coal, ground water–Exploring new methods and techniques in resources research–Western Resources Conf., 8th, Colorado School of Mines, 1966 (Western Resources Papers, V. 8): Boulder, Colo., Univ. Colorado Press, p. 107-125.

Several processes for permanent disposal of unusable inorganic waste solutions are spreading on the surface of the earth, pipeline conveyance to the ocean, deep-well injection, and placement in underground cavities. Concentrated organic wastes that cannot be biologically treated can be wet-oxidized or incinerated, but some residue usually remains to be disposed of. These methods are listed in a table in their approximate order of cost, pipeline conveyance to the ocean or surface spreading being the most economical under favorable circumstances, and incineration being the most expensive. The estimated cost of disposal per 1,000 gal of liquid waste is $0.50 for a typical deep-well injection system, as compared with $0.01 for surface spreading and $10 for incineration. Not a new method of waste disposal, deep-well injection has long been important in the disposal of oil-field brines brought to the surface during the production of oil and gas. However, interest in using injection wells for disposal of other liquid wastes, particularly industrial wastes, has increased in recent years and is expected to increase greatly in the future. In addition to more conventional industrial wastes, deep wells have also been considered for the disposal of radioactive wastes, wastes from saline water conversion plants, and wastes from advanced waste treatment plants.–Tulsa Univ., Inf. Services Dept.

Descriptors: Waste disposal, economics, injection wells, industrial wastes, methodology.

0588 Warner, D. L.; Doty, L. F.,
1967. Chemical reaction between recharge water and aquifer water [with French abs.]: Internat. Assoc. Sci. Hydrology Pub. 72, p. 278-288.

Chemical reaction between recharge water and aquifer water may influence water quality and aquifer permeability and may cause fouling in discharge wells. However, evidence suggests that the danger of permeability reduction may not be very great. Precipitates of calcium and magnesium carbonate and iron compounds are most likely reaction products. The amount and distribution of reactive chemicals remaining in solution can be related to the dispersive characteristics of a porous medium. Reactions of various rates are considered. It may be desirable to prevent reaction. It is suggested that, in some cases, this can be accomplished by emplacing a buffer zone of nonreactive water between the recharge water and aquifer water.–Authors' abstract, WSP 1990.

Descriptors: Chemical reactions, effects, injection, water quality, permeability, mixing.

Warner, D. L. *See* Cleary, E. J. 0711.

0152 **Water Well Journal.**
1962. Movements of contaminants through geologic formations: Water Well Jour., v. 16, no. 3, p. 12-13.

Problems of groundwater contamination occur mostly in shallow aquifers, but deep aquifers may suffer deliberate injection of wastes. A waste contained in groundwater moving through a homogeneous aquifer disperses at right angles to the path of the flow; experiments show that the width of a stream of contaminant increases in proportion to the square root of the distance traveled, but in a nonhomogeneous aquifer the dispersion rate is greatly increased. Because of the curvilinear path of groundwater flow, the contaminant may not be present in a shallow well between the areas of recharge and discharge, but a deep well at the same location may be contaminated. These principles are illustrated by case histories.–Tulsa Univ., Inf. Services Dept.

Descriptors: Waste water disposal, injection, water pollution, groundwater movement, migration patterns, dispersion.

0424 **Water Well Journal.**
1968. How to bury a major pollution problem: Water Well Jour., v. 22, no. 8, p. 20.

An injection well is being constructed in Middletown, Ohio, to dispose of spent steel mill pickle liquor. The disposal horizon is the Mt. Simon sandstone, about 3000 ft. deep, just above the Precambrian basement. The formation's porosity is 8 to 22%, and the disposal zone is 274 ft. thick. The well will meet rigid state specifications to eliminate any contamination of usable groundwater. It is cased and cemented from the surface to the disposal zone. The surface casing is also cemented. Oil under higher-than-injection pressure will isolate the coated injection tubing from the casing to control accidental leakage. The pumps are made of corrosion-resistant titanium-palladium alloys. All sediment over 2-micron size will be removed from the waste before injection. The planned injection rate is 70 gpm, considerably below capacity.–W68-00808.

Descriptors: Waste water disposal, injection wells, injection, industrial wastes, geologic formations, Ohio.

0425 **Water Well Journal.**
1968. Deep injection wells: Water Well Jour., v. 22, no. 8, p. 12-13.

The information available on industrial waste injection wells is summarized. The data from 110 wells listed by FWPCA [Federal Water Pollution Control Administration] are analyzed. About 82% of the wells are used by chemical and pharmaceutical plants, refineries, natural gas plants, and metal products plants. The depth range is a few hundred to over 12,000 ft., but 64% are less than 4,000 and 92% are less than 6,000 ft. deep. Injection is into unlithified sand (33%), sandstone (41%), and carbonates (22%) with the exception of 5 wells. The Rocky Mountain Arsenal well is injecting into fractured Precambrian gneiss, a paper mill well is injecting into fractured Precambrian crystalline rocks as well as younger sandstones and carbonates, and 3 wells are injecting into evaporites. Injection rates vary from a few gallons per minute to over 900 gpm, with 34% injecting less than 100 gpm and 78% injecting less than 400 gpm. Existing injection systems are concentrated in the north-central and Gulf Coast areas.–W68-00807.

Descriptors: Waste water disposal, injection wells, geologic formations, injection, industrial wastes.

0426 Watkins, J. Wade.
1950. Corrosion and chemical testing of waters for subsurface injection: Producers Monthly, v. 14, no. 4, p. 15-19. [Additional installments in v. 14, no. 5, p. 30-31 and v. 14, no. 6, p. 25-31.]

Methods of corrosion tests and chemical analyses used in a study of plants that condition surface waters and brines for water flooding, brine disposal, and reservoir pressure maintenance are described in detail. The tests and analyses described were adapted and designed to be used in the field for determining the relative corrosive and plugging tendencies of waters from various sources conditioned by different methods.—*from* Author's introduction.

Descriptors: Injection, brine disposal, corrosion control, chemical analysis, test procedures.

0427 Watkins, J. Wade.
1954. Analytical methods of testing waters to be injected into subsurface oil productive strata: U.S. Bur. Mines Rept. Inv. 5031, 29 p.

Detailed methods are presented for making corrosion tests and chemical analyses of water to be used for water flooding, brine disposal and reservoir-pressure maintenance. The tests and analyses were designed and adapted for field use in determining the relative corrosive and plugging tendencies of waters from various sources conditioned by different methods.—Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, corrosion control, chemical analysis, injection, test procedures.

0428 Watkins, J. Wade.
1955. Design and operation of plants for the preparation of water for injection into oil reservoirs: Jour. Petroleum Technology, v. 7, no. 4, p. 17-23.

Both the design of plants in which water is to be treated for subsurface injection and the operation of the plants are important to the success of waterflooding and pressure-maintenance operations. Treating plants should be designed specifically for conditioning of the water or brine to be used in the project. The principal factors to be considered in designing a plant are: (1) characteristics of water to be treated; (2) quality of treated water desired; (3) primary and ultimate capacity of plant; (4) most favorable location of plant site; and (5) type of plant and equipment that will best serve the purpose. The operation of an injection-water-treating plant is at least as important as the proper design of the plant and judicious choice of treating methods. The important considerations in operating a plant are: (1) qualifications and training of operating personnel; (2) regularity and accuracy of water analyses; (3) analytical equipment and reagents used; and (4) precise control of mechanical equipment. The design of equipment for the various steps in the treating process are discussed independently in this paper. Criteria for the optimum characteristics of treated water also are given. It is concluded that a particular effort should be made in designing and operating an injection-water-treating plant to minimize corrosion, prevent plugging, and improve the water as a flooding medium.—Author's abstract.

Descriptors: Injection wells, brine disposal, waste treatment, design criteria, operation and maintenance, corrosion control.

0429 Watkins, J. Wade.
1958. New trends in treating water for injection: World Oil, v. 146, no. 1, p. 143, 145, 146-150.

The treating of brines for subsurface injection is becoming a technology in itself. Recent developments include increased emphasis on more complete separation of oil from the accompanying produced water, and the use of closed injection systems where possible. New methods for removing dissolved acidic gases from waters include controlled aeration, "scrubbing" with combustion gases or natural gas in packed columns, use of submerged burners, and chlorination. Organic treating chemicals are available and are finding extensive experimental application as biocides, corrosion inhibitors, and wetting agents. The use of sequestering agents has been increased; specific complexing additives are used to sequester or chelate some of the more troublesome metallic ions. New and improved chemical feeders and sedimentation tanks and ponds have been designed. Changes in filtration procedures are seen in the development of corrosion-resistant element-type filters and the increased use of diatomaceous-earth filtration. Noncorrodible plastic and cement-asbestos materials and corrosion-resistant metallic alloys have been improved and are used more extensively for many purposes. Automatic controls have been utilized to a greater extent. The use of water analyses in designing plants and controlling treating processes has received recent emphasis and much attention is being given to detecting, evaluating, and controlling microorganisms in injection waters. Although good progress has been made toward solving many injection water treating problems, the available information pertinent to many other problems is scanty and incomplete. Additonal research work is justifiable to attain optimum treating procedures.—Author's summary.

Descriptors: Brine disposal, injection, waste treatment, methodology.

0430 **Watkins, J. Wade; Mardock, E. S.**
1954. Use of radioactive iodine as a tracer in water-flooding operations: Am. Inst. Mining Metall. Petroleum Engineers Trans., v. 201, Tech. Paper 3894, p. 209-216.

The accurate evaluation of reservoir-performance characteristics in the secondary recovery of petroleum by water flooding requires use of a water tracer that may be injected into water-input wells and detected at oil-production wells to supplement data obtained from core analyses, wellhead tests, and subsurface measurements. Radioactive iodine has been used successfully as a water tracer in field tests to determine: (1) relative rates and patterns of flow of injected water between water-input and oil-production wells and (2) zones of excessive water entry into oil-production wells. Laboratory evaluations of potential water tracers, previous tracer studies, the value of using a radioactive tracer, general field procedures, and the use of surface and subsurface instruments for the detection of the emitted gamma radiation are summarized. Data from the field tests are presented graphically and discussed in detail. It is concluded that the radioactive-tracer method, using radioactive iodine, may be used successfully to measure either the relative rates and patterns of flow or zones of excessive water entry into wells under conditions of comparatively rapid transit time between wells.—Authors' abstract.

Descriptors: Injection wells, groundwater movement, tracers, radioisotopes, evaluation, data collections.

0431 **Watkins, J. Wade; Wright, J.**
1953. Corrosive action on steel by gases dissolved in water: Petroleum Engineer, v. 25, no. 12, p. B50-B51, B53, B55, B57.

Corrosion of metallic equipment is a serious economic problem in the production of petroleum and, particularly, in the secondary recovery of petroleum by water flooding. Despite the tremendous amount of fundamental and applied research performed on corrosion problems, few data are available concerning the corrosivity of dissolved oxygen, free carbon dioxide, and hydrogen sulfide in the concentrations and

ratios, and at the temperatures usually encountered under actual oil-field conditions. After a field study had been made of the corrosive and plugging characteristics of water injected into subsurface formations, a series of 72-hour, dynamic laboratory tests was made to determine the corrosion caused to mild steel in water by the common dissolved gases, where all other controllable factors influencing corrosion were maintained constant. Data are presented concerning the corrosion to mild-steel test specimens caused by varying concentrations of oxygen, free carbon dioxide, and hydrogen sulfide.–Authors' abstract.

Descriptors: Injection wells, corrosion control, data collections, test procedures.

0432 **Watkins, J. Wade; Armstrong, F. E.; Heemstra, R. J.**
1960. Feasibility of radioactive waste disposal in shallow sedimentary formations: Nuclear Sci. Eng., v. 7, no. 2, p. 133-143.

One of the pressing problems of the potential nuclear-power industry is the necessity for disposing of radioactive wastes incident to operating reactors and recovering fissionable material from expended fuel elements. The Bureau of Mines has made a detailed analysis of the feasibility of solving this problem, in areas where the geology permits, by injecting liquid wastes into shallow, permeable, sedimentary rock formations. Laboratory and field research problems pertinent to the disposal of radioactive wastes by injection are outlined. Laboratory problems include ion exchange and adsorption of fission products, chemical and physical reactions between injected wastes and reservoir solids and fluids, corrosivity of wastes and corrosion resistance of special metallic alloys, injectivity of solutions of waste fission products, potential heat gradients, and techniques for determining migration of injected wastes. Field research problems include handling techniques, injectivity, and horizontal and vertical migration of injected radioactive wastes. A hypothetical example is given of a pilot plant for secondary treatment and injection of dilute fission products into a shallow, lenticular sandstone formation with well-defined boundary conditions. Monitoring facilities and techniques designed to determine horizontal and vertical migration and differentiation of the migrating radioisotopes are described. A partial cost analysis is made of the pilot system. The advantages and disadvantages of a full-scale system of this type, as compared with other methods of disposal, are discussed. It is concluded that the use of shallow sedimentary formations, including partly depleted oil-productive sands, for disposing of radioactive wastes in some areas where geology permits, is feasible and that field pilot plants to demonstrate that feasibility might be instituted with information available at this time.–*from* Authors' abstract.

Descriptors: Radioactive waste disposal, injection, sedimentary rocks, feasibility studies, economics, research and development.

Watson, K. K. *See* Pilgrim, D. H. 0689.

0847 **Watson, L. C.**
1963. Mineral exchange in Canada's waste treatment program, *in* The use of inorganic exchange material for radioactive waste treatment–A working meeting held in Washington, D. C., Aug. 13-14, 1962: U.S. Atomic Energy Comm. Div. Tech. Inf. [Rept.] TID-7644, p. 75-82.

A brief review of waste disposal to ground at Chalk River [Canada] is presented. Results of work using clinoptilolite and plans for use of this material on low-level waste streams are also included. Work in mineral preparation, waste liquor clarification, and process chemistry is emphasized.–NSA 17-19706.

Descriptors: Radioactive waste disposal, chemical reactions, ion exchange, foreign countries.

0545 Wayman, Cooper H.
1967. Adsorption on clay mineral surfaces, *in* Principles and applications of water chemistry–Rudolfs Research Conf., 4th, Rutgers Univ., Proc.: New York and London, John Wiley and Sons, p. 127-167.

Adsorption on clay minerals is important in natural water systems because clays may play a role either in keeping potential contaminants from entering underground water (by soil-water reactions) or in acting as vehicles for transport of contaminants in surface water. This paper surveys some of the available literature. An attempt is made to describe some of the properties of clays to account for their sorptive properties and to give actual examples of adsorption of various solutes on clays. Only the clay minerals kaolinite, illite, and montmorillonite are considered. The field of wastewater chemistry has been emphasized.–*from* Author's summary, NAB.

Descriptors: Hydrogeology, clay minerals, solutes, geochemistry, waste water (pollution), sorption.

0455 Webster, D. S.; Proctor, J. F.; Marine, I.W.
1970. Two-well tracer test in fractured crystalline rock: U.S. Geol. Survey Water-Supply Paper 1544-I, 22 p.

A pulse injection of tritium (300 curies) was made to flow from an injection well to a discharge well through fractures in crystalline rock buried beneath about 1,000 feet of coastal plain sediments at the Savannah River Plant near Aiken, S. C. The wells were 1,765 feet apart, and the duration of the test was 2 years. The concentration of tritium arriving at the discharge well can be duplicated by calculations based on fluid dispersion in a homogeneous medium. In developing the theoretical curve, the only unknown variables were (1) the transit time for nondispersed flow along the line connecting the two wells and (2) the characteristic dispersion length in the medium (fractured crystalline rock). These two values were obtained by curve fitting. The results of the tracer test agree with computations based on the assumption that flow was through a homogeneous medium consisting of numerous intersecting fractures.–Authors' abstract.

Descriptors: Fractures (geology), crystalline rocks, tracers, groundwater movement, dispersion, tritium, South Carolina.

0707 Weeren, H. O.
1964. Pipe radioactive wastes to shale beds: Heating, Piping, Air Conditioning, v. 36, no. 11, p. 122-123.

Piping employed in a radioactive waste disposal method, in which waste liquids are piped and injected into shale beds, is described. The experiment consists of injecting several 40,000 gal batches of intermediate level waste solution, mixed with cement and other additives, into a shale formation at a depth of approximately 900 ft. The mixer, surge tank, injection pump, and wellhead valving are installed in cells to reduce radiation exposure to operators. The process requires handling of radioactive and nonradioactive solutions at low pressure (up to 300 psi), slurries of sand or cement at high pressure (up to 7500 psi), and bulk cement. The greater part of the waste transfer line is cast iron pipe with mechanical joints. Some of it is welded carbon steel.–NSA 19-21753.

Descriptors: Radioactive waste disposal, injection, shales, piping systems (mechanical).

0708 **Weeren, H. O.**
1966. Design of ORNL's shale-fracturing plant, pt. 3 *of* Disposal of radioactive wastes by hydraulic fracturing: Nuclear Eng. Design, v. 4, no. 5, p. 108-117.

The shale fracturing program has been concerned with the development of a technique for the safe and economic disposal of large batches of radioactive waste by mixing the waste with cement and injecting the mix into beds of shale at depths of about 1000 ft. A facility was built at ORNL [Oak Ridge National Laboratory] to make a series of seven experimental injections. Large volumes of waste solution (up to 150,000 gallons per injection) were successfully injected. Precise control of the proportion of cement and waste solution remains a difficult problem. The facility is now scheduled for modification for regular disposal of laboratory waste.—Author's abstract, NSA 20-35175.

Descriptors: Radioactive waste disposal, injection, shales, fractures (geology), Tennesee.

Weeren, H. O. *See* de Laguna, Wallace. 0638.

Weimer, Robert J. *See* Hollister, John C. 0024.

Weimer, Robert J. *See* Hollister, John C. 0471.

Weisflog, D. *See* Schwille, F. 0840.

Welsch, W. F. *See* Lieber, Maxim. 0475.

Wen, W. W. *See* Smith, R. W. 0535.

0435 **West, Samuel W.**
1961. Disposal of uranium-mill effluent near Grants, New Mexico, Art. 421, *in* Short papers in the geologic and hydrologic sciences: U.S. Geol. Survey Prof. Paper 424-D, p. D376-D379.

Surface disposal of effluent at The Anaconda Co. Bluewater uranium mill was not satisfactory, and a well was drilled for injection of effluent into an unused aquifer containing water. Injection tests indicated that vertical leakage into the principal aquifers would be negligible, and routine injection of effluent began in December 1960.

Descriptors: Radioactive waste disposal, injection wells, aquifers, feasibility studies, New Mexico.

White, W. A. *See* Bredehoeft, John D. 0083.

0546 **White, W. Arthur; Bremser, Shirley M.**
1966. Effects of a soap, a detergent, and a water softener on the plasticity of earth materials: Illinois Geol. Survey Environmental Geology Notes, no. 12, 15 p.

Terms applied to plastic properties of clays are defined. Samples of clays tested in the laboratory showed changes in plasticity after additions of various amounts of soap, detergent, and water softener. Earth deposits saturated with effluent from septic tank fields or other waste-disposal facilities may become sensitive and move as creep or landslides when disturbed by vibrations. Where montmorillonite is present, the effluent may increase swelling.–NAB.

Descriptors: Clays, plasticity, sewage effluents, laboratory tests, effects.

Wiebenga, W. A. *See* Ellis, W. R. 0015.

0709 **Wilding, M. W.; Rhodes, D. W.**
1964. Removal of radioisotopes from solution by earth materials from eastern Idaho: Idaho Falls, Phillips Petroleum Co., Atomic Energy Div. [Rept.] Conf-179-5, 12 p. [Available only from U.S. Atomic Energy Comm. Oak Ridge Natl. Lab., Tenn.]

Naturally occurring earth materials from Idaho, primarily from localities near the National Reactor Testing Station (NRTS), were used in laboratory tests for the removal of radioisotopes from aqueous solutions. These earth materials included lignitic deposits, clay-like materials, and specific minerals; ion exchange resins were also considered for a specific application. The aqueous solutions were low-level radioactive cooling water or synthetic solutions made up to represent low-level radioactive wastes at the NRTS. Cation exchange capacities and other properties which affect the removal of radioisotopes from solution were determined. The cation exchange capacities varied from 0.006 to 1.0 meq/g of solid. Earth materials with cation exchange capacities greater than 0.3 meq/g, in general, had distribution coefficients in excess of 1000. The highest distribution coefficients for cesium and strontium occurred in the pH range from 6.0 to 9.0. The possible use of these materials for decontaminating low-level radioactive waste at the NRTS is discussed. The results of laboratory studies using these materials and an organic ion exchange resin for decontaminating a specific NRTS waste are given. A material high in clinoptilolite from a location near the NRTS was considered to be the most promising material for use in large beds or ion exchange-type columns.–Authors' abstract, NSA 18-33164.

Descriptors: Radioisotopes, Idaho, laboratory tests, aqueous solutions, earth materials, ion exchange.

0436 **Wilhelm, C. J.; Schmidt, Ludwig.**
1935. Preliminary report on the disposal of oil-field brines in Ritz-Canton oil field, McPherson County, Kansas: U.S. Bur. Mines Rept. Inv. 3297, 20 p.

A study of the contamination of fresh-water strata by means of seeping oil-field brines in the Ritz-Canton field, Kansas is made, from which it is concluded that the return of the brine to the formation is one method by which positive disposal may be obtained. All wells drilled for oil or gas in the Equus beds area should have the surface pipe cemented from below the Equus beds to the surface. Tests should be made to determine the effect of back pressure on wells producing large volumes of salt water. Controlled dilution of the brine by dumping it into the surface streams draining this area offers possibilities of the disposal of a part of the brine production. Larger reservoirs will have to be built to prevent seepage of the brine in storage. Analyses of crude oil from the Chat-producing horizon of the Ritz-Canton field, Kansas are tabulated.–Tulsa Univ., Inf. Services Dept.

Descriptors: Kansas, brine disposal, injection wells, hydrodynamics, oil fields, geologic formations.

0816 Wilhelm, C. J.; Thorne, H. M.; Pryor, M. F.
1936. Disposal of oil-field brines in the Arkansas River drainage area in western Kansas: U.S. Bur. Mines Rept. Inv. 3318, 28 p.

The results of a study of the oil-producing fields within the Arkansas River drainage area west of Hutchinson, Kansas, with reference to the disposal of oil-field brines, are presented. In general, most of the fields in the area are new and are at present relatively small brine producers. The general practice of impounding brines in ponds is not an effective method of disposal in this area because of the character of the surface soil and the nearness to the surface of the domestic water supply. Subsurface disposal of brine, when no attempt is made to condition the brine, often results in a deposit composed principally of corrosion products, carbonates, and sulfates being carried into the disposal well. A system under which these factors are kept at a minimum will result in extending the life of the disposal well. The design of the disposal system will have a great influence on the amount of corrosion that takes place when the materials used in the system are corroded by hydrogen sulfide, oxygen, and brine. Preliminary corrosion tests indicate an increased rate of corrosion when brine with a high hydrogen sulfide content is exposed to the atmosphere, but a reduced rate when the hydrogen sulfide content is lowered materially by considerable aeration. The corrosion rate remains constant in a system in which brine with a high hydrogen sulfide content is virtually unexposed to the atmosphere. Analyses of oil field brines from various western Kansas fields are given.—Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, Kansas, injection wells, design criteria, chemical analysis.

Wilhelm, C. J. *See* Schmidt, Ludwig. 0795.

Wilhelm, C. J. *See* Taylor, S. S. 0392.

Wilhelm, C. J. *See* Taylor, S. S. 0394.

0811 Williams, B. F.
1940. Salt of the earth—A pollution problem: Water Works Eng., v. 93, no. 19, p. 1165-1167, 1194.

A large number of oil wells in Texas are producing salt water. It is estimated by the author that about 20,000,000 pounds of salt are brought to the surface daily in the water. Several methods of disposal of this salt water are in use. Most operators dump the salt water into surface streams after flowing through a pit. Some pits provide for some solar evaporation and the seepage of some of the water into the soil. A few operators dispose of salt water in furnace evaporation pits. Waste gas is used for fuel and the water is evaporated. The pits are then shoveled out at intervals. No effort has been made to refine the salts and in many cases the salts eventually find their way into streams or underground supplies during rains. The most satisfactory method of disposal of the wastes is by returning the salt water back into the earth through abandoned oil wells. This method is used by some of the larger operators. The production, storage, and disposal of large quantities of salt water on the sheds of the surface streams and on the catchment areas of the underground water supplies have resulted in destruction of the shallow local water supplies in many oil fields, raised the salt content in many surface streams from which cities, towns, and irrigators secure water supplies, and perhaps threatened the potability of ground waters in large areas. About 80 percent of the people in the State are dependent upon ground-water supplies.—Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, Texas, injection, surface runoff, water pollution sources, groundwater.

0812 Williams, Guy F.
1967. Formation cleaner increases stimulation results: Petroleum Engineer, v. 39, no. 11, p. 81, 84.

A new formation cleaner, trademarked Paran by Dowell, is effective in stimulating producing, injection and disposal wells. The material has been used in conjunction with other stimulation treatments, as well as in separate chemical treatments, to remove hydrocarbon deposits surrounding the wellbore or to remove hydrocarbon film and plugging materials to upgrade acidizing or fracturing jobs. The material is a combination of several crude, aromatic solvents, which may be altered to meet particular well conditions, by the use of additives. The straight cleaner will remove paraffin and asphaltene deposits or it will dissolve sludges. It may be compounded with surfactants and alcohols to remove water blocks or to break emulsions. It has been successfully used for the removal of scale when introduced in conjunction with conventional acid.–Tulsa Univ., Inf. Services Dept.

Descriptors: Injection wells, cleaning, solvents, descaling.

0813 Williams, N.
1937. Preventing water pollution: Oil and Gas Jour., v. 35, no. 48, p. 153-154, 156.

At the Lake Barre field [Louisiana] on the Gulf Coast, the Texas Co. disposes of the salt water effectively in a shallow, caprock cavity well drilled on top of the dome in the center of the field. The water is pumped to the disposal well from a central accumulation tank in the field, into which all water and bottom sediment produced is emptied. Among precautions taken by the Texas Co. to prevent even traces of oil from getting into water bodies around the Gulf Coast field are: Use of overflow lines connecting all tanks in a battery; use of a trap under the floor of each pumping well for accumulation of the oil that slops out on the floor when rods or tubing are pulled; trapping of drippings from hose line connections used in loading oil from storage into barges; precautionary measures to prevent blowouts; adequate casing programs; washing or swabbing wells into a reserve tank carried on a barge; and use of a special device on producing wells so that production will be shut off automatically should the surface connections break, or become damaged so as to open the well.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, injection wells, Louisiana, waste water treatment, pollution abatement.

0814 Williams, N.
1943. Salt water disposal in Kansas: Oil and Gas Jour., v. 41, no. 47, p. 29-30.

Old wells are generally used for salt-water disposal in Kansas, and cement-lined tubing is used whenever possible to avoid corrosion in the well. Semiclosed-type disposal systems are favored at present. These depend on a thick covering of oil and sludge over the surface of the water in the pits to prevent contact of air with the water. Chlorides and sulfates are also allowed to remain in the water instead of being precipitated. When the disposal wells become clogged, they are cleaned out and reacidized; some wells do not require cleaning for several years.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, Kansas, injection wells, corrosion control, cleaning, waste water treatment.

0815 **Williams, N.**
1943. Unitized water-disposal project works effectively and economically: Oil and Gas Jour., v. 42, no. 7, p. 127, 130, 132.

The community waste water disposal system operated in Reno County, Kansas, by Barnstall Oil Co. for a number of companies is described. Water is received in a single well 4600 ft. deep. The system has been in successful operation for 2-1/2 years.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, Kansas, injection wells, operation and maintenance.

0853 **Williams, R. E.; Farvolden, R. N.**
1967. The influence of joints on the movements of ground water through glacial till: Jour. Hydrology, v. 5, no. 2. p. 163-170.

Hydrographs of piezometers installed at various depths in glacial till in northeastern Illinois indicate variations in the rate and magnitude of responses of potential to precipitation. Zones of oxidation along these joints suggest that water moves farther in joints before losing its oxygen than does water moving through intergranular pore spaces. A relatively high permeability for the joints is thus indicated. It appears, therefore, that the paths of high permeability in which some piezometers are installed are joints. Theoretical reasoning predicts the observed variation of potential in the vicinity of joints in a compressible layer. An analysis based on one-dimensional consolidation is given. The influence of joints in glacial till on waste disposal, groundwater recharge, and on the behavior of water levels in the vicinity of a pumped well in an aquifer confined by glacial till is discussed.–Tulsa Univ., Inf. Services Dept.

Descriptors: Groundwater movement, water levels, fractures, (geology), glacial drift, piezometers, Illinois.

Willis, David G. *See* Hubbert, M. King. 0201.

Wilson, James E. *See* McCann, Thomas P. 0265.

0440 **Winar, R. M.**
1966. The deepest underground sewer in Michigan–Paper presented at American Petroleum Institute, Div. of Production Eastern District Spring Mtg., Columbus, Ohio, April, 27-29, 1966: Dallas, Tex., Am. Petroleum Inst. Div. Production Paper 826-37-C (postprint), 8 p.

The title refers to a deep industrial waste-disposal well recently completed in Holland, Michigan. This well was drilled to a total depth of 5,500 ft and a dilute sulfuric acid is being injected into the disposal reservoir. Initial monthly disposal will approach 500 gph or 12,000 gpd. Drilling was accomplished with a National T-32 rig, and standard rock bits were used. Seven-inch casing was set on a formation pack-off shoe at a depth of 4,606 ft in the basal Trempealeau dolomites. A cement diverting tool was installed 900 ft from the base of the casing string, and a joint of special acid-resistant alloy was placed directly above the pack-off shoe. Cementing of the 7-in. casing was performed in 2 stages. The injection string is J-55, 2-7/8-in. tubing which has an inner acid-resistant coating. A specially fabricated Otis packer is installed at the base of the tubing, and several hundred feet of plastic tailpipe is connected below this packer. The well logging consisted of a gamma-ray neutron and a caliper log. The well was acidized.–Tulsa Univ., Inf. Services Dept.

Descriptors: Waste disposal, Michigan, injection wells, construction, equipment.

0441 **Winar, R. M.**
1967. Underground disposal of waste water: Indus. Water Eng., v. 4, no. 3, p. 21-24.

Injection-disposal of industrial effluents has emerged from the slow, steady growth of the 1950's. Although the majority of the present installations serve chemical companies and oil refineries, the great variety of effluents disposed of in this manner indicates that many diverse industries will be utilizing this disposal method in the future. Anti-pollution pressures created by the public and governmental action also suggest greater usage of injection-disposal wells. Disposal wells will continue to be installed for the chemical and refining industries, but the steel, mining, paper, and food processing industries will turn to injection-disposal in great numbers, and others will follow.—Author's summary.

Descriptors: Waste water disposal, injection wells, industrial wastes.

Witherspoon, P. A. *See* Freeze, R. Allan. 0155.

0710 **Witkowski, E. J.; Manneschmidt, J. F.**
1962. Ground disposal of liquid wastes at Oak Ridge National Laboratory, *in* Morgan, J. M., Jr., Jamison, D. K., Stevenson, J. D., eds., Ground disposal of radioactive wastes conference, 2d, Atomic Energy of Canada Limited and U.S. Atomic Energy Comm. Div. Reactor Devel., Chalk River, Canada, 1961, Proc., Book 2: U.S. Atomic Energy Comm. Div. Tech. Inf. [Rept.] TID-7628, p. 506-512.

After ten years of shallow ground disposal of liquid wastes at ORNL, confidence in the long-term safety of the operation has been shaken. All the tests that have been made thus far have not satisfactorily ruled out the very remote long-range possibility of serious Clinch River contamination. This fact, plus the public-relations problems that could be created by continued releases of Ru^{106}, even though these releases may be below tolerance levels, could have a detrimental effect on the long-term operation of the Laboratory. The Laboratory management has therefore concluded that it would serve the best interest of both the public and the Laboratory to discontinue its liquid-waste ground-disposal operation.—Authors' abstract, NSA 16-25070.

Descriptors: Radioactive waste disposal, Tennessee, water pollution.

0446 **World Health Organization.**
1957. Pollution of ground water [excerpt]: Am. Water Works Assoc. Jour., v. 49, no. 4, p. 392-396.

It has been found that ground water is of excellent bacterial quality over large areas, and this is one of the reasons why it is so widely used for public water supplies. Other reasons are its palatability, its freedom from organic matter, its relatively constant temperature, and its reliability in summer and winter alike. There is, however, in many areas an ever-present danger of pollution of underground water by ground disposal of wastes. For example, the use of diffusion wells or seepage pits for disposal of industrial effluents should be looked upon as reasonably safe only where the receiving aquifer is unfit for other use and there is no possibility that the waste will find its way into other water-bearing strata. It should be remembered that wastes disposed of in this way are beyond the control of man and that once damage has been done, the possibilities of remedy are very remote. There has been a more or less natural controversy between the interests of industry and those concerned with the prevention of water pollution. To help reconcile these interests, it is suggested that each country should proceed toward the adoption of a national water policy.

Descriptors: Groundwater, water pollution control, waste disposal, regulation.

0447 **Wright, C. C.**
1960. Water quality control for subsurface injection: Producers Monthly, v. 24, no. 12, p. 30-34.

A summary of water quality control for subsurface injection and a comprehensive bibliography are presented. The factors that go into obtaining satisfactory water quality control are discussed critically. The interrelationships of the many factors are discussed in detail. Useful diagnostic tools and observations are presented to aid in establishment of a water quality control program.–*from* Author's abstract.

Descriptors: Water quality control, waste water disposal, injection wells, chemical analysis.

0817 **Wright, C. C.; Davies, D. W.**
1967. The disposal of oil field waste water: Am. Petroleum Inst. Drilling and Production Practice, 1966, p. 191-197.

The following are possible means of disposing of waste water to render it suitable for discharge: (1) percolation into groundwater table; (2) discharge to streams or lakes; (3) discharge to the ocean; (4) discharge to storm sewers; (5) discharge to sanitary sewers; (6) evaporation; (7) use as industrial water; (8) use as domestic water; (9) use as input to chemical plants; (10) use for waterflooding; and (11) subsurface injection into brackish or saline water zones. Some of the treatment processes are common to all methods of disposal, while others are peculiar to one or more disposal methods. The major treatment processes, which may be required to process the water for disposal or reuse, are as follows: oil removal, gas removal, solids removal, and reduction in biochemical and chemical oxygen demand.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, waste water treatment, methodology, water reuse.

Wright, J. *See* Watkins, J. Wade. 0431.

0448 **Wright, J. L.**
1969. Underground waste disposal: Indus. Water Eng., v. 6, no. 5, p. 24-27.

Deep-well disposal of industrial wastes is recommended for areas where laws and geological formations are favorable. The geology of several areas with favorable geologic conditions is discussed and estimated costs of injection and surface disposal are tabulated.–W69-06943.

Descriptors: Waste disposal, industrial wastes, injection wells, legal aspects, costs, economics.

0449 **Wycoff, R. D.; Botset, H. G.**
1936. The flow of gas-liquid mixtures through unconsolidated sands: Physics [Jour. Applied Physics], v. 7, no. 9, p. 325-345.

A method is described for studying the flow of gas-liquid mixtures through unconsolidated sands. Results are given for experiments on four sands of widely different permeabilities using carbon dioxide and water as the fluids. A relation between permeability and liquid-saturation of the sand is found which permits the correlation of saturation and the steady state flow of the gas and liquid components. Generalization of these results for all unconsolidated sands seems permissible. The phenomena of equilibrium permeability and equilibrium liquid-saturation are

described and their significance discussed. It is believed that the experimental attack and type of analysis is applicable to the general problem of the flow of gas-liquid mixtures through porous media.–Authors' abstract.

Descriptors: Porous media, flow characteristics, gases, liquids, hydrodynamics.

Yeh, Gour-Tayh. *See* Li, Wen-Hsuing. 0248.

0854 **Young, Addison; Galley, John E. (editors).**
1965. Fluids in subsurface environments–a symposium: Am. Assoc. Petroleum Geologists Mem. 4, 414 p.

The objective in compiling this symposium was to present 18 papers describing the latest studies and thoughts regarding the origin, evolution or "maturation," movements, and interrelations of all important fluids in sedimentary rocks, and their relations to the geology of the rocks in which they occur. The rocks that contain and transmit fluids, together with the fluids themselves, physical conditions such as temperature and pressure, and various chemical and biologic factors, define the subsurface environment. The present characters of rocks and fluids in the subsurface are the result of the influences of many changing environments which affected them during their geologic histories.

Descriptors: Environmental effects, hydrogeology, hydrodynamics, chemical properties, biological properties.

0450 **Yudin, F. P.; Pimenov, M. K.; Nazarov, A. I.; and others.**
1968. Experience in burial of liquid radioactive wastes in deep geological formations: U.S. Joint Publication Research Service [Pub.] 46535, 10 p. [Translated from Atomnaya Energiya, v. 25, no. 2, p. 128-133. Available from CFSTI.]

Investigations conducted on the disposal of radioactive wastes by injection wells in lower Carboniferous sandstones of the Russian Platform show that injection is economically feasible on industrial scales under favorable geohydrological conditions. The top of the injection zone is at a depth of 1,432 m and its bottom is at 1,508 m. The formation water has a total dissolved solids content of 245 g/l, mainly of sodium and chloride. The zone has almost no hydraulic connection with overlying aquifers; it is separated from them by a minimum of 40 m of clay. The injection well may be flushed by pumping, and the radioactive water pumped out is filtered and returned to the well. Observation wells are 100, 500, 1300, and 550 m, respectively, from the injection well. Injection at 100-150 cu m per day for a total of 40,000 cu m did not result in any detected radioactivity at any observation well.–W69-03061.

Descriptors: Radioactive waste disposal, injection wells, research and development, geohydrologic units, economic feasibility, foreign countries.

Yudin, F. P. *See* Mal'tsev, E. D. 0685.

Yudin, R. P. *See* Spitsyn, V. I. 0383.

0457 **Zajic, J.**
1967. Geologische untersuchungen ueber moeglichkeiten der einlagerung radioaktiver abfaelle in der CSSR [Geological studies on the possibilities of storing radioactive waste in Czechoslovakia]: Kernenergie [Berlin], v. 10, no. 10, p. 312-318. [In German.]

Investigations on the utilization of geologic formations for the disposal of radioactive wastes in the C.S.S.R. are described. The possibilities of storage in an abandoned mine (chalk formation) or in an isolated nonproductive petroleum structure (neogen) are described. Finally, the state of studies on the utilization of the sorptive properties of loose rocks and soils for purifying waste liquids are discussed.–Author's abstract, NSA 22-16826.

Descriptors: Radioactive waste disposal, foreign countries, geologic formations, injection, excavation, sorption.

0848 **Zakharov, S. I.; Bagretsov, V. F.; Pimenov, M. K.; and others.**
1967. Nekotorye rezul'taty ekspluatatsii opytno-promysklennoy ustanovki po udaleniyu zhidkikh radioaktivnykh otkhodov v glubinnye formatsii zemnoy kory (SM-93/42) [Some results of operation of pilot scale installation for disposal of liquid radioactive wastes in deep formations of earth's crust], *in* Disposal of radioactive wastes into the ground–International Atomic Energy Agency and European Nuclear Energy Agency, Vienna, 1967, Symposium Proc.: Vienna, Internat. Atomic Energy Agency (STI/PUB/156), p. 577-590. [In Russian with English abs.]

A pilot-industrial testing ground was established at the Nuclear Reactor Research Institute with a view to carrying out investigations on the disposal of liquid radioactive wastes into deep ground formations. The first stage of the investigations bear on the industrial disposal of deactivated solutions with a specific activity of 1×10^{-4} -1×10^{-6} Ci/l to a depth of 1550 m. The solutions were of exceedingly complex chemical composition and contained a considerable quantity of surfactants (up to 25% in weight, pH 7-10, saline content up to 9 g/l). The porous formation was filled with highly mineralized stratal water (saline content 230-250 g/l) of the chloride-sulphate type. The compatibility of the injected solutions with the stratal water was ensured by a special device, the pH of the solution injected into the borehole being kept at 6-7. The initial solution was freed from coarse-dispersion particles by settling in a vertical settler and on mechanical filters. The treated solution was led into an intermediary tank (200 cm^3) from which it was pumped along a pipe into the borehole under a pressure of 36-42 atm. The throughput capacity was 10 m^3/h. To get rid of the gases which form at the shaft head there is a unit fitted with a device for purifying the gas before it is released into the atmosphere. In order to determine the direction and rate of distribution of the radioactive solutions through the porous formation, there are observation boreholes at varying distances from the working borehole. From April to October 1966, 27,000 m^3 of solution were injected. Work on the pilot-industrial testing ground is continuing.–Authors' abstract.

Descriptors: Radioactive waste disposal, feasibility studies, test procedures, chemical reactions, hydrodynamics, injection, foreign countries.

0818 **Zazula, S. J.**
1958. Shell's SWD [Salt water disposal] lines at Midale [Canada]: Canadian Oil and Gas Industries, v. 11, no. 5, p. 67-72.

The Shell Midale Salt Water Disposal System uses subsurface formations for disposing of the water separated from the emulsion produced in the Midale field [Saskatchewan, Canada]. Two disposal wells were located at low points in the field, with cement-asbestos pipe and fittings used throughout the gathering system. Central water treating and filtering facilities were designed to serve each of the two disposal wells, with intermittent operation and a minimum of attention. Dakota disposal wells were drilled at locations selected to facilitate gravity gathering of the produced water. One gallon of detergent and 25 pounds of citric acid diluted in the injection water restore

the receptivity index of plugging water which occurs periodically.–Tulsa Univ., Inf. Services Dept.

Descriptors: Brine disposal, injection wells, equipment, waste water treatment, foreign countries.

Zimakov, P. V. *See* Verigin, N. N. 0846.

Zuber, A. *See* Borowczyk, M. 0004.

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SUBJECT INDEX

[For general background on the subject of waste disposal the reader is referred to the case histories and summary reports under the various types of wastes. The reader interested in waste disposal in specific areas is referred to the "Geographic Index"]

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