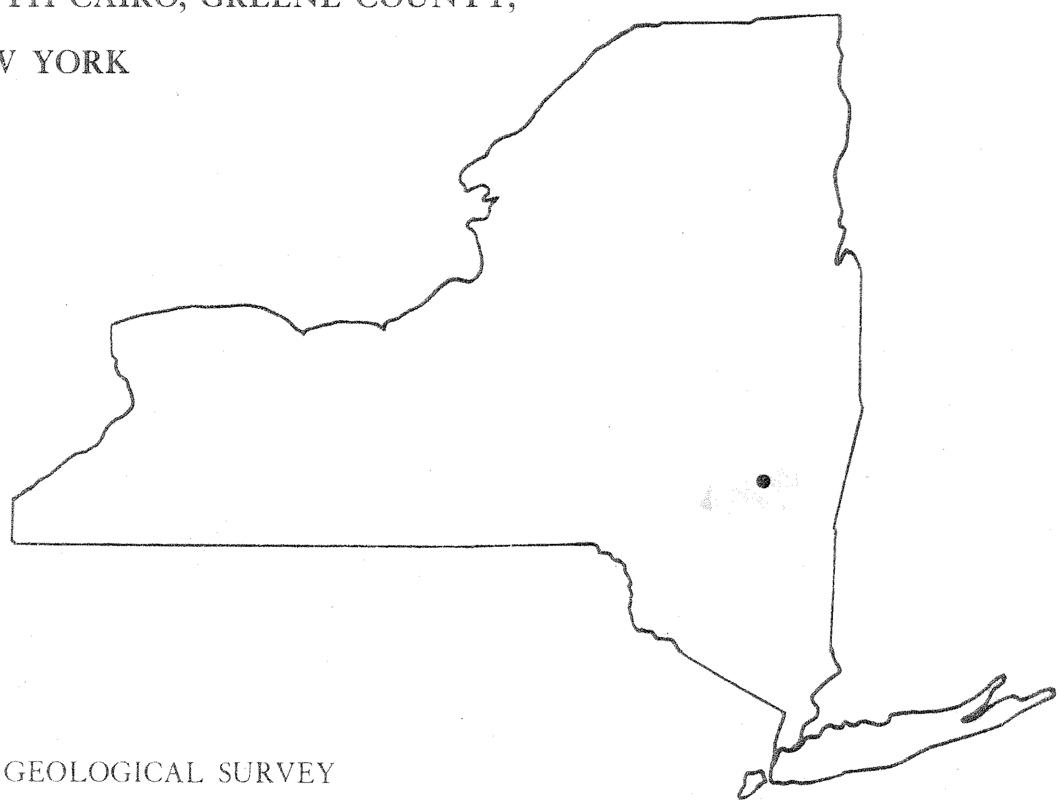
EFFECTS OF LANDFILL LEACHING ON WATER QUALITY AND BIOLOGY OF A NEARBY STREAM, SOUTH CAIRO, GREENE COUNTY, NEW YORK



U.S. GEOLOGICAL SURVEY

Water-Resources Investigations 79-13

BIBLIOGRAPHIC DATA SHEET	1. Report No.	2.	3. Recipient's Accession No.
4. Title and Subtitle Effects of Landfill Leaching on the Water Quality and Biology of a Nearby Stream, South Cairo, Greene County, New York			5. Report Date April 1979 6.
7. Author(s) Theodore A. Ehlke			8. Performing Organization Rept. No. USGS/WRI 79-13
9. Performing Organization Name and Address U.S. Geological Survey, Water Resources Division 343 U.S. Post Office & Courthouse Albany, N.Y. 12201			10. Project/Task/Work Unit No. 11. Contract/Grant No.
12. Sponsoring Organization Name and Address U.S. Geological Survey, Water Resources Division 343 U.S. Post Office & Courthouse Albany, N.Y. 12201			13. Type of Report & Period Covered Final (1971-75) 14.

15. Supplementary Notes

16. Abstracts A 1-kilometer stream reach receiving leachate-enriched water from a small municipal landfill was studied from 1971-75 to document streamflow rates and chemical quality of the stream and ground water. The distribution of benthic invertebrates and microorganisms in the stream above the landfill was markedly different from that below it; the difference is attributed to the inflow of leachate.

The Trichoptera, Ephemeroptera, and Nematomorpha have been eliminated from the reach adjacent to and below the landfill and have been replaced by large numbers of Tendipedidae and Niadidae. Certain chemical constituents, especially iron and manganese, were extremely concentrated in the ground water immediately beneath the streambed. The elevated concentrations of these and other metals may be the direct cause of the abrupt faunal shift. Algae were replaced by large masses of the iron bacterium Leptothrix in the stream reach below the landfill.

17. Key Words and Document Analysis. 17a. Descriptors

Landfill, Leachate, Benthic fauna, Iron bacteria, Trace elements, Waste disposal, Subsurface drainage, Diptera, Oligochaetes, New York

17b. Identifiers/Open-Ended Terms

Greene County, N.Y., Groundwater degradation, Chemical and biological effects

17c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report) UNCLASSIFIED	21. No. of Pages 21
No restriction on distribution	20. Security Class (This Page UNCLASSIFIED	22. Price

FORM NTIS-35 (REV. 10-73) ENDORSED BY ANSI AND UNESCO. THIS FORM MAY BE REPRODUCED USCOMM-DC 8265-P74

EFFECTS OF LANDFILL LEACHING ON WATER QUALITY AND BIOLOGY OF A NEARBY STREAM, SOUTH CAIRO, GREENE COUNTY, NEW YORK

By Theodore A. Ehlke

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations 79-13

Albany, New York

1979

UNITED STATES DEPARTMENT OF THE INTERIOR

CECIL D. ANDRUS, Secretary

GEOLOGICAL SURVEY

H. William Menard, Director

For additional information write to:

U.S. Geological Survey
343 U.S. Post Office & Courthouse
Albany, N.Y. 12201

CONTENTS

ILLUSTRATIONS

TABLES

FACTORS FOR CONVERTING INTERNATIONAL SYSTEM (SI) UNITS TO INCH-POUND UNITS, AND ABBREVIATIONS OF UNITS

Multiply SI units	By	To obtain inch-pound units
centimeter (cm)	0.3937	inch (in)
meter (m)	3.281	foot (ft)
kilometer (km)	0.621	mile (mi)
square centimeter (cm^2)	0.155	square inch (in^2)
cubic meter per second (m^3/s)	35.31	cubic foot per second (ft^3/s)
liter per second	0.035	cubic foot per second
degree Celsius (°C)	(1.8 °C) + 32	degree Fahrenheit (°F)
liter (L)	1.056	quart (qt)
gram (g)	0.035	ounce (oz)
kilogram (Kg)	2.204	pound (lb)

EFFECTS OF LANDFILL LEACHING ON THE

WATER QUALITY AND BIOLOGY OF A NEARBY STREAM,

SOUTH CAIRO, GREENE COUNTY, NEW YORK

By

Theodore A. Ehlke

ABSTRACT

A 1-kilometer stream reach receiving leachate-enriched water from a small municipal landfill was studied from 1971-75 to document streamflow rates and chemical quality of the stream and ground water. The distribution of benthic invertebrates and microorganisms in the stream above the landfill was markedly different from that below the landfill. The difference is attributed to the inflow of leachate.

The Trichoptera, Ephemeroptera, and Nematomorpha have been eliminated from the reach adjacent to and below the landfill and have been replaced by large numbers of Tendipedidae and Naididae. Certain chemical constituents, especially iron and manganese, are extremely concentrated in the ground water immediately beneath the streambed. The elevated concentrations of these and other metals may be the direct cause of the abrupt faunal shift. Algae were replaced by large masses of the iron bacterium *Leptothrix* in the stream reach below the landfill.

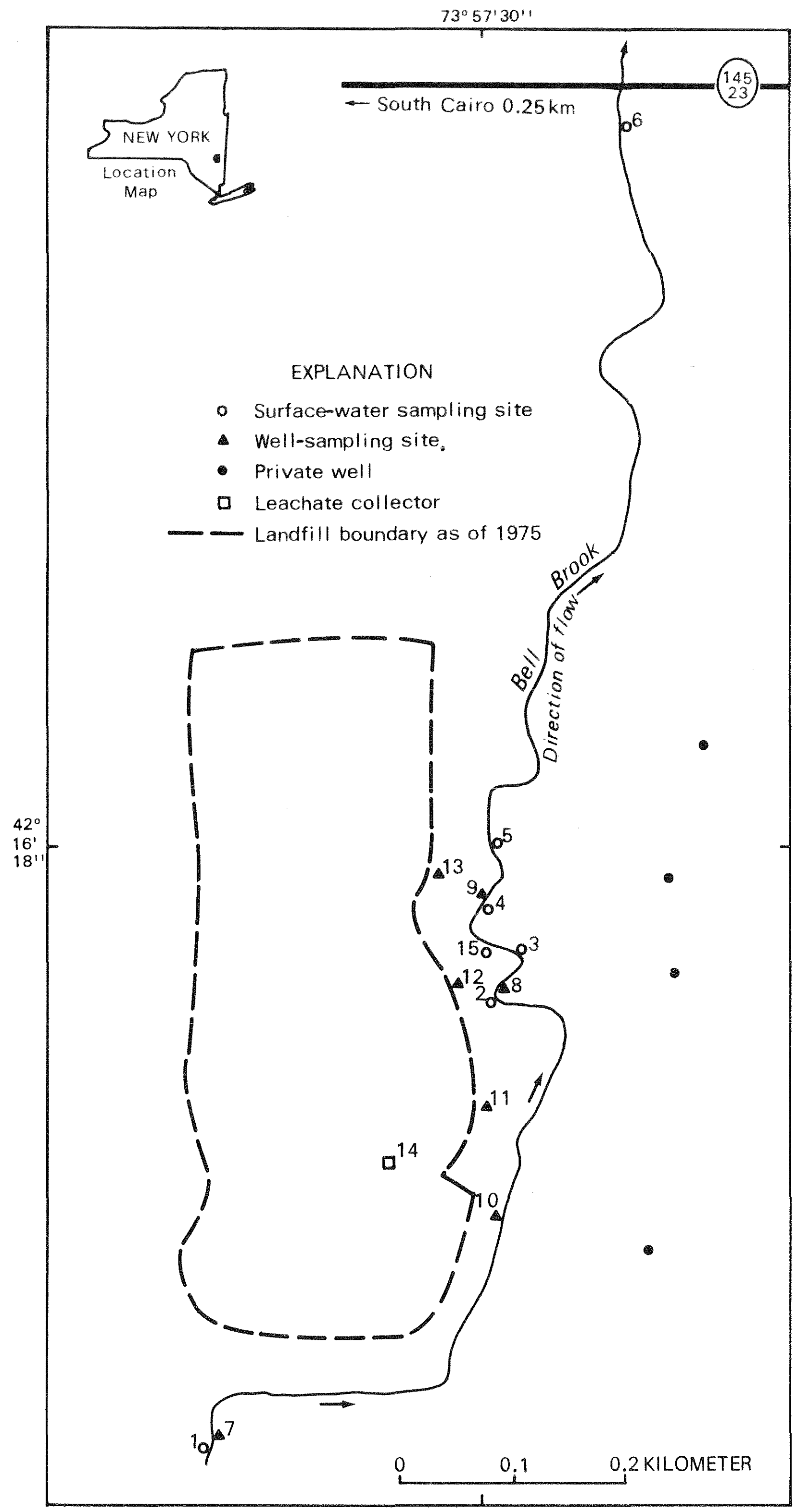


Figure 1.--Location of sampling sites at Bell Brook near South Cairo landfill.

INTRODUCTION

Burial of refuse in landfills has become the most common method of municipal refuse disposal in the United States because the resulting odors, air pollution, and rodent problems are minimal compared with those associated with other disposal methods. However, landfills may pose a serious threat to the quality of ground water, particularly in humid areas where the water table is near land surface. Rain percolating through the landfill causes the solution of both landfill contents and cover material. The resulting liquid, termed leachate, typically includes high concentrations of chloride, sodium, iron, manganese, ammonium, zinc, organic carbon, and some organic constituents such as phenol (Zanoni, 1972). The higher content of dissolved solids causes the specific conductivity of landfill leachate to be typically much higher than that of fresh ground water.

Leachate can affect living organisms in many ways. The heavy metals have long been known for their toxicity to both flora and fauna (Hart and Fuller, 1974). Among these, iron and manganese are the most common in leachate and typically occur in high concentrations. Other heavy metals, such as zinc, lead, and cadmium, may also be present in toxic concentrations. Generally, sensitive stream-dwelling invertebrates such as Trichoptera and Ephemeroptera disappear in the presence of these metals only to be replaced by more tolerant types such as certain Diptera larvae.

Typical landfill leachate is strongly reducing and consumes oxygen in the waters with which it comes in contact. This has been the suspected cause of several fish and benthic invertebrate kills (Rouse, 1973). Leachate-contaminated ground water reaching domestic wells also degrades the quality of their water and may make it unfit for drinking.

In 1971, the U.S. Geological Survey began a study of a small municipal landfill in Greene County, N.Y., to evaluate the surface-water and ground-water quality within the area and to determine the effects of leachate on the biology of a nearby stream. The landfill is near the hamlet of South Cairo, in the eastern foothills region of the Catskill Mountains (fig. 1). The site is within a northward-trending stream valley, 1.3 km wide, that is bounded on both sides by bedrock. The landfill is a typical cut-and-cover operation in which refuse was buried to a depth of approximately 6 m below land surface and covered with native soil. The filled area is approximately 200 x 200 m. The site was excavated in stratified glacial drift, part of which was mined previously for gravel. The landfill was operated from June 1970 until June 1975. The small perennial stream nearby, Bell Brook, flows north along the east side of the filled area (fig. 1) and continues northeastward into the town of South Cairo, where it joins Catskill Creek, a tributary of the Hudson River.

Methods

Samples of ground water and stream water were collected outside and within the filled area for chemical analysis from 1971-75. Fifteen collection sites were established; their locations are shown in figure 1. Sites 1 through 6 were surface-water-collection sites on Bell Brook, sites 7 through 14 were wells, and site 15 was a spring draining the landfill.

Most of the wells were constructed of 4.5-cm-diameter polyvinyl chloride (PVC) pipe with the lower 76 cm slotted and wrapped with fiberglass screen. Depths ranged from 4 m to 8.5 m below land surface. Three of the wells (sites 7-9) were screened immediately below the streambed of Bell Brook to sample the underflow. The casing and screen construction were similar to those of the deeper wells, but the screen of each was laid horizontally in a trench 0.3 m deep in the streambed perpendicular to the bank. Near the bank, a length of vertical pipe was attached to provide access, and, as the trench was backfilled, a layer of clay was placed within it to prevent movement of stream water from the channel into the well. Another well (site 14), termed the leachate collector, consisted of an open box 2.4 x 2.4 x 0.23 m that was lined with a sheet of polyethylene and filled with sand. The box was set at the bottom of the excavated landfill area and was covered with about 5.5 m of refuse and soil late in 1971. The collector drained laterally to a sump approximately 30 m distant, where a vertical pipe provided access for water-level measurement and water sampling. This well was installed to enable the collection of water infiltrating through the entire thickness of emplaced landfill material. The leachate collector was placed above the static water level so that the leachate sampled would not be diluted by the native ground water.

Streamflow was measured at representative sites (1,2,5,6) whenever stream-water samples were collected to determine losing and gaining reaches and the amount of dilution. Discharges are given in table 1. Water levels in the observation wells were measured to determine the direction of water movement within and near the filled area. Water-level contours for October 16, 1973 are depicted in figure 2 and are typical for the period of investigation.

Water and stream-bottom samples were collected monthly for chemical analysis of the constituents shown in table 3. Wells were sampled through silicone tubing with suction lift provided by a peristaltic pump. Specific conductance, pH, water temperature, and dissolved oxygen concentration were measured onsite. Analytical techniques were those described by Brown and others (1970); analyses were done by the U.S. Geological Survey laboratory in Albany, N.Y.

Benthic invertebrates were collected at sites 1 through 6 October 16, 1973, May 30, 1974, and June 12, 1975, by driving a 5.1-cm inside-diameter tubular coring device to a depth of 20 cm. Three cores were obtained across the stream at each site and were composited. The samples were preserved in the field with 40-percent (final concentration) denatured ethanol. Methods described by Greeson and others (1977) were used to sort and identify benthic organisms. Separate samples were scraped from the top 1 cm of streambed for microscopic examination. These samples were not preserved but were chilled to 4°C until they were examined. Examination was completed within 24 hours of collection.

Hydrology of Area During Study

Streamflow was highly variable in Bell Brook during the study (table 1). The study reach was characterized by both losing and gaining sections. Almost always there was a loss of streamflow between sites 1 and 2. Sites 2 through 6, on the other hand, nearly always gained some streamflow. Most of the decrease in streamflow between sites 1 and 2 was probably lost to ground water moving away from the stream channel toward the landfill, as indicated by water-level measurements (figure 2). The streamflow increase between sites 2 and 6 was the result of ground-water inflow through springs and benthic sediments.

Lateral movement of ground water was approximately determined from water-level measurements. Water levels and direction of ground-water movement on October 19, 1973 are depicted in figure 2. These values were typical of those obtained during the study. Movement of ground-water was northeastward, nearly parallel to Bell Brook and toward the town of South Cairo. Probably most of the water that was lost between sites 1 and 2 eventually reentered Bell Brook between sites 2 and 5.

Table 1.--Streamflow in Bell Brook near South Cairo Landfill, Greene County, N.Y., 1973-74

[All values are in liters per second]

Date	1	2	3	4
5-16-72	92.9	109.6	*	122.06
8- 8-72	16.4	*	*	24.3
9-12-72	4.5	1.1	4.5	5.7
9-25-72	2.8	dry	*	*
3- 9-73	*	55.5	*	64.6
3-13-73	60.9	58.4	*	66.8
6-20-73	30.0	29.7	*	37.4
7-10-73	*	49.3	55.5	62.9
10-16-73	2.3	dry	1.7	2.8
12- 7-73	5.7	2.3	4.3	5.7
1-31-74	171.6	147.3	165.4	*
5-31-74	26.6	25.8	31.4	34.8
7-25-74	5.4	4.3	*	8.2

*Flow not measured

Undoubtedly, much of the subsurface flow passing beneath or near the landfill mixes with leachate draining from the fill material and becomes contaminated to varying degrees. Some of this contaminated ground water enters Bell Brook through the streambed or discharges in springs that flow into Bell Brook. The remainder becomes part of the regional ground-water flow system. The effects of leachate-contaminated ground water on water quality at distant locations has been discussed by other investigators (Kimmel and Braids, 1974). This aspect was beyond the scope of the investigation, however.

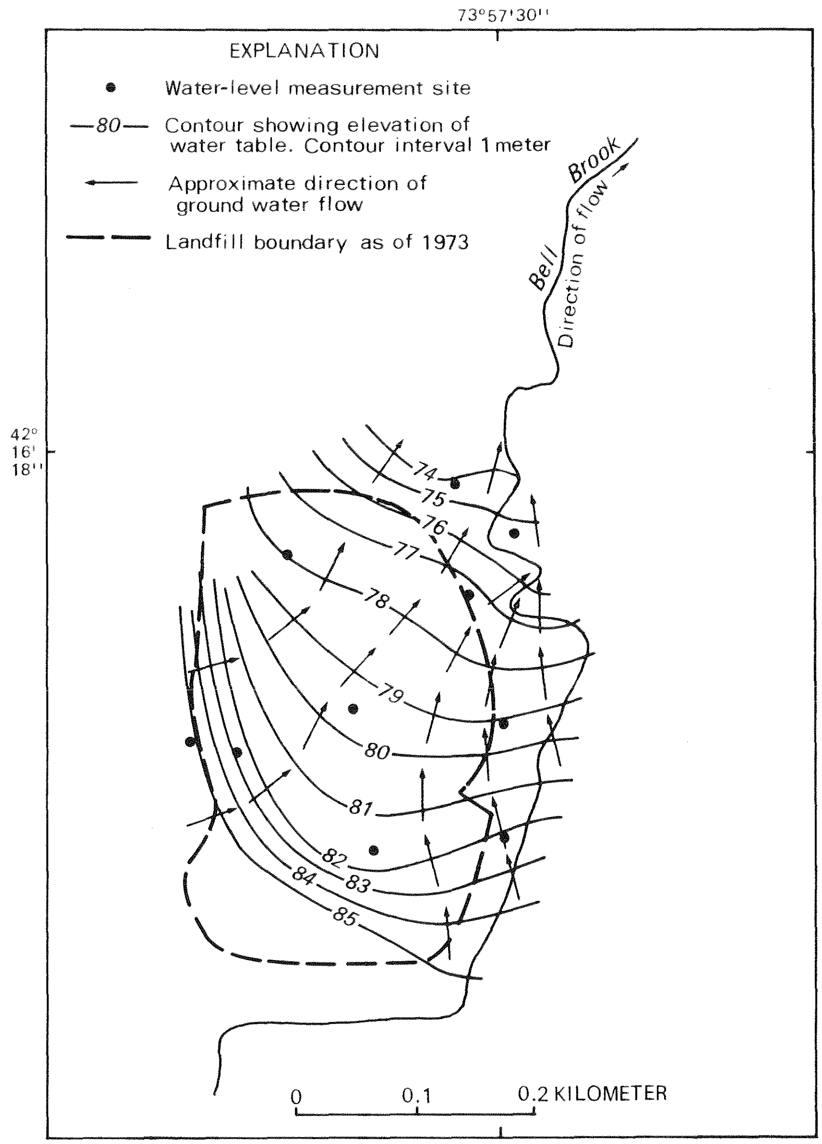


Figure 2.--Ground-water levels within study area, October 16, 1973.

CHEMICAL QUALITY OF SURFACE WATER AND GROUND WATER NEAR LANDFILL

Chemical quality of surface water and ground water within the study area ranged from no landfill influence to high concentrations of leachate-borne substances.

Surface Water

Bell Brook upstream from the landfill (site 1) is small and similar in water quality to other streams in the area (U.S. Geological Survey, 1974). Concentrations of most stream-water constituents were remarkably constant at site 1 during the study, as shown by the chemical analyses in table 2. Water temperature at site 1 ranged from 0° to 23°C on different sampling occasions.

At site 1, dissolved oxygen ranged from 78 percent to 92 percent of saturation concentration. Nitrogen species were almost all in the form of nitrate, which is less toxic to benthic invertebrates than ammonium (Hart and Fuller, 1974). The concentration of ammonium at downstream sites on Bell Brook (sites 2-6) was often greater than at site 1 because diluted leachate was entering the stream below site 1. Total organic carbon (TOC) at all six sites on Bell Brook was less than 30 mg/L. According to Wetzel (1975), the range of TOC in unpolluted surface waters has been reported to be approximately 1 to 30 mg/L. The main effect of organic carbon on biological communities is that organisms sensitive to concentrations above a threshold level may be replaced by more tolerant forms. Chemical determinations for phenol and a series of pesticides indicated the concentrations of these compounds at site 1 to be below detectable limits.

Ground Water

Well sites 7 and 10 were uncontaminated by leachate. Site 7, upstream from the landfill, was a shallow well screened 0.3 m below the streambed. Site 10, between the edge of the landfill and the stream near the upper end of the landfill (fig. 1), was screened at a depth of 7 m below land surface. Generally, the water quality at these two wells was similar to that at site 1 (unaffected by leachate) except that higher concentrations of bicarbonate, iron, and manganese were present.

Most of the other wells studied indicated some contamination from landfill leachate. The water from the leachate collector was consistently of the worst quality (site 14) and was essentially solubilized refuse and cover material. Concentrations of most constituents were much higher at the leachate collector than elsewhere within the study area. In particular, the leachate-collector samples contained high concentrations of dissolved metals, especially iron and manganese.

Table 2.--Range of chemical conditions in ground water and stream water, Bell Brook at South Cairo Landfill, 1971-1975

[Site locations are shown in figure 1. Sites 1-6 are stream-sampling sites; 7-15 are wells. Site 14 is the leachate collector.]

Constituent or characteristic	Collection-site number				
	1	2	3	4	5
bicarbonate, mg/L	27 - 132	58 - 220	71 - 260	57 - 343	98 - 313
sulfate, mg/L	12 - 16	5.7 - 12	4.5 - 12	3.6 - 16	4.2 - 10
chloride, mg/L	1 - 11	4 - 5.1	4.4 - 6.5	3.1 - 8.5	5.4 - 10
nitrate (N), mg/L	.1 - .2	.11 - .44	.11 - .44	.02 - .26	.10 - .44
ammonium (N), mg/L	.03 - .10	.03	.03	.03 - 1.6	.03
dissolved phosphorus (P), mg/L	.01 - .02			.01 - .09	
phenol, µg/L	0			0 - 6	0
total organic carbon, mg/L	.1 - 2.2	3.4 - 4.1	.1 - 5	.1 - 2.2	2.4 - 4.0
dissolved iron, µg/L	14 - 240	270 - 7,000	2,600-13,000	700 - 13,000	1,700 - 13,000
dissolved manganese, µg/L	20 - 55	3,100-32,000	4,600-35,000	1,200 - 32,000	5,600 - 25,000
dissolved lead, µg/L	1	55	15	1 - 30	60
dissolved zinc, µg/L	0 - 10	20	10 - 20	20 - 300	20
specific conductivity, µmho/cm at 25°C	87 - 153	116 - 263	141 - 400	110 - 470	175 - 580
dissolved oxygen, mg/L	9.5 - 10.0	3.6 - 10.0	3.5 - 10.0	2.5 - 10.3	
pH	6.9 - 7.5	6.5 - 7.0	6.7 - 6.9	6.8 - 7.3	
pesticides in water (µg/L)	Not detected			Not detected	
pesticides in streambed (µg/kg)	Not detected			chlordane: 50	

Table 2.--Continued.

	6	7	8	9	10
bicarbonate, mg/L	94 - 590	57		342	43 - 68
sulfate, mg/L	4.9 - 12	13 - 17		.6 - 6.4	14 - 19
chloride, mg/L	5.5 - 11	4.6		7.6	2.3 - 3.0
nitrate (N), mg/L	.08 - .17	.01 - .20		.01 - .19	.10 - .34
ammonium (N), mg/L	.12	.02 - .56		.56	.01
dissolved phosphorus (P), mg/L		.02 - .41		.41	.02
phenol, µg/L	0				
total organic carbon, mg/L	4.1 - 25	.2 - .6	7.0	3.0 - 3.6	.8 - 2.7
dissolved iron, µg/L	20 - 650	170 - 260		(22-24) x 10^3	30 - 240
dissolved manganese, µg/L	4,800-23,000	150 - 1,100		(9.8-16) x 10^3	10 - 20
dissolved lead, µg/L	18				
dissolved zinc, µg/L	20 - 30				
specific conductivity, µmho/cm at 25°C	175 - 550	116 - 130	700 - 850	440 - 850	119 - 165
dissolved oxygen, mg/L	8.0 - 10.5				
pH	7.2 - 7.8	6.8 - 7.1	6.8	6.9 - 7.2	6.4 - 6.8

	11	12	13	14	15
bicarbonate, mg/L	43 - 156	376 - 772	394 - 765	(7.3-11.2) x 10^3	258 - 556
sulfate, mg/L	15 - 20	.4 - 13	.1 - 17	28 - 1,900	.6 - 6.9
chloride, mg/L	2.7 - 7	8.1 - 35	11 - 28	1,300 - 2,700	9 - 25
nitrate (N), mg/L	.02 - .84	.01 - .44	.02 - 10	.19 - 5.4	.05 - .7
ammonium (N), mg/L	0 - .07	.35 - 3.3	.04 - .31	310 - 851	.43 - 11
dissolved phosphorus (P), mg/L	.01 - .16	.10 - .22	.01 - .25	.06 - 1.42	.05 - .06
phenol, µg/L	0 - 23	32 - 78	43 - 174	2,400 - 4,500	25 - 62
total organic carbon, mg/L	.7 - 3.9	2.7 - 221	2.9 - 44	570 - 13,000	16 - 163
dissolved iron, µg/L	60 - 290	(7.7-55) x 10^3	20 -17,000	(1.1-7) x 10^6	(4.6-37) x 10^3
dissolved manganese, µg/L	900 - 1,900	(30-54) x 10^3	(10-38) x 10^3	(2.1-5.9) x 10^5	(30-65) x 10^3
dissolved lead, µg/L	0	0	0	80 - 560	0
dissolved zinc, µg/L	20	20 - 30	20	(4.5-9.2) x 10^3	10 - 20
specific conductivity, µmho/cm at 25°C	175 - 203	320 - 830	560 - 730	(7.7-18.6) x 10^3	480 - 700
pH	6.4 - 6.6	6.5 - 6.6	6.6 - 6.9	5.8 - 6.4	
pesticides in water (µg/L)				Not detected	

Iron ranged in concentration from 1.1×10^6 µg/L to 7.0×10^6 µg/L, and manganese ranged from 2.1×10^5 µg/L to 5.9×10^5 µg/L. It is stressed that the major source of iron and manganese in the leachate was the cover material (till). Most soils in this region of New York are rich in these metals.

Concentrations of several of the chemical constituents were about the same in leachate-collector samples as at uncontaminated sites. These included nitrate, phosphorus, and pesticides. Nitrate was nearly absent because the strongly reducing conditions caused reduction of nitrate and nitrite to ammonium. No pesticides were found in detectable concentration in any leachate-collector samples, although some other organic constituents, such as phenol, were highly concentrated (2,400-4,500 µg/L).

Not all wells were affected to the same degree; wells 11 and 12, just beyond the edge of the landfill, exhibited different water-quality patterns from the rest. The concentration of TOC in well 11 ranged from 0.7 to 3.9 mg/L, whereas TOC concentration in well 12 ranged from 2.7 to 221 mg/L. In contrast, TOC concentrations in uncontaminated wells 7 and 10 were less than 3 mg/L. The four private domestic wells east of the landfill, on the opposite side of Bell Brook (fig. 1), were not affected by landfill leachate during 1971-75.

Contaminated ground water beneath the landfill flows northeast roughly parallel to Bell Brook. Some of the contaminated ground water enters Bell Brook as underchannel flow, and some discharges at land surface as springs along the east edge of the landfill (fig. 1). The chemical quality of a typical spring (site 15) indicated severe leachate contamination, as was the case at nearby wells. The concentrations of bicarbonate, ammonium, phenol, iron, and manganese in the spring were much higher than in either the uncontaminated surface water (site 1) or the uncontaminated ground water (sites 7 and 10).

Chemical quality of ground-water samples from beneath Bell Brook (sites 8 and 9) was similar to that from other contaminated wells. For instance, the specific conductivity at sites 8 and 9 ranged from 700-850 µmho/cm and 440-850 µmho/cm, respectively. The specific conductivity at a nearby contaminated well (site 12) ranged from 320-830 µmho/cm. By comparison, the specific conductivity in Bell Brook at sites 2 and 4 (the nearest surface-water sampling sites) ranged from 110-470 µmho/cm. The significance of samples at sites 2, 4, 8, and 9 is their indication that stream water was generally of good quality, whereas ground water entering the stream at sites 8 and 9 was severely degraded and would be toxic to many benthic invertebrates (Hart and Fuller, 1974). Although the quality of water in the stream is important to benthic invertebrates, the quality of water in the interstitial spaces of the benthic sediments is crucial because this is their habitat. The concentration of TOC, iron, and manganese at sites 8 and 9 exceeded the toxic levels reported by Hart and Fuller (1974) for some genera of the mayfly larvae (Ephemeroptera) observed at site 1.

Dissolved Oxygen Regime

The dissolved-oxygen (DO) concentration of stream water at sites 2 through 6 was highly variable through time, whereas at site 1, it was always near saturation concentration. During periods of moderate streamflow (1.0 L/s or more), DO concentration was uniform throughout the reach (sites 1-6). However, below-normal rainfall from mid-August through mid-October 1973 reduced the streamflow in Bell Brook to the point that a 50-m reach just upstream from site 2 became dry. At this time, all streamflow in the reach below site 2 consisted solely of ground water, mainly from sources near the landfill. As would be expected, the contaminated ground water, which was deficient in DO, caused the DO concentration of the stream to become greatly undersaturated. DO concentrations on Oct. 17, 1973 ranged from 2.5 to 8.0 mg/L at sites 2 through 6, or from 23 to 71 percent of saturation concentration. By comparison, the DO concentration at site 1 was 10.0 mg/L, or 87 percent of saturation at the same time. The low DO concentration at sites 2 through 6 selectively eliminated stream-dwelling organisms that were unable to withstand a prolonged deficiency of DO.

BIOLOGY OF STREAM

Benthic Organisms in Uncontaminated Reach

A wide variety of benthic organisms was found upstream from the landfill at site 1. (See table 3.) In general, the taxonomic groups of organisms collected at site 1 differed on each sampling occasion, probably as a result of normal seasonal succession (Hart and Fuller, 1974). The most common organisms at site 1 were *Pisidium*, a freshwater clam, in October 1973, and a variety of Diptera (fly) larvae in May 1974 and June 1975. The Diptera genera *Rheotanytarsus*, *Paratendipes*, and *Ablabesmyia* were the most common in May 1974, whereas the Diptera genera *Heterotrissocladius*, *Procladius*, and *Pentaneura* were the most abundant in June 1975. In addition, three genera of Ephemeroptera (mayflies), two genera of Trichoptera (caddisflies), and one genus each of Oligochaeta and Nematomorpha (segmented worms) was found. Only at site 1 were attached filamentous green algae abundant on submerged rocks and sticks on all three sampling dates.

Habitat requirements of benthic invertebrates are often a useful indicator of water-quality conditions, particularly if the habitat is highly specific to a certain type of fauna. Unlike larger forms, such as fish, most benthic invertebrates cannot migrate from reach to reach to escape lethal conditions such as low DO concentration. Because most benthic invertebrates have a life span of at least several months, they are indicative of water quality over a fairly long period.

Table 3.--Benthic invertebrate densities in Bell Brook near South Cairo landfill, Greene County, N.Y., 1973-75

[All values indicate number of individuals per 100 square centimeters]

Taxon	Sampling-site number and date[1/] collected																	
	1			2			3			4			5			6		
	1973	1974	1975	1973	1974	1975	1973	1974	1975	1973	1974	1975	1973	1974	1975	1973	1974	1975
Diptera (flies)																		
Procladius	--	2.81	4.2	--	--	--	--	--	--	--	84	--	--	90	--	--	--	--
Anatopynia	--	--	1.4	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Pentaneura	12.3	--	2.8	--	--	4.2	7.3	--	--	6	--	--	2.8	--	--	54	--	--
Heterotrissocladius	--	--	7	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Cryptochironomus	--	--	1.4	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Tanytarsus	--	--	1.4	--	--	--	--	--	--	--	--	--	--	--	--	--	--	13
Ablabesmyia	--	5.62	--	--	34	--	--	--	--	--	--	--	--	45	--	--	28	--
Paratendipes	--	11.23	--	--	--	1.4	--	--	--	--	--	--	--	--	--	--	--	--
Rheotanytarsus	--	14.04	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Brillia	--	5.62	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Chironomus	--	--	--	62	73	127	305	--	--	561	--	--	22	626	--	87	67	--
Diamesa	--	--	--	--	--	1.4	--	19	--	--	244	--	--	--	--	--	--	--
Prodiamesa	--	--	--	--	--	1.4	--	--	--	--	--	--	--	--	--	--	--	--
Polypedilum	--	--	--	--	84	2.8	--	22	--	--	65	--	--	--	--	--	--	--
Orthocladius	--	--	--	--	--	--	--	28	--	--	--	--	--	--	--	--	--	--
Microtendipes	--	--	--	--	--	--	--	--	--	--	458	--	--	98	--	--	--	--
Metriocnemus	--	--	--	--	--	--	--	--	--	--	--	--	4.1	--	--	--	--	--
Micropsectra	--	--	--	--	--	--	--	--	--	--	--	--	--	28	--	--	17	--
Stictochironomus	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	14
Tabanus	5.52	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Pericoma	--	--	--	--	--	--	7.3	--	--	--	--	--	--	--	--	--	--	--
Limnophila	--	--	--	--	--	--	--	--	--	--	2.8	--	--	--	--	--	--	--
Pilaria	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	4.2
Ephemeroptera (mayflies)																		
Caenis	3.68	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Ephemerella	3.68	--	--	--	--	--	--	--	--	--	--	--	--	2.8	--	--	--	--
Stenonema	1.84	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Ephemera	--	--	--	--	--	--	--	--	--	--	--	--	--	2.8	--	--	--	--
Gastropoda																		
Lymnaea	--	--	--	--	--	--	1.8	--	--	--	--	--	--	--	--	--	--	--

Table 3.--Continued.

	1			2			3			4			5			6		
	1973	1974	1975	1973	1974	1975	1973	1974	1975	1973	1974	1975	1973	1974	1975	1973	1974	1975
Mollusca																		
Pisidium	69.75	--	--	8	--	2.8	--	--	--	--	--	--	2.8	5.6	--	102	--	--
Oligochaeta																		
Naidium	4.69	--	--	338	--	--	79	--	--	52	--	--	43	--	--	633	--	--
Nais	--	--	--	--	--	--	--	--	--	--	--	--	--	182	--	--	168	--
Nematomorpha	1.84	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Trichoptera																		
Hydropsyche	1.84	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Molanna	1.84	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Unidentified Trichoptera	--	--	--	8.1	--	--	--	--	--	--	--	--	--	--	--	4.1	--	--
Crustacea																		
Bryocamptus	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	8.4	--
Cyclops	--	--	--	--	--	1.4	--	--	--	--	--	--	--	--	--	--	--	--
Plesioptera	--	--	--	--	--	7	--	--	--	--	354	--	--	--	--	--	--	1.4
Megaloptera																		
Sialis	--	--	--	--	--	--	--	--	--	--	--	--	1.4	--	--	--	--	--
Hemiptera																		
Hesperocorixa	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	2.8	--	--

1/ Sampling dates are October 16, 1973; May 30, 1974; and June 12, 1975.

As previously indicated, the clam Pisidium was the most numerous organism at the uncontaminated site (site 1) in October 1973. Pisidium is one of the most widely distributed freshwater clams because its blood contains hemoglobin, which permits it to live at low DO concentrations. It also is common in clean-water habitats (Whitton, 1975).

The Oligochaete Naidium was numerous at site 1 in October 1973 but was not found at other sampling times. Oligochaetes feed on bacteria, so that their relative abundance or scarcity reflects the bacterial numbers in the sediment. Not much is known of the growth requirements of Naidium other than their common preference for stony stream bottoms such as at site 1. However, Naidium was much more abundant at sites downstream than at site 1. Site 6 had the highest concentration of naidids.

Diptera larvae were abundant on all three sampling dates at site 1, and a total of 12 genera were collected. Of these, 10 were Chironomidae, 1 a Ceratopogonidae, and 1 a Tabanidae. None of the above genera were collected on all three occasions, but two genera were collected twice. The Chironomidae exhibit a large range of feeding habits (Bryce and Hobart, 1972); some, such as Tabanus, are predaceous, whereas others eat decaying plant matter. Some Chironomidae have a high tolerance to certain unfavorable environmental conditions, whereas others do not. Of the Chironomidae found at site 1, none are reported to have been found in habitats in which the concentration of iron exceeded 2,890 μg/L (Roback, in Hart and Fuller, 1974). Maximum observed iron concentration in the streambed at site 1 was 260 μg/L, considerably below toxic limits for Chironomidae.

Larvae of the orders Ephemeroptera and Trichoptera are generally considered, with a few exceptions, to live in clean-water habitats (Hart and Fuller, 1974). Three Ephemeroptera genera were found at site 1 in October 1973. None of these genera were collected at sites 2 through 6 on that day, but species of Ephemerella and Ephemera were later collected at site 5 in May 1974. No Stenonema or Caenis species have been reported from waters having iron concentrations greater than 2,890 μg/L (Roback, in Hart and Fuller, 1974) which may be a possible explanation for their absence at most downstream sites. Two genera of Trichoptera, Hydropsyche and Molanna, were collected at site 1 in October 1973, but neither was found at any other sampling sites. Trichoptera are sensitive to environmental conditions. Only one genus, Ptilostomis, has been reported to survive iron concentrations above 5,000 μg/L (Hart and Fuller, 1974). Hydropsyche and other net builders have been reported to be tolerant of organic loading but not of toxic pollutants (Roback, in Hart and Fuller, 1974). One Nematomorpha species was collected at site 1 in October 1973 but was not found elsewhere during the study.

Benthic Organisms in Contaminated Reach (Sites 2-6)

The benthic invertebrates found in the reach of Bell Brook adjacent to and below the landfill were primarily diptera larvae, oligochaetes, and the clam Pisidium. Of the Diptera, the greatest number were Chironomidae, of which 14 genera were identified. Some of the Chironomidae were found also at site 1, although most were far more numerous between sites 2 and 6 than at site 1. The subfamily Chironominae was numerically the most abundant of the Chironomidae in the reach from sites 2 through 6. This, again is attributed to the presence of hemoglobin in their blood, which permits survival during periods of anaerobiasis. Four Chironominae genera, Chironomus, Microtendipes, Paratendipes, and Stictochironomus, were found between sites 2 and 6 during the study. Chironomus was found at sites 2 through 6 in October 1973 but not at site 1. Chironomus was the most common organism at most sites. Bryce and Hobart (1972) report Chironomus to be better able to withstand anaerobic conditions than other Chironominae.

Microtendipes was abundant at sites 4 and 6 in May 1974 but was not found earlier or since then. Bryce and Hobart (1972) consider Microtendipes to do well in mesotropic conditions. Polypedilum and Stictochironomus were less abundant than other Chironominae. Polypedilum is reported to be tolerant to 16,000 µg/L iron (Hart and Fuller, 1974), which might be a factor in its presence in Bell Brook. Stictochironomus prefers sandy bottoms such as those at sites 5 and 6 but was found at site 6, and only once. Like the Chironominae, the Tanytarsini have hemoglobin but do not tolerate anaerobic conditions as well. The genera Microspectra and Tanytarsus were observed only at sites 5 and 6. Bryce and Hobart (1972) report Tanytarsus to often be abundant in moderately oligotrophic conditions. Two genera of Diamesinae, Diamesa and Prodiamesa, were found in Bell Brook adjacent to and downstream from the landfill. These genera prefer gravel or sand and reportedly grow best in cold water. In May 1974, Diamesa was found at site 4 in large numbers. Diamesa has been reported to be tolerant to 2,890 µg/L iron (Hart and Fuller, 1974), which correlates well with the concentrations of iron (2,800 µg/L) and manganese (4,900 µg/L) at site 4 in May 1974. The Tanypodinae, which are predaceous, are mostly free living and contain hemoglobin, and would therefore be expected to be found both upstream and downstream from the landfill.

Four genera of Diamesinae, Ablabesmyia, Anatopynia, Pentaneuna, and Procladius were collected, all but the Anatopynia were found both above and below the landfill. Of these, only Pentaneuna was collected at all sampling locations. The Orthocladiinae, which are algae feeders and do not contain hemoglobin, are restricted to waters with an adequate oxygen supply. Four genera of Orthocladiinae were found within the study area, two above and two below the landfill. Brillia and Heterotrissocladius were found only at site 1. Metriocnemus was observed once (site 5) as was Orthocladius (site 3). The absence of this subfamily from other sampling sites is puzzling because oxygen concentration probably was lowest at sites 2 and 3.

Other dipterans collected adjacent to and below the landfill included the carnivorous Limnophila and the detritus feeders, Pilaria and Pericoma.

Two oligochaetes were found in the same reaches. Naidium and Nais were occasionally the most common organisms present. Naidium was found only in October 1973 but was collected at all sites, including site 1. Naidum was more abundant at sites 2 and 6 than elsewhere on this date; its abundance at these sites is partially attributed to the soft silt bottom, which is favored by this genus. On later collections, Naidium was not present; instead, the genus Nais was found but only at sites 5 and 6. No oligochaetes were found in June 1975. It has been reported (Brinkhurst and Cook, in Hart and Fuller, 1974) that oligochaetes are sensitive to the presence of heavy-metal ions because these reduce bacteria, their food supply. The only evidence of Trichoptera adjacent to or below the landfill were unidentified empty cases at site 6 in October 1973.

Alderfly larvae of the genus Sialis were observed at site 5 in October 1973. This organism is predaceous and frequents well-aerated standing or running water. Hesperocorixa was also collected on this day at site 6. Both of these organisms are fairly tolerant to adverse conditions and have been reported from waters having iron concentrations greater than 5,000 μg/L, at low and high pH, and at high hardness (Roback, in Hart and Fuller, 1974).

Algae and Bacteria

Algae were absent from submerged rocks and sticks at sites 2-6; instead, the rocks were stained black or the color of rust. The stream bottom within this reach was covered with a rust-colored growth, about 2 cm thick, which was identified as the filamentous bacterium Leptothrix mixed with unidentified fungi and very few algae. The mass consisted of approximately 75 percent iron. It is presumed that the diluted leachate was inhibitory to most attached algae observed at site 1. Although the toxic agents between sites 2 and 4 were not identified, iron and manganese are likely possibilities. The toxic level of iron has been reported to be 80 to 280 μg/L for Ankistrodesmus braunii, a common green alga (O'Kelly, in Stewart, 1974). Observed concentrations of iron and manganese between sites 2 through 6 were at times greatly in excess of one or both of these levels.

Effects of Heavy Metals on Benthic Invertebrates

The data in table 3 and in the preceding section indicate that benthic invertebrate populations of Bell Brook at site 1 differed considerably from those at sites 2 through 6. The differences are indicated to be at least partly the result of contaminated ground water from the vicinity of the landfill entering the stream between sites 2 and 6. The unusually high concentrations of iron and manganese in the interstital water of the benthic sediment (9,800-24,000 μg/L) is far in excess of levels reported to be toxic to many benthic invertebrates (Hart and Fuller, 1974).

CONCLUSIONS

Rainfall on the South Cairo landfill percolates through the buried refuse to produce leachate, which causes the solution of minerals, notably iron and manganese, in the refuse and cover material. The leachate seeps into the ground water, some of which later emerges at land surface near Bell Brook, and some of which enters Bell Brook as upward flow through benthic sediments. Ground-water flow is northerly, roughly parallel to Bell Brook.

Wells screened just below the streambed gave data on chemical conditions in benthic sediments. Wells within and near the filled area were used to determine ground-water quality and lateral flow patterns. Bell Brook was sampled to collect data on chemical quality of the water near the landfill.

The South Cairo leachate is characterized by a high concentration of chloride, bicarbonate, ammonium, organic carbon, phenol, and heavy metals. Most of the metals were detected in concentrations considerably above limits set for potable water. Pesticides were not detected. Although the leachate is diluted considerably by ground water before reaching Bell Brook, iron, manganese, and bicarbonate concentrations and specific conductance remain relatively high. Iron and manganese are precipitated quickly after reaching the streambed and form deposits rich in iron and manganese in the benthic sediments.

Benthic invertebrate populations in Bell Brook upstream from the landfill were noticeably different from those in the reach receiving diluted leachate. Both the generic composition and the total number of organisms per square meter differed between the two reaches. This change seems to be caused by a combination of factors attributable to the presence of leachate, which causes a low dissolved oxygen content and a high concentration of dissolved metals, notably iron and manganese. Ephemeroptera and Trichoptera were absent in the reach characterized by low DO and the highest concentration of dissolved metals (sites 2-4). Fungi and filamentous iron bacteria grew well in this reach. Algae were scarce in the reach adjacent to the landfill (sites 2-5) despite a high bicarbonate concentration. It is likely that high dissolved-metal concentration was a factor leading to their absence.

REFERENCES CITED

Brown, Eugene, Skougstad, M.W., and Fishman, M. J., 1970, Methods for collection and analysis of water samples for dissolved minerals and gases: U.S. Geological Survey Techniques of Water-Resources Investigations, book 3, chap. A1, 169 p.

Bryce, Derek, and Hobart, Alan, 1972, The biology and identification of the larvae of the Chironomidae (Diptera): Entomologist's Gazette, v. 23, p. 175-217.

Greeson, P. E., Ehlke, T. A., Irwin, G. A., Lium, B. W., and Slack, K. V., 1977, Methods for collection and analysis of aquatic biological and microbiological samples. U.S. Geological Survey Techniques of Water Resources Investigations, book 5, chap. A4, 332 p.

Hart, C. W., Jr., and Fuller, Samuel L. H. (ed.), 1974, Pollution ecology of freshwater invertebrates: New York, Academic Press, Inc., 389 p.

Kimmel, G. E., and Braids, O. C., 1974, Leachate plumes in a highly permeable aquifer: Ground Water, v. 12, no. 6, p. 388-393.

Rouse, J. V., 1973, Hydrologic relationship of Jefferson County landfill leachate and Meramic Heights area springs: U.S. Environmental Protection Agency, PB 227040, 21 p.

Stewart, W. D. P. (ed.), 1974, Algal physiology and biochemistry: Berkeley and Los Angeles, Calif., University of California Press, 989 p.

U.S. Geological Survey, 1973, Water resources data for New York, pt. 2, Water quality records, 1972: Albany, N.Y., U.S. Geological Survey open-file rept., 296 p.

Wetzel, R. G., 1975, Limnology: Philadelphia, Pa., W. B. Saunders, 743 p.

Whitton, B. A., 1975, River ecology: Berkeley and Los Angeles, Calif., University of California Press, 725 p.

Zanoni, A. E., 1972, Ground water pollution and sanitary landfills--A critical review: Ground Water, v. 10, no. 1, p. 3-13.

E R R A T A

1. Page 3, paragraph 4, 7th line and 6th line from bottom:

   Landfill area should read *200 x 600 m*

2. Page 3, paragraph 4, 2d line from bottom, and page 5, paragraph 3, 2d line from bottom:

   Delete *the town of*

   South Cairo is a locality within the town of Cairo.

3. Page 10, 1st paragraph, 4th line from top:

   Delete *(till)*; add *(stratified drift)*

4. Page 5, table 1: Some streamflow measurements were made at varying distances from biological data sites. The row that reads:

   Date 1 2 3 4

   should be changed to read

   Date 1 1A[1] 5 5A[2]

   with the following footnotes:

   [1] *55 m upstream from site 2*

   [2] *250 m downstream from site 5*

Ehlke, T. A., 1979, Effects of landfill leaching on water quality and biology of a nearby stream, South Cairo, Greene County, New York: U.S. Geological Survey Water-Resources Investigations 79-13, 18 p.