CONVERSION TABLE

Multiply inch-pound units	By	To obtain metric SI units
foot (ft)	0.3048	meter (m)
gallon per minute (gal/min)	0.0631	liter per second (L/s)

A microgram, as in micrograms per liter (μg/L), is the standard reporting unit for some chemical constituents, and is 1/1000 of a milligram.

ABSTRACT

The U.S. Geological Survey, in cooperation with the Fairbanks North Star Borough, is conducting a study of the geohydrology of the Fairbanks area. This study, begun in 1975, is designed to provide basic hydrologic data for land-use planning. Studies to this date (1979) indicate that arsenic, nitrate, iron, and hardness in well water are of great concern to local homeowners and planners. Arsenic and nitrate in water can affect human health, whereas iron and hardness can be aesthetically objectionable and can also damage plumbing systems. This report presents all the arsenic, nitrate, iron, and hardness data collected in the Chena Ridge area southwest of Fairbanks through June 1979, in addition to pertinent characteristics of each of the four constituents. A previous report by Johnson and others (1978) was a compilation of all the arsenic, nitrate, iron, and hardness data collected in the Fairbanks area by various agencies through June 1977. Concentrations of arsenic, nitrate, iron, and hardness detected through June 1979 in the Chena Ridge area range as follows: arsenic, 0 to 28 micrograms per liter; nitrate, 0 to 20 milligrams per liter; iron, 0 to 18 milligrams per liter; and hardness, 72 to 1,400 milligrams per liter. For public water supplies, the U.S. Environmental Protection Agency (EPA) recommends a limit of 50 micrograms per liter arsenic, 10 milligrams per liter nitrate, and 0.3 milligrams per liter iron. No recommended limit has been established by EPA for hardness.

INTRODUCTION

The U.S. Geological Survey, in cooperation with the Fairbanks North Star Borough, is conducting a study of the geohydrology of the Fairbanks area. This study, begun in 1975, is designed to provide basic hydrologic data for land-use planning.

Studies to this date (1979) indicate that arsenic, nitrate, iron, and hardness in well water are of concern to homeowners and planners. Arsenic and nitrate in water can affect human health, whereas iron and hardness can be aesthetically objectionable and can also damage plumbing systems.

A map by Johnson and others (1978) was a compilation of all the arsenic, nitrate, iron, and hardness data collected in the Fairbanks area by various agencies through September 1978. Additional data collected in the Chena Ridge area through June 1979 are presented in this report. Discussion of the chemical constituents is from Johnson and others (1978) except for the information pertaining directly to the Chena Ridge.

The Chena Ridge study area is located within T. 1 S., R. 2 W., and the northwest corner of T. 2 S., R. 2 W., Fairbanks meridian. This is the most populated area of the ridge and offered a greater number of private wells from which to collect water samples.

Chena Ridge is composed of a pelitic schist (metamorphosed marine mud deposit) folded into a series of anticlines and synclines whose axes roughly parallel the topographic axis. Blanketing the entire ridge is an eolian (windblown) silt, or loess, originating from the Tanana River flood plain during the Pleistocene and Holocene epochs. This silt cover is thin or nonexistent at the ridgetop and gradually thickens downslope. On the lower slopes and valley floors, the loess has been reworked and is locally referred to as muck. This muck is perennially frozen and in places has a high ice content.

There are two principal ground-water aquifers in the Fairbanks area: the bedrock aquifer of the uplands, and the alluvial aquifer of the lowlands (Nelson, 1978a). The dividing line between the uplands and lowlands has been arbitrarily placed at an altitude of 500 ft (feet). In the uplands, ground water is transmitted primarily through fractures in the bedrock. Yields are generally low: many are less than 5 gal/min (gallons per minute), although drillers have reported yields as high as 15 gal/min from some wells. Recharge to the upland aquifer is local, occurring where the silt cover is thin or nonexistent. Additionally, in the Chena Ridge area, the Tanana River may also recharge wells drilled near and below the level of the river. The alluvial aquifer of the lowlands is prolific and can supply hundreds of gallons per minute to properly constructed wells. The alluvial aquifer bordered by the Tanana and Chena Rivers is recharged primarily by the Tanana River.

Data collection for this study was coordinated through the well inventory program. Samples were obtained only through solicitation of homeowners or at their request; therefore, not all wells in the area were sampled. Additionally, sample sites tend to be concentrated in the areas of greatest development and are sparse in areas of little or no development.

At each site, the following determinations were made: temperature, pH, bicarbonate alkalinity, and specific conductance. Additionally, field tests for iron and nitrate were performed. Samples for iron and nitrate analysis were collected only if the field tests were positive. Samples for arsenic and hardness analysis were routinely collected during each site visit. Depths to static water level were also measured where possible. All data collected during this study are on file at the U.S. Geological Survey office in Fairbanks.

The data presented on this map should not be used in place of sampling and analysis in the determination of water quality of unsampled wells or areas. However, the presence of contaminated wells in an area indicates that nearby wells have a high probability of also being contaminated.

DISCUSSION OF CHEMICAL CHARACTERISTICS

Arsenic

Arsenic concentrations found to date in the ground water of the Chena Ridge area have ranged from 0 to 28 μg/L (micrograms per liter), well below the maximum recommended limit of 50 μg/L for drinking water set by State of Alaska and the EPA in 1975.

A dose of 70,000 μg, or less than 1 ounce, of pure arsenic is toxic to humans (Luh, Baker and Henley, 1973). The toxic level may vary with the tolerance of the individual and probably depends on the chemical form of the arsenic (National Academy of Sciences, National Academy of Engineering, 1972). Smaller quantities taken over a long period of time can accumulate in the body and produce chronic or acute arsenic poisoning. Varied symptoms of arsenic poisoning include fatigue, skin growths, nervous system disturbances, and gastrointestinal, kidney and liver ailments. In Taiwan, the consumption of water containing more than 300 μg/L arsenic has been correlated with increased incidences of skin cancer.

The primary source of arsenic and the mechanisms by which it enters ground water in the Fairbanks area have not been conclusively demonstrated. However, mineralized bedrock in the Fairbanks area commonly contains an arsenic-bearing mineral, arsenopyrite (FeAsS). Scorodite ($FeAsO_4 \cdot 2H_2O$), a mineral formed by the weathering of arsenopyrite, may also be a source of arsenic within the bedrock. The distribution of wells containing water having arsenic concentrations above the recommended limit is sporadic. Additionally, arsenic-contaminated wells and wells in which water contains little arsenic are only a few hundred feet apart in many places. This may be caused by the presence of two or more zones bearing water having different concentrations of arsenic (Nelson, 1978b). The concentration of arsenic in the well water depends on which zone is tapped. If two or more zones are tapped by a well, the arsenic concentration may vary with the yield of each zone. The concentration of arsenic may also vary with the duration of pumping, the settling time in a pressure tank, and precipitation reactions in the water. Arsenic dissolved in water is colorless, odorless, and tasteless, and is not removed by water treatment systems commonly used by homeowners.

Nitrate

Water sampled in the Chena Ridge area had nitrate concentrations ranging from 0 to 20 mg/L (milligrams per liter). In 97 percent of the wells sampled, concentrations of nitrate were less than 10 mg/L, the recommended limit set by EPA in 1976.

The element nitrogen (N) occurs in ground water in many forms, including nitrate (NO_3), nitrite (NO_2), and ammonium (NH_4). Nitrogen is most commonly found in ground water as nitrate (NO_3). Nitrate is colorless, odorless, and tasteless, and is not removed by conventional water treatment systems. Samples analyzed at the U.S. Geological Survey central laboratory reported the sum of nitrate plus nitrite as nitrogen.

Ingestion of water containing more than 10 mg/L of nitrate may be related to hypertension, cancer, and, in some infants under 3 months of age, potentially fatal anemia. Bacterial conversion of the nitrate ion to the nitrite ion may occur in the digestive tract of infants less than 3 months of age (National Academy of Sciences, National Academy of Engineering, 1972). Nitrite absorbed into the bloodstream combines with the hemoglobin, reducing the oxygen-carrying capacity of the blood. The result, called methemoglobinemia, or more commonly "blue baby", is oxygen starvation and is a condition which can be recognized and reversed. However, many infants have consumed water containing more than 10 mg/L nitrate with no adverse effects. Factors which may affect susceptibility of nitrate poisoning include heredity, the ingestion of nitrate-rich vegetables and vitamin C-rich foods, and the use of certain medications which affect nitrate metabolism.

Metamorphic minerals such as those in bedrock of the Fairbanks area do not contain oxidized nitrogen. Thus, in the Fairbanks area nitrate in the ground water probably originates near the surface where septic tank effluents, fertilizers, or natural soil nitrates are possible sources.

The occurrences of high nitrate concentrations in ground water in the area are unpredictable. Until the source of nitrate and the areas affected by high nitrate concentrations are better known, all homeowners using private wells should be aware of the potential health hazard.

Iron

Iron concentrations in the ground water of the Chena Ridge area are generally high, the known maximum being 18 mg/L. Of wells sampled in the area, 18 percent had concentrations less than the EPA (1976) recommended limit of 0.3 mg/L, whereas 33 percent had concentrations of 1 mg/L or less. Twenty-six percent of the sampled wells contained iron in concentrations exceeding 3 mg/L.

Water rich in iron becomes unpalatable long before harmful effects to humans are noticed. Even small amounts of iron create an unpleasant taste or odor in water and cause staining of laundry, appliances, and hair. Staining caused by water with iron concentrations of less than 1 mg/L can be effectively controlled by cleaning agents and bleaches. At concentrations between 1 and 3 mg/L, water may become unpalatable, and staining becomes more difficult to control. Water containing more than 3 mg/L of iron is aesthetically unpleasant to many people, turns alcohol or coffee black, and at this concentration staining is difficult to control without the use of iron filters. When iron-rich water is oxygenated as it is in home water systems, the iron precipitates and causes iron stains. Iron removal systems which oxidize household water and filter the iron residue are commercially available. Based on these considerations, three ranges of concentrations are portrayed on the map: less than 1 mg/L, 1 to 3 mg/L, and more than 3 mg/L.

Generally, iron concentrations increase downslope. This increase may result from exposure of percolating ground water to buried organic debris in the colluvial material of the hillsides and upper creek valleys. It also may result from inorganic oxidation reactions occurring as the water moves from the recharge areas towards the valleys.

The decomposition of organic matter in soils consumes oxygen from ground water and produces oxygen-deficient environments in which iron is more readily dissolved. Such conditions are common in the alluvium of the Tanana River flood plain and in creek valley bottoms. Iron concentrations in these areas are almost always more than 1 mg/L and usually more than 3 mg/L.

Certain bacteria speed the oxidation and precipitation of iron (Hem, 1970). These bacteria live in many wells and cause some of the iron to precipitate before it reaches the plumbing outlet. They produce a jelly-like slime that can eventually plug the pore space in the aquifer near the wells and slow the influx of water. Fragments from these bacterial growths can break loose and plug pipes and filters. Heavy chlorination of the wells at frequent intervals minimizes the development of iron bacteria; however, once the bacteria are established in an aquifer near a well, there is no known effective method of removing or destroying them.

Hardness

Hardness of ground-water samples taken from the Chena Ridge area ranged from 72 to 1,400 mg/L. Hardness was more than 200 mg/L in 68 percent of the wells sampled and less than 100 mg/L in only 6 percent.

Hem (1970) stated that waters containing less than 100 mg/L hardness are generally acceptable for domestic use although the optimum amount is a matter of consumer preference. At levels above about 200 mg/L, hardness becomes evident in all uses. The EPA provides no recommended maximum or minimum levels of concentration for hardness of water. In light of Hem's observations, three ranges of hardness are portrayed on the map: less than 100 mg/L, 100 to 200 mg/L, and more than 200 mg/L.

Hardness of water is caused mainly by the presence of dissolved calcium and magnesium and is expressed as an equivalent quantity of calcium carbonate. Hard water not only retards the cleaning action of soap and detergents, but can also form scale on cookware, in water heaters, and in boilers. However, the hardness of water can be controlled by commercially available softeners. Hard water may also have some beneficial effects. In the United States, a tentative correlation has been suggested between areas of hard water and areas where the death rate from cardiovascular diseases is lower than average (Muss, 1962).

The hardness of ground water depends on the length of time the water has been in contact with minerals, the nature of the minerals, and the corrosiveness (acidity) of the water. Calcite or calcium carbonate ($CaCO_3$), a common mineral in the bedrock of the Fairbanks area, is particularly susceptible to attack by acidic water and may contribute to the hardness of local ground water.

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CHEMICAL ANALYSES

a = field determination using Hach* test kit NI-12; b = field determination using Hach* test kit IR-18B.

Site no.	Location	Arsenic (As) (μg/L)	Nitrate NO_3 (as N) (mg/L)	Iron (Fe) (mg/L)	Hardness as $CaCO_3$ (mg/L)	Sampling date
	Sec. 11, T. 1 S., R. 2 W.					
2		3	*a* 1	*b* 0	--	06/21/78
3		0	*a* 0	*b* 1	110	06/21/78
4		0	*a* 0	18	780	07/18/78
	Sec. 12, T. 1 S., R. 2 W.					
1		--	< 0.1	--	--	07/71
2		14	--	--	--	08/23/75
	Sec. 13, T. 1 S., R. 2 W.					
1		--	0.1	8.2	174	08/30/67
2		--	< 0.1	--	--	05/72
3		--	< 0.1	--	--	07/71
4		--	< 0.1	--	--	06/72
	Sec. 14, T. 1 S., R. 2 W.					
1		--	0.7	2.8	220	08/30/67
4		19	--	--	--	08/23/75
5		2	*a* 0	5.7	180	07/27/78
6		1	*a* 0	5.3	160	07/27/78
7		1	*a* 0	6.6	150	08/10/78
8		2	*a* 0	0.23	--	08/15/78
	Sec. 15, T. 1 S., R. 2 W.					
2		13	--	--	--	08/22/75
7		0	0.12	2.5	160	11/06/78
	Sec. 20, T. 1 S., R. 2 W.					
2		0	0.54	*b* 0	72	06/27/78
4		0	0.05	0.32	1,200	11/03/78
7		1	--	--	--	08/22/75
8		1	*a* 0	6.9	1,400	06/27/78
9		6	*a* 0	4.6	83	06/29/78
10		0	*a* 0	*b* 1.2	82	06/13/78
12		1	*a* 0	*b* 1	--	07/18/78
13		2	*a* 0	*b* 2	140	07/28/78
	Sec. 23, T. 1 S., R. 2 W.					
1		--	0.4	8.4	190	08/31/67
4		5	--	--	--	08/23/75
	Sec. 24, T. 1 S., R. 2 W.					
1		--	0.1	8.4	218	08/31/67
4		0	0	--	157	05/02/76
	Sec. 27, T. 1 S., R. 2 W.					
1		12	--	--	--	08/22/76
	Sec. 28, T. 1 S., R. 2 W.					
4		0	20	*b* 1.5	1,300	06/08/78
5		1	*a* 1	*b* 1.5	850	06/07/78
6		0	*a* 0	*b* 1	--	06/13/78
	Sec. 29, T. 1 S., R. 2 W.					
1		--	0.7	0.11	288	09/28/76
3		--	1.3	--	--	12/72
6		0	0.68	*b* 0.6	300	11/13/78
10		18	--	--	--	08/22/75
11		0	--	--	--	08/23/75
13		1	*a* 0	*b* 2	330	07/07/78
14		1	*a* 0	*b* 2	440	07/07/78
16		0	*a* 0	*b* 1.2	310	08/03/78
18		1	*a* 0	*b* 0.8	220	07/11/78
19		0	*a* 0	2.1	160	08/03/78
21		0	1.1	0.56	190	10/30/78
22		0	2.9	*b* 0.2	310	12/01/78
23		0	1.4	*b* 0.4	360	12/26/78
24		0	1.1	0.03	330	01/04/79
25		1	0.48	0.09	750	04/07/79
	Sec. 30, T. 1 S., R. 2 W.					
3		0	0.57	0.04	170	12/21/78
	Sec. 32, T. 1 S., R. 2 W.					
5		0	0.55	0.69	360	12/30/78
6		5	0.01	8.5	210	02/19/79
	Sec. 33, T. 1 S., R. 2 W.					
1		--	0.9	--	--	06/72
2		--	< 0.1	--	--	10/73
3		0	*a* 0	3	1,100	06/07/78
4		1	--	--	--	08/23/75
5		28	--	--	--	08/23/75
6		1	17	*b* 1.1	1,100	06/05/78
7		0	*a* 0	6.1	1,000	06/05/78
8		0	*a* 0	*b* 0	1,000	06/07/78
9		1	*a* 0	2.8	--	06/08/78
10		1	*a* 0	*b* 1.6	670	06/07/78
11		1	*a* 0.05	5.9	960	06/16/78
12		2	*a* 0	*b*10	1,200	06/16/78
13		2	*a* 0.05	*b* 2.1	800	06/20/78
14		1	*a* 0	*b* 1	460	07/12/78
	Sec. 6, T. 2 S., R. 2 W.					
1		0	2.1	0.9	420	11/20/78
4		0	0.33	0.22	380	11/27/78
5		0	0.13	1.6	600	12/08/78
6		1	0.19	1.1	590	12/08/78

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ARSENIC, NITRATE, IRON, AND HARDNESS IN GROUND WATER, CHENA RIDGE VICINITY, FAIRBANKS, ALASKA

By
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1979