University of Notre Dame Campus Water Supply[1]

INTRODUCTION

In many respects the University of Notre Dame operates as an independent municipality. As such, the University is responsible for providing services and utilities including power, sewage disposal, and water. Some utilities are subcontracted to other municipalities or firms. For example, the disposal of sewage produced by the campus is subcontracted to the city of South Bend. Electrical power for the campus is provided primarily by the Notre Dame Power Plant, but is augmented by electricity purchased from the American Electric Power Company. However, since its establishment, the University has assumed the full responsibility for the campus water supply. This includes the maintenance of wells and the water distribution system, and monitoring of the water quality. This report summarizes the findings and recommendations of the Environmental Issues Committee on the University of Notre Dame campus water supply.

The campus water supply provides water for domestic, irrigation, and laboratory uses throughout the University. It also serves as the source of water for campus fire hydrants. The maintenance of campus wells and the water distribution system is one of the responsibilities of the Notre Dame Director of Utilities, Paul Kempf. Monitoring the quality of the campus water supply is one of the responsibilities of the Notre Dame Risk Management and Safety Department, headed by Robert Zerr. The regulation of the quality of domestic water supplies is provided by the following federal statutes: the Public Health Service Act (1944), the Safe Drinking Water Act (1974), the Safe Drinking Water Act Amendments of 1986, and the Lead Contamination Control Act of 1988. The campus water system is classed as a public water supply system by the Safe Drinking Water Act because it has more than 15 service connections and regularly serves an average of at least 25 individuals daily during at least 60 days of the year.

The Safe Drinking Water Act Amendments of 1986 established an initial list of 83 substances and required that maximum levels for these substances be established by June 19, 1989. The administration of this federal law is the responsibility of the U.S. Environmental Protection Agency with much of its authority for monitoring and enforcement delegated to the states and administered in Indiana by the Indiana State Department of Health.

Notre Dame also has initiated a comprehensive Wellhead Protection Program to meet the U.S. Government requirements of Section 1428 of the Safe Drinking Water Act and State of Indiana Codes 13-18-17-6 and 13-7-26-7. The purpose of these laws is to help protect public water supply wells from contamination.

CAMPUS WATER SUPPLY PROBLEMS

Concerns have been raised about the safety and general quality of the campus water supply. These appear to stem primarily from what are often perceived to be undesirable taste characteristics of the water in some of the older buildings on campus. Local contamination of ground water by solvents and other toxic substances can be a serious problem in this geographic region. This has raised the awareness of the potential for water supply problems within the campus community.

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[1] Adapted in part from: University of Notre Dame Environmental Issues Committee. Report on the Status and Quality Of the Campus Water Supply. Report 1, October 26, 1990. 11 pp. Some information contained in that report are updated here to reflect current conditions on the campus.

SOURCE AND DISTRIBUTION

Water for the campus is pumped from 6 wells that are distributed around the University. Five of these contribute to the general campus water supply and the sixth is dedicated for irrigation of the Burke Memorial Golf Course. The Warren Golf Course is served by a separate well and water supply system. The depth of these wells generally ranges from 175 to 200 feet. The pressure of the water supply is maintained by regulating the level of water in the water tower located near the Notre Dame Power Plant. Controls located at the power plant automatically turn on as many pumps as are necessary to maintain proper pressure in the system based on consumption rates. The principal arteries of the water system are composed mostly of 10" pipes that form a closed loop through the campus and along its periphery to U.S. 31 (Michigan Avenue). The ages of the wells and water mains vary from location to location with newer facilities generally on the periphery of the campus and in areas of recent construction. The Notre Dame water supply system produces an average output of approximately 1,000,000 gallons per day, with a maximum production capacity of about 4,000,000 gallons per day. There are approximately 100 service connections that supply water to approximately 12,000 students, faculty, staff and guests.

Notre Dame wells draw water from a major, glacially derived aquifer that forms part of the Lake Michigan basin. The Lake Michigan basin has the greatest ground water potential of any Great Lakes basin. Buried bedrock channels 300-400 feet deep filled with unconsolidated glacial sediments along the St. Joseph River can support wells yielding as much as 1,000 to more than 2,500 gallons per minute (gpm). Unsustained yields from 6-inch or larger diameter wells in the area typically exceed 500 gpm.

GROUND WATER COMPOSITION AND QUALITY

Chemical quality of ground water within the sand and gravel aquifers of the Lake Michigan basin ranges from good to poor. Total dissolved solids (TDS) usually are in the 100 to 2,000 milligrams per liter (mg/L, also called parts per million or PPM) range. The water generally is hard, ranging up to 1,000 mg/L, and its iron content is regarded as objectionably high in much of the basin. Chloride and sulfate concentrations generally are less than 50 mg/L, except where bedrock water contaminates shallow unconsolidated aquifers. Normal ranges of common inorganic chemical constituents of the Quaternary aquifers of the St. Joseph River basin in Indiana are summarized below.

Hardness (mg/L as $CaCO_3$)	**Sulfate** (mg/L)	**Chloride** (mg/L)	**Iron** (mg/L)	**TDS** (mg/L)
225-400	10-150	1-50	0.1-7.5	250-500

Water supplies drawn from these aquifers reflect the chemical composition of the ground water. For example, the city of South Bend and Notre Dame water supplies have the following ranges of common ground water-supplied inorganic constituents.

Source	**Hardness** (mg/L)	**Sulfate** (mg/L)	**Iron** (mg/L)
South Bend	270-450	38-150	0.02-1.30
Notre Dame	330-349	77-91	0.05-2.92

Pollution of aquifers by the introduction of man-made contaminants or by man-caused migration of natural contaminants may be a serious local problem in this area. Septic tanks, leaching fields, well disposals, land fills, spillage, and leakage all have the potential to add waste contaminants to sand and gravel aquifers near the land surface. No comprehensive data on ground water movements in the immediate vicinity of the Notre Dame campus are available. Thus, conclusions on ground water movements on or near the campus represent educated conjecture rather than established fact. Movement of ground water often approximates the flow of surface water in this region, although significant departures are common. Divides separate drainage basins for surface flow, with their underground counterparts termed "phreatic" divides. Most of the surface and probably the subsurface flow from the northern part of the campus is directed toward Juday Creek, whereas the remainder of the campus drains toward the Notre Dame lakes or the St. Joseph River. The campus probably is protected from contaminated ground water areas in the Granger area by distance and by Juday Creek. This stream originates near the St. Joseph Farm in St. Joseph county near Granger. It flows through Notre Dame property just north of Douglas Road and intercepts a portion of the upper ground water flow from the northern part of the county and diverts it directly to the St. Joseph River. The confluence of Juday Creek and the St. Joseph River occurs north of and down-river from the Notre Dame campus.

With no active public landfills or known areas of contaminated ground water near the campus, the most serious threat to contamination of the campus water supply would appear to come from improper disposal of waste materials on the campus itself. Campus sewage is piped to the South Bend Wastewater Treatment Plant for treatment by the city of South Bend. Disposal of chemical wastes and toxic substances is regulated by the Notre Dame Risk Management and Safety Department. Over the past few years all buried tanks containing fuel or solvents have been tested for leakage and most have been removed or replaced by environmentally safe tanks. Any contaminated soil resulting from prior leakage also has been removed. The fire that destroyed the St. Michael's Laundry in 1989 did not result in leakage of dry cleaning solvents from underground storage tanks, and these tanks have been removed. Most surface runoff from the campus is directed to the Notre Dame lakes or to a low area east of Eddy Street between Edison Road and South Bend Avenue (SR 23). This area was at one time used as a landfill by the City of South Bend and has served as a disposal site for fly ash generated by the Notre Dame Power Plant. Test wells have given no evidence of ground water contamination in this area and the distance and location of this site with respect to campus wells make contamination of the campus water supply from this source unlikely. Another possible source of ground water contamination is from leakage of gas and oil from vehicles parked on grassy areas of the campus during football games and other campus events. However, no evidence of contamination from this source has been detected. The recent paving of some of the grass parking areas used most frequently should lessen this as a potential problem. However, on the negative side, the campus may serve as a major ground water recharge area. Thus, altering the water balance through extensive paving, destruction of vegetation, or redirection of surface flows ultimately could impact ground water availability and quality in this area.

CHEMICAL CONSTITUENTS OF THE CAMPUS WATER SUPPLY

The Safe Drinking Water Act requires periodic biological and chemical monitoring of water supplies. Current statutes require monitoring and reporting of the chemical constituents of water supplies at least once every three years. Two sets of federal standards exist for public water supplies. The first set, termed "Primary Drinking Water Standards," includes maximum concentration levels of substances in water supplies that are necessary to protect public health and safety. The second set, termed "Secondary Drinking Water Standards," represents unenforceable federal guidelines regarding the taste, odor, color, and certain other non-aesthetic effects of drinking water. The U.S. Environmental Protection Agency recommends them to the states as reasonable goals, but federal law does not require water systems to comply with them. In general, public water supplies that exceed the secondary drinking water standard suggested levels pose no threat to public health, but may have color, taste or odor characteristics that the public may find objectionable.

Analyses of inorganic chemicals and potential pollutants in the campus water supply have been conducted for more than a decade. Within the last year, the water has been analyzed for inorganic constituents and for both inorganic and organic contaminants. Potential contaminants include toxic metals such as Cadmium, Chromium, Lead, Mercury, Selenium and Silver; and volatile organic compounds such as Benzene, Carbon Tetrachloride, p-Dichlorobenzene, 1,2-Dichloroethane, 1,1-Dichloroethylene, 1,1,1-Trichloroethane, Trichloroethylene (TCE), Vinyl Chloride, and Trihalomethanes. The concentration of each of these substances in the campus water supply consistently has fallen below the lowest detectable concentration measurable by the analytical procedure used. This lowest detectable concentration always is much lower than the primary drinking water standard, ranging from 1/5 to 1/1000 of the maximum concentration level set by the standard. Detectable concentrations have been measured for Arsenic (0.0002 mg/L), Barium (0.05-0.06 mg/L) and Nitrate (0.7-1.5, <0.1 mg/L most recently). The maximum concentration levels for these substances established in the primary drinking water standard are 0.05 mg/L, 1.0 mg/L, and 10.0 mg/L, respectively. Thus, at least an order of magnitude of concentration separates the campus water supply from the maximum concentration level for each of these substances set by the Safe Drinking Water Act.

The concentration of coliform bacteria also is regularly determined for the campus water supply. The presence of coliform bacteria in the water supply does not in itself pose a threat to public health. However, the presence of these organisms may indicate contamination of the water supply from animal wastes or domestic sewage. Since such contamination could introduce viruses and other disease organisms into the water supply, the primary drinking water standard allows for not more than 1 coliform bacterium per 100 milliliters (ml) of sample. Chlorination can be used to purify water supplies with high bacterial counts. Recently, however, chlorination has been shown to be a double edged sword with respect to public safety. Consumption of drinking water with chlorine residuals within an order of magnitude of those found in community drinking water systems has caused an increase in serum cholesterol and produced indications of myocardial hypertrophy and arteriosclerosis in rabbits and pigeons reared on a diet marginal in calcium. Limited human clinical studies suggest that consumption of chlorinated water increases the serum cholesterol levels in a dose-dependent way in volunteers given a diet marginally deficient in calcium. There also appears to be an increased risk of bladder cancer associated with lifetime consumption of chlorinated water that may account for about 25-30% of the occurrence of this form of cancer in adults residing in communities with chlorinated drinking water supplies. The campus water supply consistently has fallen below the maximum concentration level for coliform bacteria specified in the primary drinking water standard. Therefore, chlorination of the campus water supply is unnecessary and is not performed.

Substance	**Units**	**2nd Std. (suggested)**	**N.D. Campus**	**N.D. Adm. Bldg. 2001***	**N.D. Adm. Bldg. 1994**	**N.D. Adm. Bldg. 1990**	**South Bend**
Alkalinity	mg/L $CaCO_3$	no maximum	230-238	--	--	240	200-300
Chloride	mg/L	250.0	30.0-47.0	--	--	--	20-70
Copper	mg/L	1.0	0.02	--	--	<0.02	<0.02-0.1
Hardness	mg/L as $CaCO_3$	500.0 as TDS	338-349	--	--	330	270-450
Iron	mg/L	0.3	0.05-2.57	0.1	0.4	2.92	0.02-1.3
Manganese	mg/L	0.05	0.03-0.3	0.185	0.25	0.270	0.02-0.3
pH	pH units	6.5-8.5	7.3-7.5	--	--	7.6	7.0-8.0
Sodium	mg/L	no maximum	14.0-23.2	--	--	--	10-35
Sulfate	mg/L	250.0	77.0-91.0	--	--	90	38-150
Zinc	mg/L	5.0	0.02-0.3	0.0635	0.22	0.127	0.1-0.3

* Average of water samples from 2nd and 4th floor.

The campus water supply contains measurable concentrations of some inorganic substances included in the secondary drinking water standard. The table above summarizes typical values for the South Bend city and Notre Dame water supplies.

The concentrations given above apply to cold water only. Hot water distributed throughout the campus is chemically softened. This involves the exchange of the monovalent cation sodium for the bivalent cations calcium and magnesium. Thus the hot water supply would be expected to be lower in calcium and magnesium and higher in sodium. Some iron and manganese also are removed in the softening process, so lower concentrations of these chemicals are expected in the hot water supply. The relatively high concentrations of iron, manganese, and zinc contained in water samples taken from the Notre Dame Administration Building in 1990 and 1994 reflect leaching of these minerals from the old galvanized iron pipes in the building prior to its renovation. This situation may also occur in other older buildings on the campus. Following the renovation of the building, which included replacement of water pipes, concentrations manganese, zinc and especially iron dropped dramatically.

CHARACTERISTICS OF CHEMICALS IN THE CAMPUS WATER SUPPLY

Following is a brief discussion of the taste and odor characteristics and known health effects of each of the chemicals found in significant concentrations in the campus water supply. Where possible, the probable source of the chemical also is indicated.

ALKALINITY

Alkalinity is a measure of the amount of carbon dioxide (CO_2) in water. It occurs in four principal forms: as gas dissolved in water; as a weak acid, carbonic acid, obtained by a chemical reaction between CO_2 and water; as the bicarbonate ion (HCO_3^-); and as the carbonate ion ($CO_3^=$). The relationship among these ions is shown in the following formula:

$$CO_2\uparrow + H_2O \rightleftharpoons H_2CO_3 \rightleftharpoons HCO_3^- + H^+ \rightleftharpoons CO_3^= + 2H^+$$

The equation is driven to the left under conditions of low pH and to the right under conditions of high pH. The carbon dioxide system serves as a buffer in water supplies. The CO_2 buffer system generally consists of the weak acid carbonic acid (H_2CO_3) and its salt, usually calcium bicarbonate ($Ca(HCO_3)_2$). Buffers are important in mitigating the effect on pH of additions of acids or bases. For example, in water of moderate to high alkalinity, addition of acid will result in the production of carbon dioxide gas with little noticeable change in pH; whereas additions of bases yield insoluble $CaCO_3$ that precipitates out of solution as limestone or chalk. Under conditions of very low alkalinity, water tends to be slightly acidic (due to the presence of carbonic acid) and poorly buffered. Acidity in water supplies may be undesirable, because acidic water may dissolve toxic metals such as lead and cadmium from solder in pipes. While high alkalinity poses no threat to human health, the precipitation of calcium carbonate lime deposits in pipes can have serious economic consequences for both domestic and industrial water supplies. While not included in either the primary or secondary drinking water standards, the recommended range of alkalinity for public water supplies is 30-400 mg/L. With concentrations of less than 100 mg/L most desirable. The alkalinity of the Notre Dame water supply, while over 100 mg/L, easily falls within the 400 mg/L limit and is typical of other water supplies in this area.

ARSENIC

Arsenic is an element that occurs naturally in many rocks, minerals, and soils. The toxicity of arsenic to humans is well known. It can accumulate in the body and causes arsenosis. Arsenic, when ingested, can be carcinogenic and also is known to affect the liver and heart. The federal limit of arsenic in drinking water is 0.05 mg/L. Arsenic concentrations of 0.0002 mg/L have been found in the campus water supply. At this concentration, it poses no known health threat.

BARIUM

Barium is a trace element that often occurs in low concentrations in water. In high concentrations it may have toxic effects on the heart, blood vessels, and nerves. Barium does not appear to accumulate in human bone or tissue, so there is no danger of a cumulative effect. The Federal drinking water regulations limit barium concentrations in drinking water to 2 mg/L. The highest concentration found in the Notre Dame water supply is 0.06 mg/L. At this concentration, it poses no known health threat.

CHLORIDE

While chloride is a relatively minor element on the earth, it is a major dissolved substance in many waters. The concentration of chloride ion in the ocean averages about 19,300 mg/L. Chloride concentration in fresh water typically ranges from less than 30 mg/L to more than 1,000 mg/L, with lower values associated with humid areas, and higher concentrations in arid regions. Chloride concentrations greater than 250-500 mg/L may impart a salty taste to water. This maximum concentration level of 250 mg/L set in the secondary drinking water standard is based on taste considerations. Chloride is not regarded as a health threat in concentrations of less than 1,000 mg/L. The highest concentration of chloride detected in the Notre Dame water supply is 47 mg/L. At this concentration it imparts no taste and poses no known health threat.

COPPER

Copper is both essential and beneficial to humans and its absence can lead to nutritional anemia in very young children. Adults require about 3 mg per day. In general copper is readily passed from the body in waste, although in high concentrations, it may accumulate in the liver. Concentrations of copper in water in excess of about 0.05 mg/L are generally the result of pollution, either from industrial or mining wastes or the corrosion of copper plumbing. Copper sulfate is used to control plankton and rooted aquatic vegetation in the Notre Dame lakes. Some cases of ground water contamination from this source are known. The Federal drinking water standard maximum concentration level of 1.0 mg/L. for copper, is based on taste rather than health considerations. The highest concentration of copper found in the campus water supply of 0.02 mg/L is well below the taste threshold, poses no known health threat, and suggests little or no contamination from copper plumbing or the copper sulfate used for algae control in the Notre Dame lakes.

HARDNESS

Hard water and soft water are relative terms that are derived from the effect of the bivalent cations calcium (Ca^{++}) and magnesium (Mg^{++}) on soaps. Soap does not clean efficiently in water with high concentrations of Ca^{++} and Mg^{++}. Hard water also leaves insoluble residues in bathtubs, sinks, and clothing and forms scale in water heaters, boilers and pipes, reducing their capacity and heat-transfer properties. In the U.S. hardness is generally reported as the concentration calcium carbonate ($CaCO_3$) in grains per gallon (gpg) or mg/L, with 1 gpg equal to 17.12 mg/L. While the concept of hardness is relative and somewhat subjective, waters with hardness values of up to 17 mg/L or 1 gpg are generally considered soft, whereas those with values greater than about 180 mg/L or 10 gpg are considered very hard. By this standard, the ground water of this area, which typically has a hardness of 225-400 mg/L, would be classed as exceptionally hard. In 1962, a study by the U.S. Geological Survey, which examined the chemical composition of water supplies in the 100 largest American cities, found the highest concentration of calcium and bicarbonate ions (145 mg/L and 380 mg/L, respectively) in the water supply of South Bend, Indiana. The hardness of the Notre Dame water supply is around 350 mg/L as $CaCO_3$, with calcium and magnesium ion concentrations of 85-90 mg/L and 28-30 mg/L, respectively. In this area, hardness typically contributes 80-90% of the total dissolved solids found in drinking water.

Despite its effect on laundry and pipes, even extremely hard water does not pose a health threat to humans. In fact, $CaCO_3$ scale may reduce the leaching of copper, lead and cadmium from water pipes and solder joints into water. Water can be softened by substituting monovalent cations such as sodium (Na^+) and potassium (K^+) for calcium and magnesium. Hardness commonly is reduced through the use of ion-exchange water softeners. An ion-exchange water softener consists of a tank containing an insoluble plastic resin that has a negative charge with positive sodium ions attached to it. The resin has a stronger affinity for Ca^{++} and Mg^{++} ions than it does for Na^+. Therefore, when hard water is passed through the resin, calcium and magnesium are exchanged for an equivalent amount of sodium. Once all of the sodium attached to the resin has been replaced by calcium and magnesium the softener resin must be recharged. This is accomplished by passing a concentrated solution of sodium chloride (NaCl) through the resin. The calcium and magnesium released during the regeneration process must be disposed of as liquid waste. Commonly this is included as part of domestic sewage. Since the water softening process increases the sodium content of the water, the resulting soft water may be less healthful for persons on sodium restricted diets. In homes with water softeners, it is a common practice to run unsoftened water to the cold water faucet of the kitchen sink for use in drinking and cooking, and soft water to all other faucets in the house. The hot water supply distributed throughout the campus is chemically softened. The cold water supply of the campus is untreated.

IRON

Iron compounds are common in rocks and soil and easily are leached by water. It is not unusual for natural waters to have dissolved iron concentrations of up to 5.0 mg/L. Two forms of ionic iron are commonly present in water. Under neutral and alkaline pH conditions oxidized ferric iron (Fe^{+++}) tends to form insoluble colored (red-brown) deposits. Reduced ferrous iron (Fe^{++}) is more soluble, tends to appear in higher concentrations in water, and is colorless. Except under low pH conditions, ferrous iron is easily and quickly converted to the ferric form by the addition of oxygen to water. Several groups of so-called iron bacteria (e.g., *Crenothrix*, *Gallionella*, *Leptothrix*, *Ochrobium*, *Siderocapsa*), can derive metabolic energy through the conversion of ferrous iron to ferric iron. These organisms may be responsible for rusty water in water supplies and can form a slimy coating in toilets, pipes and pumps.

High concentrations of iron in water supplies pose no known health threat to humans. However, many people find such water has an objectionable taste or color. Concentrations in excess of 0.3 mg/L can cause staining of laundry and utensils. Potatoes boiled in iron rich water may turn black and tannins in tea and coffee may combine with iron resulting in a black inky appearance and an objectionable taste. The secondary drinking water standard gives a recommended concentration limit for iron of 0.3 mg/L based on taste and aesthetic criteria. However, the threshold for metallic taste in drinking water from iron to humans may be as low as 0.1 mg/L. The concentration of iron in the Notre Dame water supply varies substantially with the age of plumbing. This suggests that iron is being leached from older iron water pipes and cast iron water mains on the campus. Drinking water drawn from most newer buildings on the campus does not have a metallic taste to most individuals. However, many people find the taste of drinking water in the Administration Building and other older buildings on campus to be objectionable. Iron is relatively easy to remove from water. Ferrous iron may be removed by converting it to its oxidized ferric form and then filtering out the insoluble precipitate. Reduction of hardness through ion exchange water softening also can reduce iron. Unfortunately, centralized iron removal from the campus water supply would not be effective if significant amounts of iron are being derived from old water mains and plumbing. However, installation of iron removal systems or water softeners combined with replacement of pipes to drinking fountains could be effective in buildings served by old water mains. Replacement of old campus water mains and water pipes in older buildings on campus as part of any major remodeling operation probably is the most effective long term method of reducing the iron content in the campus drinking water.

MANGANESE

Manganese and iron in water have many similar qualities and often are treated together in discussions of water quality. Like iron, manganese occurs in both oxidized and reduced states, imparts an undesirable taste to water, and has a variety of other aesthetically unpleasant attributes. The presence of moderate concentrations of manganese in water is not known to pose a health threat to humans. The maximum concentration level of manganese recommended by the secondary drinking water standard, 0.05 mg/L, is based on taste and aesthetic considerations. Upon oxidation manganese concentrations in excess of 0.2 mg/L precipitate and form black deposits on food and utensils during cooking, and black stains on plumbing fixtures and laundry. The taste threshold for manganese in water is 0.5 mg/L. The process of manganese removal from water supplies is similar to that of iron. The concentration of manganese in the Notre Dame water supply varies throughout the campus, but generally is close to or exceeds the recommended limit in the secondary drinking water standard. It may contribute to the unpleasant taste characteristics of drinking water in some areas of the campus.

NITRATE

Nitrate (as N) has been found in the campus water supply in concentrations of 0.7 to 1.5 mg/L, although the most recent analysis indicated less than 0.1 mg/L. While it is a major component of the atmosphere, gaseous nitrogen generally is inert. Chemically combined forms of nitrogen such as nitrate, nitrite and ammonia in water normally are the result of biological processes or additions of fertilizers. These may enter water supplies from shallow wells or surface contamination. Nitrate concentrations in excess of 10 mg/L can cause the disease methemoglobinemia in infants. This is the basis for the maximum concentration level set in the primary drinking water standard. High concentrations of nitrate and chloride in water supplies may be an indication of contamination of the water supply by animal wastes. There is no evidence of this type of contamination in the campus water supply.

pH

pH, an abbreviation for the potential of hydrogen, is a measure of the hydrogen ion (H^+) content of water on a scale of 0 to 14, with 7 being neutral. Pure water in equilibrium with the atmosphere tends to be slightly acidic (pH <7) due to the presence of carbonic acid that forms from dissolved carbon dioxide. Acidic water tends to be somewhat corrosive and can dissolve toxic metals from pipes and solder joints. Waters with high alkalinity, such as those of the campus water supply, tend to be slightly basic (pH >7) and are well buffered. This means the pH will remain relatively stable with modest additions of acids or bases. The secondary drinking water standard suggests a pH range for domestic water supplies of 6.5-8.5. The range of pH found in the campus water supply (7.3-7.5) is ideal for drinking water.

SODIUM

Probably all natural waters contain some sodium. Sodium tends to be very soluble in water and is precipitated only under extraordinary circumstances. Sodium may be introduced into water supplies through softening. The small amount of sodium in drinking water appears to pose no health threat to humans, and is usually a minor contributor to sodium in the diet compared to most foods. Because of the relationship between sodium and hypertension, addition of even small amounts of sodium to drinking water by softening may be undesirable for some individuals placed on sodium-restricted diets. While there is no maximum concentration level specified for sodium in the primary or secondary drinking water standards, levels in excess of 20 mg/L must be reported. Sodium levels in excess of 500 mg/L in combination with chloride give drinking water a detectably salty taste. The amount of sodium found in the unsoftened campus water supply of 14-23 mg/L is typical of water supplies in this area.

SULFATE

Many sulfate compounds originating from the oxidation of sulfite ores are soluble in water. Sulfate also is common in rain water and sedimentary rocks and may appear in ground water in relatively high concentration. Sulfate can produce a detectable taste in water at concentrations of 300-400 mg/L. The taste becomes bitter at concentrations of 500 mg/L and may be cathartic at concentrations in excess of 600 mg/L., although most people develop some resistance to its laxative effects with time. The secondary drinking water standard recommends a maximum concentration level for sulfate of 250 mg/L. The Notre Dame water supply, with a sulfate concentration of 77-91 mg/L, falls well within the standard.

TOTAL DISSOLVED SOLIDS (TDS)

The total dissolved solids (TDS) content of water is determined by weighing the residue after 105^{O}C evaporation of a filtered sample. The TDS include both salts and organic residue. Some confusion exists about the relationship between hardness and TDS. The secondary drinking water standard for TDS of 500 mg/L sometimes is called hardness. Hardness, which is a measure of the amount of bivalent cations Ca^{++} and Mg^{++} in water expressed as mg/L of $CaCO_3$, is the major contributor to the TDS in most public water supplies. However, since other inorganic and organic substances also contribute to the TDS, the hardness of a water sample nearly always is an underestimate of the TDS value. In this area, hardness typically accounts for 80-90% of the TDS. Therefore, while the TDS of the campus water supply has not been determined, it almost certainly falls well under the maximum concentration recommended by the secondary drinking water standard. The TDS of water has no relevance to public health. It is the chemical composition of the dissolved substances in drinking water that is important.

ZINC

Zinc salts are used in galvanizing and in paint pigments, pharmaceuticals, cosmetics, and several insecticides. Except at very high concentrations, zinc has no known adverse health effects on humans and is an essential micronutrient in the diet. High concentrations of zinc may result in an objectionable taste and can cause the water to appear milky. The secondary drinking water standard recommended maximum concentration level for zinc of 5.0 mg/L is based largely on taste considerations. The general campus water supply contains very low concentrations of zinc (0.02-0.03 mg/L). However, higher concentrations (1.27 mg/L) have been found in the Administration Building. The most likely cause of the relatively high zinc concentration is a gradual breakdown of the galvanized interior coating of old water pipes in the building. This hypothesis is consistent with the high amount of iron also found in water drawn from this building.

CONCLUSIONS

Examination of the quality of the campus water supply has revealed no evidence of contamination or other indication that it poses a threat to human health. High concentrations of iron and manganese in some parts of the campus may make the water unpalatable to some individuals, but this does not represent a cause for concern in terms of public health. As is typical of other water supplies in the region, the campus water also is extremely hard. Hard water may form lime scale in pipes and appliances. It is likely that iron removal by oxidation and filtering or by softening the drinking water in some older buildings would improve the flavor of the water. However, the addition of sodium to the water through the softening process could adversely affect individuals on sodium-restricted diets. This makes oxidation and filtering systems a more desirable alternative for iron removal. Since it appears that the most important source of iron in the campus water supply may be its plumbing, any attempt at central removal of iron is likely to be ineffective. Use of bottled water on the campus cannot be justified on any but aesthetic grounds. It is unfortunate that the human palate is incapable of serving as a reliable detector of water quality. Water that tastes unpleasant to some individuals because of relatively high concentrations of iron or manganese may in fact be quite healthful; whereas water containing toxic amounts of lead or cadmium or disease-producing organisms may taste perfectly fine. Continued biological and chemical monitoring of the water supply is essential to protect the health of the campus population. The best solution for improving the aesthetic quality of the drinking water in older parts of the campus is to replace the interior plumbing and water mains whenever there is an opportunity to do so.

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