Is Tap Water a Health Hazard?

by Ben Best

I am very sensitized to environmental factors which could lengthen or shorten life. For this reason I am interested in the health benefits of water and the health hazards of impure water. Unfortunately, most scientific studies of water are concerned with health hazards, whereas the sources extolling the benefits are harder to validate in terms of scientific rigor. Some websites describing purported benefits of water are: Mayo Clinic water info, Top four benefits of water-drinking and The 8 glasses per day myth.

Concerning the hazards of water -- tapwater in particular -- I concentrated my attention on the city in which I lived: Toronto, Ontario, Canada. But I do discuss other regions. And a large portion of my information is relevant in evaluating tapwater quality for anyone living anywhere. Another good website for information on tapwater is the Fairfax County Water Authority.

Before getting into details about water purity I want to raise the issue of ***bias***. Obviously, manufacturers of water purifiers and bottled water have vested interests which are likely to color the information they give you. But public health and water purification plant authorities have vested interests too, because ***they*** are to blame if something is wrong with the water. Conversely, an independent environmentalist group like Pollution Probe has a vested interest in alarmism -- the more they agitate, the more attention and donations they get. You should even take what I say with a grain of salt, because I am a borderline hypochondriac who has been worrying about drinking water for years -- and I have a vested interest in proving I am not a nutcase.

Pollution Probe estimates that our exposure to chemical pollutants is about 86% from food, 4% from air and 10% from water (the Toronto Public Health Department says 20% from water). Geographical location probably makes a significant difference in the proportions.

Historically, the greatest health hazard from public drinking water has been due to micro-organisms, such as typhoid fever, dysentery and cholera. Serious cholera outbreaks occurred in Toronto at the time the city was being incorporated -- and it was widely believed that "swamp gas" was behind the epidemic. Chlorination and ozone-treatment of water has virtually eliminated this danger. Nonetheless, water-borne viruses like hepatitis A and polio are more resistant to chlorination than bacteria. The protozoan **Giardia lamblia** (which causes giardiasis: severe diarrhea and abdominal pain) is also relatively chlorine-resistant. As recently as 1985, a **Giardia** outbreak in Scranton, Pennsylvania forced residents to boil their water.

Drinking water originates either from **surface water** (rivers, lakes, reservoirs, etc.) or **groundwater** (water in porous rocky material under the land surface). In the United States, 5% of all fresh water is surface water, and the other 95% is groundwater. Most public water supplies in rural areas use groundwater.

Both groundwater and surface water can contain contaminants. The most contaminated water tends to be found where there are small, rural groundwater treatment facilities. Groundwater can contain gasoline or oil, pesticides, inorganics and the natural radioactive gas radon. Surface water is more likely to contain organic contaminants from bacteria, decayed vegetable matter and even sewage.

Toronto drinking water is surface water. In Toronto, four water filtration plants draw water from Lake Ontario and daily treat nearly 2.5 billion litres for distribution. Water treatment consists primarily of the killing of bacteria and of particulate filtration. Of indoor water use in Toronto, 45% is for toilets, 28% bathing & personal, 23% laundry & dishes and 4% for drinking & cooking.

In general, **dioxins** are defined as coplanar polychlorinated biphenyls and polychlorinated & polybrominated dibenzodioxins & dibenzofurans. The average American ingests one picogram per kilogram of body weight per day, primarily from the animal fats of food. Over two-thirds of these dioxins originate from incineration, landfill fires and backyard trash burning sends dioxins to air, to water and is ultimately concentrated in the fat of animals. **The most heavily contaminated foods are freshwater fish, marine fish, pork, beef, poultry and dairy products, in that order.**
[CHEMICAL & ENGINEERING NEWS, 28-May-2001, p.25-27].

Although dioxin is perhaps an extreme example, it does serve to illustrate that concentrations in the parts per trillion range cannot be dismissed as being inconsequential. This is especially of concern in the case of organic compounds that, in contrast to water-soluble substances, cumulatively concentrate in fatty tissues (and brains) of animals over a lifetime. For humans who eat fatty tissues of animals, the concentration of organics becomes multiplied orders of magnitude. For this reason, the pesticide DDT was banned in the 1960s and **PCBs** (PolyChlorinated Biphenyls) were banned in the 1970s.

All the Great Lakes have had warning fish advisories concerning PCBs & Dioxins, but only Lake Superior and Lake Michigan have had advisories concerning Mercury & Chlordane. Lake Ontario, often called the least great of the Great Lakes, is downstream from the other four — which might imply that it is a dumping ground for the other four. But, in fact, the most serious entry-site for contaminants is on the Niagara River (between Lake Erie and Lake Ontario) itself.

Because of cheap energy and plentiful fresh water, the Niagara Falls area is a popular industrial site. It is also the location of the four worst toxic dumpsites in the United States: Love Canal, S-area, 102nd Street and Hyde Park, which contain 22,000, 63,000, 89,000 and 80,000 tons of toxic waste, respectively. Hyde Park contains 2 tons of a type of dioxin (2,3,7,8 TCDD) which is possibly the most toxic substance that has ever been produced. In higher organisms, TCDD is transported to the cell nucleus where it attacks DNA. Seventy parts per trillion (70 ppt) of TCDD is enough to kill 50% of monkeys. But, as is common with organics, TCDD tends to concentrate in tissues over time because it is not excreted.

The US Fish and Wildlife Service estimates that dioxin tissue concentrations of 0.04 ppt can produce toxic effects in rainbow trout — and that these tissue concentrations may be 86,000 times greater than the concentration in the surrounding water. Dioxin is a common pulp mill effluent which can enter bleached paper products (coffee filters, paper plates, toilet paper, etc.) According to Pollution Probe, a shovelful of dioxin in Lake Ontario would devastate the ecosystem all the way to the St. Lawrence River. Thus far, the threat is more potential than present, although the limestone bedrock at Hyde Park is known to be cracking. Dioxin has not been detected in Toronto drinking water, but it has been detected at St. Catherines and Mississauga.

PCBs are **extremely** resistant to biological or other kinds of breakdown. Almost every capacitor manufactured between 1930 and 1980 contains PCB dielectric liquids. Although PCBs were banned in the US and Canada in 1977, almost all the PCBs ever manufactured remain intact. Levels of 8ppm (parts per million) in Lake Trout and 4ppm in Coho Salmon caused the banning of commercial fishing for many species of fish in Lake Ontario. Pollution Probe found that 50% of the lake's white sucker fish had lip cancer.

Nearly 100 organic and inorganic chemicals have been identified in Toronto drinking water, and there are probably many others that have not been identified. Pollution Probe has detected more than 50 hazardous contaminants in Toronto drinking water, 16 of which are carcinogens. Nonetheless, the fact that most of these agents are present in highly dilute amounts should not be ignored. For example, Pollution Probe's 1983 report claims Toronto tap water contains the pesticide Lindane, but the concentration is only about 2 parts per trillion. This amount may be negligible, but to counter this idea Pollution Probe mentions that for a person who drinks 2 litres of water daily, this is 50 billion lindane molecules every day.

The best-studied organics in Toronto tap water are the TriHaloMethanes (THMs), such as chloroform. These substances are actually **produced** by the water purification process. Chlorine is added to kill bacteria, but chlorine reacts with the Lake's humus (decomposed leaves and similar vegetable matter) to produce THMs. In 1983, water coming out of a Toronto tap contained 3.5 ppb (parts per billion) of THMs, according to the Toronto Department of Health. Based on animal studies, this dose should produce about one cancer death every 3 years in Toronto. This may seem negligible, considering that 30,000 people die of cancer in Toronto every year. The animal studies also pose a problem, because to prove that a substance causes one death in 10,000 rats in a year's time, one would have to watch at least 10,000 rats for a year. This is impractical, so fewer rats are given higher concentrations of the carcinogen — and the results are extrapolated back to smaller doses (a questionable process).

The use of chloroform (trichloromethane) for anesthesia (dating from the 1940's) has been demonstrated to cause necrosis of liver, kidney and central nervous system tissue in humans. Chloroform is often formed due to reaction of chlorine with organic matter in water. Chloroform causes cancer in experimental studies on rodents. An epidemiological study of water chlorination in Wisconsin which looked only at data for white females found a significant association between municipal water chlorination and colon cancer,

but no association with any other form of cancer [JNCI (Journal of the National Cancer Institute) 67(6):1191-1198 (1981)].

Toronto Public Health authorities have defined "acceptable" levels of concentrations for cancer-causing and non-cancer-causing chemicals. A cancer-causing chemical is "acceptable" if a person drinking two litres of water daily for a 70-year lifetime would have less than a 1-in-a-million chance of getting cancer (the equivalent risk of smoking 1.5 cigarettes per year). A non-cancer-causing chemical is "acceptable" if a person drinking two litres of water daily for a 70-year lifetime would have less than a 1-in-a-million chance of an observable adverse health effect. Based on these criteria, according to a 1990 report of the Toronto Public Health authorities, there are only 6 chemicals at or above the "acceptable" concentration: lead, aluminum, bis(2-ethylhexylphthalate), chloro- form, alphahexachlorcyclohexane and tetrachloroethylene. (Interestingly, the 1990 report put chloroform at 5.45 ppb and total THMs at 12.5 ppb — in contrast to 3.5 ppb THMs in the 1983 report.) There are 7 more chemicals which are slightly below the "acceptable" level. For most people, the official level of acceptability means there is no cause for worry. There are other factors one could consider, however, such as the interactions of several carcinogens. For example, a nonsmoking asbestos worker is 9 times more likely to get cancer as a nonsmoking nonasbestos worker, but a smoking asbestos worker is 92 times more likely to get cancer. And what of the subclinical effects, especially the cumulative accumulation of unstudied chemical cocktails in the brain? In these areas of speculation and questionable data, emotions and vested interests tend to be the deciding factors.

The issue of lead contamination, however, is not so ambiguous. Water leaving a Toronto water treatment plant is typically one part per billion (ppb) lead. But 80% of pipes in Toronto are lead-based, and much interior plumbing is soldered with 50-50 lead-tin solder. (Lead pipes were **required** in the city of Chicago until 1986 when federal law made them **illegal**.) Lead concentrations at the tap are typically 5 ppb if the tap has been unused for less than 5 hours. Concentrations will be closer to 18 ppb if the tap has been unused for 5 to 8 hours — and 28 ppb if unused for over 8 hours. Hot or soft water can increase these concentrations by greater pipe corrosion. The US Environmental Protection Agency estimates that 30 ppb of lead correlates with brain damage corresponding to a loss of 3 IQ points for chronic exposure in children. Of 34 schools sampled in the Toronto area, 41% had lead concentrations in excess of 50 ppb when samples were collected early Monday morning (the schools have now instituted a flushing program). The Toronto Public Health Department advises city citizens to run a tap at least one minute before drawing water for drinking if the tap has not been turned-on for over 5 hours.

The Toronto treatment plants not only add chlorine to the water, but fluoride and aluminum sulfate as well. Residents of communities with 1 ppm (part per million) of fluoride have 60% less tooth decay than communities with unfluoridated water. The amount added to Toronto water is about 1.2 ppm. Claims have been made that fluoride can protect against osteoporosis by hardening bone tissue. Skeletal fluorosis (wherein bones become thicker and denser) is a known health hazard for kidney patients who cannot excrete fluoride, but the health effects in normal people are debatable. Fluoride is a known mutagen and may have other cumulative toxic metabolic effects.

Mottled tooth enamel (brown or yellow stains) have been shown for fluoride levels above 4 ppm. Concern with possible toxicity and the right of individual choice has resulted in water not being fluoridated in areas like Los Angeles, California and Portland, Oregon.

Aluminum sulfate (alum) is added to Toronto water to cause clumping of microscopic debris (removing cloudiness). (This is a common process for treating surface water that is not usually done for groundwater.) Aluminum levels in Toronto drinking water range from 50 ppb in the winter to 325 ppb in the summer. There are disputable claims that aluminum is toxic to certain central nervous system neurons and may lead to Alzheimer's Disease. A chemist I know has denied this by saying that Alzheimer's Disease is no more prevalent among workers in the aluminum industry than the general population. Nonetheless, the September 1990 Summary Report on drinking water by the City of Toronto Department of Public Health makes the statement "Aluminum at comparable levels to that found in Toronto's drinking water has been linked to Alzheimer's Disease in a limited number of studies." One such study is [AMERICAN JOURNAL OF EPIDEMIOLOGY; Rondeau,V; 152(1):59-66 (2000)].

The net health hazard of drinking Toronto tap water is not easy to quantify and, considering the other dangers of modern life, may not seem worth worrying about. The lifetime risk of being killed by lightening is 1 in 30,000; of being killed by drowning is 1 in 400 and of being killed by auto accident is 1 in 60. Daily toxin ingested in food may be five to ten times the toxin intake from water. Nonetheless, water toxin intake **is** controllable (perhaps moreso than is food toxin or other hazards), but there is a cost.

Softening water may offer some advantages, but probably no health advantage. Water "hardness" is mostly due to calcium and magnesium. Hard water causes spotting on glassware, rings in bathtubs and dingy films on clothes. The fact that calcium and magnesium precipitates soap means that more soap is needed for all washing. Hard water can also clog plumbing and make water taste bad.

Studies in the United States show that people who drink soft water have a mortality rate that is 15 to 20% higher, mostly due to cardiovascular disease. Not only are calcium and magnesium protective of the cardiovascular system, but soft water causes more lead and cadmium to leach out of pipes. A 1975 Seattle study showed that 76% of tap water samples had lead in excess of 50 ppb. (Vancouver also has soft water.) Water softening devices typically use ion-exchange resins to replace calcium and magnesium with sodium, which can raise blood pressure.

Arsenic in drinking water can contribute to cancer (especially of the bladder & lung). A National Research Council report concluded that people who consume about one litre per day of water with 3ppb (parts per billion) arsenic have about a 1-in-1,000 risk of developing bladder or lung cancer during their lifetime. At 20ppb the risk rises to 7-in-1,000 [CHEMICAL & ENGINEERING NEWS, 17-Sep-2001, p.12]. The risk of cancer from arsenic is more than 100 times greater than that of any other water contaminant with a recognized minimum contaminant level [SCIENCE 296:2145-2145 (2002)]. Arsenic is also implicated in diabetes & cardiovascular disease. Most arsenic enters groundwater from the weathering of minerals in rocks & soils rather than from pollution. In the United States, groundwater arsenic increases toward the Southeast — being highest in Arizona

and Southern California [CHEMICAL & ENGINEERING NEWS, 21-May-2001, p.51-55]. The amino acid taurine has been shown to protect heart tissue from arsenic intoxication associated with apoptotic-stress pathway damage [TOXICOLOGY AND APPLIED PHARMACOLOGY; Ghosh,J; 240(1):73-87 (2009)].

A 2008 investigation by the Associated Press found that pharmaceutical drugs (anti-epileptic, anti-anxiety, anti-asthma, antibiotics, sex hormones, etc) are being excreted or otherwise flushed down toilets and re-entering the water supply because water treatment plants don't remove them and there is no testing for the presence of such agents. The treated water is released into rivers, lakes and reservoirs and treated again when it enters the drinking water system — but such treatment is mainly intended to remove particulate matter, microorganisms and selected chemicals. Although the concentration of drugs in the water supply is very low, the long term affect they would have is unknown. Watersheds are also affected, so "spring water", deep underground aquifers or water from wells (especially those near landfills) can contain drugs. Drinking water treatment plants that used ozone removed more than 50% of 25 of 29 pharmaceuticals and endocrine disrupting compounds tested for, but treatment plants that used chlorine only removed more than 50% of 16 of 36 [ENVIRONMENTAL SCIENCE & TECHNOLOGY; 43(3):597-603 (2009)].

Substituting bottled water for tap water may not improve matters — depending on the brand. Some brands of bottled water studied by the Toronto Public Health authorities had less aluminum, lead and nickel than tap water, but more barium and cadmium. Plasticizing and other organic agents can leach into the water from the bottle (this is less the case for hard plastics, such as the one used by Evian). Glass bottles can release heavy metals into water.

Activated charcoal filters remove chlorine, organic chemicals and pesticides, but not fluoride, nitrate, lead or other heavy metals. Because activated charcoal removes chlorine, these filters can breed bacteria. To prevent this, carbon filters are often impregnated with silver, which kills bacteria. Silver is toxic to humans as well, so one must be careful to not buy a unit that releases too much silver into the water.

Reverse osmosis filters operate by using water pressure to force pure water through a membrane against the direction of osmosis (which is a flow from the pure to the salty side of a membrane). Reverse osmosis filters remove lead and other large minerals and organics, but do not remove the smaller minerals and organics (such as chlorine and chloroform). The most effective units are those which combine reverse osmosis with charcoal filtration.

Distillation is sterilizing and eliminates most metals, but volatile organics (chloroform, phenol, trichloroethylene, etc.) may simply boil-along with the water. (Faucet devices that aerate water remove some, but not much, of the volatile organics.) Distillers accumulate hard residues, primarily composed of calcium and magnesium. The most effective distillation systems provided charcoal filters to remove organic volatiles as well as citric acid monohydrate to remove residues.