Water Fluoridation and the Environment:

Current Perspective in the United States

HOWARD F. POLLICK, BDS, MPH

Evidence of water fluoridation's effects on plants, animals, and humans is considered based on reviews by scientific groups and individual communities, including Fort Collins, CO, Port Angeles, WA, and Tacoma-Pierce County, WA. The potential for corrosion of pipes and the use of fluoridation chemicals, particularly fluorosilicic acid, are considered, as is the debate about whether fluoridation increases lead in water, with the conclusion that there is no such increase. The arguments of anti-fluoridationists and fluoridation proponents are examined with respect to the politics of the issue. *Key words*: fluoridation; environment; toxicology.

INT J OCCUP ENVIRON HEALTH 2004;10:343–350

Prior to 1945, epidemiologic and laboratory studies confirmed the association between the environment (naturally-occurring fluoride in water supplies) and the health and cosmetic appearance of teeth.[1] Where fluoride levels were low, prevalences and severity of dental caries were high among lifetime residents, yet where fluoride levels were high, the prevalences and severity of dental caries were low, but dental fluorosis occurred with high prevalence and severity. This led to the concept of creating an ideal environment for optimal dental health through adjusting the naturally occurring fluoride level to about 1 mg/L (1 part per million). In 1986, the U.S. Environmental Protection Agency (EPA) set the maximum contaminant level (MCL) for naturally-occurring fluoride in public drinking water at 4 mg/L, with a secondary standard at 2 mg/L.[2]

Water fluoridation, then, is the controlled adjustment of fluoride concentrations of community water systems to optimal levels to minimize the incidence of dental caries (tooth decay) and dental fluorosis (enamel mottling). From initial efforts begun as community trials in 1945, water is now fluoridated in thousands of public water systems and reaches two thirds of the U.S. population served by such systems.[3] Community water fluoridation and other uses of fluorides, such as in toothpaste, have significantly reduced the prevalence of dental caries in the United States.[1]

Early investigations into the physiologic effects of fluoride in drinking water predated the first community field trials.[4–7] Since 1950, opponents of fluoridation have claimed it increases the risks for cancer, Down's syndrome, heart disease, osteoporosis and bone fracture, acquired immunodeficiency syndrome, low intelligence, Alzheimer disease, allergic reactions, and other health conditions.[8] The safety and effectiveness of water fluoridation have been re-evaluated frequently, and no credible evidence supports an association between fluoridation and any of these conditions.[9,10]

The Environment

Environmental concerns have been investigated in literature reviews for the Tacoma–Pierce County Health Department, Washington (August 2002),[11] and the City of Port Angeles, Washington (October 2003),[12] and no negative impact of water fluoridation on the environment has been established. Issues related to discharge to water; emissions to air; production, storage, or release of toxic or hazardous substances; or production of noise have been found to be nonsignificant. Emissions of fluoride into the air are not released outside the well houses. Fluoride concentrations in rivers downstream of the discharges increase by less than 0.01 mg/L due to adding fluoride to the water supply system.

Fluoridated water losses during use, dilution of sewage by rain and groundwater infiltrate, fluoride removal during secondary sewage treatment, and diffusion dynamics at effluent outfall combine to eliminate fluoridation related environmental effects. In a literature review, Osterman found no instance of municipal water fluoridation causing recommended environmental concentrations to be exceeded, although excesses occurred in several cases of severe industrial water pollution not related to water fluoridation.[13] Osterman found that overall river fluoride concentrations theoretically would be raised by 0.001-0.002 mg/l, a value not measurable by current analytic techniques. All resulting concentrations would be well below those recommended for environmental safety.

A study conducted in Phoenix, Arizona, to test the efficacy of soil aquifer treatment systems indicated that fluoride concentrations decline as water travels under-

Received from the Department of Preventive and Restorative Dental Sciences, School of Dentistry, University of California San Francisco, San Francisco, California.

Address correspondence and reprint requests to: Howard Pollick, Department of Preventive and Restorative Dental Sciences, 707 Parnassus Avenue, San Francisco CA 94143-0758.

ground. This study suggests that 40–50% of the fluoride discharged to groundwater is removed as the water travels through the soil and aquifer. Thus, fluoride does not concentrate in groundwater.[14]

PLANTS AND ANIMALS

The concentration of fluoride in the treated water does not reach levels that could harm any plant or animal species.[11,12] A report of the effect of industrial pollution, from an aluminum plant on salmon indicated that the usual fluoride concentration of the river was 0.1 mg/L, and when the concentration was raised experimentally to 0.5 mg/L, there was an effect on the salmon.[15] Since rivers and streams are not fluoridated and the increase in the fluoride concentration of a river as a result of runoff from fluoridated water would be insufficient to raise the level to even 0.2 mg/L, fluoridation of water can have no effect on salmon.

There is no evidence that fluoridated water has any effect on gardens, lawns, or plants. Although silver fluoride is not used in water fluoridation, silver fluoride at 1 mg/L used as a disinfectant had no effect on growth of wheat.[16] There is evidence that very high concentrations of fluoride have no toxic effect on plants in ponds:

> The fate of fluoride in a simulated accidental release into an experimental pond was observed for 30 days in Grenoble, France. The components investigated were water, sediments, plants, algae, molluscs, and fish. Twenty-four hours after the release, most (99.8%) of the fluoride was distributed in the physical components (water and sediments), and the biological agents contained only 0.2% of the fluoride released. Despite an exposure to hot spots of 5,000 ppm at the beginning of the accidental release, no visible toxic effects were observed on the biological components such as plants, algae, molluscs, and fish.[17]

There is evidence that ladyfinger (okra) can withstand up to 120 mg/L fluoride. The consumption by people of this plant grown with fluoridated water at 1 mg/L would be 0.2 mg per kg:

> Because of suggestions that food is a rich source of fluoride to humans and the absence of permissible and upper limits of fluoride for irrigation water, plant uptake studies were conducted using fluoride-rich irrigation water. Ladyfinger was grown in sand and soil cultures for 18 wk and the accumulation of fluoride in various plant parts was studied. The potential for ingestion of fluoride by humans through this route was also considered. The percentage uptake was greater in sand-cultured plants than in soil-cultured plants. The root accumulates most of the fluoride supplied through irrigation water and the fruit accumulates the least. Up to 120 mg/L fluoride of irrigation water did not harm the plants. The ingestion of fluoride by humans from plants irrigated with water containing 10 mg/L fluoride would be 0.20 mg per 100 g ladyfinger.[18]

HUMANS

The Institute of Medicine, Food and Nutrition Board has estimated that the tolerable upper limit for human daily intake of fluoride is 10 mg per day for adults and children over 8 years of age.[19] Ten independent U.S. and Canadian studies published from 1958 to 1987 showed that dietary fluoride intakes by adults ranged from 1.4 to 3.4 mg/day in areas where the water fluoride concentration was 1.0 mg/L. Where the water concentration was less than 0.3 mg/L, daily intakes ranged from 0.3 to 1.0 mg/day.[19]

Several municipal or territorial reviews of the water fluoride issue have concluded that available information indicates that there is no significant adverse health impact associated with water fluoridation. The Fort Collins review[20] included reviews from other communities, including Brisbane, Australia (1997),[21] Natick, Massachusetts (1997),[22] Calgary, Alberta, Canada (1998),[23] Ontario, Canada (1999),[24] and Escambia County Utilities Authority, Florida (2000).[25] Additionally, the Fort Collins review considered several "Tier One" reviews, including reviews by or for the Centers for Disease Control and Prevention,[1] the Institute of Medicine (1999),[19] the World Health Organization (1994),[26] the National Research Council (1993),[9] the U.S. Public Health Service (1991),[27] the International Programme on Chemical Safety (1984),[28] the Medical Research Council, UK (2002),[29] the Agency for Toxic Substances and Disease Registry, U.S. Public Health Service (2001 draft and 1993),[30] and York, U.K. (2000).[31]

The Fort Collins report found that:

- The weight of the evidence suggests that there is caries (cavities) reduction in populations exposed to water fluoridation at or near an optimal level
- Likely total exposure values for children older than six months living in communities with water fluoridated at up to 1.2 mg/L (ppm) do not exceed the upper limit set to be protective of moderate dental fluorosis by the Institute of Medicine. Total dietary exposures of fluoride can exceed this threshold amount (0.7mg/day) in infants fed formula reconstituted with optimally fluoridated water.
- There is no consistent evidence from human or animal studies that exposure to optimally fluoridated drinking water and other sources causes any form of cancer in humans, including bone and joint cancer
- The FTSG agrees with the conclusion of the Medical Research Council of Great Britain that states, "The possibility of an effect on the risk of hip fracture is the most important in public health terms. The available evidence on this suggests no effect, but cannot rule out the possibility of a small percentage change (either an increase or a decrease) in hip fractures." [Medical Research Council 2002, page 3]

- At the concentrations of fluoride provided in Fort Collins water including exposures from all sources over a lifetime, skeletal fluorosis caused by drinking water exposure is not likely to be a health issue.
- At the concentrations of fluoride provided in Fort Collins water, in combination with other sources of fluoride, as many as one in four children under age 8 may develop very mild to mild dental fluorosis. This degree of fluorosis may or may not be detectable by the layperson. With oral health as the goal, this degree of dental fluorosis is considered an acceptable adverse effect given the benefits of caries prevention.
- In the literature reviewed, doses appropriate for caries reduction were not shown to negatively impact thyroid function. Studies in which humans received doses significantly higher than the optimum fluoride intake for long periods of time showed no negative impact on thyroid function.
- Overall, evidence is lacking that exposure to fluoride through drinking water causes any problems to the human immune system.[20]

In general, there is no credible evidence indicating a cause-and-effect relationship between water fluoridation and increased health risks.

CORROSION

According to the U.S. Environmental Protection Agency and the National Association of Corrosion Engineers, corrosion is not related to fluoride.[32] Corrosion by potable water is primarily caused by dissolved oxygen, pH, water temperature, alkalinity, hardness, salt, hydrogen sulfide, and certain bacteria. Fluoride, at concentrations found in potable water, does not cause corrosion. A small increase in the corrosivity of potable water that is already corrosive may occur after treatment with alum, chlorine, fluorosilicic acid, or sodium silicofluoride, which decreases pH. This may occur in some potable water sources with little buffering capacity; it can easily be resolved by adjusting the pH upward.[11,12,33]

CHEMICALS USED FOR FLUORIDATION

Fluorosilicates

Urbansky reviewed available information on fluorosilicates, with three objectives:

> (1) to enumerate unresolved chemical issues germane to understanding fluoridation and ascertaining the fate of fluoride and fluorospecies, (2) to critically review what is known or reported, and (3) to assemble a knowledge base to provide a starting point for future study.[34]

Urbansky states:

> Since [1962], toxicity and adverse health impacts have tested fluoride rather than fluosilicates. As a recent example, in 2001, the FDA reported that Americans' exposure to fluoride had increased from dentifrices, and it demonstrated that any increases did not produce observable health effects in rats. Fluoride salts were continually tested instead of fluorosilicates because the complete and fast dissociation-hydrolysis (eq 1) of fluorosilicates to fluoride and (hydr)oxosilicates was generally accepted as a chemical fact. Accordingly, no reason was apparent to test fluorosilicates separately.
>
> $$H_2SiF_6(aq) + 4H_2O(l) = 6HF(aq) + Si(OH)_4(aq) \quad \text{(eq 1)}$$
>
> all the rate data suggest that equilibrium should have been achieved by the time the water reaches the consumer's tap if not by the time it leaves the waterworks plant. . . . The most common fluoridating agents used by American waterworks are sodium fluoride (NaF), fluorosilicic acid (H_2SiF_6), and sodium fluorosilicate (Na_2SiF_6) (see table below).
>
> TABLE[34]
>
> | | Sodium Fluoride | Sodium Fluorosilicate | Fluorosilicic Acid |
> |---|---|---|---|
> | (a) Number of Utilities | 2491 | 1635 | 5876 |
> | (b) People served | 11,700,000 | 36,100,000 | 80,000,000 |
>
> *Data for the United States from the CDC's 1992 F*luoridation Census*[35]: (a) Number of utilities using specific additives as reported by those that fluoridate their water; (b) Populations served by specific additives (millions of people) of those drinking supplementally fluoridated water (does not include waters with naturally occurring fluoride).
>
> Although 25% of the utilities reported using NaF, this corresponds to only 9.2% of the U.S. population drinking fluoride-supplemented tap water. The ease in handling NaF rather than fluorosilicates accounts for the disproportionate use of NaF by utilities serving smaller populations. On the other hand, the cost savings in using fluorosilicates result in large systems using those additives instead. The reduced cost of large volume offsets the costs associated with handling concentrated stocks of the fluorosilicates, which require accommodations similar to hydrochloric acid, which is sometimes used to adjust pH. In acidic solution, the dissociation and hydrolysis of fluorosilicic acid, which occurs upon dilution, is given by eq 1. In drinking water, pH is adjusted with the addition of base (e.g., NaOH, $NaHCO_3$). $H_2SiF_6(aq) + 4H_2O(l) = 6HF(aq) + Si(OH)_4(aq)$ (eq1).[34]

While there may be evidence of toxicity of these substances when workers involved in their production are not protected, there is no credible evidence of toxicity when they are diluted for use in fluoridated water. Fluorosilicic acid is diluted with water from an initial aqueous concentration of about 23–24% by about 1:250,000–1:300,000 when used for fluoridating water.[36] This produces the final concentration of between 0.7–1.2 mg/L, the specific level set according to CDC guidelines.[37]

Concerns have been raised about arsenic and lead in fluorosilicic-acid–treated water.[38,39] However, there is no credible evidence that this is of concern.[40] Urbansky and Schock add:

> The vast preponderance of the lead(II) in nearly all tap waters originates from the plumbing materials located between the water distribution mains and the end of the faucet used by the consumer.

Arsenic and lead may be present at minute undetectable concentrations, well below all current (50 ppb) and proposed (10 ppb) EPA standards. Following dilution with water, the calculated range of arsenic concentrations in the finished water contributed by fluorosilicic acid feed is 0.10 to 0.24 µg/L (parts per billion, ppb).[36] The analytic detection limit for arsenic is 2 µg/L, so the amount added by the fluorosilicic acid would not be detected.[36] In Fort Collins, the concentration of lead in the source waters was below the detection limit for lead in the department's laboratory of 1.0 µg/liter (ppb). Because lead levels are below the detection limits both before and after the addition of fluorosilicic acid, the actual changes in lead concentrations were not measurable.[36]

Masters and Coplan have alarmed the public with their reports linking fluoridation, increased lead levels and crime.[39.41] Urbansky and Schock criticize the conclusion reached by Masters and Coplan by stating:

> Interestingly, the bibliographies of the Masters and Coplan study most strongly asserting the adverse effects of silicofluoride shows only a single reference related to sampling of drinking water or the control of lead or other metals by water treatment, so the level of awareness in the design of the studies and interpretation of the data is highly questionable. By not measuring or statistically testing numerous other water and plumbing characteristics that could correlate with lead(II) levels with equal to or greater statistical significance than those relationships that were put forth, the studies of [Reference 2] are intentionally biased towards what appears to be a preconceived conclusion. Even simple analytes that are known to affect lead mobility, such as pH or alkalinity, or analytes known to play important dietary roles in health, such as calcium, sodium or magnesium, were not reported to be measured in their study, so possible confounding variables are conspicuously excluded from evaluation.
>
> . . . Recent reports [41, 39] that purport to link certain water fluoridating agents, such as fluorosilicic acid and sodium fluorosilicate, to human lead uptake are inconsistent with accepted scientific knowledge. The authors of those reports fail to identify or account for these inconsistencies, and mainly argue on the basis of speculation stated without proof as fact. The sampling scheme employed in the studies is entirely unrelated to any credible statistically-based study design to identify drinking water lead and fluoride exposure as a significant source of blood lead in the individuals. The authors use aggregated data unrelated in space and time and then attempt to selectively apply gross statistical techniques that do not include any of thousands of other possible water quality or exposure variables which could show similar levels of correlation utterly by accident. Many of the chemical assumptions are scientifically unjustified, are contradicted by known chemistry data and principles, and alternate explanations (such as multiple routes of PbII exposure) have not been satisfactorily addressed. The choice in water fluoridation approach is often made for economic, commercial or engineering reasons that may have a regional component that could also be related to various community socio-economic measures, and so should not be considered to be a purely independent variable without investigation. At present, the highly-promoted studies asserting enhanced lead uptake from drinking water and increased neurotoxicity still provide no credible evidence to suggest that the common practice of fluoridating drinking water has any untoward health impacts via effects on lead(II) when done properly under established guidelines so as to maintain total water quality. Our conclusion supports current EPA and PHS/CDC policies on water fluoridation.[40]

Nevertheless, concerns have been raised about the acidity of drinking water that may be created by fluoridation. According to Urbansky and Schock, "one cannot demonstrate that an increase in blood lead(II) ion levels can be linked to acidity from $SiF_6{}^{2-}$ hydrolysis any more than one can demonstrate it results from consuming soft drinks." Additionally they state: "Note that the species $PbSiF_6{}^0$ is present at such low concentrations that we would expect to find *only one molecule of this complex in more than 1,000 liters of tap water* at pH 6, which of course, far exceeds the volume possible for water consumption and the human stomach."

A critique of this review was included in "Comments on The April 17, 2002 ICCEC Approach to Silicofluorides Study" by Coplan.[42] The ICCEC is the U.S. Public Health Service National Toxicology Program (NTP) Interagency Committee for Chemical Evaluation and Coordination. Coplan states his concerns about the way in which Urbansky and the EPA and CDC have investigated silicofluorides. For example, he provides the following headings in his review: "EPA's acknowledged ignorance about a position they have adamantly held"; "EPA's continued effort at misdirection"; "Why Urbansky and Schock cannot be trusted"; "Why the CDC cannot be trusted"; "A substantial body of evidence has been submitted to the NTP clearly supporting the need for a comprehensive program of animal testing for health effects from chronic ingestion of SiF treated water. This is true now and would remain true no matter what the EPA may learn about dissociation chemistry from a contractor selected by EPA employees whose objectivity and scientific integrity are less than impeccable."

Coplan's comments are in keeping with his stance as an anti-fluoridationist (one who is strongly opposed to the fluoridation of public water supplies).[43] It should be pointed out that Urbansky and Schock have been highly critical of the work of Masters and Coplan. It appears that the main thrust of contemporary anti-fluoridation tactics is to assert that the chemicals used in fluoridation are causing problems of one sort or another. Such tactics have emanated from the work of Masters and Coplan.

The toxicology of sodium fluorosilicate and fluorosilicic acid has been reviewed for the EPA.[44] The authors of that review state:

> In water, the compound (sodium fluorosilicate) readily dissociates to sodium ions and fluosilicate ions and then to hydrogen gas, fluoride ions, and hydrated silica. At the pH of drinking water (6.5-8.5) and at the concentration usually used for fluoridation (1 mg fluoride/L), the degree of hydrolysis is essentially 100%. . . . Like its salt, its (fluorosilicic acid) degree of hydrolysis is essentially 100% in drinking water. At equilibrium, the fluorosilicate remaining in drinking water is estimated to be <<1 part per trillion.[40] In addition, exposure to impurities in the fluoridating agent is judged to be of low health risk when properly treated water is ingested. For example, in fluorosilicic acid, iron and iodine are usually below the levels considered useful as a dietary supplement; the phosphorus level is reported to be insignificant; and silver is usually <4 parts per septillion in the fluoridated water.[45]

The Colorado City of Fort Collins has been fluoridating with fluorosilicic acid and has responded to concerns raised about that chemical.[36] The Report of the Fort Collins 2003 Fluoride Technical Study Group, April 2003, provides a comprehensive review that includes "The Potential for Increased Contaminant Levels Due to the Use of Hydrofluorosilicic Acid."

> The FTSG's review identified three potential concerns associated with hydrofluorosilicic acid (HFS). 1) co-contamination (i.e., arsenic and lead), 2) decreased pH leading to increased lead solubility or exposure, and 3) potential toxicological effects from incomplete dissociation products of HFS. The FTSG used the raw and finished water quality data for the City of Fort Collins to determine whether the addition of HFS was responsible for the potential addition of contaminants such as heavy metals to the city's drinking water. There was no evidence that the addition of HFS increased the concentrations of copper, manganese, zinc, cadmium, nickel, or molybdenum. The concentrations of arsenic and lead were below the detection limit for the Fort Collins Water Quality Control Laboratory in both the source water and the finished water and below the maximum contaminant level (MCL) for these naturally occurring elements. There was no evidence that the introduction of HFS changed the pH of the water appreciably. Concern that HFS incompletely disassociates may be unfounded when the fundamental chemical facts are considered. Therefore, it is unlikely that community water fluoridation poses a health risk from the exposure to any of these chemicals present in the water as it leaves the plant. Further studies related to the health effects of HFS are in progress.[36]

Reeves (fluoridation engineer at the CDC) outlined the process by which the safety of fluoridation chemicals is assured:

> Concern has been raised about the impurities in the fluoride chemicals. The American Water Works Association (AWWA), a well-respected water supply industry association, sets standards for all chemicals used in the water treatment plant, including fluoride chemicals. The AWWA standards are ANSI/AWWA B701-99 (sodium fluoride), ANSI/AWWA B702-99 (sodium fluorosilicate) and ANSI/AWWA B703-00 (fluorosilicic acid). The National Sanitation Foundation (NSF) also sets standards and does product certification for products used in the water industry, including fluoride chemicals. ANSI/NSF Standard 60 sets standards for purity and provides testing and certification for the fluoride chemicals. Standard 60 was developed by NSF and a consortium of associations, including the AWWA and the American National Standards Institute (ANSI). This standard provides for product quality and safety assurance to prevent the addition of harmful levels of contaminants from water treatment chemicals. More than 40 states have laws or regulations requiring product compliance with Standard 60. NSF tests the fluoride chemicals for the 11 regulated metal compounds that have an EPA MCL. In order for a product [for example, fluorosilicic acid] to meet certification standards, regulated metal contaminants must be present at the tap [in the home] at a concentration of less than ten percent of the MCL when added to drinking water at the recommended maximum use level. The EPA has not set any MCL for the silicates as there is no known health concerns, but Standard 60 has a Maximum Allowable Level (MAL) of 16 mg/L for sodium silicates as corrosion control agents primarily for turbidity reasons. NSF tests have shown the silicates in the water samples from public water systems to be well below these levels.[46]

Sources of Fluoride Pollution Unrelated to Water Fluoridation

The principal sources of fluoride pollution are industries, particularly phosphate ore production and use as well as aluminum manufacture, mining, and coal burning.[28,47,48] In the absence of adequate emission control in such settings environmental pollution can be a problem. Such pollution has been a problem in the past in industrialized countries, and the WHO warns that unless proper environmental safeguards are adhered to, there is a danger of its occurring in developing countries with increasing industrialization. Fluoride pollution is therefore recognized as an industrial hazard; however water fluoridation is not considered a potential source of fluoride pollution.[46]

Arguments of Opponents and Proponents

Whereas anti-fluoridationists try to prevent the unnecessary exposure of living things to fluoride, often in the misguided belief that any amount of fluoride is toxic, pro-fluoridationists try to reduce tooth decay through the judicious use of fluoride, with the understanding that there is an optimum amount, appropriately delivered, that is both beneficial and safe. This distinction leads to a difference in interpretation of the scientific and popular literature on this topic, whether related to the effects of water fluoridation on teeth or other organs of the body, or the effects on the environment. Similarly, there are those who may judge water fluoridation on political or philosophical grounds, such as being supportive or opposed to what government agencies may advocate. Some may have personal or anecdotal experience that is counter to what opponents or proponents recommend. Newbrun has characterized the fluoridation debate as a religious argument.[49]

While opponents of fluoridation are not without their supporters and supporting groups,[50] almost every reputable, recognized, competent scientific and/or public health organization or government unit endorses fluoridation of drinking water as safe and effective.[51,52] Furthermore, community water fluoridation has been heralded as one of the ten great public health measures of the 20th century.[53]

Proponents of fluoridation assert that the dose of fluoride determines whether it is beneficial or toxic, and that there are threshold levels that must be exceeded before there are toxic effects. This is a basic principle of toxicology and is true of every chemical approved for use in treating drinking water. "All substances are poisons: there is none which is not a poison. The right dose differentiates a poison and a remedy." Paracelsus (1493-1541).[54]

While there has been considerable scientific study of the effects of fluorides on health and the environment, there will *always* be the need for more research.[29] However, proponents argue that it is not rational that the gains made from water fluoridation should be undone because not all the research has been completed. Further, it is strongly recommended that those communities that have not yet fluoridated their water supplies should do so to protect the dental health of their current and future residents.[55]

Both sides use arguments related to freedom of choice. Those supporting fluoridation argue that the public water supply is designed to protect public health and it is more important to protect people's health than to protect some people's concern for their freedom to use unfluoridated water.[56,57] Additionally, pro-fluoridationists invoke the ethical principle of social justice arguing that the safe public health measure is socioeconomically equitable, providing greater benefit to the disadvantaged.[1]

Current anti-fluoridation tactics have focused on chemicals used to fluoridate water supplies. As has been shown above, there is no credible evidence to support the notion that the chemicals are unsafe. In the past, tactics have focused on studies that purported to show that fluoridation was linked to cancer and myriad other health problems.[48] However, such assertions were based on improper science, and numerous subsequent studies found no association between fluoridation and cancer.[58]

CONCLUSION

Scientific evidence supports the fluoridation of public water supplies as safe for the environment and beneficial to people. Reports at the local, national, and international levels have continued to support this most important public health measure. There appears to be no concern about the environmental aspects of water fluoridation among those experts who have investigated the matter. Furthermore, since the chemicals used for water fluoridation are co-products of the manufacture of phosphate fertilizers, and the raw material used is a natural resource (rocks excavated for their mineral content), water fluoridation could accurately be described as environmentally friendly, as it maximizes the use made of these natural resources, and reduces waste.[59]

Note: In the text, the term "fluorosilicic" has been substituted for fluosilicic, hydrofluorosilicic, and hexafluorosilicic (all being synonymous); similarly, "fluorosilicate" for fluosilicate, hexafluorosilicate, and silicofluoride. However, the original terms in all references have not been substituted.

References

1. Centers for Disease Control and Prevention (CDC). Achievements in public health, 1900–1999: fluoridation of drinking water to prevent dental caries. MMWR. 1999;48:933-40. <http://www.cdc.gov/mmwr/preview/mmwrhtml/mm4841a1.htm>.
2. U.S. Environmental Protection Agency. Ground Water and Drinking Water. Drinking Water Contaminants (Online 2003) <http://www.epa.gov/safewater/hfacts.html#Inorganic>.
3. Centers for Disease Control and Prevention (CDC). Populations receiving optimally fluoridated public drinking water — United States, 2000. MMWR. 2002;51:144-7. <http://www.cdc.gov/mmwr/preview/mmwrhtml/mm5107a2.htm>.
4. McClure FJ. A review of fluorine and its physiological effects. Physiol Rev. 1933;13:277-300.
5. McClure FJ. Fluoride domestic waters and systemic effects. I. Relation to bone-fracture experience, height, and weight of high school boys and young selectees of the Armed Forces of the United States. Public Health Rep. 1944;59:1543-58.

6. McClure FJ, Kinser CA. Fluoride domestic waters and systemic effects. II. Fluorine content of urine in relation to fluorine in drinking water. Public Health Rep. 1944; 59:1575-91.
7. McClure FJ, Mitchell HH, Hamilton TS, Kinser CA. Balances of fluorine ingested from various Sources in food and water by five young men (excretion of fluorine through the skin). J Ind Hyg Toxicol. 1945;27:159-70.
8. Hodge HC. Evaluation of some objections to water fluoridation. In: Newbrun E (ed). Fluorides and Dental Caries. 3rd ed. Springfield, IL: Charles C Thomas, 1986:221-55.
9. National Research Council. Health Effects of Ingested Fluoride. Washington, DC: National Academy Press, 1993. <http://stills.nap.edu/books/030904975X/html>.
10. McDonagh MS, Whiting PF, Wilson PM, et al. Systematic review of water fluoridation. BMJ. 2000;321:855-9.
11. Tacoma-Pierce County Health Department. Tacoma–Pierce County Health Department Fluoridation Resolution. WAC 197-11-960 Environmental Checklist. August 2002. <http://www.tpchd.org/NEWS/RELEASES/FluorideSEPA.htm>.
12. City of Port Angeles Public Works and Utilities, Washington. SEPA Fluoridation Checklist. October 2003. <http://www.ci.port-angeles.wa.us/menus/planning.htm>.
13. Osterman JW. Evaluating the impact of municipal water fluoridation on the aquatic environment. Am J Public Health. 1990; 80:1230-5. <http://www.ajph.org/cgi/content/abstract/80/10/1230?maxtoshow=&HITS=10&hits=10&RESULTFORMAT=&author1=Osterman&titleabstract=Fluoridation&searchid=1034872639658_1424&stored_search=&FIRSTINDEX=0&journalcode=ajph>.
14. Pescod MB. Food and Agriculture Organization of the United Nations (FAO). Wastewater treatment and use in agriculture—FAO irrigation and drainage paper 47. 1992. Wastewater use case studies. <http://www.fao.org/docrep/T0551E/t0551e0b.htm#9.3%20soil%20aquifer%20treatment:%20arizona,%20usa>.
15. Damkaer DM, Dey DB. Evidence for fluoride effects on Salmon passage at John Day Dam, Columbia River, 1982–86. North Am J Fisheries Management. 1989; 9:154-62. [Abstract] <http://afs.allenpress.com/afsonline/?request=get-abstract&issn=0275-5947&volume=009&issue=02&page=0154>.
16. Salisbury FB, Gillespie LS, Campbell WF, Hole P. Ground-based studies with super-dwarf wheat in preparation for space flight. J Plant Physiol. 1998;152:315-22.
17. Kudo A, Garrec JP. Accidental release of fluoride into experimental pond and accumulation in sediments, plants, algae, molluscs and fish. Reg Toxicol Pharmacol. 1983;3:189-98. [Abstract] <http://www.ncbi.nlm.nih.gov:80/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=6635267&dopt=Abstract>.
18. Singh V, Gupta MK, Rajwanshi P, et al. Plant uptake of fluoride in irrigation water by ladyfinger (*Abelmorchus esculentus*). Food and Chemical Toxicology. 1995;33:399-402.
19. Standing Committee on the Scientific Evaluation of Dietary Reference Intakes, Food and Nutrition Board, Institute of Medicine. Dietary reference intakes for calcium, phosphorus, magnesium, vitamin D, and fluoride. Washington, DC: National Academy Press, 1999. <http://books.nap.edu/books/0309063507/html/288.html#pagetop>.
20. Fluoridation Technical Study Group City of Fort Collins, Colorado. Report of the Fort Collins Fluoride Technical Study Group. 2003. <http://www.ci.fort-collins.co.us/utilities/fluoride-study.php>.
21. The Lord Mayor's Taskforce on Fluoridation—final report. Brisbane, Australia: Brisbane City Council, 1997. <http://fluoride.oralhealth.org/links.asp?pg=22&sc=375>.
22. Natick Fluoridation Study Committee. Should Natick Fluoridate? A Report to the Town and the Board of Selectmen. Natick, MA, October 23, 1997. <http://www.fluoridation.com/natick.htm>.
23. Report of the Expert panel for Water Fluoridation Review. (March 1998). City of Calgary, Alberta, Canada, 1998. <http://www.calgaryhealthregion.ca/hlthconn/items/fluor.htm>.
24. Locker D. Benefits and risks of water fluoridation. An update of the 1996 federal–provincial sub-committee report. Prepared under contract for the Public Health Branch, Ontario Ministry of Health, First Nations Inuit Health Branch, Health Canada. University of Toronto, Toronto, ON, Canada: Community of Dental Health Services Research Unit, Faculty of Dentistry, 1999. <http://www.gov.on.ca/MOH/english/pub/ministry/fluoridation/fluor.pdf>.
25. Lepo JE, Snyder RA. Impact of fluoridation of the municipal drinking water supply: review of the literature. Prepared for the Escambia County Utilities Authority. The Center for Environmental Diagnostics and Bioremediation. University of West Florida, 2000. <http://fluoride.oralhealth.org/papers/2001/leposnyderuwfescambia.htm>.
26. World Health Organization. WHO Technical Report Series #846: Report of a WHO Expert Committee on Oral Health Status and Fluoride Use. Geneva, Switzerland: World Health Organization, 1994.
27. Report of the subcommittee on fluoride of the Committee to Coordinate Environmental Health and Related Programs, USPHS. Review of fluoride: benefits and risks. Public Health Service: Department of Health and Human Services. 1991. <http://www.health.gov/environment/ReviewofFluoride/default.htm>.
28. International Programme on Chemical Safety (IPCS) Task Group on Environmental Health Criteria for Fluorine and Fluorides. Environmental Health Criteria 36. Fluorine and Fluorides. Geneva, Switzerland: World Health Organization, 1984. <http://www.inchem.org/documents/ehc/ehc/ehc36.htm>.
29. Medical Research Council. Medical Research Council working group report: Water fluoridation and health. September 2002. <http://www.mrc.ac.uk/prn/index/public-interest/public-news/public-fluoridation_report-2.htm>.
30. Agency for Toxic Substances and Disease Registry, U.S. Public Health Service. Toxicological profile for fluorides, hydrogen fluoride, and fluorine (2001 draft and 1993). <http://www.atsdr.cdc.gov/toxprofiles/tp11.html> and <http://www.atsdr.cdc.gov/toxprofiles/phs11.html>.
31. NHS Centre for Reviews and Dissemination, University of York. A Systematic Review of Public Water Fluoridation. York, U.K.: York Publishing Services Ltd. 2000. <http://www.york.ac.uk/inst/crd/fluores.htm>.
32. U.S. Department of Health and Human Services, Centers for Disease Control, Dental Disease Prevention Activity. Water Fluoridation: A Manual for Engineers and Technicians. Atlanta, GA, CDC, September 1986.
33. American Dental Association. Fluoridation Facts. Question 33: Does fluoridation present difficult engineering problems? (online 2003). <http://www.ada.org/public/topics/fluoride/facts/safety.asp>.
34. Urbansky ET. Fate of fluorosilicate drinking water additives. Chem Rev. 2002;102:2837-54.
35. Centers for Disease Control and Prevention. Fluoridation Census 1992. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service, CDC, September 1993.
36. Fluoridation Technical Study Group City of Fort Collins, Colorado. Report of the Fort Collins Fluoride Technical Study Group. Finding #4—The Potential for Increased Contaminant Levels Due to the Use of Hydrofluorosilicic Acid. <http://fcgov.com/utilities/fluoride-report.php> and <http://fcgov.com/utilities/pdf/fluoride-report030903.pdf>.
37. Centers for Disease Control and Prevention. Engineering and administrative recommendations for water fluoridation, 1995. MMWR Recomm Rep. 1995 Sep 29;44(RR-13):1-40. <http://www.cdc.gov/mmwr/preview/mmwrhtml/00039178.htm#00001289.htm>.
38. Masters RD, Coplan MJ, Hone BT, Dykes JE. Association of silicofluoride treated water with elevated blood lead. Neurotoxicology. 2000;21:1091-100. <http://homepage.tinet.ie/~fluoridefree/neurotox.htm>.
39. Masters RD, Coplan M. Water treatment with silicofluorides and lead toxicity. Int J Environ Studies. 1999:56:435-49.
40. Urbansky ET, Schock MR. Can fluoridation affect lead(II) in potable water? Hexafluorosilicate and fluoride equilibria in aqueous solution. Int J Environ Studies. 2000;57:597-637. <http://fluoride.oralhealth.org/papers/pdf/urbansky.pdf>.
41. Masters RD and Coplan M. Brain biochemistry and the violence epidemic: toward a "win–win" strategy for reducing crime. In: Nagel SE (ed). Super-Optimizing Examples: Across Public Policy Problems. New York: Nova Science Publishers, 1999.

42. Comments on The April 17, 2002 ICCEC Approach to Silicofluorides Study by MJ Coplan. <http://216.239.33.100/search?q=cache:5FsSKIaEaekC:ntp-server.niehs.nih.gov/Meetings/2002/Coplan_081502.pdf+2002+ICCEC+Approach+to+Silicofluorides+Study&hl=en&ie=UTF-8>.
43. The American Heritage Dictionary of the English Language. 4th ed. 2000.
44. Haneke KE, Carson BL. Prepared for Scott Masten, PhD, National Institute of Environmental Health Sciences. Contract No. N01-ES-65402. Toxicological Summary for Sodium Hexafluorosilicate [16893-85-9] and Fluorosilicic Acid [16961-83-4], October 2001. <http://ntp-server.niehs.nih.gov/htdocs/Chem_Background/ExSumPDF/Fluorosilicates.pdf>.
45. Colorado Springs Dental Society fluoride information page 2001 [on-line]. <http://www.cs-ds.org/feature_article_fluoride_body.htm#fluoride_silicofluoride_facts>.
46. Reeves TG. Current technology on the engineering aspects of water fluoridation. Paper presented at National Fluoridation Summit, September 8, 2000 Sacramento, CA. <http://fluoride.oralhealth.org/papers/pdf/reevesnsf.PDF>.
47. Expert Committee on Oral Health Status and Fluoride Use. Fluorides and oral health. WHO Technical Report Series No. 846. Geneva, Switzerland: World Health Organization, 1994.
48. International Programme on Chemical Safety (IPCS) Environmental health criteria, No. 227. Fluorides. Geneva, Switzerland: World Health Organization, 2002. <http://www.inchem.org/documents/ehc/ehc/ehc227.htm>.
49. Newbrun E. The fluoridation war: a scientific dispute or a religious argument? J Public Health Dent. 1996;56(5 Spec No):246-52. Review. [Abstract] <http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=retrieve&db=pubmed&list_uids=9034969&dopt=Abstract>.
50. Fluoride Action Network [online 2003]. <http://www.fluoridealert.org/about-fan.htm>.
51. American Water Works Association [online]. Fact Sheets. Fluoridation. 2003. <http://www.awwa.org/Advocacy/pressroom/fluoride.cfm>.
52. American Dental Association. Fluoridation Facts. National and International Organizations that Recognize the Public Health Benefits of Community Water Fluoridation for Preventing Dental Decay [on-line 2003]. <http://www.ada.org/public/topics/fluoride/facts/compendium.asp>.
53. Centers for Disease Control and Prevention (CDC). Ten great public health achievements—United States, 1900-1999. MMWR. 1999;48:241-3. <http://www.cdc.gov/mmwr/preview/mmwrhtml/00056796.htm>.
54. Society of Toxicology. Some Basic Principles of Toxicology: Teacher's Notes. [Online 2003] <http://www.toxicology.org/publicoutreach/EducationOutreach/prinnote.html>.
55. Centers for Disease Control and Prevention (CDC). Recommendations for Using Fluoride to Prevent and Control Dental Caries in the United States. MMWR. 2001;50(RR-14):1–42. <http://www.cdc.gov/mmwr/preview/mmwrhtml/rr5014a1.htm>.
56. Pratt E Jr, Rawson RD, Rubin M. Fluoridation at fifty: what have we learned? J Law Med Ethics. 2002;30(3 suppl):117-21. <http://www.findarticles.com/cf_dls/m0DPE/3_30/95843945/p1/article.jhtml?term=>.
57. Fielding JE, Marks JS, Myers BW, Nolan PA, Rawson RD, Toomey KE. How do we translate science into public health policy and law? J Law Med Ethics. 2002;30(3 suppl):22-32. <http://www.findarticles.com/cf_dls/m0DPE/3_30/95843930/p1/article.jhtml>.
58. National Cancer Institute. Cancer Facts. Fluoridated Water. [Online reviewed 2000] <http://fluoride.oralhealth.org/papers/2001/ncicancerfacts101000.htm>.
59. British Fluoridation Society. The environmental aspects of water fluoridation. [Online 2003] <http://www.liv.ac.uk/bfs/environbrief.htm>.