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Current Comments®

EUGENE GARFIELD
INSTITUTE FOR SCIENTIFIC INFORMATION®
3501 MARKET ST., PHILADELPHIA, PA 19104

Fluoridation, "Texas Teeth," and the Great Conspiracy. Part 2. The Evidence

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Recently we surveyed the history of water fluoridation and the conflicts that this process provoked. We noted that unusually high natural levels of fluoride in the water were associated with dental mottling and staining, resulting in a phenomenon known as "Texas teeth."[1] Opponents of fluoridation have questioned the safety and desirability of water fluoridation; let's examine the scientific evidence regarding fluoridation and the directions of recent research.

Fluorine and Fluoride Chemistry

Fluorine is a member of the halogen family.[2] It is the most electronegative of all the elements, which makes it extremely reactive. Fluorine combines with almost every element. It is also reactive with organic radicals.

Fluoridation of water involves the addition of one of several fluoride compounds to the water supply. These compounds are discussed in a book by the Safe Drinking Water Committee, National Research Council, Washington, DC. According to the committee, the compounds in general use are sodium fluoride, hydrofluosilicic acid, sodium silicofluoride, and ammonium silicofluoride.[3] (p. 370-1) In addition, sodium fluoride, stannous fluoride, and monofluorophosphate are used in toothpastes and other dental preparations.

In our recent discussion of water chlorination, we noted that chlorination can cause the formation of potentially harmful compounds (see end note), including halomethanes, by promoting reactions with organic material in water supplies.[4] Fluoridation does not present this hazard because the fluorine is present as a simple ionic salt, in contrast to the hypochlorite that forms the compounds used in chlorination. In addition, fluorocarbons, organic compounds consisting of carbon and fluorine, tend to be very stable and do not react chemically the way chlorinated compounds do.[2]

Fluoride for Caries Prevention

A 1984 conference directed by Stephen H.Y. Wei, professor and head, Department of Children's Dentistry and Orthodontics, University of Hong Kong, reviewed the effectiveness of fluorides in preventing dental caries.[5] Addressing this conference, Robert Mecklenburg, chief dental officer, US Public Health Service, Rockville, Maryland, asserted that water fluoridation and other caries-prevention measures currently save four to five billion dollars a year in the US by reducing the amount of necessary dental care.[6]

How does fluoridation work? The body absorbs fluoride from a variety of sources. It is present in varying amounts in foods, toothpaste, and even in the air. Where water contains natural or supplemental fluoride, water represents the primary source of fluoride in the body. Fluoride concentrates in calcified tissues, that is, in bones and teeth. Until fairly recently, dental researchers believed the principal decay-preventing

mechanism to be the incorporation of fluoride into tooth enamel. The formation of the mineral fluorapatite, $Ca_5(PO_4)_3F$, renders the enamel more resistant to the acids that cause tooth decay. Exactly how this occurs is not entirely understood. In addition to strengthening intact enamel, James S. Wefel, associate professor of pediatric dentistry, Dow's Research Institute, University of Iowa, Iowa City, notes that fluoride applied topically (directly to the teeth) promotes remineralization, or repair, of areas of the enamel that have already been weakened by the loss of calcium.[7]

J.A. Weatherell and colleagues, Department of Oral Biology, School of Dentistry, University of Leeds, UK, discuss the mechanisms by which fluoride is assimilated into tooth enamel. Their review article is core to two ISI® research fronts, "Carbonate and fluoride dissolution of synthetic apatites" (#83-1092) and "*In vitro* and clinical studies of the effects of fluoride on tooth enamel and hydroxyapatite dissolution" (#84-0009).[8] We will have more to say about research fronts later.

O. Fejerskov and colleagues, Department of Dental Pathology and Operative Dentistry, Royal Dental College, Copenhagen, Denmark, believe, however, that the fluoride content of enamel is not the principal factor in decay prevention. They find a more important mechanism in the local effects of fluoride in the oral fluids upon the bacteria that produce decay-causing acids.[9] Norman Tinanoff, associate professor of pediatric dentistry, University of Connecticut Health Center, Farmington, takes a similar view, citing growing evidence that at least one fluoride compound, stannous fluoride, prevents the accumulation of the bacterial plaque that causes tooth decay.[10] The compound seems to do this by reducing the growth and adherence of the bacteria, rather than by actually killing the organisms. Further, stannous fluoride appears to reduce harmful bacteria more than other microorganisms found in the mouth.

Early reports suggested that fluoridation benefits only children who are exposed to fluoride before or during the development of their permanent teeth and that dental protection might not last into adulthood. According to Mecklenburg, however, current evidence indicates that continued exposure to low levels of fluoride can give lifelong protection from tooth decay.[6] Thus, today's children will continue to benefit from fluoridation as tomorrow's adults, if they continue to drink fluoridated water.

According to proponents, fluoridation of water supplies offers the cheapest and most effective way to afford large numbers of people the benefits of fluoridation. Maintenance of a fluoride level of about 1 part per million (ppm) in the water can reduce the incidence of dental caries in fluoridated areas by up to 65 percent without producing the mottling of teeth that can result from higher fluoride levels.[9]

There are other ways, however, for individuals to benefit from fluorides. George K. Stookey, professor of preventive dentistry, Indiana University School of Dentistry, Indianapolis, has reviewed a variety of dentifrices that contain fluoride in one form or another.[11] From clinical studies he concludes that, while preparations differ in their effectiveness, fluoride dentifrices are effective in controlling tooth decay. He also states that, of all the forms of fluoride used, sodium fluoride is the most effective.

Alice M. Horowitz, National Caries Program, National Institute of Dental Research, Bethesda, notes that other sources of fluoride for dental prophylaxis include mouthwashes and fluoride tablets. These methods are effective in preventing dental caries, but a comparison of different methods shows fluoridation of drinking water to be the most effective.[12]

A note of caution is advisable here. Fluoridation of water does not prevent

all tooth decay. Furthermore, as Horowitz points out, fluoridation of water is not practical in all locations. She also emphasizes the importance of a variety of decay-prevention measures, including public-education programs on dental health.[12]

With fluoride available in the water, food, toothpaste, and other sources, it may be possible to consume more fluoride than is necessary to control tooth decay. Dennis H. Leverett, chairman, Department of Community Dentistry, Eastman Dental Center, Rochester, New York, voices concern that increasing exposure to fluorides, particularly in the food chain, may increase the incidence of fluorosis. He cites evidence that this has indeed occurred among children in some areas. The only manifestation of this fluorosis, however, has been mild dental mottling that is generally evident only to a dentist.[13]

One of the issues that has helped to heat up public discussion of fluoridation is that of alleged harmful effects of fluoride. The Safe Drinking Water Committee points out that fluorides can be toxic when absorbed in large amounts.[3] (p. 376-7) However, it is relevant to consider only whether the amounts introduced in water fluoridation are harmful. Antifluoridationists have blamed fluoridation for a great many health problems. We will now examine the claims most often raised.

Alleged Harmful Effects

Claims that fluoridation causes human cancer stem from two biochemists, John Yiamouyiannis, formerly of the National Health Federation, Delaware, Ohio, and Dean Burk, Dean Burk Foundation, Washington, DC. In 1975 they examined mortality figures for 20 US cities. Their analysis showed that 10 cities, after fluoridating their water supplies, had higher death rates from cancer than the 10 cities with unfluoridated water.[14] Other researchers have criticized that conclusion, however. Robert N. Hoover and colleagues, Environmental Epidemiology Branch, National Cancer Institute (NCI), Bethesda, pointed out that Burk and Yiamouyiannis had not considered factors such as age, sex, and racial or ethnic groupings that affect cancer incidence and mortality.[15] The NCI researchers demonstrated that, when these factors are taken into consideration, the apparent association of higher mortality with fluoridation disappears.

The NCI conclusions were supported by independent work conducted by Donald R. Taves, Department of Pharmacology and Toxicology, University of Rochester, School of Medicine and Dentistry, [16] and by Sir Richard Doll and Leo Kinlen, Radcliffe Infirmary, University of Oxford, UK.[17] They reevaluated the data that Burk and Yiamouyiannis had used. Both Taves and Doll state that the apparent associations between fluoridation and cancer mortality actually resulted from changes in population characteristics. P.D. Oldham, MRC Pneumoconiosis Unit, Llandough Hospital, Penarth, S. Wales, and D.J. Newell, University of Newcastle upon Tyne, UK, reached the same conclusion.[18]

J. Clemmesen, former chief pathologist, Finsen Institute, Copenhagen, and member, World Health Organization Advisory Group on Cancer, reviewed the issue of cancer and fluoridation in 1983.[19] After examining data from many nations, he concluded that there was no evidence to link water fluoridation to cancer. A 1985 report by E.G. Knox and colleagues, Working Party on the Fluoridation of Water and Cancer, Ministry of Health, London, UK, reached a similar finding.[20]

In 1956 Ionel Rapaport, Psychiatric Institute, University of Wisconsin, Madison, published a study of the incidence of Down's syndrome, a genetic disorder characterized by mental retardation.[21] He found that water supplies containing more than 0.1 ppm of fluoride were associated with an increase in the incidence of this genetic anomaly. Britain's

Royal College of Physicians pointed out, however, that all of Rapaport's figures, even the incidence associated with naturally fluoridated water, were below the expected rates. This suggests that Rapaport overlooked many cases of Down's syndrome, a fact that would make any comparison of rates invalid.[22]

Also in the 1950s, George L. Waldbott, a Wisconsin allergist, reported what he described as allergic reactions to fluoride in drinking water.[23] Waldbott reported a double-blind study in which patients he believed to be sensitive received either measured amounts of fluoride or a placebo. He found that the patients reacted to the fluoride. In addition, when some of the patients moved to areas without fluoridated water, their allergic symptoms disappeared.

While rebuttals to Waldbott's position have not included a reexamination of his patients, a number of researchers have questioned his conclusion that a sensitivity to fluoride was involved. The Safe Drinking Water Committee points out that, in spite of the millions of people who have been exposed to fluoridated water, reports of allergic reactions have not been forthcoming from other sources. Further, no one has reported fluoride sensitivity in tea drinkers. Tea contains high levels of fluoride.[3] (p. 378-9) The committee nevertheless concludes that sensitivity is possible, though unproven, and recommends further research.

In 1971 the Executive Committee of the American Academy of Allergy, Milwaukee, Wisconsin, responded to Waldbott and others, stating that "there is no evidence of allergy or intolerance to fluorides as used in the fluoridation of community water supplies."[24] According to Donald L. McNeil, executive director, American Academy of Allergy, in a letter to John S. Small, information specialist, National Institute of Dental Research, this position was reaffirmed at a February 1980 meeting of the Academy's Executive Committee.[25]

Beneficial Effects

There is evidence that fluoridation has other beneficial effects besides the prevention of dental caries. For example, the tendency of fluoride to concentrate in bones is being investigated in the treatment of certain bone diseases. Elderly people, particularly postmenopausal women, frequently suffer from osteoporosis, a softening of the bones owing to the loss of calcium. Fluoride, by combining with the calcified matrix of bone, makes the calcified material less soluble and therefore less subject to the resorption of calcium. A recent study by Olli Simonen and Ossi Laitinen, National Board of Health of Finland, and Department of Rheumatology, Kivelä Hospital, Helsinki, indicates that a level of one milligram of fluoride per liter of drinking water may be sufficient to protect the elderly from fractures resulting from bone fragility.[26] Although the study findings are preliminary, they suggest an interesting direction for further research.

Actually, suggestions of an inverse relationship between fluoride in the water and the occurrence of osteoporosis are not new. In 1966 Daniel S. Bernstein and colleagues, Department of Nutrition, Harvard School of Public Health; Harvard Medical School; and Peter Bent Brigham Hospital, Boston, reported that high levels of fluoride were associated with reduced incidences of osteoporosis and calcification of the aorta.[27] Their paper is a core document for the research front on "Fluoride treatment for osteoporosis and bone fractures" (#83-2589).

Another Finnish study, by H. Luoma and coworkers, Department of Dentistry, University of Kuopio, suggests that fluoride in drinking water may reduce the risk of heart attack.[28] Among other things, the researchers found that very low levels of fluoride (below 0.1 ppm) were associated with an increased risk; this supports the hypothesis that a fluo-

Table 1: The 1983 and 1984 *SCI®/SSCI®* research fronts on fluoridation. A = number. B = name. C = number of core papers. D = number of citing papers.

A	B	C	D
83-0862	Effect of fluoride toothpaste and dental-health education on changes in caries patterns of children	3	11
83-1092	Carbonate and fluoride dissolution of synthetic apatites	38	179
83-2133	Microscopic analysis of rat bones after fluoride ingestion	2	11
83-2589	Fluoride treatment for osteoporosis and bone fractures including the role of calcium in such disorders	2	23
83-2778	Community attitudes and fluoridation for dental-caries prevention	6	20
84-0009	*In vitro* and clinical studies of the effects of fluoride on tooth enamel and hydroxyapatite dissolution	19	88
84-0386	Use of fluoride for the prevention of dental caries	4	22
84-0995	Effect of fluoride and other factors on the formation and remineralization of artificial caries-like lesions in tooth enamel	6	31
84-1123	Compositional alterations in tooth enamel induced by fluoride and other elements	2	10
84-5505	Effects of fluoride exposure on dental enamel in children	5	27
84-8462	Cariostatic effect of fluoride and other bactericidal agents used to prevent dental disease	2	10
84-8706	Metabolic effect of fluoride on bone histomorphometry	2	10

ride deficiency contributes to the development of atherosclerosis, or hardening of the blood vessels, which causes heart disease.

Our review highlights research on the effects, real and alleged, of fluoridation. The scientific consensus is perhaps best summarized in a 1984 letter from C. Everett Koop, US Surgeon General of the Public Health Service, to William D. Ruckelshaus, then administrator, US Environmental Protection Agency.[29] Koop concludes that fluoride, as currently found in US drinking water supplies, does not constitute a hazard. He adds, however, that there is still room for research.

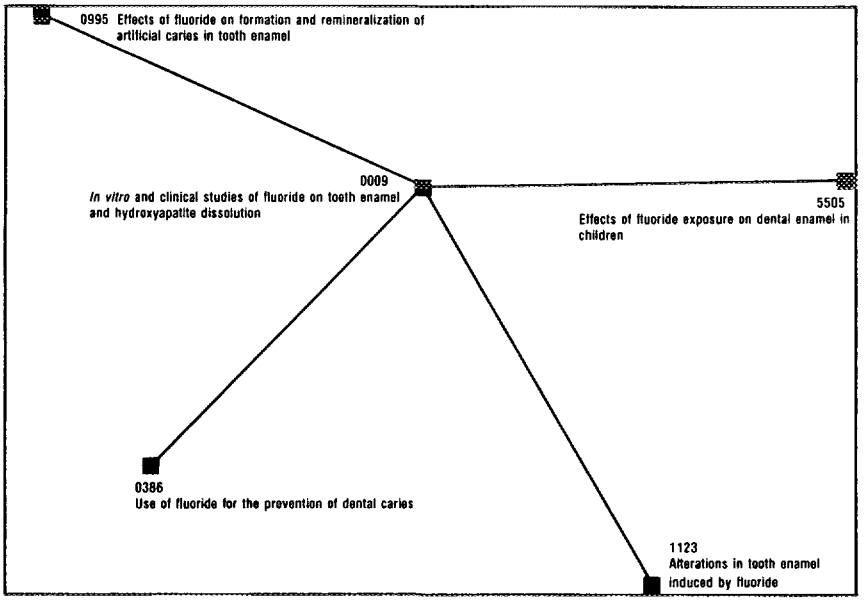
Safety and effectiveness aside, there is one more aspect to consider: the costs versus the benefits of fluoridation. Walter Künzel, Department of Preventive Dentistry, Erfurt Medical Academy, German Democratic Republic, describes the factors involved in calculating the consequences of water fluoridation.[30] These factors include the amount and cost of the equipment, the cost of maintenance, the level of technology required, and the volume of water delivered to a given region. Künzel's analysis of data from Switzerland, the German Democratic Republic, and the UK shows that, in comparison with the overall costs of running a water-supply system, fluoridation is a very economical measure. In addition, the process yields benefits that are difficult to measure. These include improved dental health, reduced costs for dental treatment, and reduced demand on dental personnel.

T.B. Dowell, Avon Area Health Authority, UK, also examined the economics of fluoridation.[31] He concludes that the process is economical for any system that delivers at least one million gallons of water per day and possibly for some smaller systems, too. Dowell estimates that the annual cost of fluoridation is less than one dollar per capita. We have already mentioned Mecklenburg's estimate of the savings in dental-care costs.[6]

ISI Research Fronts

The scientific literature related to fluoridation is extensive. In Part 1 we examined the research front on "Community attitudes and fluoridation for dental-caries prevention" (#83-2778), which deals in part with the political controversy surrounding fluoridation. Table 1 shows this front and 11 other 1983 and 1984 research fronts covering the scientific issues. The most active of these

Figure 1: Multidimensional-scaling map for research front #84-0006, "Effects of fluoride and other elements on tooth enamel and prevention of dental caries," showing links between research fronts.



fronts is "Carbonate and fluoride dissolution of synthetic apatites" (#83-1092). This front centers on 38 core papers, which were cited in about 180 papers in 1983. Another very active front is "*In vitro* and clinical studies of the effects of fluoride on tooth enamel and hydroxyapatite dissolution" (#84-0009). A cluster of 19 core papers was cited in 1984 by 88 other papers that comprise this research front.

Figure 1 is a multidimensional-scaling map of five of the research fronts from Table 1. It demonstrates the citation relationships among those fronts and shows how different areas of research are linked in the literature.

Summary

Our review indicates that there are two types of issues involved in the fluoridation debate. On the one hand are the scientific questions on the effects of a particular public-health measure and its benefits in relation to the costs. The history of fluoridation shows that research can provide answers to these questions. On the other hand, the continuing controversy shows that the availability of scientific evidence does not guarantee that issues of public policy can be settled easily. While there are legitimate questions about what government agencies, here represented by water authorities, are permitted to do for our own good, decisions about fluoridation have too often been affected by emotional appeals and charges that are not related to the available scientific evidence.

* * * * *

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NOTE

In our earlier essay on chlorination of drinking water (vol. 8, p. 334), we cited a paper by Jack Coughlan, Marine Biological Laboratory, Fawley Power Station, Southampton, and John Whitehouse, Central Electricity Research Laboratories, Leatherhead, UK. In connection with water-cooling systems, we used their work to show that "chlorinated water released by electric power plants has affected all classes of marine and freshwater plankton."[1] The effects noted in their paper involved organisms that passed *through* the cooling systems of power plants, *not those remaining in nearby waters*. Their paper did indeed note the difficulties in measuring the impact of processes such as chlorination on the environment.

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