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Science, Bureaucracy, and Public Policy: Can Scientific Inquiry Prevail Over Entrenched Institutional Self-Interest?

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I. Obstacles to Using New Scientific Findings in Policy Making: Bureaucrats, Professional Self-Interest, and Intellectual Paradigms

Contradictions between established governmental policies and new scientific research, illustrated by revolutionary changes in human biology and the neurosciences, are probably inevitable. There is, of course, an extensive literature on conflicts over scientific information relevant to public policymaking and the obstacles to effectively integrating scientific innovation with decision making (Nelkin 1984; Nelkin 1992; Nelkin and Lindee 1995; Nelkin and Pollak 1981; Nelkin and Tencredi 1989; Nelkin, Willis, and Parris 1991; Rochefort 1979; Rochefort 1986; Rochefort 1993). Accounts of this problem often emphasize bureaucratic and political factors that block attention to new discoveries (Elder and Cobb 1983a; Elder and Cobb 1983bKingdon 1992; Rochefort and Cobb 1994). As was argued a generation ago, for example, where existing policies have been sponsored or endorsed by a government agency, resistance to new information is likely to be particularly strong (Wollan 1968). However, that familiar argument is not the whole story.

As a result of radical advances in many scientific fields, obstacles to using science when formulating governmental policies are probably even worse now than several decades ago. The issues are illustrated by recent research in cognitive neuroscience, neurotoxicology, and behavior genetics, rapidly changing fields with great relevance to education and crime control (policy areas in which the government administrators concerned are often unfamiliar with the biological sciences). A case study of recent policy debates concerning water "fluoridation" indicates, however, that additional obstacles to more effective scientific policymaking can arise from the resistance of both professors in relevant academic fields and health care professionals whose traditional practices are questioned by new scientific data. To be sure, the Environmental Protection Agency and Centers for Disease Control the government agencies most involved in the issues of toxins and human health—have been slow to respond to new research. In addition, however, refusal to consider recent findings or open hostility has frequently come from individuals and associations representing academic and health care professionals.[1]

Students of public policy often focus on "interest groups," usually defined as those whose economic and political interests are challenged in the competition for power over legislation and resources (Di Gioacchino, Ginebri, Sabani 2004; Epstein, George, and Kobylka 1993; Key 1984; Miller 2001; Wooten 1985). Professors and Physicians typically claim to be "professionals" devoted to developing and applying scientific information for the collective good. Although individuals in these professions may have personal economic benefits or ideological commitments that result in hostility to a new scientific approach, their resistance is often due to the tenacity of established ways of thinking and performing professional duties. A college professor may be said to have an interest in giving courses without revising last year's lecture notes. A doctor or

* Research described in this article was suggested by and conducted jointly with collaborators whose professional experience, insights, and analysis have been indispensable—but they are not responsible for the views expressed, below.

1 For illustrations, see the Appendix, below, as well as Christopher Bryson, *The Fluoride Deception* (N. Y.: Seven Stories Press, 2004).

dentist has an interest in convincing patients that last year's diagnosis and therapy were appropriate. In short, the fields of education and health care reveal powerful "interests" of a nonmaterial sort insofar as prestige, control over one's turf, and avoiding criticism from outsiders are important for a professor or a health care provider. If so, which is more important as an obstacle to introducing scientific findings to a policy debate: bureaucratic inertia or professional hostility?

The nonmaterial interests of academic and health care professions can be described as a commitment to existing patterns of thought and accepted behavior. As Thomas Kuhn pointed out a generation ago, throughout the history of science major changes in theory have entailed conflict as an accepted "paradigm" is challenged by new patterns of conceptualization (Kuhn 1996). To cite a recently discovered example, resistance to Copernicus' heliocentric model of the earth's motion originally occurred not because—as once suggested—no one read his *De Revolutionibus*; rather, leading scientists who read Copernicus were interested in his geometric model of circular motion of heavenly bodies but did not apply it to the actual movements of the earth.[2] Today as well, whether in medicine or the social sciences, where new findings challenge established scientific paradigms, professionals continue to have multiple "interests" of which

2 Owen Gingerich, "A Radical Reorientation," *Nature* 430 (22 July 2004), 407. Gingerich, himself a well-known astronomer, came across a first edition of Copernicus' *De Revolutionibus* while on vacation in England and found it was extensively annotated by Erasmus Reinhold, "the leading astronomy teacher of the generation following Copernicus"; Reinhold's summary was "the motto he inscribed on the title page: 'The Axion of Astronomy: celestial motions are uniform and circular, or composed of uniform and circular parts.'" While recognizing that Copernicus also presents a heliocentric view of the solar system, Reinhold focused his attention on the model describing "non-uniform orbital motion of the planets by combinations of uniform circular motions." Gingerich subsequently found many other annotated copies of Copernicus' *De Revolutionibus* with annotations by scientists who "were reading the book as a manual of geometrical model building, not as a physical description of the cosmos." (Ibid.) It is intriguing to consider the parallel in the 20th century, during which a generalized acceptance of Darwin's theory of evolution was combined with

control over resources can be secondary to protecting established ways of thinking (Baumgartner and Jones 2002; Baumgartner and Leech 1998; Jones 1994; Jones 2001; Jones and Baumgartner 1993). To be sure, money and power are also involved, but the intellectual effort of open-minded consideration of new ideas and the novelty of respectful dialogue with "outsiders" may sometimes be even more important.

If this factor can indeed inhibit the introduction of scientific advances to policymaking, the implications go beyond a modification of our theories about the public policy process. One important lesson may be that political scientists and other social scientists interested in public policy need to abandon the insularity of their own disciplinary practices. For example, research in biological sciences from ecology to cognitive neuroscience and behavior genetics is increasingly crossing the traditional divide between the natural and social sciences. Since our universities are divided into "Departments" organized on the assumption that natural and social sciences are fundamentally different, the "paradigm" being challenged is pervasive in academic thinking and sometimes has ideological overtones—such as the timeworn complaint that "sociobiology" is "reactionary." This charge was often based on the assumptions that sociobiology entailed "biological determinism" (and, therefore, served as an ideological defense of the status quo) whereas contemporary evolutionary psychology has neither of these implications (Masters 1993; Ridley 2003). In short, when complaining about contradictions between scientific research and policy making, it may be that "We have met the enemy, and he is us."

These issues can be examined using the example of new biological findings that reveal how toxins change brain chemistry and behavior in ways that significantly effect educational performance, substance abuse, and violent

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widespread resistance to applications of the theories and findings of evolutionary biology to *Homo sapiens*.

crime.[3] As predicted by most accepted theories of science and public policy, is bureaucratic resistance within government agencies the biggest obstacle to applying new discoveries in this area? Or, while the CDC and EPA have been slow to respond to the revolution in cognitive neuroscience, does a crucial problem arise from similar resistance within academic and professional communities? Despite theories that blame bureaucrats and economic "special interests," this case study shows that it is important to consider the hypothesis that respected professionals for whom new scientific discoveries require new ways of thinking may present a more important problem in contemporary policymaking.

II. A Case Study: Water Treatment Chemicals, Lead, and Behavioral Dysfunctions

A. A ParticipantObserver's View of the Policy Implications of Research on Brain Chemistry and Behavior.

Studies of work linking contemporary biology to the study and practice of law in the 1980s led to research on the behavioral effects of exposure to toxic chemicals. At a meeting of the Gruter Institute for Law and Behavioral Research, I learned of research showing that violent criminals were likely to have absorbed lead and/or manganese, elements known to have effect on neurotransmitters like dopamine or serotonin.[4] With EPA funding, I studied the epidemiological relationship between industrial pollution with lead and manganese (as measured by the EPA's Toxic Release Inventory) and rates of violent crime for all U.S.

3 The following article is a participant-observer's view of the gap between decision makers and new scientific information. Based on a research project funded by the EPA that led to collaboration with experts in other fields, this account is entirely personal and does not reflect the judgments or opinions of collaborators.

4 I am deeply indebted to Everett "Red" Hodges of the Violence Research Foundation not only for this original information of the role of manganese in alternations of brain chemistry that increase rates of violent crime, but for more recent confirmation based on controlled laboratory experimentation.

counties (Table 1).[5] Statistical analysis of national rates of violent crime was consistent with evidence reported for individual criminals. For example, in a multiple regression analysis controlling for ten socioeconomic variables (Population Density, per capita income, Unemployment, % Black Poverty, % Hispanic Poverty, Police per Capita, Infant Death Rate, % housing built before 1950, Public water supplies per capita, Median Grade Completed), factors linked with toxins – including not only the presence of industrial releases of lead AND of manganese, but also the simultaneous presence of both toxins and higher rates of alcoholism in various combinations were significantly associated with higher rates of violent crime (Table 1). This analysis, confirmed by other statistical tests, indicates that conventional assumptions concerning the socio-economic factors responsible for crime need to be supplemented by findings in neuroscience and toxicology.

The link between environmental toxins and violent crime is confirmed by evidence that lower crime was apparently an unintended effect of the Congressional ban on the sale of leaded gasoline. Although this policy was based on awareness of the association of high blood lead with lower IQ scores (Kitman 2000), early brain damage due to fumes from leaded gas seems to account for an otherwise unexplained decline in rates of violent crime after 1991. Although contemporary behavioral effects of exposure to tetraethyl lead as measured by the correlation between each year's sales of leaded gasoline and the same year's crime rate are virtually nil, the correlation rises sharply ($r > .90$) when leaded gas sales are compared to crime rates 15 to 20 years later (Table 1). Since children 17

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[5] For a survey of evidence linking lead and manganese neurotoxicity to aggressive behavior and crime, presenting multivariate analysis correlating Toxic Release Inventory for lead and manganese with crime data for 1991 from all 3141 US counties, see Masters, R,, Hone, B, and Doshi, A. (1998). "Environmental Pollution, Neurotoxicity, and Criminal Violence," in J. Rose, ed., *Environmental Toxicology: Current Developments* (London: Gordon and Breach, 1998), pp. 13-48. Legal implications of the evidence linking neurotoxicity and crime, including data from Toxic Release Inventory and crime

years or younger rarely engage in violent crime, the very high association between leaded gas sales and violent crime rates 18 to 26 years later points to fetal or neonatal exposure to lead as a significant but not generally noted factor in violent crime.

When the first study linking violent crime to environmental exposure to lead or manganese was ridiculed by a commentator on national media, a chemical engineer in Massachusetts contacted me concerning the effects of two chemicals—fluosilicic acid (H2SiS6) or sodium silicofluoride (Na2SiF6) added to public water supplies in many U.S. communities.[6] On learning that these potentially dangerous compounds are used to treat water delivered to over 116 million Americans and realizing his extraordinary intelligence and scientific knowledge, I decided to collaborate to determine whether water treated with silicofluorides could have harmful effects.

Experiments with water "fluoridation" using sodium fluoride (NaF) began in the 1945. After early experience with water fluoridation appeared to be safe and effective, the substitution of silicofluorides for this purpose was begun without testing in 1947 and approved without testing by the Public Health Service in 1950. While debates on "fluoridation" have generally ignored the differences between the chemicals involved, silicofluorides are now used in over 90% of artificial water fluoridation (CDC 1993a, xviii).[7] Using a survey of children's blood lead levels in Massachusetts,[8] we combined our

for partial sample of US counties, are examined in Masters, Way, Hone, Grelotti, Gonzalez, and Jones (1998).

6 It is relevant to the hypothesis being presented that the commentator who criticized my work was Rush Limbaugh, whose acerbic "conservative" commentaries are anathema to many liberal academics. Whereas to this day, public policy "experts" have simply ignored my findings, Rush immediately realized that it had important implications for the notions of criminal responsibility and crime control.

7 On the early history of fluoridation in the U.S., see Bryson (2004), ch. 6, and Rymer 2000.

8 We were fortunate to be given access to this data by Professor James Sargent of the Dartmouth Medical School, without whom it would have been difficult if not impossible for us to begin this research in a timely manner.

interdisciplinary approaches to conduct and publish the first empirical research on the effects of water treated with silicofluoride (SiF). Suddenly I found myself co-author of scientific work indicating that, contrary to prevailing beliefs among dentists and the public health officials, these chemicals are associated with harmful effects on children's health and behavior—including substance abuse, learning deficits, and violent crimes.

Our first publication was roundly attacked on the basis of irrelevant assumptions by two employees of the E.P.A. As we continued to find evidence for serious neurotoxic harm, government agencies, dentists, and professional dental associations were increasingly hostile to our work while a few critics of fluoridation contacted or quoted us as allies. On both sides of the issue, however, the tendency persisted to assume that the only question concerns the safety of elemental fluoride without distinguishing between the chemicals used to treat water supplies ("fluoride is fluoride is fluoride"). This tendency is evident even in Christopher Bryson's vigorous critique of water fluoridation in *The Fluoride Deception* (Bryson 2004), which cites our work and mentions silicofluorides at several points (pp. xvii, 150151, 172, 224-225, 318, 349) but usually speaks simply of "fluoride." As a result, Bryson does not deal directly with the chemical issues that distinguish the effects of silicate residues from water treated with silicofluorides from "fluoride" after the dissociation of sodium fluoride. This is all the more unfortunate because he does explain the reasons for using silicofluorides (e.g., 150) and cites the English trial in which an expert witness (Dr. Hunter) included "silico fluoide" as among the "worse of the lot" of toxins in the pollution from a Reynolds aluminum plant (172). Before turning to our findings, therefore, it is necessary to describe in detail how government agencies and public health professionals have approached the debates over "fluoridating" public water supplies.

B. The Problem: Government Agencies, Dentists, and Water Fluoridation

On August 16, 2001, the U. S. Centers for Disease Control and Prevention (CDC) announced release of a document that—in the best of worlds—would have been questioned (CDC Office of Communication 2001). The document, entitled "*Recommendations for Using Fluoride to Prevent and Control Dental Caries in the United States,*" was authored by a "working group" of 11 "fluoride experts"—two government employees, nine representatives of dental schools, and two dental specialists in graduate schools of public health—who "evaluated the scientific evidence for the various fluoride products used in the United States. (Fluoride Recommendations Work Group 2001). The authors, all of whom are associated with institutions having a vested interest in current dental policies, recommended that the U.S. "continue and expand fluoridation of community drinking water" (CDC 2001, 1). The report thereby confirmed the wisdom of policies initiated in the 1940s, adding only marginal suggestions in the light of practical changes in dental care over the last half century.

This report did NOT mention new "scientific evidence" concerning the "various fluoride products" added to public water systems in the United States. New scientific research has been noteworthy in two areas. The first concerns the effectiveness of adding fluoride to public water supplies as a strategy for reducing tooth decay, especially for poor and disadvantaged populations with poor dental care. The second concerns evidence that the chemicals normally used for water fluoridation two untested compounds (hydrofluosilicic acid and sodium silicofluoride—jointly, "silicofluorides") may have unexpected and extremely harmful biological effects on consumers. In the CDC *Recommendations for Using Fluoride,* the Work Group does not mention the second of these issues and treats the first in a puzzling manner (CDC 1993b). Because public policies are conventionally assessed by comparing costs and benefits, the principal question concerns a recommendation for government policy that fails to consider potentially harmful consequences identified by new research. Granted that both costs and benefits of fluoridating public water supplies needed more thorough reassessment before the CDC officially "recommended" its expansion in August 2001, why did the report ignore the need to consider new evidence of possible harm to the public? Could this omission be due to bureaucratic reluctance to question the 1950 decision to approve the addition of silicofluorides to a public water supply?

Before concluding that this is the full story, it is useful to consider legislation recently proposed by the American Dental Association. This text argues not only that all evidence indicates that "water fluoridation" is beneficial, but also asserts that all known tests show its safety. Although described as a text for legislation, the ADA begins as follows:

> 1. Findings of fact:
>
> • Fluoridation of community water supplies is the single most effective public health measure to prevent tooth decay and to improve oral health for a lifetime.
>
> • The Centers for Disease Control and Prevention has proclaimed community water fluoridation one of 10 great public health achievements of the 20th century.
>
> • Fluoridation of community water supplies is supported by the American Dental Association, the U.S. Public Health Service (USPHS), the American Medical Association and the World Health Organization.
>
> • Studies over the past 60 years have repeatedly confirmed the safety of water fluoridation and its effectiveness in preventing dental decay.[9]

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[9] For the full text, see the APPENDIX (which, like these statements of "facts," makes no reference whatever to the specific chemicals used in treating public water supplies for the purpose of "fluoridation").

Not only does the ADA give prominent place to support from professional associations like the AMA and WHO (as well as government agencies like the CDC and USPHS) but the assertion that the "safety of water fluoridation" has been "repeatedly confirmed" ignores the specific chemicals used and the findings to be described below, which challenge the ADA's supposed "facts." Similar statements could be cited from the AMA and hundreds of individual spokesmen for the dental and medical communities.

When actually testing the "safety" of water "fluoridation," dental researchers and epidemiologists have frequently ignored the potential differences between chemicals actually used to treat public water supplies (Karagas, Baron, and Jaconsen 1996, 209-216). One striking example concerns a study of "fluoridation" and osteosarcoma by John Bucher of the NTP, who used sodium fluoride as the measure of exposure to fluoride even though this compound is used for less than 10% of the water supplies treated with fluoride (Bucher et al. 1991). When asked in person why he had used sodium fluoride instead of one of the silicofluorides, Bucher said (without further explanation) that he wanted "a clean experiment."[10]

C. Harmful Effects of Fluoridating Public Water Supplies.

Over 90% of the U.S. population receiving artificially fluoridated water is exposed to water treated with either hydrofluosilicic acid (H2SiF6) or sodium silicofluoride (Na2SiF6). Whereas sodium fluoride (NaF) the chemical originally used for water fluoridation and familiar in toothpaste—has been tested for

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10 While not germaine at this point, those curious about the phrase should know that a reasonable hypothesis for the words "clean experiment" concerns the origin of silicofluorides as a waste product from processing phosphate rock that is the source of weapons grade uranium as well as phosphate fertilizer. Because silicofluoride delivered to water plants often carries radioactive elements (such as lead 210), Bucher's choice would be reasonable if the goal was a test of toxicity that focused solely on the element "fluoride" alone without reference to the actual chemistry of "fluoridated" water delivered to most American households.

safety,[11] silicofluorides have have largely replaced them without adequate testing and are now used in water delivered to over 115 million people. Hence, although these chemicals are added to water used by about 45% of the U.S. population, the Chief of the Treatment Technology Evaluation Branch of the EPA's Water Supply and Water Resources Division admitted in 2000 that his agency is "unable to find any information on the effects of silicofluorides on health and behavior." (Thurnau 2000).

This admitted lack of knowledge about silicofluoride safety increased the importance of epidemiological data concerning effects of these chemicals on health and behavior. Although some critics of fluoridation cited these findings favorably while several government scientists and dental professionals attacked them, why did both a recent government report and the American Dental Association's draft legislation recommending fluoridation make no mention whatever of the controversy?

The habit of discussing fluoridation without reference to the chemicals involved is evident in many public and professional contexts. For example, although the CDC *Recommendations for Using Fluoride* names specific chemicals when discussing fluoride mouthwashes ("sodium fluoride"), gel and foam ("acidulated phosphate fluoride," "sodium fluoride," or "stannous fluoride"), and varnish ("sodium fluoride " or "difluorsilane"), this document does not discuss

11 Although sodium fluoride has been tested, critics point out that studies of this chemical do not adequately measure chronic effects and were sometimes contrived. As one critic put it (Albert Burgstahler, pers. com.): "I do NOT think NaF has been PROPERLY "tested for safety"! Yes, it has been "tested" in many carefully contrived experiments, but in the honest experiments, as by Mullenix, Varner, and others, it has FAILED the test for safety, even at 1 ppm! Short-term experiments sometimes seem to give it a clean bill of health, but chronic toxicity studies do not, even with the less sensitive laboratory rat." For an example of the research showing that even sodium fluoride can be toxic, see: Mullenix et al. (1995), 169-177. In the current context, however, the most striking point is that whatever the adequacy of tests of sodium fluoride, a number of animal tests of that compound have been conducted, whereas this has not been the case for the silicofluorides, which are now used for over 90% of water fluoridation in the U.S.

silicofluorides. Even if the research associating silicofluoride usage with harmful effects is questioned on methodological grounds—as two EPA employees have claimed (Urbansky and Schock 2000, 597-637)—it would seem normal for the "fluoride experts" to *name* the compounds used and provide some evidence of their safety. That paper presents a critical analysis previously outlined in a memoradum to Stan Laskowski, Director, Region III Environmental Services Division, US EPA, dated January 14, 1999 (Urbansky and Schock 1999) entitled "Review of work … about the effects of common water utility fluoridation practices on (1) lead concentrations in drinking water and (2) the bioavailability of lead." In criticizing the first article in a series of research studies, on grounds of faulty methodology and presentation, Urbansky and Schock state its thesis inaccurately (Urbansky and Schock 1999).

Earlier governmental publications show that silence on the use of silicofluorides has been an established practice. The Agency for Toxic Substances and Disease Registry (ATSDR) is responsible for publishing toxicological *Profiles* on chemicals that are likely to pose important risks. In the 1993 edition of the ATSDR *Profile on Fluorine, Hydrogen Fluoride, and Fluorides*, there was virtually no mention of silicofluorides despite their known danger to employees in water treatment plants; after a memorandum was submitted on the importance of rectifying this omission, the 2003 revision of this document mentioned the compounds in several places, cited our first paper, but did not cover risks of direct exposure to water plant workers or our specific findings.[12]28 In *Health Effects of Ingested Fluoride*, published in 1993

[12] ATSDR (1993), has virtually no reference to the silicofluorides. E.g., the *Profile* introduces the topic by saying: "Examples of fluorides include sodium fluoride and calcium fluoride." (12); summarizes industrial exposures as: "Workers may be exposed to high levels of hydrogen fluoride or cryolite in the air if their work involves certain machinery, air transportation, medical and other serviceds, textile and metal manufacturing, or petroleum and coal production." (3); and for exposures of the public: "Several medicines that contain fluoride are used for treating skin diseases and some cancers. In addition, small amounts of sodium fluoride are added to toothpaste or

drinking water to help prevent dental decay." (5). With regard to toxicity, the 1993 *Profile* states: "Fluorine, hydrogen fluoride and sodium fluoride have been named hazardous substances by EPA." (ATSDR 1993, 7). [This document was prepared for the ATSDR by the "Clement International Corporation (i)].

In reply to the "Solicitation for Public Comment on Proposed Update of Toxicological Profile for Fluorides" (docket # ATSDR173), a member of our team submitted a 30 page memorandum ("ATSDR Should Report on Health Effects of Silicofluorides" 2002). In the 2003 revision of the *Profile*, summarized in the *Public Health Statement for Fluorides, Hydrogen Fluoride, and Fluorine*, Section 1.1 ("What are fluorine, hydrogen fluoride, and fluorides?") begins as follows: "Fluorides are properly defined as binary compounds or salts of fluorine and another element. Examples of fluorides include sodium fluoride and calcium fluoride. Both are white solids. Sodium fluoride readily dissolves in water, but calcium fluoride does not. Sodium fluoride is often added to drinking water supplies and to a variety of dental products, including toothpastes and mouth rinses to prevent dental cavities. Other fluoride compounds that are commonly used for water fluoridation are fluorosilicic acid and sodium fluorosilicate. Calcium fluoride is the compound in the common minerals fluorite and fluorspar.…" After this passing remark, there is no reference to silicofluorides or water fluoridation in Sections 1.2 ("What happens to fluorine, hydrogen fluoride, and fluorides when they enter the environment?"), 1.4 ("How can fluorine, hydrogen fluoride, and fluorides enter and leave my body?"), 1.5 ("How can fluorine, hydrogen fluoride, and fluorides affect my health?") or 1.6 ("How can fluorine, hydrogen fluoride, and fluorides affect children?") Section 1.3 ("How might I be exposed to fluorine, hydrogen fluoride, and fluorides?") contains a single sentence on artificial water fluoridation: "Many communities fluoridate their water supplies; the recommended level of fluoride is around 1 ppm.

In the United States, approximately 15,000 water systems serving about 162 million people are fluoridated in the optimal range of 0.71.2 ppm, either occurring naturally or through adjustment." As this *Public Health Statement* (which presents Chapter 1 of the full *Profile*), contains no further mention of either fluosilicic acid or sodium silicofluoride, the relative silence on the toxic risks the pose for workers in public water supplies is all the more puzzling because the CDC warns water plant personnel that fluosilicic acid "must be handled with great care because it will cause a 'delayed burn' on skin tissue" or, more generally, "injury to operators and damage to equipment from acid splatter or fumes" CDC (1993b), 1,819, cf. also 93, 96. In at least one recent case, serious harm to a water plant employee was not prevented by adequate safety measures and the plant operators refused to pay damages for the resulting injury. Mullinex (2004). The request for extensive consideration of silicofluorides in the revision of the ATSDR *Profile* was Coplan 2002) For the results, see ATSDR (2003a).

The character of references to silicofluorides in this revision is illustrated by the only mention of these compounds in the Summary Chapter, which is published separately for more general use: "Sodium fluoride readily dissolves in water, but calcium fluoride does not. Sodium fluoride is often added to drinking water supplies and to a variety of dental products, including toothpastes and mouth rinses to prevent dental cavities. Other fluoride compounds that are commonly used for water by a committee of National Research Council, sodium fluoride is often mentioned in eight different chapters while a computer word search confirms that neither silicofluoride is mentioned anywhere in the book (Subcommittee on Health Effects 1993). To be sure, most critics of water fluoridation, like government policymakers and dentists supportive of this policy, have also spoken of "fluoridation" without referring to the chemicals used. With the recent publication in peer reviewed journals of a series of studies questioning the safety of silicofluorides, however, as critics have begun to discuss these chemicals, silence on their existence and apparently harmful effects by professionals or government bureaucrats takes on a different character—compare the letter by Dr. William D. Glenn, III with the response of our team (Masters et al. 2004).

At least one earlier publication of the CDC indicates that the agency is fully aware of differences in the chemicals used to fluoridate public water supplies. In *Engineering and Administrative Recommendations for Water Fluoridation, 1995*, the discussion of "Technical Requirements" includes separate instructions for:"Sodium Fluoride Saturator Systems," (section III,B), "Fluorosilicic Acid Systems" (Section III.C), and "Dry Fluoride Feed Systems" which include those "when sodium fluorosilicate (i.e., silicofluoride) is used" (Section III.D). That some danger from fluorosilicic acid is recognized is clear from the first recommendation for systems using that chemical: "To reduce the hazard to the water plant operator, fluorosilicic acid (hydrofluosilicic acid) must not be diluted.

Small metering pumps are available that will permit the use of fluorosilicic acid for water plants of any size" (CDC 1995, 8). In contrast to the distinction in this manual, CDC documents proclaiming the benefits of fluoridating public water supplies are generally silent on the chemical compounds involved (CDC 1999, 933-940). The second paragraph of Introduction

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fluoridation are fluorosilicic acid and sodium fluorosilicate. Calcium fluoride is the compound in the common minerals fluorite and fluorspar," ATSDR (2003b), 3.

to the CDC's *Recommendations for Using Fluoride* makes it seem that the treatment of fluoride chemistry in this document is intentionally selective:

> Fluoride is the ionic form of the element fluorine, the 13th most abundant element in the earth's crust. Fluoride is negatively charged and combines with positive ions (e.g., calcium or sodium) to form stable compounds (e.g., calcium fluoride or sodium fluoride). Such fluorides are released into the environment naturally in both water and air. Fluoride compounds also are produced by some industrial processes that use the mineral apatite, a mixture of calcium phosphate compounds. In humans, fluoride is mainly associated with calcified tissues (i.e., bones and teeth) because of its high affinity for calcium (CDC 1995, 1).

While true in general, this paragraph—like the ATSDR's *Toxicological Profile on*

Fluorides—does not mention that as delivered to a water treatment plant, hydrofluosilicic acid and sodium silicofluoride are potentially toxic compounds that originate as byproducts in the production of phosphate fertilizer and uranium. The difference matters because a crucial issue in the safety of using silicofluorides concerns the chemical reactions when they are added to water—on the differences between silicofluorides and sodium fluoride, see Guest Editorial (2001, 161-164; also, Coplan and Carton (2001) and *idem*. In 1950, the Public Health Service formally approved their use based on the assumption – unsupported by empirical data that, like sodium fluoride, the silicofluorides dissociate completely into their component elements when added to water. Although this claim was supported by a theoretical argument, it was not confirmed by empirical data (Morkin and Hodge 1957, 192-202).[13] In 1975,

[13] The first sentence of this article confirms that, at the time of their approval in 1950, the extent of dissociation of silicofluorides injected in a water supply was unknown: "The widespread use of sodium silicofluoride in fluoridating drinking water has made it important to determine the state of the fluoride in such water, specifically,

incomplete silicofluoride dissociation was found in Westendorf's laboratory findings in Germany, which have subsequently been translated into English (Westendorf 1975). This German study suggests that the "residual complexes" remaining after silicofluorides are added to public water supplies are not necessarily compounds like calcium fluoride or sodium fluoride, which are formed from "a positive ion (e.g., calcium or sodium)" and the fluoride anion. Evidence on the extent of SiF dissociation into its component elements is at odds with the assumption that SiF and NaF are equivalent sources of free fluoride when used for water fluoridation.

This thesis, presented at the University of Hamburg, found that, at physiological conditions and in the regime of 1 ppm fluoride, the dissociation of the silicofluoride anion [SiF6]2 stopped when four of its six fluorides had been released If the dissociation had occurred equally among the SiF involved, the resulting incompletely dissociated species would be the anion [SiF2(OH)4]2. Although this product could account for the observed cholinesterase inhibition

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how much is fluoride ion, how much, if any, is unchanged silicofluoride, how much is fluoride bound to other ions. If all or nearly all of the fluoride is the ion F, the great body of information about the biologic effects of fluorides can be brought forward as a guarantee of safety. If considerable amounts of silicofluoride remain, a question can legitimately be raised since comparatively little work has been done on the biologic effects of silicofluorides." (192). Despite the authors' claim to present (in 1957) "experimental results," their analysis is essentially a theoretical extrapolation which does not provided a direct test of chemical and biochemical effects under conditions approximating actual usage. Compare the citation in the next note. As confirmation that U.S. governmental agencies (including the EPA as well as CDC) still lack scientific evidence on the chemical effects of treating public water with silicofluorides, a letter to the author, dated March 15, 2001 from Sally C. Gutierrez, Director, Water Supply and Water Resources Division, Office of Research and Development, National Risk Management Research Laboratory, U.S. EPA, Cincinnati, wrote of a meeting in January 2001: "Several fluoride chemistry related research needs were identified including; (1) accurate and precise values for the stability constants of mixed fluorohydroxo complexes with aluminum (III), iron (III) and other metal cations likely to be found under drinking water conditions and (2) a kinetic model for the dissociation and hydroloysis [sic] of fluosilicates and stepwise equilibrium constants for the partial hydrolyisis products. As a result of these discussions, ORD is exploring options to initiate research in the identified research areas."

by so-called "noncompetitive" mechanisms, the experimental data also indicates that other "residual compounds" are found in water after the dissociation of SiF has taken place. Due to such incomplete dissociation, use of SiF probably introduces toxic substances in public water supplies. The effects of silicofluoride treated water are addressed in Knappwost and Westendorf (1974, 275). Moreover, Westendorf found that, when humans drink water treated with silicofluorides, the residuals left by SiF act to inhibit a key enzyme (acetylcholinesterase) with important biological consequences (Knappwost and Westendorf 1974, 275). The CDC *Recommendations for Using Fluoride* are so written that the existence of this and other scientific questions surrounding the use of silicofluorides remain invisible.

D. ***Evidence Justifying the Use of Silicofluorides.***

The U.S. Public Health Service approved the addition of fluosilicic acid and sodium silicofluoride to public water supplies in 1950. At the time, the principal scientific evidence for replacing sodium fluoride with silicofluorides was an article by F. J. McClure entitled "Availability of Fluorine in Sodium Fluoride vs. Sodium Fluosilicate" (McClure 1962, 527-532). The stated reason for the substitution was the cost differential between the two chemicals: "the cost of chemicals for the fluoridation of 1 million gallons of water at an optimum level of 1.0 p.p,m. fluorine is approximately $2.15 using sodium fluoride and 76 cents for an equivalent quantity of sodium fluosilicate" (McClure 1962, 527-532).[14]

[14] It is worth citing complete the first paragraph of this article, from which this sentence it taken: "Sodium fluoride is the source of fluorine for the majority of current studies testing the efficacy of fluoridation of community drinking water for the partial control of human dental caries (*1,2,3,4,5*). On the basis of solubility and availability of fluorine, as well as the innocuous character of the accompanying sodium, sodium fluoride is the logical source of fluorine. At the same time any large-scale program of community water fluoridation must calculate its cost, and other fluorine compounds may be available at less expense and may be equally efficacious. Thus with sodium fluosilicate currently selling at about half the price of sodium fluoride, the cost of chemicals for the fluoridation of 1 million gallons of water at an optimum level of 1.0 p.p.m. fluorine is approximately $2.15 using sodium fluoride and 76 cents for an equivalent quantity of sodiul fluosilicate. The market price of these chemicals, according

McClure begins by dismissing "physiological effects" due to known "differences in solubility" of the compounds ("NaF at 18o C. is approximately 4.0 percent soluble whereas Na2SiF6 is soluble to the extent of about 0.65 percent") because "quantities of fluoride ingested are very small." He then considers the difference in chemical reactions of each compound: "In dilute aqueous solutions the hydrolysis of these two fluorine salts yielding fluoride ions is comparatively simple in the case of sodium fluoride, which is practically completely ionized, but quite complex and somewhat obscure in the case of sodium fluosilicate" (McClure 1962, 527-532). Following the specific chemical reactions "postulated" or suggested by chemists, he turns to "physiological effects of sodium fluosilicate vs. sodium fluoride." The remainder of McClure's paper considers "the rate of retention and paths of excretion of fluorine" when ingested from these compounds. He begins by summarizing data in a 1935 study by Kick et al., whose results are summarized as finding "there was no difference between sodium fluosilicate and sodium fluoride as regards the ultimate percent of fluorine retained in the rat's body, i.e., the percent fluorine balance in the above data. There were some differences, however, in the paths of excretion, i.e., in urine or feces." McClure himself then presents results of his own experiments showing no difference in "ultimate retention" of fluorine in various bodily tissues in "groups of rats ingesting fluorine in their drinking water *ad libidum* at levels of 5, 10, 15, 25, and 50 p.p.m. fluorine" from the two compounds (McClure 1962, 529).

McClure's results focus entirely on the retention of fluorine in bone (femurs and mandibles), molar teeth, and incisor teeth, which were statistically indistinguishable for rats exposed to the two compounds. He thus ignored completely the different paths of excretion found by Kick, et al., even though this

to Chemical and Engineering News for April 24, 1050, is sodium fluoride 95 percent c. 1., wks.0.10 1/2 cents per pound.; sodium fluosilicate, bbl., cl. 0.04 1/2 cents per pound. The latter compound is also known as sodium silicofluoride," McClure (1962), 527.

is essential to many physiological reactions since fluoride or other compounds resulting from incomplete dissociation can only reach the kidneys through the blood stream and hence will have effects that are not the case for ingested chemicals excreted in feces. In short, as the title of his article indicates, McClure's data only concern the "availability" of fluorine from sodium fluoride and sodium silicofluoride, with no evidence whatever concerning toxicological or health effects of the two compounds.[15] This unusual basis for approving the exposure of millions of citizens to a compound for medical reasons results in cost-benefit calculations where the only cost is the market price of two chemicals (which differed at the time by six cents a pound). In short, at the time of the approval of silicofluoride usage, no animal testing had been conducted to confirm the biological safety of water treated with these chemical compounds.

E. Benefits of Fluoridating Public Water Supplies.

Serious new questions have also been raised about the efficacy of controlling caries by *ingesting* fluoride. Recent studies of this issue have emphasized that the effects of fluoride in reducing tooth decay depend primarily on topical contact of fluoride with the tooth surface, as occurs with fluoridated toothpaste, gels, varnishes, or mouthwash. One widely used measure of such topical contact is the fluoride content of saliva, which—as will be seen in Section III, below—is increased to a much lesser degree by fluoridated water than by fluoridated toothpaste or other topical treatments). In this case, the CDC

15 Although I will return to the unusual focus on fluoride retention ("balance") when considering recent discussions of silicofluorides, two other areas on which McClure is silent deserve mention. First, by ignoring greater excretion in urine from sodium silicofluoride, his analysis necessarily excludes all questions of neurotoxicology and effects on brain and behavior. Second, even in the measurements of retention in body tissue, bone and teeth, McClure is selective in a puzzling manner. His research design carefully controlled amounts of copper (10 p.p.m.) and iron (100 p.p.m.) in the rats' diet, but the only elements for which retention was measured were calcium and phosphorous (ibid, p. 529). As a result, any effects of either compound in modifying uptake of *other* toxins in the environment were excluded even though, especially in the case of copper, potentially toxic effects might occur. In the light of contemporary toxicology, as will be shown, below, neither of these omissions is innocuous.

Recommendations for Using Fluoride refers to some of the relevant evidence, but does so in a puzzling manner.

For example, despite recent findings on the mechanisms by which fluoride influences tooth decay (to be discussed in Section III below), the CDC apparently bases its support of water fluoridation on historical evidence of an overall decline in dental caries after water fluoridation began. As evidence in the *Recommendations for Using Fluoride*, the CDC Working Group states that "National surveys have reported that the prevalence of any dental caries among children aged 12-17 years declined from 90.4% in 1971-1974 to 67% in 1988-1991" (Fluoride Recommendations Work Group 2001, 6). The reduction, between 1971-1974 and 1989-1991, amounts to 23.4% of the overall incidence or about 26% of the earlier rate (Fluoride Recommendations Work Group 2001, 6). No evidence is presented to compare increases in water fluoridation with increased sales of fluoridated toothpaste or other fluoridation modalities that might contribute to this outcome. As has often been noted, an uncontrolled time series comparison is subject to a very high risk of confounding co-variation. Later in the *Recommendations for Using Fluoride,* the authors admit that the proportion of this decline in caries due to fluoridated water has been open to disagreement: "Initial studies of community water fluoridation demonstrated that reductions in childhood dental caries attributable to fluoridation were approximately 50%60% (1994-1997). More recent estimates are lower—18%-40% (1998-1999). This decrease in attributable benefit is likely caused by the increasing use of fluoride from other sources" (Fluoride Recommendations Work Group 2001, 6). The divergence of these estimates of effectiveness indicates methodological problems from time series data that could be avoided by controlled ecological comparisons between fluoridating and non-fluoridating communities.

The extent of benefits due to fluoridated water is further questioned by data showing that untreated public water supplies are not a major risk factor underlying higher levels of tooth decay. "Populations believed to be at increased risk for dental caries are those with low socioeconomic status (SES) or low levels of parental education, those who do not seek regular dental care, and those without dental insurance or access to dental services" (Fluoride Recommendations Work Group 2001, 6).[16] That water fluoridation does not effectively counteract such risk factors is demonstrated by recent studies of dental disease and access to dental treatment among minorities (see Section III, below). Moreover, skepticism about the claimed size of benefits is reinforced by data showing that the decline in dental disease since 1940 is parallel in communities that do and that do not fluoridate their public water supplies (Figure 1—this figure and its accompanying list of sources was prepared by my research colleagues and has been presented at a number of scientific meetings and included with memoranda to government officials). It is interesting that one such study was co-authored by a critic of work distinguishing between silicofluorides and sodium fluoride at the 2003 meeting of the American Association for Dental Research—to be discussed, below (Adair, Hanes, Russell, and Whitford 1999, 81-85—for the abstract of a presentation by Whitford and Nicholson to the March 2003 meetings of the AADR/IADR, see Section VI, below).

Published evidence that silicofluoridetreated water seems to be associated with harmful effects puts these questions in a different light. Whatever the benefits of water fluoridation in reducing tooth decay, the most urgent policy issue should be an open-minded assessment of the hypothesis that silicofluorides have harmful effects on health and behavior not observed where sodium fluoride is used. Consideration of this research is especially important because the effects observed in recent epidemiological studies are influenced by biological processes unknown when silicofluorides were first approved.

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[16] Although this list of factors does not specifically identify Blacks and other racial minorities as at higher risk for dental disease, others have made this link and related it to evidence that Blacks are denied dental treatment under Medicaid and confront discrimination from dental care providers.

F. A Preliminary Conclusion: Bureaucratic Inertia, Science, and PolicyMaking

The historical background and original debates over water fluoridation confirm the relevance of the traditional perspective on science and policy making. Most particularly, Wollan's discussion of the role of those agencies most directly involved in the sponsorship or regulation of a policy area is clearly illustrated by the early reactions of the Public Health Service, ATSDR, or EPA when considering hydrofluosilicic acid or sodium silicofluoride as the chemicals used to fluoridate a public water supply (Wollan 1968). Before turning to more recent evidence to assess the nomination of SiF for study by the NTP and the hypothesis that professionals also contribute to delays in linking scientific evidence to public policymaking, it will be useful to describe the deliberations of the Surgeon General's Ad Hoc Committee on "NonDental Health Effects of Fluoride," which met on April 1819, 1983.

This committee was composed of 8 medical specialists and 6 government administrators, with 3 medical advisors and 5 EPA participants and observers—not counting Dr. Jay Shapiro, Acting Director of the Clinical Center of the NIH, who was in the Chair. As a result of the relatively even number of professionals and government officials, the verbatim transcript of the proceedings provides a good illustration of the parallel assumptions made in these two groups (Surgeon General's Ad Hoc Committee 1983—a list of personnel are listed on the pages preceding the Table of Contents, vol. I). Although tests of safety using sodium fluoride are cited, there is no discussion of fluosilicic acid or sodium silicofluoride. Perhaps more telling, the participants were not able to agree on the definition of "adverse health effects" when they focused on the question: "are there any adverse effects from fluoride?" (Surgeon General's Ad Hoc Committee 1983, vol. II, especially 390-391, 470).[17] As the Committee focused on the exact

[17] In this dialogue, there is no discernable difference in the views of government officials and physicians. One of the participants, Dr. Stanley Wallach (Chief of the Medical Service at the Albany, N. Y. VA Hospital), asked: "why do not you redefine what we are talking about. We are talking about fluoridation, fluoride content of the

wording of a recommendation with regard to "dental fluorosis in the Stage III level" (which a number of participants considered an "adverse health effect" while others called it only a "potential health effect"), Dr. James P. Carlos (Associate Director of the National Caries Program at the National Institute of Dental Research) made a telling observation:

> I think it might be well worth considering how you phrase the recommendation, the rationale for the recommendation very carefully in terms of potential adverse effect.
>
> The reason is that we have on record the Surgeon General, the American Medical Association, the American Dental Association all saying that there is no adverse health effect.
>
> I think, in the case of dental fluorosis, we can't find any data to the contrary (Surgeon General's Ad Hoc Committee 1983, vol. II, 472-473).

Dr. Robert Marcus (Asst. Professor at the VA Medical Center in Palo Alto, Cal.) immediately answered: "I do not think that is the sense of the committee. I think that the sense of the committee is that the cosmetic effect represents an adverse health effect, that this is an adverse health effect" (Surgeon General's Ad Hoc Committee 1983, vol. II, 473).

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drinking water or are we talking about fluoride administration in general?" Dr. Jay Shapiro (Acting Director of the NIH Clinical Center) answered: "I think we have to be talking about fluoride in drinking water. I do not think we have to be concerned with the pharmacological effects of fluoride right now." (Surgeon General's Ad Hoc Committee 1983, 393). Later, without ever considering the specific chemicals used to add fluoride to water supplies, Dr. Shapiro—acting as leader of the discussion—commented that "What I will do is report the fact that it was not unanimous within the committee, that there would be some recommendation framed in the letter as regards to the need for additional study in populations at risk so that there is a better answer three years hence when this might again be up for consideration." (470). Over time, however, these concerns and hesitations disappeared without the proposed studies.

It is worth noting that Dr. Shapiro of the NIH added: "I think the Surgeon General left a big loophole, frankly, when he raised this cosmetic issue. I think he, in effect, was saying there is still some room for doubt…" (Surgeon General's Ad Hoc Committee 1983, vol. II, 473). Dr. Carlos' reply makes it clear that he did not consider it justified contradicting previous public statements by the Surgeon General, AMA, and ADA in favor of fluoridation:

> It is all very well to say that you think that may be the case and I am not arguing that, but we have no data, not a shred. What I am concerned with is that we will come into conflict with statements that are already in the public record without any data on which to base the conflict.
>
> I think we can get around the whole thing by saying there is substantial belief that there are potential health effects, psychological, structural, functional, whatever and this may turn out to be the case (Surgeon General's Ad Hoc Committee 1983, vol. II, 474).

As more recent statements confirm, the position of the American Medical Association and the American Dental Association played an important role in establishing and maintaining the policy that water fluoridation is safe and effective without reference to the chemicals used. To reverse professional judgments at this level may be even more difficult than reversing a legal or administrative decision.

III. Silicofluoride Treated Water, Enhanced Lead Uptake, and Dysfunctional Behavior

A. The need for Studies of Biological Effects of Silicofluoride Treated Water

Despite some early studies showing differences in evoked metabolic response between sodium fluoride and sodium silicofluoride, to this day the substitution of silicofluorides in public water treatment facilities has still never been subjected to appropriate animal or human testing.[18] Because silicofluorides are by-products of processes by which fertilizer is produced and uranium extracted from phosphate rock, some observers have questioned uncertain standards and protocols for determining the toxicity of silicofluorides prior to their use in public water supplies ("ATSDR Should Report on Health Effects of Silicofluorides" 2002; Surgeon General's Ad Hoc Committee 1983, vol. II, 472-473). The principal issue, however, lies elsewhere.

It is the biochemical effects of consuming water treated with silicofluorides—not the chemistry of these compounds themselves – that is in need of study. For supporters, silicofluorides are as safe as sodium fluoride because when silicofluorides are added to water, the dissociation of fluoride is "almost" complete. For many critics, in contrast, silicofluoride is a toxin that is contaminated with dangerous levels of lead, arsenic, or other harmful elements. In these debates, both sides have tended to focus on chemistry without considering whether silicofluorides leave behind "residual species" of chemical compounds, such as silicic acid or siloxanes, that could have biological effects not found when sodium fluoride is in use. This concern is relevant because, in addition to showing that silicofluoride dissociation is incomplete (i.e., that there are indeed "residual species"), Westendorf's research in Germany (apparently unknown to the EPA and CDC) found that acetylcholinesterase inhibition by water treated with silicofluorides occurs at a lower threshold and to a greater

[18] A "stakeholder consensus" process managed by a private agency, NSF-International, a contractor to the EPA, establishes safety standards and testing procedures for silicofluorides. A direct inquiry of senior staff of NSF-International revealed that neither NSFI nor any agency it accepts as qualified to do standards compliance tests on silicofluorides has ever conducted animal studies of their toxicity. Specifications for SiFs are established for individual producers, individual plants of any producer, and for different processes of any one producer, all of which are treated as protected by proprietary rights of confidentiality. And only one sample per year needs to be tested for compliance with such individualized specifications with no regard for product variability from time to time within any year.

extent than similar enzyme inhibition when water is treated with sodium fluoride (Westendorf 1975).[19] Other chemical properties have been hypothesized to explain the neurotoxic effects apparently associated with water treated with silicofluorides to produce 1 ppm of free fluoride (Masters et al. 2000a; Masters et al. 2000b).

To assess the biological effects of water *after* it has been treated with fluosilicic acid or sodium silicofluoride, the best approach entails controlled animal experimentation. Having neither a laboratory nor funds for this purpose, we adopted an epidemiological approach used to determine whether an environmental factor is likely to cause a disease and hence needs further study. To do so, we located reliable data for potentially harmful effects in large geographical samples. We then analyzed the statistical association between each outcome and socioeconomic or demographic variables that might account for effects that otherwise coincide with silicofluoride useage. For example, because evidence has shown American Blacks are more likely than Whites to have high blood lead levels, studies of lead uptake need to consider ethnicity along with per capita income, education, population density and other similar factors in each geographic area. A survey of our results will permit a more detailed assessment of the role of both professionals and government agencies in maintaining gaps between current scientific research debates and public policy making.

[19] At the biochemical level in a cell, Westendorf found that inhibition of cholinesterase enzymes by a silicofluoride was significantly stronger than by sodium fluoride and began to be expressed with no concentration threshold. By contrast, inhibition of acetylcholinesterase by sodium fluoride was not found until a threshold of fluoride was exceeded, and then did not increase with concentration at rates similar to those found when a silicofluoride was the agent. These results were found at fluoride concentrations in the parts per million range, and include exposures comparable to those of humans drinking silicofluoride treated water in the U.S. communities where it is used.

B. Silicofluoride Treated Water and Children's Blood Lead Levels

We first studied children's blood lead levels in three samples totalling over 400,000 children in Massachusetts, New York, and the National Health and Nutrition Survey (NHANES) of counties with a population over 500,000). Epidemiological methods were used to compare blood lead levels of those living in communities using silicofluoridetreated water with blood lead in communities using sodium fluoride or with nonfluoridated water. Taking economic, social and racial factors into account, silicofluoride treated municipal water was always significantly associated with increased blood lead levels.

This effect was evident in a Massachusetts survey of lead levels in 280,000 children—see Figure 2, comparing blood lead levels among children exposed to silicofluorides from the Greater Boston water system or from towns that add silicofluorides locally, communities using sodium fluoride, and towns without fluoridation (Masters et al. 1999a).[20] For the state of New York, data was available on venous blood lead levels for 151,225 children in communities of 15,000 to 75,000. Controlling for other factors associated with higher blood lead, silicofluorides were significantly associated with higher uptake of lead from the environment (Masters et al. 2000c, 1,091-1,100). As in other studies (see Figures 6 and 7 below), this effect was especially pronounced among Black children, who were more likely to have lead over 10µg/dL and correspondingly less likely to

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[20] In the criticism by two EPA employees, Urbansky and Schock to Laskowski (1999), the "main assertions" in this article are not stated accurately. Urbansky and Schock state: "The authors suggest that the hexafluorosilicate ion (SiF6 2) promotes the solubilization of lead (II) from the distribution system, thereby increasing the lead (II) concentration at the tap. In addition, they believe that residual SiF62is responsible for lowering gastric pH and, therefore, converting particulate lead (0) to bioavailable lead (II) ion or for complexing with Pb (II) to make it more amenable to permeating the gastric wall and being absorbed into the bloodstream." While the last phrase at least refers to the hypothesis that residues of silicofluorides enhance lead uptake, the claim that epidemiological findings of such an association is due to increase "solubilization of lead (II) from the distribution system" is contradicted by the data reproduced in Figure 13 of the present article.

have low blood lead (Figure 3) (Masters et al. 1999b, 591-624; Masters 2001, 345-369).

As our first study on Massachusetts was greeted with charge of "junk science" from two EPA scientists, additional statistical tests were run to confirm that these results are not due to other socioeconomic or demographic factors. For the New York sample, we compared the "odds" of having blood lead over 10µg/dL if silicofluorides were in the water (the percentage of such children in silicofluoride treated communities divided by the percentage in communities without these chemicals in the water). An odds ratio of 1.0 means that the risk of high blood lead is identical whether or not a child is exposed to silicofluoride treated water. Taking into consideration a series of risk factors linked with high blood lead, the data show that odds of blood lead levels over 10µg/dL are often higher in communities where silicofluorides are in use but other risk factors for high blood lead are *below* average (Figure 4).

To doublecheck that this was not a statistical artifact, we then looked at the difference in lead levels of Black and non-Black children in New York communities with overall low or high risk for blood lead. Three main findings appeared. First, when New York children living in communities with less risk for lead uptake (0 to 4 "risk factors" for high blood lead) are compared with those living in high risk communities (5 to 7 "risk factors"), those exposed to silicofluoride treated water are always worse off than those without these chemicals in their water. Second, these silicofluoride effects are worse when children are also exposed to more environmental risk factors for blood lead uptake. Finally, these effects are strikingly worse for Black children than for Whites (Figure 5).

The third study concerned children's blood lead levels in the National Health and Nutrition Evaluation Survey (NHANES III), which had reports for 7224 children from 80 counties with populations over 500,000. As only 4 of these counties had any communities that used sodium fluoride, analysis of the

NHANES III data focused on the percentage of the entire county population exposed to silicofluoride treated water. Among the 1543 children of all ages from large urban counties with over 80% of the population exposed to fluoridation (almost all of whom receive water treated with silicofluorides), average blood lead was 5.12 µg/dL whereas the average for 1139 children in low fluoride exposure counties was 3.64 µg/dL Blood lead in the 473 children sampled from the medium fluoridation counties was 3.23 µg/dL, which was significantly different from the high fluoridation counties but not from either low fluoridation counties or those with unknown fluoridation status, where average blood lead levels were 3.16 µg/dL (standard deviation = 2.83).

Broken down by age and ethnicity, among children aged 3 to 5, although Blacks have higher levels of blood lead than Hispanics, who, in turn, have higher levels than Whites, blood lead is significantly higher for each race where silicofluorides are found to be in use (Figure 6). The same pattern occurs for children aged 513 (Figure 7). To see whether this could be attributed to poverty rather than chemicals in water supplies, we compared children living in counties with relatively lower and higher percentages of the population living in poverty. Although silicofluoride use is, again, associated with higher levels of lead in children's blood, this effect is significantly worse for Blacks than Whites (Figure 8).

In all three populations studied, multivariate statistical analyses confirmed that those children in each ethnic category and each age group who were likely to be exposed to silicofluorides differ strongly in levels of blood lead from those not exposed. These results reflect higher absorption of lead from environmental sources, such as lead paint in old housing or high lead levels in water. For example, when Mass. towns are divided into those above and below the mean proportion of old housing and lead levels in 90th percentile of first-draw water, the ANOVA shows that silicofluorides are associated with higher average blood lead levels in each category. As the data show, therefore, increased lead levels cannot be attributed solely to contamination of the silicofluoride itself (Figure 14). This evidence of harm was then checked by analyzing data for health and behavioral traits that are associated with high blood lead.

C. Silicofluoride Use and Violent Crime

For possible effects on behavior, the clearest data concern rates of violent crime, for which the evidence of harmful effects of lead have already been noted. Although the findings to be described have been published in peer reviewed articles and described in media reports, no specialist in criminology, sociology, or public policy has ever contacted the authors to get more information about our findings or to challenge them. A detailed presenting of the scientific results will indicate both the character of the evidence linking water treatment chemistry to violent crime AND the gap between academic fields that can produce fierce professional resistance to new findings.

Recent research in neurotoxicology indicates that exposure to lead has the effect of disturbing the function of the neurotransmitter dopamine. As neuroscientists have shown, neuronal pathways activated by this neurotransmitter are associated with learning deficits, impulse control, substance abuse, and aggressive behavior. Other tests have confirmed that violent behavior is more likely among those who have high levels of lead in their blood and bodily organs. For example, in two studies, blood lead was measured in groups of children at the age of 6, and then the same children were studied for arrests for violent crime by the late teenage years. In both studies, the children with high blood lead at age 6 were much more likely to engage in violence before the age of 20 (Denno 1994, 80-180; Needleman, Schell, Bellinger, Lenton, and Allred 1990, 83-88).

Like lead, manganese can also reduce impulse control and increase risks of violent crime. Because blood lead tests of individual violent offenders indicate high levels of manganese or lead and environmental pollution with both metals contributes to higher rates of crime (see Table 1) (Masters, Hone, and Doshi 1998, 13-48), it is unfortunate that available geographic data is limited to children's blood lead.

Although we, therefore, do not know whether silicofluoride also increases absorption of manganese or other toxins, the behavioral effects of water treated with silicofluorides *can* be assessed by using county-level data for rates of violent crime. In this case, the dependent measure is likely to be recorded with reasonably accuracy and is available for all 3,141 counties in the U.S. Because silicofluoride usage can be coded as the percent of the county's population receiving water treated with these chemicals, statistical techniques used included the contrast between counties where less than 10% of the population and counties where over 80% of residents drink silicofluoride treated water (Tables 25).

If silicofluorides are dangerous for the reasons outlined above, one can hypothesize that pollution with either lead or manganese is more strongly associated with higher crime rates where there is, *also*, silicofluoride treated water. Data show this is the case not only where lead pollution occurs (Figures 9 & 10), but where manganese pollution is present (Figure 11). In short, the use of silicofluorides in a public water supply not only is associated with increased rates of violent crime, but this effect is substantially worse where combined with environmental exposures to either lead or manganese. In contrast, as predicted there is no significant association between silicofluoride usage and rates of property crime (which is typically less impulsive than violence).

D. Lead, Silicofluorides, Learning Disabilities and Educational Outcomes

Although the evidence linking lead poisoning to cognitive deficits (such as IQ) is widely known, the educational effects of environmental pollution are too rarely mentioned by those in the fields of Education and Public Policy. Once again, our findings have been ignored by social scientists. Statistics for learning disabilities associated with lead toxicity are not as reliable as those for rates of violent crime, but where we found statewide data by community, there is a statistically significant association between silicofluoride treated water and higher rates of children in special education (Figure 12). More reliable, however, are the Massachusetts statewide data for community average scores on standardized educational tests (MCAS) for different subjects and grades. Here, the effect of lead uptake is striking, since our data analysis shows the proportion of children with blood lead over 10 μg/dL is the strongest single factor predicting community averages for every test in each grade reported (Masters 2004a).

These findings show that environmental pollution can be a major factor influencing the standardized testing that is the basis of the "No Child Left Behind" policy. As the association between lead poisoning and IQ deficits is well known, is it a matter of professional insularity or incompetence that the Educational establishment has failed to consider the role of neurotoxins in educational performance? Equally important, however, is the failure of scholars in public policy and minority activists to show interest in work in this area. But perhaps most devastating has been the failure of the medical profession to consider the effective treatment of ADHD, autism, and other cognitive dysfunctions by the nutrient therapies that has been pioneered by clinics like the Pfeiffer Treatment Center of Warrenville, Illinois. Of course, it is easy to understand the short term benefits of prescribing Ritalin for ADHD. But this finding hardly justifies the failure of pediatricians and toxicologists to consider the long term advantages of nutrient therapies that have resolved the behavior dysfunctions of over 80% of the hyperactive and autistic children treated by this innovative medical facility (Masters 2004b, 8-15).[21]

E. Substance Abuse (Alcoholism, Cocaine)

We located a study that provides reasonably good data on substance abuse among criminals. Since lead uptake undermines dopamine function in a

[21] For more information, contact: Health Research Institute-Pfeiffer Treatment Center,1804 Centre-Point Circle, Suite 102, Naperville, Il 60563.

way that has been linked to higher rates of addiction, data from a National Institute of Justice study were used to compare the frequency of substance abuse at time of arrest among 30,000 criminals. Consistent with the hypotheses and evidence outlined above, where silicofluorides are in public water, cocaine use by criminals at time of arrest was more pronounced in communities that use silicofluorides (Figure 13).

Whatever the benefits to teeth (and this remains controversial), this research indicates that silicofluoride chemistry, toxicology, and the effects on behavior or health should be matters of scientific research and public discussion. Before SiF chemicals are used, one would assume that citizens and policymakers need to know that they are safe for all. Pending extensive biological testing, a moratorium on using silicofluorides in public water supplies could contribute to reduced rates of learning disabilities, substance abuse, violent crime, and possibly asthma (all of which have been associated with lead and other toxins). As noted above, moreover, there are also ethnic differences in vulnerability that raise questions of environmental justice.

F. Silicofluorides and Environmental Justice: Black and Hispanic Vulnerability to Lead

Although this is a national issue, the epidemiological data show that the harmful effects of exposure to silicofluorides are particularly severe among Blacks and Hispanics. The reasons for this difference are probably a combination of socioeconomic, environmental, and biological factors. Children are likely to have higher blood lead where there are environmental sources of lead, such as old housing with lead paint or lead in public water supplies (Figure 14). Other factors that are also more likely among minorities, such as diets low in calcium, probably contribute to observed outcomes. Whatever the mixture of causes, it is unpardonable to add chemicals to public water that have particularly negative effects on minorities. As a society, we ought to clean up the toxins that harm all of our children but are especially dangerous for those who are socially disadvantaged.

As an illustration of resistance due to paradigm change, it was surprising that despite a lengthy personal conversation, the leader of a major civil rights organization failed to show an interest in these findings. Of course, silicofluorides have never been tested for safety. Nonetheless, it is frustrating to encounter public health authorities, dentists, and other professionals who object to a moratorium on silicofluoride usage pending tests that demonstrate conclusively their safety. The data cited here indicate that such a step might well help reduce children's blood lead levels and associated problems of health and behavior, which are especially serious for thousands of Blacks living in poverty in many American cities.

V. The Urgent Need for Further Study

From a strictly scientific perspective, all propositions concerning the fluoridation of public water supplies—whether supportive or critical of current policies must be viewed as falsifiable empirical hypotheses (Hempel and Oppenheim 1948; Popper 1959).[22] The puzzles outlined above indicate that the CDC, Public Health Service, EPA as well as Dental Associations or AMA have been committed to fluoridating public water supplies for so long that they seem unwilling or unable to consider the possibility that the chemical most frequently used for that purpose may be harmful rather than beneficial. Unfortunately, although confronted with the call for a moratorium on the use of silicofluorides pending testing that demonstrates the safety of these residues from the production of phosphate fertilizer and uranium, governmental scientists, dental authorities, and public health advocates have refused to admit the possibility of error.

[22] On the weakness of postmodernist criticisms of scientific objectivity, especially as related to issues such as those posed in public policy, see Masters (1993).

The refusal of officials to discuss the issue of silicofluoride safety is particularly disquieting. For example, in one case, an official of the Department of Health testified (at a state legislative committee hearing) that all water fluoridation was safe. But when he was invited, after the hearing, to participate in a university seminar on "Fluoridation Revisited," the official demurred on the grounds that he was not "expert." In another instance, the Director of a state Dental Society refused to appear at a university seminar on fluoridation because his association has endorsed the practice, the CDC *Recommendations for Using Fluoride* confirm endorsement of this policy, and he was unwilling to "re-debate" it.

On Sept.9, 2004, days before a referendum in Manchester, N. H. on water fluoridation using fluosilicic acid, Dr. C. Everett Koop and other health care professionals held a Press Conference at which no speaker referred to the need for more research on silicofluorides. On the same day, Dr. William Kassler (Medical Director of the N.H. Dept. of Health & Human Services) wrote an Opinion column in the *Manchester Union Leader* extolling water fluoridation without reference to the untested chemical now used in most instances. Such parallel attitudes of government officials and academics are disconcerting in any public policy issue, but they pose serious ethical as well as scientific issues when new research findings call into question a practice that has never been properly studied.

The CDC's assertions of safety in the absence of adequate scientific testing along with its refusal to discuss the specific chemicals used in fluoridation is not new. Indeed, in 1951 (the year after silicofluorides were formally approved for use), the same rhetorical combination was explicit in a statement to a meeting of State Dental Directors with representatives of the Public Health Service and the Children's Bureau:

> Now, in regard to toxicity – I noticed that Dr. Bain used the term "adding sodium fluoride." We never do that. That is rat poison. You add fluorides. Never mind that sodium fluoride business, because in most instances we are not adding sodium fluoride anyhow. All of those things give the opposition something to pick at, and they have got enough to pick at without our giving them any more. But this toxicity question is a difficult one. I can't give you the answer on it. After all, you know fluoridated water is not toxic, but when the other fellow says it is, it is difficult to answer him… So when you get the answer on the question of toxicity, please write me at once, because I would like to know…(Bull 1951).

The speaker, Francis Bull of Wisconsin, was known as one of the most outspoken proponents of fluoridation and played a major role in the decision to fluoridate Madison, Wisconsin in 1947—perhaps the first community to use a silicofluoride chemical agent.[23] Bull was a leading activist pushing for the spread of fluoridation even before the comparison studies between several fluoridated and non-fluoridated communities, originally planned for ten years using sodium fluoride, were completed. "Dr. Bain" was the administrator responsible for these studies, which began in 1945 and were to run for 10-12 years.

These rhetorical tactics of fluoridation supporters and persistent claims of safety by governmental agencies may explain why attempts to secure funding for animal studies of the neurochemical effects of silicofluoride treated water have

23 In Madison, Wisconsin, where Francis Bull was instrumental in a decision to begin fluoridation in 1947, the local water authority was unable to purchase sodium fluoride from the only major supplier, Alcoa Co. As a result, the Madison water system introduced fluosilicic acid as the fluoridation agent. By 1951, after the approval of silicofluorides by the Public Health Service, Bull therefore was quite conscious of the chemicals involved when he said that "in most instances we are not adding sodium fluoride anyhow." On the history of fluoridation, see Rymer (2000).

not been successful. Today, both governmental bureaucracies and dental associations may have good reason to fear opening this issue to debate since the Clean Water Act establishes legal liability for causing water supplies to be polluted (Crawford 2000, 341-390). It follows that huge suits for tort liability might be filed should this provision be extended to toxic effects like the hypothesis that silicofluorides brain chemistry and increase rates of learning disabilities, substance abuse and violent behavior.

It should be evident that, in a scientific age, such self-interest should not outweigh the social and human benefits of further study. If the "Neurotoxicity Hypothesis" with regard to silicofluorides is confirmed, many of the negative educational and behavioral outcomes among Blacks and other minorities (corresponding to racist stereotypes) would seem to be substantially aggravated by current water treatment practices. Moreover, even among middle class populations, the effect of lead uptake on rates of hyperactivity ("Attention Deficit Hyperactivity Disorder" or ADHD) is sufficient to call for careful consideration. For example, a recent study shows that over 70% of children diagnosed as having ADHD are receiving stimulant medications such as Ritalin (Rowland, Stallone, Naftel, Bohlig, and Sandler 2002, 231-234).[24] Although such drug treatment of ADHD children provides a rapid improvement in behavior, recreational misuse of drugs like Ritalin (not to mention the human and monetary costs of hyperactivity) would more than justify ending treatment of public water supplies that apparently enhances lead uptake from the environment (Winter 1998).

This conclusion is further strengthened by the evidence linking silicofluoride usage with higher rates of violent crime. Not only is there an

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[24] This study is unusual as a virtually complete sample of "all children enrolled in grades 1 through 5" in the county, and it shows higher rates of medication for White children than for Blacks diagnosed with ADHD. But since Johnston county has no large cities communities range in size from Pine Level (population 953), Princeton (1034), or Four Oaks (1047) to Smithfield (7,288) silicofluoride water treatment is not a factor for most children, making it impossible to use this database to explore differential rates of ADHD.

association between counties in the US whose populations are exposed to silicofluorides and higher rates of violent crime but multiple regression and other statistical tests show that this effect is highly significant after controlling for other factors traditionally linked to violent crime. Indeed, if the statistics in these analyses are correct, usage of silicofluorides for the purpose of water fluoridation would be unwise whether or not the CDC Work Group's Recommendations on tooth decay are valid.

To conclude, there is great danger in the practice of relying on precedent and "argument from authority" to defend an established policy from scientific question. Even if the approval of silicofluorides in 1950 had been based on extensive scientific research, new theories and methods of analysis might lead to a different conclusion. Since our society has become so dependent on science and technology, it is imperative that bureaucratic resistance to research reconsidering an established policy should be replaced by acceptance of scientific controversy as a necessary element in public policy. As the foregoing analysis of the CDC *Recommendations for Using Fluoride* has indicated, the public deserves careful reconsideration of the implications of new scientific evidence. The Health Committee of the New Hampshire State House of Representatives recently voted (13-0) to form a Committee for this purpose. Perhaps it would also be timely for hearings by the U.S. Congressional committee.

VI. Recent Developments

After the first version of this paper was presented to the 2002 meeting of the Association for Politics and the Life Sciences, it seemed prudent to delay publication in order to assess developments that occurred after it was first drafted. Consideration of events in recent months shows that some attention has now been paid to the questions detailed here by both government agencies and dental researchers—but that the ultimate consequences are uncertain and often disquieting.

First, Senator J. Bingaman of New Mexico introduced legislation concerning dental health (S. 1626). Section 301 (b) (3) of this bill includes the following provision:

> (3) carry out activities to reduce the disease burden in high risk populations through the application of best science in oral health, including programs such as community water fluoridation and dental sealants.

After learning of this proposal, I wrote Senator Bingaman and his legislative assistant in early July 2002, proposing an amendment to replace Section 301 (b) (3) with a "national research program to determine safe, effective and efficient policies of preventing dental disease and caries in the light of recent developments in biological and health science." Subsections of this proposed amendment required that "all compounds to be added to public water for fluoridation or other purposes shall be subjected to animal studies of possible harmful effects on health and behavior" and that "no untested chemical compound may be used in a public water supply system after December 31, 2002." At no time have I received any response from Senator Bingaman or his office. To my knowledge, there have not been hearings or action on his bill.

Second: the *Federal Register* for June 12, 2002 (vol. 67, no. 113, 40,319-49,333) reported the "Substances Nominated to the National Toxicology Program (NTP) for Toxicology Studies and on Study Recommendations Made by the NTP Interagency Committee for Chemical Evaluation and Coordination (ICCED)." Among 14 substances for which "one or more types of toxicological studies are recommended" were "Hexafluorosilicic acid and Sodium hexafluorosilicate—primary agents used to fluoridate public drinking water supplies" (*Federal Register* 2002, vol. 67, no. 113, 40,319-49,333). This is a major change in the recognized status of silicofluorides, since it is the first official admission by a governmental agency that there are valid questions that have been raised about the safety of these compounds.

Under the "Nomination rationale," the announcement lists the source of the nomination as "Private Individuals (multiple nominations). Drinking water systems: lack of toxicity information; assumed complete dissociation to free fluoride under normal conditions of use not supported by experimental evidence." Under "other information," the nomination specifies: "Primary agents used to fluoridate public studies to assess chemical fate under aqueous conditions; Toxicological studies may be considered when results of chemical characterization studies are available for review." However, under "toxicological studies," the only entry is "Chemical characterization" (*Federal Register* 2002, vol. 67, no. 113, 40,330).

While it is reassuring to see that our work has been recognized, it is not clear whether the National Toxicology Program's research will be limited to chemical studies of dissociation of floride (without reference to residual chemical species) or will extend to testing the many toxic effects for which evidence has been found. Following the official procedures, a colleague drafted a detailed Comment indicating the reasons for such extensive testing. At present, we can only hope that the NTP will act favorably on this recommendation.

Exchanges of correspondence with other government agencies are not encouraging. CDC, whose *Recommendations for Using Fluoride* (dated August 17, 2001) were quoted above, does not seem to have changed its view that American communities should "continue and expand fluoridation of community drinking water" without reference to the chemicals used for this purpose. In reply to a letter in which I raised a series of questions about current CDC views, the agency's Director, replied on December 24, 2002, enclosing the CDC's "responses to your specific questions" and stating that "The CDC is in the process of determining if data exists to better answer the questions you have raised.

However, given their limitations, the studies that you cite provide an insufficient basis on which to alter current policy" (Gerberding 2002).

The specific answers enclosed in this letter were oddly ambiguous. First, in response to the question whether the CDC supported the NTP nomination of silicofluorides for further toxicological study, this document replies that "CDC encouraged the National Toxicology Program (NTP) to consider if additional toxicologic testing of silicofluorides was warranted. We trust they will reach a sound decision based on the merits of available scientific evidence. CDC supports the use of high-quality scientific evidence to guide public health and environmental policy." Then, in reply to a question on the "lack of testing of silicofluorides and the empirical evidence that (unlike sodium fluoride) their dissociation is incomplete," the CDC reply states that "Current scientific evidence on dissociation of silicofluorides under the conditions used in water fluoridation supports the position that the safety and effectiveness of fluoridated water is identical, regardless of whether sodium fluoride, sodim silicofluoride, or fluorosilicic acid is used. Because of the virtually complete dissociation, findings from studies using sodium fluoride are applicable to the other proucts currently used in water fluoridation" (Gerberding 2002, enclosure: "The Centers for Disease Control and Prevention's Responses to Professor Roger D. Masters' Questions Regarding Water Fluoridation, December 2002").

This second reply is genuinely puzzling. If the CDC "supported the NTP nomination of silicofluorides," had the authors of these replies actually *read* the nomination published in the *Federal Register* on June 12, 2002? That document specifically stated as a reason for the nomination "lack of toxicity information; assumed complete dissociation to free fluoride under normal conditions of use not supported by experimental evidence." While the NTP did not also refer to the finding of biochemically active "residual species" (which could exist even with "virtually complete" dissociation of the fluoride from the full silicofluoride molecule), that finding by Westendorf (which also is consistent with some of the supposed pathways of dissociation which McClure cited from the literature in his 1950 article) is consistent with the need for further "toxicity information." Nonetheless, the CDC boldly states that "findings from studies using sodium fluoride are applicable to the other products currently used in water fluoridation." In short, the CDC appears to feel that its prior position is not in need of modification, dismissing not only our findings but such other evidence as Westendorf's observation of incomplete dissociation and acetylcholinesterase inhibition when silicofluorides are in use.

Recently, further attempts to avoid the questions raised above are evident in the abstracts of two papers to be presented at the March, 2003 meeting of the American Association for Dental Research/International Association for Dental Research (AADR/IADR) in San Antonio, Texas. The first of these presentations will reply to "criticism" of silicofluorides by presenting data on the metabolism of the fluoride from water treated with either sodium fluoride or fluosilicic acid. Instead of directly replicating and verifying our research (the only peer reviewed publications with data on harmful effects of silicofluorides), the published abstract of the forthcoming presentation by Whitford and Johnson returns to the focus of McClure's 1950 article on the equivalence in fluorine uptake of sodium fluoride and sodium silicofluoride.

Because the paper to be given has not yet been sent to me (despite a written request), it is only possible to assess the issues by quoting the abstract in its entirety.

> 0081 Comparison of Fluoride Metabolism When Administered as NaF or Silicofluorides to Rats G.M. WHITFORD, and N.A. JOHNSON, Medical College of Georgia, Augusta, USA.
>
> Drinking water is fluoridated using NaF, fluorosilicic acid (HFS) or sodium fluorosilicate (SFS). Critics of the use of silicofluorides claim that they are metabolized differently from NaF

and could cause higher tissue F concentrations. Objective: To compare the general features of fluoride metabolism when administered as NaF, HFS or SFS to rats. Methods: Weanling, female SD rats (8/group) were given free access to AIN76A food (0.7 ppm F) and deionized water containing 24ppm F added as NaF or commercial grades of HFS or SFS for five months. While housed in pairs, five 48h metabolic balance studies were done during the 4th and 5th months. Food and water intake and the output of urine and feces were determined gravimetrically. Water and urine F concentrations were determined with the electrode after buffering with TISAB; plasma, food and fecal concentrations were determined after HMDS-facilitated diffusion. Results: There were no significant differences among the groups for body weight gains during the study, plasma F concentrations, nor for the intake of food or water.

The balance data (mean ± SE, µg/48h) are shown in the table. There were no significant differences among the groups for any of the six variables.

Group	**F Intake**		**F Excretion**		**F Balance**	**Retention %**
	Food	Water	Urine	Feces		
NaF	33.1 (+/- 1.6)	1,507 (+/- .61)	379 (+/- 24)	129 (+/- 15)	1,032 (+/- 67)	66.2 (+/- 2.2)

HFS	36.1 (+/- 1.7)	1,532 (+/- 57)	336 (+/-27)	153 (+/-20)	1,079 (+/- 74)	68.1 (+/- 2.7)
SFS	35.5 (+/- 1.3)	1,655 (+/- 90)	407 (+/- 43)	165 (+/- 37)	1,118 (+/- 95)	64.8 (+/- 4.0)

Conclusion: The chemical form used to fluoridate the drinking water had no effect on the intake, excretion, balance or retention of fluoride.

Seq #17 Oral Tissues, Toxicology I
2:00 PM-4:00 PM, Wednesday, 12 March 2003 Henry
B. Gonzalez
Convention Center Room 217D"

The research summarized in this abstract raises two principal questions. First, Whitford and Johnson focus on the retention of fluoride from different chemical compounds in water. The authors only considered the retention of fluorine in body, bone, and teeth; like McClure, Whitford and Johnson are concerned with fluoride "balance" (i.e., the difference between consumption and excretion) and thus the percent "retention." As should be clear, this factor has never been used as evidence of toxicity in our studies and indeed replicates the traditional defense of silicofluorides by ignoring other biochemical, toxicological and behavioral effects.

The second issue, however, concerns the reliability of the data presented in the table contained in the Abstract and reproduced above. In the research of Kick et al, which had been cited in detail by McClure in his 1950 article, fluoride excretion in urine is greater for test animals exposed to silicofluoride than for those exposed to sodium fluoride. This difference was confirmed in a 1993 volume (*Health Effects of Ingested Fluioride*) prepared by a committee that included Whitford and published by the National Academy Press (Subcommittee on

Health Effects 1993). Yet the data on excretion in urine contradicts the findings of Kick, et al and those of Whitford himself as cited in 1993 volume of which he was co-author.

The second abstract prepared for the March 2003 meetings of the AADR/IADR also focuses on an issue which is not central to our research. While our publications have emphasized enhanced uptake of lead from environmental sources (such as lead paint in old housing), Le, Gansky, and Newbrun propose to rebut "objections" to silicofluorides by showing that their use neither changes water acidity (as measured by pH) nor increases the levels of lead in water by leaching lead from pipes or faucets. Once again, it is necessary to cite the abstract in full because at this writing a request for the paper to be delivered has not been answered.

> 0435 Fluoride and Lead Concentrations Related to pH in Drinking Water
>
> V. LE, S.A. GANSKY, and E. NEWBRUN, 1 University of California San Francisco, USA, 2 University of California, San Francisco, USA
>
> Opponents of water fluoridation claim hexafluorosilicic fluosilicic acid used in water fluoridation does not dissociate completely, specifically lowering pH, leaching lead from pipes, and thereby increasing lead exposure from ingested fluoridated water. OBJECTIVES: 1) assess the relation of fluoride concentration (F) to pH level in drinking water collected in the San Francisco Bay area (SFBA) before and after the addition of hexafluorosilicic acid, and 2) assess the relation of lead concentration (Pb) and pH level from San Francisco Public Utility Commission (SFPUC) and Presidio Water Plant (PWP) data. METHODS: Drinking water samples (98) were collected in SFBA, from both fluoridated and nonfluoridated

sites, in 50mL capped plastic tubes, labeled with random numbers. Collection sites were recorded separately and samples analyzed under blinded conditions. pH was measured <8 hours from collection. F was measured using fluoride ion electrode and a standard curve. Pb was determined using Graphite Furnace Atomic Absorption on 731 water samples SFPUC collected from 19922001 as a monitoring program. Pearson correlation estimated the association of pH with F. Partial Pearson correlation estimated the association of pH with Pb after adjusting for area (SFPUC/PWP) and date. Loess (local polynomial regression) smoothing examined departure from linearity. RESULTS: The correlation for F and pH level was 0.287 (p = 0.004), showing pH increased as F increased. The partial correlation for Pb and pH level was 0.043 (p = 0.244), not significant. Loess did not indicate departure from linearity. CONCLUSIONS: Water fluoridation using hexafluorosilicic acid is not associated with an acidity increase at the tap site. Fluoride concentration was modestly related to the pH level, but in the opposite direction than some opponents to water fluoridation previously claimed. In our samples, there was no correlation between lead and pH levels. (Support: NIH Training Grant T35 DE07103 and U54 DE14251).

Seq #63 Fluoride
Treatments, Fluorosis
1:45 PM3:
45 PM, Thursday, 13 March 2003 Henry B. Gonzalez
Convention Center Room 210"

Because our data included statistical measures of the the *interaction effects* of environmental risk factors for lead in the environment (e.g., percent of houses built before 1950) and use of silicofluorides, the authors' assertion that their data is a rebuttal of "opponents" of these chemicals cannot apply to our peer-reviewed scientific publications. The two abstracts of presentations to the AADR/IADR meetings thus confirm the disquieting indications that many dental researchers who have previously supported fluoridation still refuse to consider seriously evidence that silicofluorides have toxic effects not observed where sodium fluoride is used. Hitherto, both Whitford and Newbrun have been prominent supporters of water fluoridation One is left with the question: will failures of many dental researchers and public officials to consider scientific data on silicofluorides with an open mind continue to be the pattern in the future, or will nomination of silicofluorides for study by the National Toxicology Program lead to an open-minded reassessment of their harmful effects?

VII: Conclusion: Benefits of Listening to Science

By way of conclusion, it is useful to consider briefly an example from the past to illustrate the long term benefits of scientific findings that are used to block activities and practices of immense advantage to specific business or political interests. The ban on the sale of leaded gasoline was justified by the finding that lead is a neurotoxin that causes great harm to children. Among the negative effects now associated with lead uptake are lower intelligence (as measured by IQ scores), higher rates of learning disabilities, poor impulse control (hyperactivity), and higher likelihood of engaging in violent criminal behavior. While not all of these behavioral dysfunctions now associated with lead were fully established at the time the U.S. Congress banned the addition of Tetrethyl lead to gasoline, enough was known of the harmful character of this product to justify ending the benefits leaded gasoline generated for powerful industrial interests (Kitman 2000, 11-44).

As this survey points out, the studies cited as "scientific" evidence for the safety of tetrethyl lead were frequently severely flawed if not flagrantly dishonest. Indeed, the practices of both the Kettering Institute (a laboratory funded by General Motors) and the Public Health Service provide a striking parallel to the claims of the American Dental Association and the CDC. For example, General Motors held the patents on the production of Tetrethyl lead. Hence each gallon of leaded gasoline used in a Ford or Chrysler also benefitted GM. Whether anyone was aware of this advantage, the challenge to both the automobile industry (which had to redesign automobile and truck engines) and the oil industry was substantial, yet the Congress was not deterred.

The willingness to ban leaded gasoline despite its costs to powerful business interests turned out to have been especially prudent. As two recent studies have shown, the ban on leaded gasoline seems to have had an unanticipated benefit with a lagtime of about 18 to 20 years. Time series analyses indicate that ending leaded gas sales apparently had the effect—with a delay of over a decade of lowering rates of violent crime in the U.S. As the uptake of lead from the environment and its harmful effects are particularly severe early in infant development, it has been suggested that fumes or particles from leaded gas probably had serious effects on prenatal and early childhood brain development. Even though this precise link between early infant exposure and crime was unknown at the time, the ban on leaded gasoline is an excellent illustration of the benefits of basing public policies on the best available scientific findings even when they challenge established policies and interests.

Unfortunately, responses to date on silicofluorides suggest that obstacles to considering scientific findings that challenge an established public policy may be greater when the initiative and support for the policy has been largely based in government agencies. The practice of adding chemical compounds including fluoride to public water supplies ("fluoridation") was first introduced as an experiment in 1945. Intended to last 10 to 12 years, this governmentally sponsored experiment was ruled a success before completion and, since that time, both the CDC and the dental profession have assumed that fluoridation is an unqualified success as a means of reducing tooth decay. To be sure, opposition to radically new theoretical perspectives and findings is also frequently observed within scientific disciplines. Nonetheless, where public policy errors may include such outcomes as increased rates of educational failure, substance abuse, and violent crime, the consequences may be far greater in an issue like the one described above (Masters 2001, 345-369; see also a parallel study, Nevin 2000, 1-22).

Table 1
Table 4: Multiple Regression Analysis of Violent Crime Rates in US – 1991

Variable	Unstandardized Coefficient	t-Ratio	Probability
Population Density	82.42	20.24	<.0001
Per-Capita Income	–.0007	–2.74	<.0001
Unemployment	*Not Significant*	*Not Significant*	*Not Significant*
% Black Poverty	40.06	2.33	<.05
% Hispanic Poverty	62.11	2.79	<.005
Police *Per Capita*	153,423	16.56	<.0001
Infant Death Rate	1.813	2.78	<.005
% Housing (Pre-1950)	–526.75	–13.43	<.0001
Public Water *Per Capita*	225.34	4.07	<.0001
Median Grade Complete	24.68	3.50	<.005
Lead TRI Present	40.80	4.67	<.0001
Manganese TRI	58.71	6.68	<.0001
Alcohol Death Rate	101.62	11.55	<.0001
Alcohol and Lead Number	21.48	2.54	<.05
Alcohol and Manganese Number	55.40	6.54	<.0001
Lead and Manganese Number	34.89	4.11	<.0001

Alcohol, Lead, and Manganese Number	19.21	2.27	<.05

Adjusted R-Square: 0.369. F 97.45; DF 17.2783; p . 0000 # interaction terms.
Source: Masters, et al., *Environmental Toxicology* , Table III.

Table 2
Factors Influencing U.S. Violent Crime Rate, 1985
Multiple Regression – 2880 US Counties
(Variables Listed in Order of Strength of Standardized Coefficient)

Variable	Standardized Coefficient	t-Value	Probability
% Black	.2798	15.895	.0001
Poverty/Wealth Ratio	.2262	6.564	.0001
Population Density	.1956	9.383	.0001
****% SiF**	**.1150**	**6.191**	**.0001**
% High School Graduate	.0795	3.461	.0005
Per Capita Income	.0457	1.851	.0642
% Houses (Pre-1939)	–.1071	5.091	.0001
Population	–.02587	0.823	n.s.
Lead Toxic Releases	.0042	0.262	n.s.
Manganese Toxic Releases	.0196	1.246	n.s.

DF 10, 2869;. R squared = .3238; Ftest= 137.401; p = .;0001

** When both percent of population on silicofluorides and toxic release inventory (TRI) of lead and manganese are included in the analysis, silicofluoride usage is a significant predictor of violent crime whereas heavy metal pollution ceases to have a significant additional effect. This probably explains the significance of the variable "public water supply *per capita*" in the 1991 multiple regression in Table 4, which was calculated before RDM knew of the issue of silicofluoride toxicity.

Table 3a

Multiple Regression Causal
Factors associated with Rates of Violent Crime, All U.S. Counties, 1985

Variable	Coefficient	Standard Error	Standard Coefficient	t-Value	Probability
Intercept	–.005056				
****%SiF**	**.000368**	**.000133**	**.044933**	**2.779132**	**.0055**
Unemployment	.000076	.000013	.106014	5.988623	.0001
Black *Per Capita* Income	–9.92E–09	5.69E–09	–.028883	1.742151	.0816
Overall *Per Capita* Income	9.53E–08	1.91E–08	.115025	4.989345	.0001
Median Grade	.000205	.000069	.081833	2.971707	.003
Median Year	.000003	.000004	.01226	.719065	.4722
% Black	.00005	.000003	.313211	17.565442	.0001
% High School Graduate	–.000022	.000007	–.096468	2.965084	.0031
% Rural	–.000027	.000001	.349944	18.728391	.0001

** Again, presence or absence of Silicofluorides is a significant predictor of violent crime. Interestingly, in this group of nine predictive variables, only the median year of house construction is NOT significant.

Table 3b

Multiple Regression Causal
Factors associated with Rates of Violent Crime, All U.S. Counties, 1985

Confidence Intervals

Variable	95% Lower	95% Upper	90% Lower	90% Upper	Partial F
****%SiF**	**.000108**	**.000628**	**.00015**	**.000587**	**7.723575**
Unemployme nt	.000051	.000101	.000055	.000097	35.863607
Black *Per Capita* Income	–2.11E–08	1.25E–09	–1.93E–08	–5.50E–10	3.035091
Overall *Per Capita* Income	5.78E–08	1.33E–07	6.39E–08	1.27E–07	24.893561
Median Grade	.00007	.00034	.000091	.000318	8.831041
Median Year	–.000005	.000011	–.000004	.00001	.517055
% Black	.000044	.000056	.000045	.000055	308.544769
% High School Graduate	–.000036	–.000007	–.000034	–.00001	8.791723
% Rural	–.00003	–.000024	–.000029	–.000024	350.752619

** Again, presence or absence of silicofluorides is a significant predictor of violent crime. Interestingly, in this group of nine predictive variables, only the median year of house construction is NOT significant.

Table 4a

Multiple Regression – Causal Factors associated with Rates of Violent Crime, All U.S. Counties, 1991

Variable	Coefficient	Standard Error	Standard Coefficient	t-Value	Probability
Intercept	–.026874				
****%SiF**	**.000922**	**.00019**	**.076136**	**4.847215**	**.0001**
Unemployment	.000064	.000017	.062928	3.693542	.0002
Black *Per Capita* Income	–3.96E–09	8.09E–09	–.007926	.489639	.6244
Overall *Per Capita* Income	1.28E–07	2.63E–08	.108872	4.869223	.0001
Median Grade	.000504	.000095	.140963	5.304905	.0001
Median Year	.000014	.000006	.039495	2.411564	.0159
% Black	.00008	.000004	.351002	20.358866	.0001
% High School Graduate	–.000058	.00001	–.178521	5.719072	.0001
% Rural	.000041	.000002	–.376415	20.749842	.0001

** In 1991, silicofluorides are, again, a significant predictor of violent crime controlling for eight other variables. Unlike 1986, in 1991, age of housing is a significant predictor whereas per capita income among blacks is no longer significantly associated with rates of violent crime in the U.S.

Table 4b

Multiple Regression – Causal Factors associated with Rates of Violent Crime, All U.S. Counties, 1991

Confidence Intervals

Variable	95% Lower	95% Upper	90% Lower	90% Upper	Partial F
%SiF	**.000549**	**.001295**	**.000609**	**.001235**	**23.495494**
Unemployme nt	.00003	.000098	.000035	.000092	13.642253
Black *Per Capita* Income	–1.98E–08	1.19E–08	–1.73E–08	9.36E–09	.239747
Overall *Per Capita* Income	7.65E–08	1.80E–07	8.48E–08	1.71E–07	23.70933
Median Grade	.000317	.00069	.000347	.00066	28.142022
Median Year	.000003	.000026	.000004	.000024	5.81564
% Black	.000072	.000088	.000074	.000087	414.483444
% High School Graduate	–.000078	–.000038	–.000075	–.000041	32.70778
% Rural	–.000045	–.000037	–.000044	–.000038	430.555948

** In 1991, silicofluorides are, again, a significant predictor of violent crime controlling for eight other variables. Unlike 1986, in 1991, age of housing is a significant predictor whereas per capita income among blacks is no longer significantly associated with rates of violent crime in the U.S.

Table 5

**Factors Associated with Rates of Drunkenness per Capita
649 U.S. Counties, 1991–Stepwise Regression**

**Variable	Standard Coefficient	F to Remove	Total Adjusted R-Square
% High School Graduate	–.3555	126.58	.167
% Black	–.3003	84.262	.216
% Unemployed	–.2129	34.221	.258
% SiF	**.141**	**18.037**	**.276**
Median Year Housing Built	.154	17.462	.293

Resulting equation: DF 5, 644

** Variables not significant and, hence, not entered, above: population size, population density, poverty/income ratio (social inequality), per capita income, percent Hispanic, lead TRI, manganese TRI.

Figure 2

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"Self Silicofluorides" = communities with local water treatment using silicofluorides; "MWRA" = Greater Boston Communities served by Metropolitan Water Resource Authority, which adds silicofluorides; NaF" = sodium fluoride. "None" no fluoride. Excluded: 3 communities with naturally fluoridated water.

Figure 3

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Figure 4

Logistic Regression for Odds of Higher Blood Lead if Exposed to Silicofluorides, Controlling for Other Risk Factors For High Blood Lead: Black Children, New York State

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For each of seven factors associated with children having blood lead over 10µg/dL, communities below the mean (diagonal stripes) and above the mean (solid bar) were compared. An odds ratio of 1.0 (horizontal line) equals a 5050 chance of higher blood lead where silicofluorides are used; hence all bars above that level reflect more children with high blood lead where silicofluorides are in public water, It will be noted that five of seven environmental risk factors for lead uptake in blood (% poor, population density, % unemployed, % B.A., and per capita income), silicofluorides actually have even worse effects where the risk factor is below the mean. This demonstrates that the association in question is not an artifact of measurement.

Figure 5

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This figure divides all New York communities into those with above average levels of 04 of the risk factors and communities with 57 of these risk factors. For each level of risk, blood lead levels are higher where silicofluorides are in use; and this effect especially pronounced for Blacks.

Figure 6

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For NHANES III Children 35, mean blood lead is significantly associated with fluoridation status (DF 3, F 17.14, p < .0001) and race (DF 2, F 19.35, p < .0001) as well as for poverty income ratio (DF 1, F 66.55, p < .0001). Interaction effect between race and fluoridation status: DF 6, F ;3.333, p < .0029.

Figure 7

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Significance for ages 517: fluoridation status (DF 3, F 57.67, $p < .0001$), race (DF2, 28.68, $p < .0001$), PovertyIncome Ratio (DF 1, 252.88, $p < .0001$). Interaction between race and fluoridation status DF 6, F 11.17, $p < .0001$.

Figure 8

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Counties with <12.8% Poor Counties with >12.8% Poor

Overall population averages: Counties with < 12.8% Poor (wealthy) < 10% SiF = 3.72µg/dL>80% SiF = 5.17µg/dL Counties with > 19.8% Poor (poor): <10% SiF = 4.10µg/dL > 80% SiF = 5.07µg/dL Anova for BLACKS: SIF Usage: F 6.634, p = .0042; %County in Poverty: n.s.; Interaction – n.s. WHITE: SiF Usage: n.s., % County in poverty, n.s., Interaction, n.s.

Figure 9

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Lead Pollution: Industrial Release of Lead in EPA Toxic Release Inventory.

Figure 10

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Figure 11

Significance

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Silicofluoride Usage: p = .0001, F 27.605;
Manganese Pollution: p = .0001, F 79.005;
Interaction of SiF and Mn: p = ..0239, F 3.739

For the 369 US counties where over 60% received water treated with silicofluorides, and there is no Toxic Release Inventory record for manganese, the violent crime rate in 1991 (3.53 per 1000) was intermediate between rates in the 109 counties with manganese TRI and no silicofluorides (4.40) or the 217 counties with between 0.1 and 60% receiving silicofluorides (3.49). Where both silicofluorides are delivered to over 60% of the population and manganese TRI is present, the crime rate was 5.34. In 1991, the national county average was 3.12 violent crimes per 1000.

Figure 12A

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Figure 13

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Figure 14

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Houses pre 1940
Less than 29.5%

Houses pre 1940
Over 29.5%

ANOVA Significance:
Main EFFECTS
% Houses pre 1940: $p = .00901$, F 21.17
90th percentile 1st Draw Lead > 15ppb: $p = .0101$, F 6.75
Silicofluoride use: $p = .0177$, F 5.63
Interaction effect: silicofluoride use AND 1st Draw Lead in Water: $p = .0422$, F 4.18

Appendix

ADA's Proposed Legislation, June 2004[25]

Fluoridation Ordinance Suggested Elements

1. Findings of Fact

- Fluoridation of community water supplies is the single most effective public health measure to prevent tooth decay and to improve oral health for a lifetime.
- The Centers for Disease Control and Prevention has proclaimed community water fluoridation one of 10 great public health achievements of the 20th century. The American Dental Association, the U.S. Public Health Service (USPHS), the American Medical Association, and the World Health Organization support fluoridation of community water supplies.
- Studies over the past 60 years have repeatedly confirmed the safety of water fluoridation and its effectiveness in preventing dental decay.
- A United States national health objective for the year 2010 is to increase to at least 75 percent the portion of the population served by community water systems providing optimal levels of fluoride. According to the Centers for Disease Control and Prevention, approximately 66 percent of the population received fluoridated water in 2000.
- Community water fluoridation is a public health measure that benefits individuals of all ages and socioeconomic groups, especially those without access to regular dental care.

2. Authorization, Direction and Responsibility

[25] This draft is available at www.ada.org/ public/topics/fluoride/ fluoridation_ordinance.pdf and at www.ada.org/public/ topics/fluoride/fluoridation_ ordinance.pdf.

The city [insert title of appropriate person or entity, given the state and local regulatory scheme, e.g. director of health/board of health] (the ,Äú Responsible Party,Äù) is authorized and directed to fluoridate the city's water supply by [date] and is thereafter responsible for the fluoridation of that supply—Rationale: Identifies individual/entity to maintain authority over the fluoridation process.

3. Funding

Funding shall be provided [describe funding mechanism]. [Modify as needed to reflect funding mechanism.] (Rationale: Need money to get the job done.)

4. Introduction of Fluoride

Upon the direction of the Responsible Party, the [insert name of public works entity that will fluoridate] (the ÄúAgency,Äù) shall take the steps necessary to fluoridate the city, Äôs water supply, and shall introduce a fluoride compound meeting American Water Works Association (AWWA) standards into the city water supply in such quantities as required to maintain throughout the distribution system a fluoride concentration at levels recommended by the USPHS, or otherwise required by the state health department—Rationale: Helps assure optimal fluoridation of the water; allows the state to provide necessary guidance.

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