Water Fluoridation

MISUSE OF VALID SCIENCE TO CREATE DOUBT

This story highlights four tactics of science misinformation and disinformation efforts: fabrication of wide support to create the illusion of a scientific controversy, promoting conspiracy theories, and appeals made directly to the public. See our website article [Characteristics of Science Misinformation/ Disinformation Efforts]() for more information regarding these tactics.

In 2018, the small town of Ida Grove, Iowa, was informed that upgrades to the city's fluoridation equipment would be needed to continue to fluoridate the public water. Instead, the city council unanimously decided to stop fluoridation. Other towns in the area had previously discontinued fluoridation, so the decision was not unprecedented. However, within two months, the issue of fluoridation was again being brought before the city council—this time by a not-for-profit organization dedicated to fighting poverty in the area. The representative for the group pointed out that the naturally occurring levels of fluoride in the city's water (0.4 mg/L) were below the recommended level for combating tooth decay (0.7 mg/L). Over the next several months, the council heard arguments from people both in support of, and against fluoridation, culminating in a narrow 3-2 vote in November to once again add fluoride to the water.

However, as the divided vote foreshadowed, the issue was still far from settled. Every council meeting for the next few months included debate on the topic, leading to the city eventually polling residents about whether or not fluoride should be added to the water. The results of the poll were overwhelming—70% of residents who responded stated that fluoride should no longer be added to the municipal water. People who spoke at council meetings raised a number of issues, including concerns about having health decisions imposed upon them, apprehension about the type of fluoride added to the water (i.e., hydrofluorosilic acid), doubts about the benefits of fluoridation, and uncertainty about the safety of water fluoridation in general.

In response, some people cited the dental benefits of water fluoridation that had previously been presented to the council and the need to listen to professionals (e.g., the American Dental Association) regarding the issue. The heated debate within city hall spilled into the local newspaper and onto the internet as well, with residents writing numerous comments and posts about fluoridation on social media (Figure 1). By March, 2019, the city council was prepared to vote again—the results of which

Figure 1. An example of a social media post from a resident of Ida Grove in January 2019.

promised to finally provide some closure on the issue that had pitted neighbor versus neighbor as the city oscillated back-and-forth on the issue.

NATURE OF SCIENCE CONNECTIONS

Science is by far the most powerful way of understanding the natural world in terms of breadth, depth, and coherence. This is undeniably evident in the way that science knowledge has impacted technological development and human welfare (resulting in far fewer childhood deaths, longer average human life-spans, less physical suffering among humans, and a human population that could not be sustained in the absence of science's way of knowing). While the scientific community alone decides what is valid scientific knowledge, citizens and policymakers should have a role in societal issues involving science. This is why science literacy is so important in democratic nations. For example, whether water fluoridation, should be imposed on the public is a legitimate question, but the issue demands that citizens are accurately informed by authentic experts in science so they can weigh that information alongside economic, ethical, and other values.

History of Fluoridation

How did water fluoridation come to be an acceptable and largely preferred intervention? In 1901, a dentist in Colorado noted that large numbers of children in certain communities in the state had teeth with permanent, dark brown discoloration of the enamel (Figure 2) (McKay, 1917). The dentist, Frederick S. McKay, began diligently investigating the disorder, which locals referred to as Colorado Brown Stain. By 1916, McKay suspected that something in the drinking water was to blame, but he was unsure of what the exact cause was (McNeil, 1985).

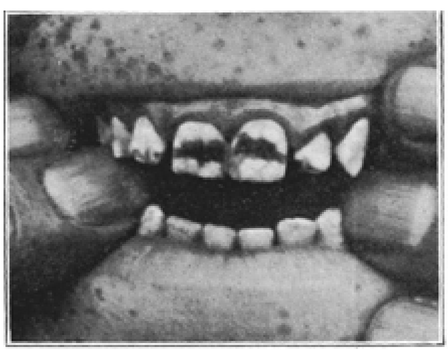
Figure 2. Fluorosism, first known as “Colorado Brown Stain” (McKay, 1917)

In the late 1920s, the small town of Bauxite, Arkansas would finally yield some answers. The children of the mining town had high levels of brown stain, and residents were already sufficiently confident that water from the wells in town was to blame that they had begun work on drawing water from a river that was seven miles away (Dean et al., 1938). Water collection surveys conducted in the area provided significant evidence to support those suspicions. Researchers noted that cases of brown stain began shortly after the wells were drilled, and that children in the area who obtained water from other sources did not have disfigured teeth.

Aluminum Company of America (Alcoa), who owned the mining company that had built the town of Bauxite, were concerned that aluminum would be blamed for the dental issues, so they sent their chief chemist, H.V. Churchill, to investigate the matter (McNeil, 1985). Churchill conducted extensive tests, which included spectrographic examination of the water for rare elements that were not normally identified in standard tests of the era. Instead of aluminum, Churchill identified extremely high rates of fluoride in the water (13.7 mg/L)—something that McKay had never thought to test for (Dean et al., 1938). In Churchill's (1931) report, he also provided an analysis of water from many cities across the United States, and noted a positive relationship between high levels of fluoride and prevalence of brown stain. As evidence mounted, brown stain became known as “fluorosis.” Communities with high levels of fluorosis began to change their drinking water source to lower fluoride sources, which quickly lowered levels of the dental disfigurement (Dean et al., 1938).

Henry Trendley Dean, a researcher at what is now called the National Institutes of Health, utilized the work of McKay and Churchill to further investigate the relationship between fluoride and teeth (Fagin, 2008). Dean's work not only quantitatively established a positive relationship between fluoride levels and fluorosis, but it also identified a negative relationship between fluoride levels and dental caries (i.e., cavities). Importantly, at a fluoride level of approximately 1 mg/L, Dean noted that levels of fluorosis only negligibly increased, and yet dental caries dropped substantially—a result that explained observations made decades earlier by McKay that children with brown stain often had fewer cavities (Carstairs & Elder, 2008; Lennon, 2006). The natural variance of fluoride in drinking water allowed researchers to compare the health of residents in cities with high levels with the medical condition of those people living in communities with lower levels of fluoride. Even when the differences in fluoride levels were dramatic, the only adverse effects of the high fluoride that were reported were fluorosis of the teeth, and occasional, non-clinical fluorosis of bones (Lennon, 2006).

Recognizing the potential dental benefits of water fluoridation and the seemingly minimal adverse effects at carefully controlled levels, an experiment was proposed to test the impact of artificially fluoridating the water supply for the public. The investigation began in 1945 with fluoride levels in the water in Grand Rapids, Michigan, raised to 1.0 mg/L while the nearby city of Muskegon would retain its naturally lower levels of fluoride (Lennon, 2006). Within six months, communities in New York and Ontario had already chosen to adopt fluoridation (Carstairs & Elder, 2008; Ripa, 1993). Enthusiastic promoters of fluoridation led to many other cities soon following suit—a move that was defended against accusations of prematurity on the basis that people had long been drinking naturally fluoridated water at much higher levels than were being suggested without documented adverse effects (McNeil, 1985). Promising early results of the Michigan experiment and endorsement of fluoridation by the United States Public Health Service (USPHS), American Medical Association (AMA), and American Dental Association (ADA) in 1950-1951 led to even higher demand for fluoridated water (McNeil, 1985). Even Muskegon, which was supposed to be a control for the Michigan study, chose to adopt fluoridation in 1951 (Hicks, 2011).

Despite municipalities' quick adoption of fluoridation that impacted the original experimental design, researchers were still able to eventually report fifteen years of analysis that revealed that the number of dental caries for children in Grand Rapids had dropped by half for children ages 12-14 (50-63% reduction) and 15-16 (48-50% reduction) (Lennon, 2006). Fluorosis rates for the children were low (10.6%), and 96% of those cases were imperceptible or mild (Lennon, 2006). The fluoridation in Grand Rapids and other early adoption communities were widely deemed to be successful, and by 1960, 50 million Americans were drinking artificially fluoridated water (Lennon, 2006). By that time, medical consensus had largely been reached on fluoridation, marking the end of significant debate about the safety of the procedure within the appropriate scientific communities (Carstairs & Elder, 2008). Professor James M. Mather (1959) from the University of British Columbia forcefully stated such an opinion when he wrote:

> [Dr. D. W. Mills] speaks of the "current controversy" concerning the fluoridation of communal water supplies. One should be clear that this is a political controversy, indeed a political football, and has no reference to any division of opinion in the medical, dental or allied professions. I don't think there has ever been a more nearly unanimous opinion as to the safety, desirability, efficacy and practicability of any health measure. Any controversy that exists is outside of the healing professions. (p.918)

A history of misinformation

Mather's assertion was perhaps a bit overstated, since some skepticism and resistance to fluoridation certainly did still exist within the medical community (Carstairs & Elder, 2008). However, he was correct that controversy was far more prevalent in the political and popular arenas, with opposition and suspicion arising in those areas from fluoridation's very beginning. For instance, in Stevens Point, Wisconsin, pro- and antifluoridation groups battled throughout 1949-1950, leading to rejection, adoption, and ultimately, overwhelming rejection of fluoride via referendum (Hicks, 2011; McNeil, 1985).

Across the nation, people opposed to fluoridation attacked it, labeling it "poison," "forced experimentation," and a cause of cancer, memory loss, and brittle bones (McNeil, 1985). The leaked, *preliminary* results of a University of Texas study that identified fluoridated water as a carcinogen in 1950 would go on to become widely disseminated for decades, despite USPHS researchers almost immediately identifying a critical flaw in the study—the study mice had inadvertently been given food with extremely high levels of fluoride (McNeil, 1985). In the 1950s and 1960s, a conspiracy theory gained popularity: Communists in the USPHS were behind the attempts to fluoridate the water supply of Americans (Carstairs & Elder, 2008; Hicks, 2011).

RED FLAG

Promoting conspiracy theories

Those who promote science misinformation and disinformation often put forward conspiracy theories to bolster their position and explain away the science consensus. Note those used by anti-fluoridation advocates. Such arguments are also often used in an attempt to explain why pseudoscientific articles have not been published in scholarly journals, or why the global community of scientists has adopted the consensus position.

Others argued that medical professionals were tampering with evidence, that Alcoa was using fluoridation as a means of disposing of toxic waste, and some even made unfounded racist accusations of fluoridated water causing “mongolism” in children (Carstairs & Elder, 2008).

QUESTION 1
The idiom “Three may keep a secret if two are dead” means that beyond a small number of people, secrets are impossible to keep. Conspiracy explanations are often elaborate and require, at minimum, hundreds of people to stay silent. Given the size and global nature of the scientific community, why should conspiracy explanations involving scientific knowledge not be taken seriously?

One opponent to fluoridation who rose to prominence during the 1970s was John Yiamouyiannis, a biochemist who founded and worked for a variety of anti-fluoridation groups. In 1974, the National Health Federation—a group opposed to government restrictions on health choices, including fluoridation of water—hired Yiamouyiannis as their Science Director, and tasked him with thwarting communities' efforts to fluoridate their water (Newbrun, 1980). As part of those efforts, Yiamouyiannis investigated links between cancer and fluoridation, and reported that communities who added fluoride to their water had higher rates of cancer. However, the research was published in booklets which were not peer-reviewed, and the studies were later heavily criticized for failing to account for other relevant factors that accounted for the differences in cancer rates (Carstairs & Elder, 2008).

RED FLAG

Fabrication of wide support to create the illusion of a controversy

Pseudoscientific sources often attempt to manufacture a false sense of legitimacy through the formation of scientific sounding organization. For example, the National Health Federation (NHF) was once called a “front for promoters of unproven remedies, eccentric theories, and quackery” (as cited in McNeil [2]) by the Food and Drug Administration. However, one can easily see how conflicting advice from the NHF versus the NIH (National Institutes of Health) could easily lead to confusion, and cause the public to errantly believe that experts were divided on an issue.

Regardless, Yiamouyiannis went on to score a major victory in helping to defeat the fluoridation of Los Angeles' water in 1975, in part due to evidence he presented to voters that had been “selectively culled from reputable scientific sources” (McNeil, 1985).

RED FLAG

Appeals made directly to the public

During the peer review process, experts in the relevant field rigorously scrutinize the research and conclusions described by the authors. This critical step in science improves the final papers that are accepted, and reduces the number of errant, trivial, irrelevant, or otherwise problematic articles that are published. A major red flag of pseudoscientific work therefore is when scientists bypass the peer review process and instead bring their unvetted work directly to the public.

After parting with the National Health Federation in 1979, Yiamouyiannis went on to found the Safe Water Foundation, which he used to publish the *Lifesavers Guide to Fluoridation*—an eight-page document that contained over 250 references and became a highly utilized source of information for many opponents of fluoridation (Armfield, 2007). However, upon inspection, most of the references were from sources that had not been peer-reviewed. Armfield (2007) describes the booklet as a “classic example of bamboozling with science” and went on to state:

> Almost all references were found to be incompletely cited and Yiamouyiannis was found to make superficial observations, leap to unwarranted conclusions and present a pervasive bias in his evaluation of data. However, more than two decades later the same studies continue to be cited in anti-fluoridation literature. (p. 9)

By 1985, communities in the United States had already held approximately 1,500 referendums on whether or not their water should be fluoridated, and in part due to activists such as Yiamouyiannis, over half of those cases resulted in rejection of fluoridation (McNeil, 1985). In addition to Los Angeles, notable cities that rejected fluoridation included Jersey City, Newark, San Antonio, and San Diego (McNeil, 1985).

QUESTION 2
What are some warning signs of misinformation/disinformation that illustrate some of the antifluoridation efforts were pseudoscientific in nature?

Fluoridation today

Despite antifluoridation efforts, the number of Americans with access to fluoridated water has continued to increase. However, as children began to be exposed to higher levels of fluoride through their diet and dental treatments, investigations revealed that the prevalence of dental fluorosis was also beginning to increase (U.S. Department of Health and Human Services, 2015). As a result, the USPHS' recommendation of 0.7-1.2 mg/L fluoride in drinking water was lowered to 0.7 mg/L in 2015 (U.S. Department of Health and Human Services, 2015). Many questions about the health impacts of fluoridated water are also still being debated within the research community. A literature review conducted in 2006 by the National Research Council (NRC) outlined some of these issues (Table 1), leading them to recommend lowering the EPA's maximum-contaminant-level goal (i.e., the maximum level of fluoride allowed in drinking water) from the current limit of 4 mg/L. In the 15 years since the NRC published its review, numerous studies have been conducted on the health impacts of fluoride at high levels, or for specific members of the public (e.g., unborn children and infants), often yielding conflicting results (e.g., Guth et al., 2021).

The potential health impacts listed above were noted at Fluoridation levels nearly 3 to 6 times higher than the current recommendation of 0.7 mg/L of fluoride for drinking water. Without that knowledge, the concerns listed by many residents of Ida Grove and others seem not only reasonable, but directly supported by research. For example, an Ida Grove council member stated in one meeting:

> [Council member] also points out the debate on fluoride had been ongoing since 1945 and as with any case, it is good to listen to both sides. In this instance, he feels a cautionary approach is the best method as there has to be something wrong if this has been going on for so long. “You have to ask yourself if there is something more to this. You don't know where it comes from, you don't know if it's tested. That's why I couldn't vote for it before and I can't vote for it today” [council member] stated, as he went on to explain research has shown adverse effects linked to items such as thyroid issues, arthritis, cancer and more. (City of Ida Grove, 2018, paragraph five)

QUESTION 3

Fabrication of a fake controversy is a hallmark of misinformation/disinformation efforts. How does the quotation above accurately and inaccurately reflect characteristics of science misinformation/disinformation?

However, like all socioscientific issues, the science behind fluoridation is complex and nuanced, and the implications of it can easily be distorted when presented to non-expert members of the public. Much of what the city council member stated above contains an element of truth, but it lacks critical details and context. For instance, the NRC's summary of health impacts, which did include issues related to cancer, thyroid, and skeletal effects, were for *2-4 mg/L of fluoride*, whereas *Ida Grove had natural fluoride levels of just 0.4 mg/L*. Scholarly debate about health impacts of fluoridated water have indeed occurred since 1945, and research is

Body area	Conclusions regarding effects of fluoride at 2-4 mg/L
Musculoskeletal	Insufficient evidence to draw a conclusion regarding bone fractures at 2 mg/L. Chronic exposure likely to increase fractures at 4 mg/L. More research needed.
Neurotoxicity and neurobehavioral	Studies reporting negative impacts on IQ of children at fluoride level of 2.5-4 mg/L warrant further investigation.
Endocrine	A number of effects, including decreased thyroid function, are possible. While the impacts are usually classified as subclinical, further research is needed.
Carcinogenicity	Conflicting results related to osteosarcoma—a type of bone cancer. Osteosarcoma is rare, but further research is needed.

Table 1. Selected conclusions from the National Research Council's (2006) comprehensive analysis of the EPA's fluoride standards for drinking water. **Note that the NRC was examining effects of fluoride at levels of 2-4 mg/L, which is well above the current recommendation of 0.7 mg/L of fluoride for drinking water.**

ongoing as we continue to refine our understanding of the issue. However, those discussions are generally inappropriate to apply to a community discussing whether or not to raise their fluoride levels from 0.4 mg/L to 0.7 mg/L. This is why emphasis should be placed on the consensus statements of professional organizations such as the ADA and AMA, rather than attempting to independently seek out answers that may contain misinformation or statements that have been taken out of context.

NATURE OF SCIENCE CONNECTIONS

Many scientific issues are complex, nuanced, and based on scholarly debates that have occurred in conferences and journals. Limitations related to time, expertise, and access to information therefore restrict what scientific knowledge most all citizens can personally analyze and reasonably challenge. We therefore turn to relevant experts to inform us about scientific issues. However, that can also be problematic. For example, John Yiamouyiannis was a legitimate biochemist with a bachelor's degree in chemistry from the University of Chicago, and a Ph.D. in biochemistry from the University of Rhode Island, yet he espoused non-consensus positions regarding fluoridation. Such dissenters can be found for nearly any scientific issue, due to a range of factors including personal idiosyncrasies, differences in prior knowledge, ideology, and prejudice. The collective nature of scientific work is a safeguard against such factors, which is why the consensus position of the scientific community should be emphasized over the views of individuals—even those with legitimate credentials.

As of 2018, fluoridated water was available to over 207 million Americans (CDC, 2020). While continued research is ongoing to help clarify lingering questions within the research community (e.g., disagreement regarding developmental neurotoxicity of fluoride), fluoridation at recommended levels is still regarded as safe and a significant means of reducing childhood tooth decay according to recent meta-analyses and literature reviews (Belotti & Frazão, 2021; Parnell et al., 2009; Rugg-Gunn & Do, 2012; Yeung, 2008). Furthermore, fluoridation has been defended from a social justice perspective, because it ensures that those children at highest risk of dental caries receive fluoride, even if they do not have access to regular dental care or toothpaste containing fluoride (Armfield, 2007; Broadbent, 2013). Economically, McGinnis (1980) estimated a 30-40 fold return on investment for every dollar spent on fluoridation by avoiding costly future dental treatment. Fluoridation of drinking water has nearly universal support from professional medical organizations including the AMA, ADA, World Health Organization, and American Association for Pediatrics (AAP). The Centers for Disease Control and Prevention even deemed water fluoridation to be among the top 10 greatest achievements in public health of the 20th century (CDC, 2020). Millions of cases of tooth decay and untold human suffering have undoubtedly been avoided due to fluoridated water.

Conclusion

The residents of Ida Grove were undoubtedly doing their best to research, understand, and agree on a course of action regarding water fluoridation. However, like all socioscientific issues, fluoridation is complex and includes ethical, economic, and scientific dimensions. The scientific aspects of fluoridation that are often raised in community debates about the topic require specialized knowledge of chemistry and biology to deeply understand and engage with. Unfortunately, that inaccessibility has long made fluoridation a difficult topic for the public to assess. Not only has fluoridation been the target of significant, often pseudoscientific, misinformation efforts, but legitimate scientific research is also frequently taken out of context and applied to debates in appropriate ways. In the end, Ida Grove's story ended up closely paralleling that of Stevens Point from 70 years prior: In March, 2019, the city council chose for a final time to stop fluoridation of the public water by a vote of 3-2. That vote may have reflected public sentiment regarding the economic and ethical considerations. What is important to understand from a science misinformation/disinformation perspective is that the decision does not reflect the overwhelming consensus among authentic experts regarding the empirical evidence surrounding the fluoridation of water for public health.

QUESTION 4

Individually evaluating science rather than trusting the consensus among authentic science experts reflects a reasonable desire for understanding and control. However, consider the difficulty most everyone experiences learning elementary science ideas in high school, and the years of specialized study required to actually do science. Why must citizens and policymakers instead learn to know who are the authentic experts, the consensus science position, and use that alongside values and economics in making personal and social decisions involving science?

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