12-20-2015

Revisiting Community Water Fluoridation

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B.S., Rutgers University, 2010

A Thesis

Submitted in Partial Fulfillment of the

Requirements for the Degree of

Masters of Public Health

At the

University of Connecticut

2015

APPROVAL PAGE

Masters of Public Health Thesis

Revisiting Community Water Fluoridation

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2015

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Abstract

There is a bourgeoning controversy unknown to many surrounding one of the CDC's top ten public health achievements of the 20th century. After more than 50 years of implementation, community water fluoridation may not have achieved the declines in caries rates we once thought or hoped for, especially in light of alternative approaches to preventing caries including but not limited to other sources of fluoride supplementation, changes in diet, and tooth brushing behavior.

In fact, a survey of past research highlights the fact that this policy decision may be based on out of date and/or a lack of research all together. With 92% of adults ages 20-64 having dental caries in 2004, caries rates continue to be an issue today.[1] Dental caries are not just a cosmetic problem, they are a serious health condition that have many negative consequences in a person's quality of life.[2] The use of community water fluoridation has remained controversial in terms of the rights of the individual to make his/her own health care decisions versus the right of the state to make public health interventions, and it remains costly. Estimates in pre-2002 dollars put a town's cost of community water fluoridation between $0.40 and $2.70 per person based on the size of the community.[3] This paper explores the scientific discoveries and social factors influencing the decision to recommend community water fluoridation, highlighting conflicting information and timelines.

Introduction

The story of how we ended up fluoridating our drinking water is exciting, it started in 1901 with a young dentist's curiosity of brown stained teeth in certain geographic areas of the United States. While he was not the first person to observe what we now consider dental fluorosis, he was the one who drove the field towards discovering the cause of what he had observed. In researching the brown stains, Frederick McKay and his colleagues eventually realized around 1915, that the stained and pitted teeth were more resistant to decay than teeth without this condition. This set off a series of scientific inquiries culminating in the discovery of naturally occurring fluoride in the water and thus giving way to a series of controversial experiments resulting in recommendations in the 1950s to support community water fluoridation (CWF).[4,5]

Even though it is now hailed as one of the top ten public health achievements of the 20th century, CWF is still controversial more than 50 years after its implementation. The debate has had many reincarnations, and many themes have become apparent. No longer simply a scientific debate over whether or not CWF is effective in preventing dental caries, now "the essence of the issue defies resolution."[6] The debate now spans economic, political, ethical, psychological, democratic and demographic interests. This does not mean there is evidence of the scientific disagreement being resolved, rather there are more factors to consider if a resolution to this decades long debate will be achieved. Underlying all the branches of controversy is an inadequate body of research. Until the international conversation begins to consider these social influences in future research, the debate is likely to continue.

Perhaps contributing to the controversy, is the fact that there is nothing else quite like fluoride in our lives. As a dietary supplement, it can be compared to Vitamin D fortification in

milk, or the addition of Niacin in flour. For one thing, the verdict on whether fluoride is an essential nutrient like Vitamin D or Niacin, is not yet in. For another, milk and flour can be more easily avoided than tap water. A comparison also can be drawn to medication. Fluoride is a simple element that affects the body like a medication – yet it does not bind with any enzymes or receptor proteins, and it does not dissolve in cell membranes causing a modulation in cell activity. Instead, it is involved in a simple chemical reaction,[7] causing a not so simple debate.

Tooth decay and caries prevention are complex processes with many variables, making it a difficult topic to study. A common criticism and the conclusion of many reports is that the quality of studies that exist both supporting and disputing the science of fluoridation are of poor quality. Proponents argue that there is no longer a legitimate scientific debate, and opponents argue there is in fact a controversy over the efficacy and safety of the practice. The original and most widely recognized fluoridation study in Grand Rapids, Michigan reported CWF provided a 50-75% reduction in the prevalence of caries in permanent teeth of children born after the addition of fluoride.[8,9] Recent studies, however, put the reduction at levels much lower, ranging from 26% down to an 18% reduction in dental caries when compared to water systems that do not fluoridate.[9-11]

Now 85 years after this discovery, it is still being debated how exactly we need to be exposed to fluoride to receive this dental benefit. Today's opponents argue that CWF merely delays the onset of caries,[12] and ask if it is effective, why is tooth decay still a top issue affecting the population? Not to be ignored in either side of the debate, is the fact that dental caries are still a very real issue affecting 92% of adults ages 20-64.[1] Poor oral health is not merely a cosmetic problem, it is associated with a poor quality of life in terms of, "altered appearance on speech, eating, and other functions, as well as on self-esteem, social interaction, education,

career achievement, and emotional state." Poor oral health can negatively impact diet and nutrition if there are not enough teeth, or tooth pain is so great that eating becomes difficult. Pain and/or treatments result in economic hardships, sleep deprivation, missed days of work or school and many other restrictions on quality of life. Often not considered to be a dangerous disease, tooth decay can in fact lead to death. Knowing that oral health is an issue affecting the vast majority of our population, and that it is often considered an early warning system for other health conditions,[2] it is important that society's limited resources be put towards the most effective treatment in decreasing the oral health burden. This paper will outline some of the contradictory evidence of community water fluoridation, and highlight where more research is needed to make an informed policy decision.

Original Research

The first CWF trial in Grand Rapids, Michigan began in 1945. The epidemiologic study compared three towns; artificially fluoridated Grand Rapids, Michigan, naturally fluoridated (around 1.2 ppm) Aurora, Illinois, and non-fluoridated Muskegon, Michigan.[13] The Grand Rapids study sponsored by the Surgeon General[5], and four other studies, commissioned by other interested health departments, sought to compare the rates of dental caries in populations with natural, artificial and no fluoride in the drinking water. The Grand Rapids study found a remarkable decline in dental caries among residents in the newly artificially fluoridated city, and a lower baseline of decay rates in the naturally fluoridated city.[13] Probably due to its sponsorship, the Grand Rapids study is the one most frequently cited. The lack of coordination between the studies makes it difficult to compare data from the five that measured the rates of decay in a variety of different ways. Below are graphs showing the discrepancies in reporting, but all highlighting the decline in caries over time.

Table 1: Dental Caries experience, permanent teeth, observed among 33,955 children, age 5-16, of Grand Rapids, Muskegon, and Aurora, expressed as DMF teeth per child with percentage reductions observed (continuous residents)[14]

Age	Grand Rapids, MI (Artificial Fluoride 1.0ppm)			Aurora, IL (Natural Fl 1.2ppm)		Muskegon, MI (No Fluoride)		
	Examinations Made		% Reduction	Exams 1945-46	% less G.R. 1944-45	Examinations Made		% Change
	1944-45	1949-50				1944-45	1949-50	
5	.11	.03	72.7	.06	45.5	.06	.14	+ 133.3
6	.78	.38	51.3	.28	64.1	.81	.63	- 22.2
7	1.89	.76	59.8	.70	63.0	1.99	1.43	- 28.2
8	2.94	2.16	26.5	1.04	64.6	2.81	2.58	- 8.2
9	3.90	2.48	36.4	1.52	61.0	3.81	3.88	+ 1.8
10	4.92	3.56	27.7	2.02	59.0	4.71	4.44	- 9.6
11	6.41	4.69	26.8	2.67	58.4	6.32	5.93	- 6.2
12	8.07	7.02	13.0	2.95	63.5	8.66	7.21	- 16.8
13	9.73	8.11	16.7	3.09	68.3	9.98	9.52	- 4.6
14	10.94	8.90	18.6	3.64	66.7	12.00	11.08	- 7.7
15	12.48	11.80	5.5	4.54	63.6	12.86	10.32	- 19.8
16	13.50	11.83	12.4	5.19	61.6	14.07	12.51	-11.1

Table 2: Proportion of caries-free children at the outset of fluoridation and 5 years later, Montgomery and Prince Georges Counties, Maryland (All children are native born and are continuous residents of the area, none has received topical fluoride or other caries-preventive treatment). Fluoridated with 1ppm sodium fluorosilicate.[15]

Age	Numbers Examined		% Caries-free in permanent dentition	
	1952 (N=1,950)	1957 (N=2,872)	1952	1957
5	60	67	98.3	98.5
6	171	245	81.3	94.3[1]
7	211	256	50.7	74.2[1]
8	181	251	32.6	53.3[1]
9	223	239	19.7	37.2[1]
10	199	220	16.6	25.5[1]
11	191	157	12.6	14.0
12	228	397	8.3	7.3
13	233	468	6.9	5.3
14	188	446	3.7	4.3
15	65	126	7.7	3.4

[1]Difference significant at the P=.01 level

Table 3: Evanston, IL: Decayed and missing (extracted due to caries) and filled permanent teeth. Rate per hundred children. 1ppm Sodium fluoride used.

Year	Rate		
	6 yrs.	7 yrs.	8 yrs.
1946 (Pre-F) 1,991 exams	48.85	153.49	249.93
1948 (Post-F) 2,034 exams	23.54	103.58	194.09
1950 1,244 exams	15.33	80.93	153.52
1951 1,853 exams	12.36	66.97	161.40

Differences are not statistically significant

Table 4: Evanston, IL: Decayed, missing and filled permanent teeth: rate per hundred children.

Year	Age (#exams) Rate		
	12	13	14
1946 (Pre-F)	(418) 763.16	(688) 1009.59	(595) 1165.88
1949 (Post-F)	(522) 681.99	(677) 857.02	(570) 1086.84
1952	(512) 596.87	(533) 795.49	(509) 1019.84
% Reduction	21.79	21.21	12.53

Probability of difference due to chance = 0.00

These 1940s trials were the only large scale studies looking at the effectiveness of CWF. While their sample sizes were very large, they encountered many limitations based on the knowledge and resources available to them at the time. Opponents of CWF call it bad form that the control city was fluoridated only 6 years into the 10 year study,[16] and that 13 years in, after the study pretty much ended, the chemical agent was changed from sodium fluoride to sodium silicofluoride.[13] Opponents also hypothesize that Grand Rapids was cherry picked as the study town for various reasons, such as having a higher prevalence of dental caries than other cities. Considering all the controversy surrounding the topic, it is unfortunate that other ecological, if not prospective cohort studies were never conducted.

The scientific work leading up to the discovery that naturally occurring fluoride in drinking water reduces dental caries was extraordinarily exciting and a great example of how epidemiology is the backbone of public health research. However, this work was done in the early half of the 20th century and there have been many more scientific discoveries and advances that better suit us to look at this phenomenon with a more critical eye. Looking at these

shortfalls allows us to understand why many scientists say that these studies are not the be all and end all.

The original studies did not seem to account for many confounding variables. Race, for example, is something known to be related to the incidence or outcomes of many diseases for various reasons. From 1933-34, the USPHS conducted a study looking at the rate of decay before the fluoridation trials began. The study looked at 94% (1,356,435) white children and 6% (81,883) "colored children."[17] Just as the original studies looked at a majority of white children, both studies may be failing to account for possible differences in the decay process that could be affected by, for example, race.

Socioeconomic status is another factor that is widely agreed upon to affect the course of a person's health outcomes. Children in poverty experience dental caries at a significantly higher rate that those not living in poverty.[18]

Diet is another thing that affects decay rates. Those whose diets are low in sugar and processed foods tend to have very low rates of tooth decay.[19] Anything we eat or drink touches our teeth, so to not account for regional or personal diets in studies could confound results. Consider the ebb and flow of food processing advances when looking at decay rates, it is likely the introduction of mass amounts of carbohydrates, or the invention of sugar substitutes, taking the sugar out of chewing gum, the introduction of sugary beverages, or the continual competition to make junk food taste better by adding more sugar and chemicals, all have an effect on caries rates.

Other confounders that may have played a part in the original studies include educational achievement of parents, the availability and utilization of dental services and other naturally

occurring agents in the water. Perhaps the most concerning confounder the old studies failed to consider, is the toothbrush.

Toothbrushes, and many past incarnations such as chew sticks and bristle brushes have been around since ancient times.[20] Throughout the years they were often made of bone handles and animal hair bristles. The first American to patent a toothbrush similar to what we use today was H. N. Wadsworth in 1857.[21] It wasn't until 1909 that the toothbrush was endorsed by the National Dental Association through a document on oral hygiene that says decay can be prevented by, "scrubbing the teeth thoroughly with a tooth brush, tooth powder, and water…"[22] Still by 1924, only about 20% of Americans were using a toothbrush. In 1938 DuPont introduced the first toothbrush made with nylon bristles and by 1948, 50% of American toothbrushes were made with these new bristles. Some dentists were initially resistant to these new bristles as they felt they were abrasive to gums. As time went on, the research came out in favor of nylon bristles and that is still often what is used today.[20]

It is known in the healthcare field that even once we figure out the science, it is difficult and takes time to change peoples' behaviors. Fifteen years after the National Dental Association endorsed brushing one's teeth daily, only 20% of Americans changed their behavior. Though not mentioned in the original Grand Rapids study, taking into account tooth brushing habits would have given a better picture of the effectiveness of fluoride. A confounding variable that profound could certainly affect the data. The decline in dental caries that is attributed to community water fluoridation may very well have been due to combined discoveries and efforts promoting oral health that were occurring at the same time as these studies.

Decline in Dental Caries

The process of tooth decay is complicated and multi-faceted. Today we know it is influenced, among other things, by oral hygiene, socioeconomic status, dental care, diet, genetic predisposition, and geochemical factors.[19] There is no arguing that decay has declined over the last 50 years, but as of 2008, more than one in five people still had untreated dental caries.[23] The fact that tooth decay is still one of the most common chronic diseases of children in the United States today,[24] only adds fuel to both sides of this debate. Opponents of fluoridation ask, if CWF is effective at reducing dental caries, why are the rates of caries still so high? Supporters argue that with all the factors such as dietary changes and issues with accessing dental care possibly increasing the risk of caries, it is CWF that is keeping the decay rates low?

In a 1986-7 National Institute of Dental Research report, results were published that over 50% of children (aged 5-17 years) in the USA were caries free and the publicity that surrounded that number indicated that the caries problem was essentially solved.[25] Unfortunately, we see today that dental caries are still an issue with 42% of children (2-11 years) having dental caries in their primary teeth, 23% having caries in their permanent teeth, on through 92% of all adults (20-64 years) having dental caries.[1] It is still an issue today warranting more attention and resources to be devoted to decreasing the incidence.

A 1983 report looking at ten cities that fluoridated their public water supplies found roughly one third less decay than non-fluoridated cities. Because today's base decay rates are so low, this translates to an average 12 year old in a fluoridated city as having 0.6 fewer cavities.[19] While we have seen a definite decline in caries in fluoridated areas, we have also seen the decline in non-fluoridated areas. The Journal of American Dental Association published an article stating, "the current reported decline in caries in the U.S. and other Western industrialized

countries has been observed in both fluoridated and non-fluoridated communities, with percentage reductions in each community apparently about the same."[26]

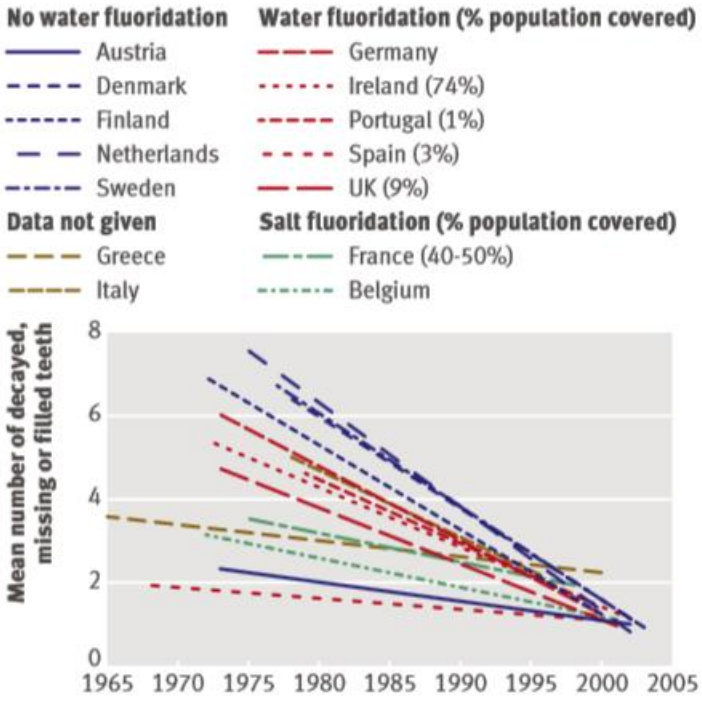


Figure 1: Cheng, et al. Tooth Decay in 12 year olds in European Union Countries

Similar to Cheng, et. al's above, there have been many graphs produced by CWF opponents who plot tooth decay comparing fluoridated and non-fluoridated countries and make the case that rates of decay decrease at the same rate in both countries. These graphs are difficult to compare due to different sources of data, time periods, ages considered, whether or not they are primary or secondary teeth, how they measure decay, and so on. While the rates of decline may be similar, to get a full picture of comparison, the prevalence of caries in those born since the onset of artificial fluoridation would be helpful. This would be an easy study to publish that could shine more light on the effectiveness of CWF.

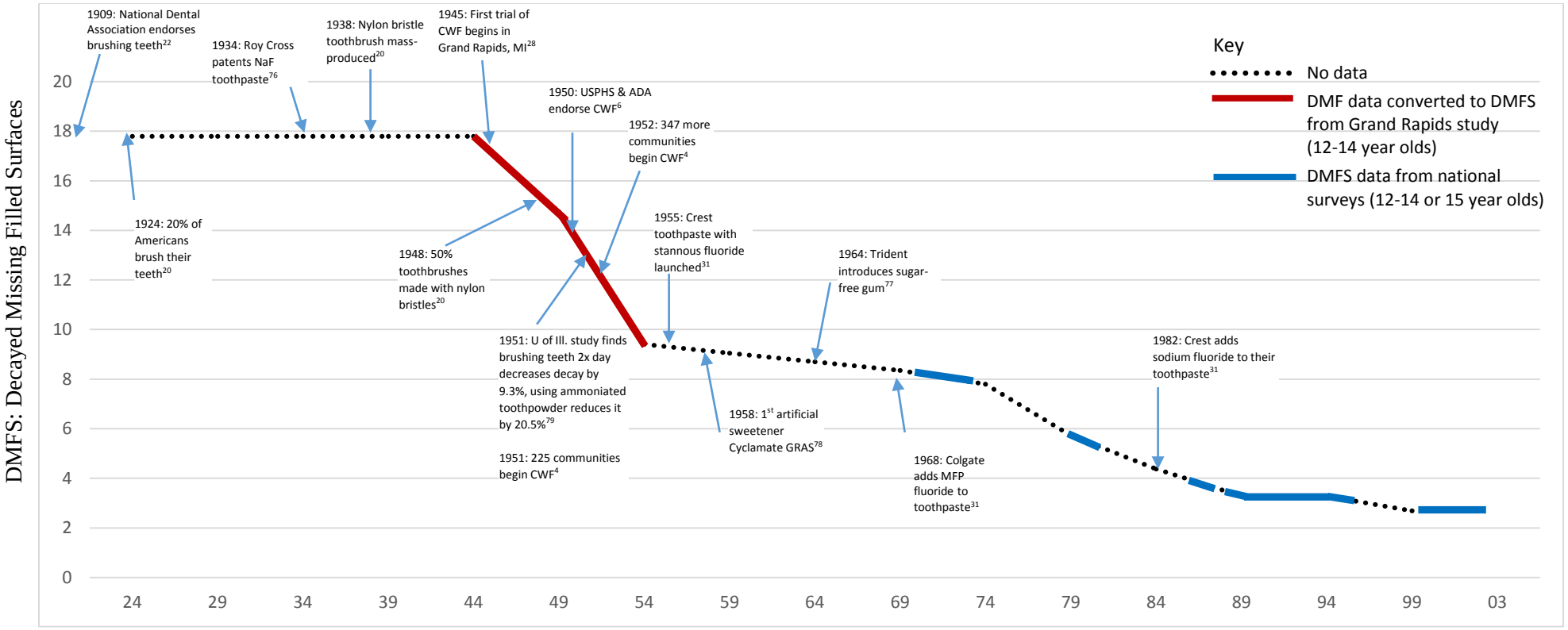
A study published by Bratthall et. al, in 1996, cited in scholarly papers over 500 times, surveyed 55 experts and asked a series of questions about the main reason 20-25 year olds had fewer caries than they did 30 years before. The study asked 24 experts from countries with CWF, and 28 experts from non-fluoridated countries. "The factor most experts agreed upon being a very important factor, thus itself explaining more than 40% of the total caries reduction, was the use of fluoride toothpaste." That being said, there were still experts who felt toothpaste with fluoride was "less important," or simply "important" (the choices were zero, minor, less, important or very important). The same question was asked with regard to CWF; 75% of those who lived in a fluoridated country felt it was a very important factor contributing to the decline, but this image is incomplete because those who did not live in a fluoridated country were told to mark "not used." In the discussion of their paper, Bratthall et. al concludes that, "no study has shown so clearly the wide range of opinions that are present within the oral health field." They quip that this lack of consensus is a surprising result as all experts have access to the same publications. The writers also remark that this shows, "the interpretation of available data is quite different for different persons, which for example can be based on personal experience and observation, as well as on local highly successful (or the reverse) preventive [programs] in which the respective experts may have been involved."[27]

In a commentary piece, Diesendorf concludes that some of the decline in caries may be a result of the introduction of fluoridated toothpastes, tablets and mouth rinses, though he argues many of these declines began before these fluoridated products were available.[19] Diesendorf believes changes in nutrition, oral hygiene and possibly even the immune status of the population are responsible for the decline.

Hileman also points out contradictions to the central tennet of fluoridation theory which says that the ideal fluoridation level of 1ppm produces a low rate of decay with minimal damage to teeth. Studies cited show children with exposure to 0.3-0.4ppm fluoride in their water have the lowest decay rates, while other studies say the natural level needs to be 1.0ppm or higher.[19] There is agreement that decay has declined since the early 19th century, however the most common theme seen throughout the debate is the contradictory conclusions among the studies of differing qualities. There is agreement in the health community that caries rates have decreased, but it is still unknown what has helped, and how much of a decline each method is responsible for.

A graph showing the decline in dental caries overlaying these potential confounding variables can be seen below. This graph should be interpreted carefully, as the sources of dental caries data is not uniform. The first study that attempted to collect data on the nation's dental caries prevalence was conducted by the United States Public Health Service between 1933-34. Unfortunately the observational study only measured the number of children with caries so it could not be used in the graph.[17] The first data available to illustrate the prevalence of caries is data from 1944 at the beginning of the Grand Rapids study.[28] It wasn't until 1971 that the National Center for Health Statistics did a systematic national survey to obtain DMFS prevalence data.[29] This data, some of which had to be converted into DMFS with Jarvenin's[30] formula, is graphed on a timeline of other dental discoveries and scientific advances that may have attributed to the decline in dental caries often attributed to community water fluoridation.

History of Dental/Scientific Discoveries & Prevalence of Caries



Essential Nutrient

In 1941, the National Research Council defined an essential nutrient as those nutrients found in food which are essential for human life, tissue growth and repair. They are identified when a dietary deficiency leads to a well-defined disease or failure to grow. Typically, to decide if a nutrient is essential, a diet devoid of the nutrient is observed and if an adverse physiological or metabolic condition occurs that ends once the nutrient is reintroduced, it is considered essential.[32] There are contradictions among the different health agencies as to whether or not fluoride is considered an essential nutrient.

The Centers for Disease Control and Prevention (CDC) cites the National Research Council's (NRC) 2007 *Report on Earth Materials and Health: Research Priorities for Earth Sciences and Public Health* which concluded that not only does fluoride positively influence human health, it is an element, "essential for human life based on its role in cellular functions involving metabolic or biochemical processes."[33]

The American Association of Pediatrics in their 1972 Committee on Nutrition's report *Fluoride as a Nutrient* wrote that, "Fluoride is regarded as an essential nutrient," as it is a normal component of tooth enamel and bone.[34]

However, the 10th Edition of the Recommended Dietary Allowances (RDA) states, "the status of fluorine as an essential nutrient has been debated…[and] these contradictory results do not justify a classification of fluorine as an essential element, according to accepted standards. Nonetheless, because of its valuable effects on dental health, fluorine is a beneficial element for humans."[35] Since RDAs are traditionally established only for essential nutrients when there is sufficient data to make a reliable recommendation, the designation of "Safe and Adequate

Intakes" was created. This designation is given to those nutrients with data insufficient for developing an RDA, where we know there is a toxic upper level limit. A Safe and Adequate Intake RDA for the trace element fluoride exists and varies based on age[35].

In the 1997 *Dietary Reference Intakes (DRI) for Calcium, Phosphorous, Magnesium, Vitamin D and Fluoride*, the authors write that, "the lack of exposure to fluoride or the ingestion of inadequate amounts of fluoride at any age places the individual at increased risk for dental caries."[36] The report outlines the recommendation of fluoride intake by gender and age, except for pregnancy. Fluoride crosses the placenta, and it is debated even within this paper whether or not prenatal fluoride exposure has any effect on primary teeth.

The report goes on to state, "at this time scientific evidence is insufficient to support a recommendation for prenatal fluoride supplementation. This is also in line with the current recommendation of the American Dental Association. Further, when fluoride supplements are taken during pregnancy, the United States Food and Drug Administration prohibits making claims of benefits to the teeth of children."[36] However, in a 2001 Morbidity and Mortality Weekly Report (MMWR) while highlighting the mixed evidence on the effectiveness of fluoride supplements, they report, the "use of fluoride supplements by pregnant women does not benefit their offspring."[37]

The American Dietetic Association has the same stance, even quoting the 1997 DRI report stating that fluoride is, "a beneficial nutrient at optimal levels and is present in trace amounts."[38] Opponents argue that there have not been any studies on the essentiality of it due to the fact that it has not been possible to remove all fluoride from a living organisms or their environment to adequately investigate.[39]

There does not seem to be a medical condition resulting from a lack of fluoride as there is with an excess of exposure. The 2006 update of *Dietary References Intakes: The Essential Guide to Nutrient Requirements* writes that inadequate fluoride intake is thought to put individuals at an increased risk of dental caries.[40] If that is the case, not having fluoride does not result in a condition that cannot otherwise be prevented by other means. These are the contradictory stances of the health agencies, there are many more studies that exist with conclusions that range from saying, "fluoride is not in any natural human metabolic pathway,"[41] to, "fluoride is a trace element that is necessary for the human body."[42] Whether or not fluoride is an essential nutrient or not is another piece of this debate without an answer backed up by replicated science.

In terms of how fluoride affects dental caries, it is thought that fluoride increases the rate of remineralization. After demineralization occurs and leaves the tooth susceptible to caries, it is the natural progression of remineralization that occurs to prevent the development of caries. Remineralization relies on calcium and phosphate ions and is expedited by fluoride.[43] If fluoride is present, it also becomes incorporated into the tooth structure by replacing the OH- ion in pure hydroxyapatite, resulting in fluorapatite, which is "very resistant to dissolution by acid."[25] It seems adding fluoride to the process of remineralization is advantageous, but not necessarily essential.

Biological Process

Early publications by Dean (who is generally considered to be the father of fluoridation) wrote that exposure to fluoride in water is beneficial only during the period of calcification of children's teeth. He also hypothesized that the "other constituents of the water may have some influence on the activity of the fluoride."[44] The Grand Rapids-Muskegon study began in 1945

and after ten years it was reported that not only were they seeing less decay in children's teeth who had drank fluoridated water their whole lives, but there seemed to also be a decline in caries in those who already had teeth before the artificial fluoridation began.[28]

In 1958 the World Health Organization (WHO) published a report that among other things described the biological process of fluoride in the body.[45] The report explained that the fluoride ion penetrates cells, and when the concentration is high enough it inhibits some enzymic reactions. At this time, the mechanisms of these inhibitions were unknown. The report hypothesizes that, "enzymatic inhibition presumably accounts for the bacteriostatic effects of fluorides." This report also highlights other dental, safety, health and engineering aspects of fluoridation, concluding many of the sections stating that the mechanisms of actions are unclear and that more research should be done.[45]

As time went on, new theories of how fluoride prevented caries continued to develop as science progressed. The belief that fluoridated water passed over the teeth and provided a topical benefit solidified. Systemically, it was said to be ingested and then recirculated to the oral cavity via saliva with a concentration of fluoride. Through ingestion, fluoride was also said to become incorporated into dental plaque that provides a reservoir during remineralization.[46]

In 1999, the CDC published a MMWR that wrote, "laboratory and epidemiologic research suggests that fluoride prevents dental caries predominately after eruption of the tooth into the mouth, and its actions primarily are topical for both adults and children."[9]

The CDC writes that fluoride prevents caries in three ways, the first is by inhibiting demineralization by becoming concentrated into dental plaque when it is present in the mouth. The second, enhancing remineralization, is achieved after cariogenic bacteria produces acid

when fluoride is released from plaque in response to a decrease in pH and the fluoride along with the calcium and phosphate is taken back up by demineralized enamel, resulting in a crystal structured enamel that is more resistant to bacteria. Third, through interfering with the enzymic activity of the bacteria *Streptococcus mutans* which decreases its production of acid. However, the CDC reports in a 1999 MMWR that this "directly reduces the dissolution rate of tooth mineral,"[9] but also reports in the 2001 MMWR that, "whether this reduced acid production reduces the cariogenicity of these bacteria in humans is unclear."[9,37]

Topically applied fluoride products (dentifrice, rinses and gels) initially cause a high fluoride concentration in saliva that falls off with time as it is cleared from the mouth. Studies that show fluoride is retained in saliva found concentrations between 0.03 and 0.1 parts per million (ppm) for 2-6 hours after application, depending on the person and the product.[25] One report found the contribution of fluoride from CWF to ductal saliva to be approximately 0.016 ppm in fluoridated areas and 0.006 ppm in non-fluoridated areas.[37] Another report writes that mean baseline fluoride concentrations in saliva for people in both fluoridated and un-fluoridated water were the same, between 0.02-0.04ppm. These studies found that fluoride concentration in saliva was not related to drinking water concentration, but to caries level.[25] MMWR writes that, "this concentration of fluoride is not likely to affect cariogenic activity…however, drinking fluoridated water, brushing with fluoride toothpaste, or using other fluoride dental products can raise the concentrations of fluoride in saliva present in the mouth 100-1,000 fold."[37]

Featherstone concludes that, "the concentration of fluoride in dental enamel and dentin provided by fluoridation of drinking water or by natural fluoride levels at about 1ppm is insufficient to provide protection against caries. The mechanism of action of fluoride in the

drinking water is therefore as a topical delivery system. The role of systematically incorporated fluoride is of very limited value.[25]

Using fluoride products regularly can maintain salivary fluoride concentrations in excess of 0.03 ppm to provide marked protection against caries. Suggestions of fluoride tablet use has been looked at and studies show that tablets swallowed immediately had nearly no topical benefit, as opposed to tablets dissolved in the mouth which had dramatic caries reductions. The issue with this is of course, patient compliance.[25]

A seemingly simple concept of whether or not fluoride needs to be ingested, or if the benefits are obtained from topical exposure, is still one of the most widely debated aspect of the fluoride conversation. The likely explanation for the differing opinions on this is because fluoride is so prevalent today, therefore it is difficult to distinguish the benefits of purely pre-eruptive fluoride exposure.[37] The general scientific consensus is that the benefits of fluoride are from topical exposure, the disagreement however is that some believe there is also a systemic benefit, and some do not.[25,47]

The condition resulting from too much exposure to fluoride is called fluorosis. There is little disagreement that excess fluoride causes it, but there is disagreement on the levels of fluoride which cause fluorosis. There is even more controversy surrounding whether or not fluorosis at any level is a cosmetic or health effect. Considering it merely a cosmetic effect allows the EPA to not include fluorosis when creating their secondary maximum contaminant levels (SMCL)[19] of 2.0ppm[48]. Interestingly enough, The U.S. Public Health Service just lowered their recommendation of 0.7-1.2ppm, down to 0.7ppm, due to an increase in fluorosis around the country.[49]

Safety

It is likely that based on how the benefit of fluoride was discovered, it was initially assumed the benefit came from a systemic exposure. It is under this assumption that the original studies operated. As described earlier in this paper, that may not be the case. Studies since then have rarely focused on physiological effects of fluoride, and they tend to rely on observational epidemiologic data.[50] If the Grand Rapids era studies were proposed today, exposing the population to a chemical in their drinking water with limited evidence of its safety would likely not be approved. There were safety studies done on the topic, but many of them consisted of recording heights, weights, eye and ear tests, taking x-rays of the right hand, both knees and lumbar spine, estimating bone density and bone age,[51] and analyzing fluoride content in urine, sweat and bones.[52] These studies were looking for systemic effects, and compared to the resources we have now, they had analytical limitations.

It has been reported that when designing the original studies, Dean was unable to determine the dietary fluoride intake, and therefore could not conclude an accurate measure of the prevalence and severity of dental fluorosis in the community.[53] Not knowing the amount of fluoride a person ingests is a common criticism of CWF, contributing to the difficulties involved in studying the topic. Without knowing how much fluoride a person is exposed to, it is almost impossible to know what level of fluoride prevents caries, let alone create a safety recommendation.

In terms of safety assessments, having only these epidemiologic studies may not allow scientists to feel confident that they have seen all of the possible side effects. Feasibility wise, it is difficult to control for confounding variables in large scale epidemiologic studies, therefore their validity may not be as strong. "Small relative increases in risk are difficult to estimate

reliably by epidemiological studies, even though lifetime exposure of the whole population may have large population effects."[41] Specific potential errors need to be taken into account, such as exposure estimates, potential lack of variation in exposure, potential latency effects, presence of confounders, and so on.[41] Due to the fact that the early trials did not control very well for most non-fluoride variables, today many scientists[19] regard them as only part of the evidence one must consider in assessing the size of fluoridation's benefit.

In in the 1990s, the EPA requested that the NRC independently review the, "health effects of ingested fluoride and the scientific basis for EPA's Maximum Contaminant Level (MCL)." The Maximum Contaminant Level Goal (MCLG) establishes an "exposure guideline to prevent adverse health effects in the general population." The goal of the secondary maximum contaminant level (SMCL) is to, "reduce the occurrence of adverse cosmetic consequences from exposure to fluoride." The MCL is, "the enforceable standard that is set as close to the MCLG as possible, taking into consideration other factors such as treatment technology and cost."

Currently, the MCL and MCLG are 4.0 mg/L and the SMCL is 2.0 mg/L.[54] In 1993, a committee of the NRC concluded that the MCL was an, "appropriate interim standard, but that further research was needed to fill data gaps on total exposures to fluoride and its toxicity."

Another safety concern often raised is the safety of the chemicals used in artificial fluoridation. Today, only about 9% of those receiving fluoridated water receive sodium fluoride (NaF). More commonly used is fluorosilic acid (H_2SiF_6) and sodium fluorosilicate (Na_2SiF_6) reaching 63% and 28% of fluoridated public water supplies, respectively.[55] Some have safety concerns surrounding silicofluorides. This can be seen in Phyllis Mullenix's study looking at prenatal neurotoxicity in rats. While the rats were fed levels of fluoride much higher than what

humans are exposed to through CWF, she felt the findings warranted further investigation into prenatal exposure to fluoride in humans.[56]

Years later, Mullenix performed another study analyzing CWF additives to see if they contained other metal contaminants as a result of their production from phosphate fertilizers. The additives are known to contain metal contaminates, but they are supposed to be diluted to meet drinking water regulations. In 2014 her team sampled seven different additives that were commercially available and intended for use in fluoridation at USA water facilities, all labeled American Water Works Association (AWWA) and National Sanitation Foundation (NSF) certified. The study found that metal contaminant levels varied by batch, with many of them containing levels of aluminum, arsenic, barium, calcium, iron, lead, magnesium, potassium and zinc levels that exceeded Method Detection Limits (MDL). There was as much as a 10-fold difference between batches.[57] While the levels of these contaminants are often low, and not every single batch has contamination, this is still a concern. Many of these contaminants are naturally occurring, but are under the MDL. To combine the contaminants of the fluoridating agent with the naturally occurring ones, could raise exposures to above recommendations and can potentially cause synergistic effects. The 2006 NAS study also writes that, "further research is needed to elucidate how fluorosilicates might have different biological effects from fluoride salts."[54]

Safety: Developmental Neurotoxin & Intelligence

The latest addition to the list of suspicions by opponents is that fluoride may be a developmental neurotoxin. Studies have found that babies born to mothers living in fluoridated areas were at a higher risk for Down syndrome. Other studies on the same topic have conversely found the opposite to be true.[19] There is very little research on CWF in this area, but in the past

few years two new studies were published. The first study received a lot of attention as it was done by a Harvard researcher. Choi, et al. performed a systematic review and meta-analysis because acute fluoride poisoning is known to be a neurotoxin in adults, and some animal models have pointed in a similar direction. Very little was known about the effects of fluoride on children's neurodevelopment, so this was an attempt to add to the body of literature. The paper analyzed 27 research studies that were conducted in China and Iran with fluoridation ranges that were higher than the artificial fluoridation levels in the USA (though they were of similar ranges to some naturally occurring fluoride concentrations in the country). The study cautiously concluded, "the possibility of an adverse effect of high fluoride exposure on children's neurodevelopment." They went on to suggest that future research, "include detailed individual-level information on prenatal exposure, neurobehavioral performance and covariates for adjustment."[58]

The following year, the Harvard team conducted a pilot study looking at whether or not there is an association between lifetime fluoride exposure and cognitive functions, again completed in China. Their hypothesis was that, "elevated concentrations of fluoride in water is neurotoxic during development."[42] This time the group studied 51 children, controlled for more variables, utilized biomarkers and streamlined the IQ tests. The fluoride in water levels (average 2.20 ppm) was still higher than the artificial fluoridation levels in the USA. The study concluded that moderate and severe dental fluorosis was significantly associated with poorer test scores suggesting a deficit in working memory. The study is by no means conclusive, but it is one of the first steps in the direction of building the knowledge base for the topic. As public health is tasked with protecting the public, especially vulnerable populations, it is encouraging to see this work being done. The Choi et al. study and the 2006 NRC report agree, calling for additional

research on the effects of fluoride in drinking water on intelligence with different exposure concentrations be studied. The main goal of the Choi et al. study was to assess the feasibility of utilizing neurodevelopmental tests in populations of children who had been exposed to a range of concentrations since conception, as the NRC recommended.[58]

Another study out of New Zealand was published in 2014 addressing the possible association between CWF and intelligence. The "Community Water Fluoridation and Intelligence: Prospective Study in New Zealand" was done using data collected by the Dunedin Multidisciplinary Health & Development Study, an ongoing prospective cohort study that began in 1972. This study found no association between the two,[59] and the author was quoted saying their findings, "will hopefully help to put another nail in the coffin of the complete canard that fluoridating water is somehow harmful to children's development."[60] This study hypothesized that any association between CWF and lower IQ in childhood and adulthood can be explained by confounding." The study took great care to control for confounders, but as much effort as they put into this can easily be dismissed when considering the fact that there was no adequate control group. The authors report there were 891 subjects living in an area with CWF at age 5 years, and that 99 subjects never lived in an area with CWF. The authors also write that 139 subjects consumed fluoride tablets, but they do not break down as to which of them lived in an area with CWF. Without this data, the reader cannot know if this study had a control group that did not ingest fluoride from CWF or tablets. The study concluded that the "findings do not support the assertion that fluoride exposure in the context of CWF can affect neurologic development or IQ." Without a no exposure group, this conclusion could have added to the body of literature proving that CWF is not associated with a decrease in intelligence. Instead, it is added to the list of

mediocre studies that add fuel instead of remove it from the ongoing controversy. A more detailed exploration of whether or not fluoride could be a neurotoxin is included in Appendix 1.

Ethics & Mass Medication

Some opponents oppose fluoridation due to the ethical argument that imposed fluoridation is mass medication and is a violation of an individual's choice.[19] This opposition to fluoridation is likely to persist even if the scientific debate was resolved. Considering the lengths drug companies must go to prove their drugs are safe and effective, it is a stark difference what fluoridation was put through prior to being put in the public's drinking water supply. Whether or not CWF is considered mass medication is another long standing debate. Some argue that it affects a physiological process, therefore it is medication. Others argue that since it occurs naturally at the same concentrations we fluoridate to, it is not a medicine.[41]

The European Union legally defines a medication as, "any substance or combination of substances "presented as having properties for treating or preventing disease in human beings" or "which may be used in or administered to human beings either with a view to restoring, correcting or modifying physiological functions by exerting a pharmacological, immunological or metabolic action.""[41] In The USA, the Food & Drug Administration's (FDA) Federal Food, Drug & Cosmetic Act defines drugs, "in part, by their intended use, as "articles intended for use in the diagnosis, cure, mitigation, treatment or prevention of disease" and "articles (other than food) intended to affect the structure or any function of the body of man.""[61] Under either of those definitions, evidence in this paper points to fluoride being considered a medication. However, if fluoride was considered a medication, it would be subject to far more stringent safety evaluations and proof, such as randomized clinical trials. Due to the difficulties in designing one, there has never been a randomized clinical trial of CWF.

There have been many court cases regarding the legality of CWF. Fluoridation is seen by the courts as, "a proper means of furthering public health and welfare. No court of last resort has ever rendered an opinion against fluoridation." Citing that "no substantial federal or constitutional questions were involved," the US Supreme Court has refused to review CWF cases 13 times.[62]

In the USA, claiming a product provides "caries prevention" is considered to be a drug claim, and according to the CDC, "companies would be required to submit appropriate clinical trial evidence for review by the FDA before this product could be marketed as an anti-carries agent." However, if a dentist wants to use, for example, a fluoride varnish, they can prescribe it as an "off-label" use based on their professional judgement.[37] Following that logic, if CWF were to make the claim that it prevented dental caries, it would have to be approved by the FDA. However, some opponents consider it a loophole that under the Safe Drinking Water Act, the EPA sets the standards for drinking water quality, as well as oversees those who implement the standards.[63] While the FDA sets the standards for bottled water, it is based on the recommendations from the EPA.[64]

Endorsements

Another criticism of the fluoridation movement is that many of the decisions are seen as rushed.[4] The United States Public Health Service and American Dental Association endorsed CWF only 5 years into the first CWF trial.[6] These endorsements were, "accompanied by an immediate, vocal and persistent opposition: a pattern which has been repeated almost everywhere that fluoridation has been introduced."[6] Endorsements generally are a result of a body of convincing scientific literature. When many of these endorsements were put forth, that may or may not have been the case. Still in place today, it is unclear whether or not these

endorsements are revisited to decide whether or not the agencies still feel fluoridation is worth endorsing. Opponents argue that there are more endorsements than scientific studies on the topic, and that endorsements cannot replace replication of studies.

Scientific Proof

Neither opponents nor proponents have given each other a rational moment in the debate. There are almost no individuals or experts who can be classified as neutral on the topic. Neither side seems to listen to the other, and in the rare occasion that they do engage, it is not in a constructive debate.[19] In fact, if a person comes out against the establishment's position, they are often interpreted as opponents. This does not lend itself to scientific discussion. In order for this controversy to ever be resolved, scientists need to be able to have constructive debates. True scientific debate should occur between scientists who are neutral in terms of everything except the hypotheses they are testing.

This lack of scientific debate is exacerbated by complications around publishing. It is helpful to look at which journals will publish pro and anti-fluoridation articles. Pro-fluoride articles are more often published in America and Australia (who fluoridate), while anti-fluoridation articles tend to be published in Europe (where most countries do not fluoridate). Hileman writes about researchers sending papers to journals and receiving responses saying the papers were interesting, but will not be published at this time due to politics and the sensitivity of the subject.[19] Hileman's plea is seen in her work, remarking, "if the lifeblood of science is open debate of evidence, scientific journals are the veins and arteries of the body scientific. Yet journal editors often have refused for political reasons to publish information that raises questions about fluoridation."[19]

Opponents want proof that fluoridation is safe and effective. If proof is defined as a consensus of experts, we can find proof in either direction. As for effectiveness, it is pretty clear that fluoride on teeth reduces dental caries. Even though science is imperfect, as there is always a chance however small that the effect could be due to chance, the remaining questions should be determined by science and not endorsements. Marcia McNutt, editor of *Science*, who once headed the U.S. Geological Survey, is quoted saying that, "science is a method for deciding whether what we choose to believe has a basis in the laws of nature or not."[65] Intellectually we can accept precepts of science, even though subconsciously we often cling to our intuitions – or what researchers call our, 'naïve beliefs.' Scientists have the scientific method to guide them so they stick to the statistics and unbiased methods, but just as we all are, scientists are vulnerable to confirmation bias. This is, "the tendency to look for and see only evidence that confirms what they already believe." However, scientists have a next step, something that the general public does not do, they submit their work for peer review before publication. Perhaps one of the missing pieces in the fluoridation debate is the fact that, "scientific results are always provisional, susceptible to being overturned by some future experiment or observation. Scientists rarely proclaim an absolute truth or absolute certainty. Uncertainty is inevitable at the frontiers of knowledge."[65] Scientists know this because they are trained on these topics. It is when they become too involved in other parts of the debate that they sometimes misplace this fact and consider their findings to be absolute. These biases we develop are exacerbated by political and social forces, as is becoming very evident in this debate. Ultimately, more research needs to be done. More papers can be written to show the disagreements and shortfalls in the science, but the only way to begin to resolve this debate is to replicate studies.

There have been a few big reports commissioned, the aforementioned 1993 and 2006 NRC reports, The York Report, the Royal Society of New Zealand Report, a 2015 Cochrane Report, and a European Union's Scientific Committee on Health and Environmental Risks (SCHER) report. The 2006 NAS report was commissioned because under the Safe Drinking Water Act, the EPA is required to perform a review of the MCL and SMCL every 10 years.[66] The NRC convened a Committee on Fluoride in Drinking water to produce the report. The charge to the committee was to review the toxicologic, epidemiologic, and clinical data on fluoride, as well as evaluate the scientific basis of the EPA's MCLG and SMCL in drinking water, and how well those protect children and others from adverse health effects. The committee was to consider the relative contribution of various fluoride sources to total exposure. The committee was not charged with addressing questions of artificial fluoridation, economics, risk-benefit assessment, and water-treatment technology.[54] While it is certainly important to evaluate the MCLG and SMCL, it is unfortunate that in a 507 page report by experts in the field, the remainder of those controversial issues could not have been discussed.

Many of the conclusions from the NRC report are mentioned within this paper. An entire paper could be written about the conclusions of this huge report, but the general consensus is that more research needs to be done, and they provide recommendations as to what studies should be considered. The study also concluded that the MCLG of 4.0 mg/L should be lowered, and that more studies should be done to conclude whether or not the SMCL of 2.0 mg/L should be reconsidered.[54]

The York Report was commissioned by the Chief Medical Officer of the Department of Health, "to carry out an up to date expert scientific review of fluoride and health." The study's aim was to, "provide a systematic review of the best available evidence on potential positive and

negative effects in order to assess the effects of water fluoridation." However, similar to the NAS report, studying the ethical issues, environmental and ecological impacts, cost and legal issues of fluoridation were considered to be outside the scope of the review.[67] Again, it is unfortunate that the committee of experts could not consider those factors, but at least the committee was aiming to put the scientific controversy in the debate to rest.

The conclusions from the York review were marginal at best. Breaking down each conclusion by objective, the overwhelming majority of such conclusions were that there was not enough data to come to any conclusions because the studies that exist are of moderate to poor quality and of limited quantity.[67]

The Royal Society of New Zealand and the Office of the Prime Minister's Chief Science Advisors produced their report in 2014 to review the scientific evidence for and against the efficacy and safety of fluoridation of water. This committee was to take into account the, "various concerns that have been raised in the public domain about the science and safety of fluoride." However, it was not to consider the ethical and philosophical issues within the controversy. Their conclusions are, "from a medical and public health perspective, water fluoridation at the levels used in New Zealand poses no significant health risks and is effective at reducing the prevalence and severity of tooth decay in communities where used."

The Cochrane review set out to, "evaluate the effects of fluoride in water (added fluoride or naturally occurring) on the prevention of tooth decay and markings on teeth (dental fluorosis). Again, it did not look at the other factors or side effects. Their conclusion was that, based on the studies analyzed, CWF is effective at decreasing tooth decay among children. They qualified that conclusion by saying, "these results are based predominantly on old studies and may not be applicable today." The report writes that the quality and quantity of studies is inadequate.

Cochrane is known to have one of the strictest levels of review for study inclusion, however, the other studies with less strict levels of review's conclusions aligned.[68]

The European Union (EU)'s SCHER report had a wider breadth of information to study, including the safety and efficacy of CWF, as well as to consider whether or not there may be other health effects from exposure. The study also compared European Union countries that did and did not have CWF and found that both had steady rates of decay decline. They interpret that for those countries not practicing CWF, the decline in decay can be attributed to topical fluoride preventive treatments, supplements, fluoridated salt, improved oral hygiene, changes in nutrition/care practices and any change that may result from improved education and wealth. The SCHER report concludes that, "water fluoridation plays a relatively minor role in the improvement of dental health," and that, "topical application of fluoride is most effective in preventing tooth decay." The report also concludes that evidence from available studies, "does not clearly" support any health effects, other than fluorosis.[69]

With the resources associated with a government commissioned reports, it is disappointing that the studies did not look at the bigger picture of the controversy. Each study had similar pitfalls so we cannot even pull bits and pieces from each to see the bigger picture. If resources are going to be allocated to the controversy, the scope of work should be clearly defined to add to the body of literature, instead of adding to the controversy.

The Social Controversy Continues

When fluoridation research began, the lines between proponents and opponents were clear, most doctors, dentists many public health officials and scientists avidly supported fluoridation. As one might expect, many extreme right wing groups (think John Birch Society, Ku Klux Klan, etc) opposed fluoridation arguing that it was a communist plot. Considering the

historical context throughout the controversy can be helpful to understand the impetus of the debate.

When the idea of fluoridation first came about, it was often considered to be a 'communist plot' for Nazi mind control. Today this seems far-fetched, but this was during the time period where anxiety about socialism was prevalent because of the Cold War. Then from the 1950s-70s the political threats of socialism included socialized medicine, and fluoridating the public's water supply certainly looked like such. In the 1960s, though the USA's FDA did not officially approve Thalidomide, many countries did allow something that caused serious harm to our most vulnerable population into circulation[70]. Today we are seeing a resurgence in the fears over socialized medicine and a distrust of science by those who oppose vaccination. Contemporary concerns express many of the same fears about chemicals, paternalism, medical dominance and the environement.[6] Recently, however, resources have been put towards proving the safety of vaccination, something that has not yet been done to attempt to squash the anti-fluoridation movement.

Continuing a thorough look at the competing factors of the debate, one would be remiss to exclude capital interests. Many opponents cite the fact that the chemicals used for fluoridation are "industrial waste" that if not sold to municipal water supplies would need to go through the expensive process of being discarded as hazardous waste. Block, citing Varney, writes that the fluoridation program is a, "result of an unholy alliance of capitalist forces" and that sometimes the medical system has been shaped by more powerful classes within the socio-economic system.[6] This is something that has certainly been seen before with, for example, the tobacco industry. Varney argues that reclassifying hazardous waste into a 'health-giving' product allows industries such as the fertilizer and aluminum companies to financially benefit from fluoridation.

She argues fluoridation distracts attention away from other industries such as the sugary food industry by diverting attention away from the real cause of dental decay, sugary food/beverage consumption. It is far simpler for a dentist to support fluoridation efforts than to try to change the dietary habits of patients.[6]

Dr. Groth III describes the different views of proponents and opponents in the debate. He writes that proponents, "see it as a simple public health measure, effective and safe, which they need to 'sell' to the public…[whereas] opponents tend to be much more concerned with risks than with benefits, and view fluoridation the same way society views many other 'environmental hazards' – granting that the risks may be small and uncertain, they believe society's attitude should be 'better safe than sorry.' Since any risks fluoridation may present are imposed involuntarily when a water supply is fluoridated, those risks - even if they are tiny or unsubstantiated – tend to provoke a disproportionate amount of outrage."[19]

There is a difference in the level of information opponents and proponents feel satisfied with. Most proponents argue there are no risks. There are some who will acknowledge there are a few recognized potential risks, but they are satisfied by "enough research of good enough quality to show that these risks are very remote and that the large benefits justify society's taking those risks."[19]

Another group of opponents are those who say that fluoride causes harms such as cancer, birth defects, and other ills. These claims are often made by unscientific individuals with poorer quality studies in their toolkit. In this group there are also less extreme opponents making health claims that feel research has not adequately answered critical questions about potential risks. They also often argue that the dental benefits of fluoridation are either nonexistent or greatly

exaggerated. This group demands objective assessment, putting the onus of proof on the proponents.[19]

Environmental concerns are also involved in the debate. They resist being called opponents, though these arguments tend to align more with opponents than proponents. Blocking a lawsuit in 1986 when the EPA tried to relax drinking water standards for fluoride in natural waters, the National Resources Defense Council (NRDC) argued that overlooked possible harm, and that an inadequate evaluation of the full range of possible hazards evidenced incomplete and unconvincing information. Environmental advocates feel fluoride needs to be investigated in the same way that other environmental pollutants have been studied in the past. Total intake needs to be assessed, and effects on susceptible individuals and the levels that these effects begin to occur needs to be determined.[19]

The argument is often made that CWF is the most fair and equitable way to provide anti-carries measures to the entire population. Proponents argue that CWF provides those of a lower SES access to fluorides that would otherwise not be available to them. Peckham argues that children with decreased calcium and magnesium in their teeth (usually due to undernutrition), ingesting fluoride and receiving it topically can actually place them at an increased risk of hypo-calcification and/or hypoplasia, which paradoxically can be placing these individuals in a more vulnerable position for developing dental caries.[50] Others argue that children consuming water fluoridated with silicofluorides increases the child's uptake of lead.[71] Considering almost half of all children in the USA do not have annual dental checkups,[72] perhaps we should be putting our resources to increasing access to care in a way that is more understood to prevent the spread of dental caries.

Conclusion

There is a solid argument against the method of CWF delivery now that scientists seem to agree that the benefit of fluoride is purely topical. Perhaps the most efficient way to prevent tooth decay is through dental products and the debate over the efficiency of CWF will end. Either way, more research needs to occur in order to solve the question.

It is difficult to ignore the fact that there has been at least a stir of controversy over the past 50 years, one that is growing instead of receding. It is important for proponents and public health law makers to assess all new data objectively, and resist falling victim to confirmation bias. It is equally important for opponents and research scientists to critically interpret their data without allowing conclusions to be influenced by their hypotheses. We cannot ignore the fact that we are one of the only countries to fluoridate. Outside of the USA, various countries' public health agencies have deemed fluoridated water to be unsafe or not to be instated due to lack of adequate research.[19]

In order for a productive scientific debate to occur, proponents and opponents need to fight fair. Opponents have been compared to those who believe the earth is flat.[6] Once a passionate assertion like that is put forth, it is hard for either party to consider the others' research. Just because something was once deemed a scientific achievement, does not mean it always remains on that pedestal. We have things in our past that were once thought to be remarkable in their time, fall down to newer evidence. This new evidence sometimes shows that our past findings are no longer the best, or in extreme cases – that they actually cause severe harm. This was seen with lead, thalidomide, mercury, and many more. At one point in history both sugar and cigarettes were considered 'health promoting' agents. The process of collecting that evidence base proving otherwise was slow and political. The former Director of the US

National Institute of Environmental Health, David Rall, once noted that, "if thalidomide had caused a ten-point loss of intelligence quotient (IQ) instead of obvious birth defects of the limbs, it would probably still be on the market."[73]

There is a serious lack of human studies when it comes to the chemicals we use to fluoridate. CWF is so pervasive that we need to be as close to sure as we can that we are not harming anyone, especially vulnerable populations. "Since the early 1960s, most studies on the long-term effects of chronic exposure to fluoride on human biological systems other than teeth have been carried out in foreign countries."[19] Research needs to look at more diverse groups of people, and consider that there may be people who are sensitive to the chemicals used.

When considering a subject as important as the health of our communities, an absence of evidence cannot be considered evidence of an absence. One of the two expert panels that exists to make prevention-oriented, evidence-base recommendations, The Community Preventive Services Task Force, recommends community water fluoridation. It does so based on, "strong evidence of effectiveness in reducing dental caries across populations." The Task Force makes this recommendation based on the effectiveness of CWF, and does not mention safety or other health effects, except in its list for "Evidence Gaps." Adding to the concern, they write that their findings are mainly based on research included in the York Review.[74] As mentioned above, the York Review concluded, based on the same information, that almost no definitive conclusions could be drawn regarding safety or other health effects until more research was performed. This theme of CWF evaluations continues on.

The second expert panel, The U.S. Preventive Services Task Force, which usually outlines clinical recommendations, does not have a recommendation published about CWF. Our nation's recommendation to expose the majority of its public to community water fluoridation

needs to be based on more sound, replicated evidence. Until that evidence is produced, the safest way to proceed is to pause community water fluoridation. During this hiatus, data should continue to be collected on the rates of dental caries, as well as the occurrence of syndromes or diseases that are hypothesized to potentially be a result of exposure to systemic fluoride via drinking water. Once this data is analyzed, then a more informed decision can be made on the best way to prevent our communities from developing dental caries.

Appendix 1: Is it plausible that fluoride is a developmental neurotoxin?

The latest addition to the list of suspicions by opponents is that fluoride may be a developmental neurotoxin. Development of the human brain is an extraordinarily complex process which includes different windows of unique susceptibilities to toxic interferences that are not paralled in the mature brain. During development, the placenta offers some protection against exposure from unwanted chemicals, but it is not effective against all environmental pollutants (including fluoride). Though mature brains have a blood brain barrier to protect them from chemicals, it is not completely formed until about 6 months after birth. If the brain's developmental process is halted or inhibited, there is little potential for later repair, and therefore the consequences can be permanent,[75] such as what we saw with lead. Further enhancing the susceptibility of the developing child and infants to industrial chemicals is their, "increased exposures, augmented absorption rates, and diminished ability to detoxify many exogenous compounds, relative to that of adults."[75] It is easy to see how some could argue that fluoride might be a developmental neurotoxin.

In 2006, Grandjean and Landrigan published a study, "Developmental neurotoxicity of industrial chemicals." They cite that one in every six children in the United States has a developmental disability. In 2014, the same authors wrote that genetic factors seem to account for 30-40% of neurodevelopmental disorders. They posit that environmental exposures are involved in the causation of the rest of the cases, some of which may even interact with genetically inherited dispositions.[73] Over the past decades, as more chemicals are put on the market, evidence has been accumulating that industrial chemicals can cause neurodevelopmental damage, and that, "subclinical stages of these disorders might be common."[75]

"One solidly established concept in environmental health is that the effects of toxic agents fall on a continuum of biological change, ranging from undetectable effects at the lowest levels of exposure to severe health damage at very high doses."[19] It is understood that those who are exposed to high levels of fluoride suffer debilitating effects, but these levels and exposures to fluoride far exceed any level that we use for CWF. Historically, in figuring out a chemical is a developmental neurotoxin, chemicals are often first seen to cause poisoning at high doses of those working with them industrially. Once this is seen, it usually triggers further research to look at the effects of lower doses of the chemical[75]. Grandjean & Landrigan write that, "this sequence of discovery led to the recognition that environmental pollutants exert a range of adverse effects- some are clinically evident, but others can be discerned only through special testing and are not evident on standard examination, hence the term subclinical toxicity."[75]

Studies included in the 2006 NAS report cite that at increased rates of fluoride, the reproductive environment was altered. The Committee's findings were that there was an increase in reproductive and developmental animal studies, and that at very high levels of fluoride, adverse reproductive and developmental effects do occur. The committee reports that there are very few human studies on the topic, and, "a few studies of human populations have suggested that fluoride might be associated with alterations in reproductive hormones, fertility, and Down's syndrome, but their design limitations make them of little value for risk evaluations."

The 2006 NAS report writes that with the information they have derived from histological, chemical and molecular studies, "it is apparent that fluorides have the ability to interfere with the functions of the brain and the body by direct and indirect means. To determine the possible adverse effects of fluoride, additional data from both the experimental and the

clinical sciences are needed." They also conclude that most of the studies dealing with fluoride and neural/behavioral responses have used NaF, and that futures studies should include other forms of fluoride[54] (which as mentioned before, are used over 90% of the time in CWF).[55]

Grandjean & Landrigan recommend that, "protection of the developing brain should be a paramount goal of public health protection" due to the vulnerability of the human nervous system and its unique susceptibility during early development.[75] They posit that we may have created a "silent pandemic" in modern society with the slew of industrial chemicals that are so prevalent in our lives today. They write that, "although these chemicals might have caused impaired brain development in millions of children worldwide, the profound effects of such a pandemic are not apparent from available health statistics." They also posit that perhaps the effects of early subclinical chemical injury may be silently killing, "a fraction of the cells needed to sustain brain function later in life…these latent impairments cause no symptoms in childhood, but could be unmasked during the natural neuronal attrition associated with ageing." This could be increasing risks for neurodegenerative diseases at different stages of life.[75] It is not clear whether or not fluoride exposure through CWF is a developmental neurotoxin, but what is clear is that more research on the topic must be done.

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