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Public water fluoridation

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PUBLIC WATER FLUORIDATION

A Thesis or Project
Submitted
in Partial Fulfillment
of the Requirements for the Designation
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INTRODUCTION

This thesis project addresses the issue of public water fluoridation. There is a debate within the United States as to whether or not public water systems should be fluoridated. Because of the large scale potential health impact, it is critical to determine whether or not this practice is in the best interest of the public. This paper provides an extensive review of scientific literature on the effectiveness, safety, and cost effectiveness of public water fluoridation. Following the review of scientific literature, I will present an overview of pseudo-scientific¹ literature which advocates against public water fluoridation that, although often not scientifically sound, may have a profound impact on public opinion. That section will display both a description of these arguments and an analysis of them which will uncover faulty reasoning, incorrect information, or other inappropriate tactics used to make unsupported claims against water fluoridation. Finally, the paper will feature a small case study of a town with an un-fluoridated water supply and the issues it has faced with a recent fluoridation initiative. Considering all factors, I will come to a conclusion as to whether or not cities should fluoridate their public water supplies and offer recommendations that coincide with that decision.

LITERATURE REVIEW

Fluoridation Basics

Fluoride is a naturally occurring ion derived from the pure element fluorine. Although fluorine is an abundant element in nature, it rarely exists in its free state. Instead, it usually bonds with other elements to form fluoride compounds. Fluoride compounds are widely incorporated into the rocks and soil of the earth. When water flows over rocks and soil, it picks up fluoride compounds from them. Once these compounds are immersed in water, they dissolve

¹ “Pseudo-scientific” refers to information and literature which is of doubtful scientific merit or origin.

to release fluoride ions. Thus, all water sources contain some amount of fluoride (American Dental Association, A, 2005).

The amount of fluoride present in a particular water sample varies based on the concentration of fluoride-bearing minerals in the area and the depth at which the water is found (US Dept. of Health and Human Services, 1986). Shallow water sources, such as lakes, rivers, and streams, typically have relatively low concentrations of fluoride (City of Chicago, 2008). The natural fluoride concentration of water in the United States ranges from very low levels, such as 0.15 parts per million (ppm) in Lake Michigan, to levels of over 4 ppm in some well water and other sources (City of Chicago, 2008; Thompson & Taylor, 1933).

Because areas with low natural concentrations of fluoride do not offer the dentally protective effects of higher levels, many cities choose to adjust the natural fluoride concentration of their water supplies to the amount recommended for optimal dental health. The United States Public Health Service has concluded that optimal fluoride concentration in water ranges from 0.7 to 1.2 ppm, depending on the average maximum daily air temperature in the area (US Department of Health, Education and Welfare, 1962). This averages out to be a generally recommended level of 1 ppm, or one part of fluoride diluted in one million parts of water. This is equivalent to one milligram of fluoride per liter of water. To visualize the meaning of one part per million, consider one inch in 16 miles, one minute in two years, or one cent in \$10,000 (American Dental Association, A, 2005). Clearly, one part per million is not a large concentration, but it does have a significant impact on the dental health of those ingesting it.

In the United States, one of three different fluoride compounds is used to fluoridate a given water supply. These three compounds are 1) sodium fluoride, a white, odorless powder or crystalline material; 2) sodium fluorosilicate, a white or yellow, odorless crystal; and 3)

fluorosilicic acid, a white or straw-colored liquid (US Department of Health and Human Services, 1986; AWWA, 2000). Sodium fluoride was used at the onset of fluoridation in 1945. Sodium fluorosilicate and fluorosilicic acid were introduced in the late 1940s and had surpassed sodium fluoride in usage by 1951. Today, fluorosilicic acid is the most widely used compound to fluoridate water supplies in the United States (US Department of Health and Human Services, 1986; Maier, 1963). All three additives are derived from the mineral apatite, a type of limestone deposit containing 3-7% fluoride (US Department of Health and Human Services, 1986). The compounds meet health and safety standards of the American Water Works Association and NSF International (American Dental Association, A, 2005). Additionally, the additives are regulated by the Environmental Protection Agency, which is charged under the Safe Drinking Water Act to monitor the safety of public drinking water (44 Fed.Reg., 1979).

History of Water Fluoridation

In the early 1900's, Dr. Frederick McKay moved to Colorado Springs, Colorado to open a dental practice. When he began seeing patients, he noted that, interestingly, many of the local residents had brown stains on their permanent teeth. Dr. McKay began working with Dr. G.V. Black, dean of the Northwestern University Dental School in Chicago, to investigate the condition. The dentists discovered that the mottled enamel, as they referred to it, was caused by developmental imperfections. In the 1920's, Dr. McKay proposed the idea that something in the drinking water was causing the mottled enamel². He noted that these symptoms had been identified in Colorado, New Mexico, Arizona, California, Idaho, South Dakota, Texas, and

² "Mottled enamel" is no longer an accepted medical term. The condition is now called "dental fluorosis" and will be discussed in a later section.

Virginia. Additionally, Dr. McKay realized that the stained teeth were incredibly resistant to decay (McKay, 1933; McClure, 1970).

Additional studies were conducted in St. David, Arizona and Bauxite, Arkansas in the 1930's, which determined that naturally high levels of fluoride in the drinking water were causing the stained teeth. The fluoride levels in the water supplies of these two towns were abnormally high – 3.8 to 7.15 ppm in St. David and 13.7 ppm in Bauxite (McClure, 1970). Since these levels were clearly extreme, researchers began to wonder how high fluoride levels could be before visible, severe dental fluorosis would occur (Dean, 1936). During the 1930's, Dr. H. Trendley Dean, a dental officer at the U.S. Public Health Service, completed epidemiological studies on the geographical distribution and severity of fluorosis in the United States (Dean, 1938). Dr. Dean and his associates found that fluoride levels of up to 1 ppm in the drinking water did not cause visible dental fluorosis. Instead, they found a positive correlation between fluoride levels in the water and decreased incidence of dental caries (Dean, 1938; Dean et al., 1942).

In 1939, Dr. Gerald J. Cox and his staff at the Mellon Institute conducted independent laboratory experiments which reinforced the findings of Dr. Dean. Additionally, they published a paper in which they proposed adding fluoride to water in areas where it is naturally deficient to prevent tooth decay (Cox et al., 1939). In the 1940's, this idea was carried out with the addition of sodium fluoride to four city water supplies that exhibited fluoride deficiency, beginning in Grand Rapids, Michigan, in January, 1945. The definitive success of these trials demonstrated that fluoridation is a safe and effective means of preventing dental caries (Cox et al., 1939; Dean et al., 1950). Throughout the next several years, multitudes of other communities began fluoridating their public water supplies as well (American Dental Association, A, 2005).

Support for Water Fluoridation

Public water fluoridation is widely supported by major health authorities. In 2005, the American Dental Association (ADA) celebrated 60 years of public water fluoridation. In a statement released for the occasion, ADA President Dr. Richard Haught highlighted the effectiveness of community water fluoridation in reducing dental decay and stressed its continued importance, even where other resources, such as fluoridated toothpaste, are available. He also lamented the fact that a large number of communities have not adopted water fluoridation and emphasized the fact that water fluoridation benefits everyone, even those who lack professional dental care (American Dental Association, B, 2005). In the same release, U.S. Surgeon General Dr. Richard H. Carmona stated, “Community water fluoridation is the single most effective public health measure to prevent dental decay and improve oral health over a lifetime for both children and adults” (American Dental Association, B, 2005).

Furthermore, public water fluoridation is supported by the American Medical Association, the World Health Organization, the U.S. Public Health Service (American Dental Association, A, 2005), and the Centers for Disease Control and Prevention (CDC), which named fluoridation of public water systems one of the ten great public health achievements of the 20th century (Centers for Disease Control and Prevention, 1999). The CDC and the Surgeon General have also noted the importance of water fluoridation in reducing discrepancies in the dental health of people from different education or income levels (American Dental Association, B, 2005; US Department of Health and Human Services, 2001).

Effectiveness of Water Fluoridation

Despite the prominent advances in healthcare over the last several years, dental decay, also known as tooth decay or dental caries, is a common infectious disease that continues to cause serious problems. It is without a doubt the most common and costly oral health problem across the population. Dental decay has a significant effect on those suffering from it, as it interferes with the ability to eat certain foods, causes pain and discomfort, and can detract from appearance (US Department of Health and Human Services, 1993). Risk factors for developing tooth decay include inadequate exposure to fluoride, irregular dental visits, pits or fissures in the chewing surfaces of teeth, inadequate saliva flow, high sugar intake, and above normal oral bacteria levels (American Dental Association, A, 2005).

Tooth decay is one of the most common childhood diseases, occurring five times as often as asthma and seven times as often as hay fever in the five to 17 year old age group. Fifty-one million school hours are lost per year in the United States due to dental illness, and this number would be much higher without the protective effects of water fluoridation (Gift, 1997). Decay continues to be a problem for adults, especially for older adults, as gum recession in old age can contribute to root decay (Griffin et al., 2004).

Adequate fluoride exposure is necessary to decrease an individual's risk for dental caries. Although there are other fluoride sources available, such as toothpastes and rinses, ingesting fluoride through water provides optimal benefits. While toothpastes and rinses provide topical protection, fluoride obtained through the water supply protects teeth both topically and systemically (American Dental Association, A, 2005). Maximum protection against dental caries will occur when fluoride is present both systemically, prior to tooth eruption, to allow assimilation during tooth development, and topically, after tooth eruption, at the tooth surface.

Water fluoridation maximizes both types of exposure (Newbrun, 2004; Hargreaves, 1992; Singh et al., 2003; Singh & Spencer, 2004).

Systemic substances are those ingested through water and incorporated into the body. Early in life, during tooth formation, systemic fluorides become integrated into the teeth. Because fluoride actually becomes part of the teeth, it provides more sustainable protection than the application of topical fluoride alone (Newbrun, 1986). In addition, since systemic fluoride is incorporated into the body, it is present in saliva. Saliva continually washes over the teeth, providing further fluoride protection to the surface of the teeth and even allowing fluoride to become ingrained in plaque that forms on the teeth, aiding in remineralization (Lambrou et al., 1981).

In addition to providing systemic benefits, fluoride taken in through water provides topical benefits, strengthening teeth that have already erupted. Topical fluoride provides additional protection to the surfaces of teeth, further increasing their resistance to decay. Topical fluoride also contributes to fluoride levels in saliva and plaque, which help to prevent and reverse the progression of tooth decay (Featherstone, 2000).

As previously mentioned, fluoride present in the saliva and plaque has a remineralizing effect on the teeth. Decay, chemically a demineralization process, is caused by acids produced by bacteria that break down the minerals in tooth enamel. Fluoride ions, which are incorporated into the enamel or at the enamel surface, are able to reverse that chemical reaction in early dental decay, remineralizing teeth (Newbrun, 1986; Backer-Dirks et al., 1978; Silverstone, 1993; Featherstone, 1987; Fejerskov et al., 1981; Silverstone et al., 1981).

At the onset of water fluoridation, studies found that water fluoridation reduced the occurrence of cavities in primary teeth by up to 60% and the amount of decay in permanent teeth

by 35%. Studies today show that water fluoridation is still responsible for a 20-40% overall reduction in dental decay (data summarized by American Dental Association, A, 2005).

Numerous studies have demonstrated the positive effects of public water fluoridation on caries reduction. In fact, so many studies have been completed that water fluoridation has been one of the most widely studied public health measures in history (Newbrun, 1989; Brunelle & Carlos, 1990).

The first evidence of the effectiveness of water fluoridation comes from a 15 year study in Grand Rapids, Michigan, the first town in the United States to adjust its water fluoride content. The study showed that children in Grand Rapids who ingested optimally fluoridated water throughout their lifetimes had 50-63% lower dental caries rates than children in nearby non-fluoridated Muskegon, Michigan (Arnold et al., 1962).

Fluoridated Newburgh, New York and non-fluoridated Kingston, New York, have been studied several times since the onset of water fluoridation to determine the differences in caries prevalence between fluoridated and non-fluoridated areas. After 10 years of fluoridation, six to nine year old children in Newburgh showed 58% less decay than six to nine year old children in Kingston. After 15 years of fluoridation in Newburgh, that same generation of children (now ages 13 to 14) had 70% fewer cavities than those in Kingston (Ast & Fitzgerald, 1962). Similar data was collected in Evanston, Illinois. After 14 years of fluoridation, 14 year old lifetime residents had 57% less decay than children in non-fluoridated Oak Park, Illinois (Blayney & Hill, 1967).

An epidemiological study was conducted in 1987, surveying 40,000 children across the United States. A similar study in 1980 had shown that 37% of children were cavity-free. During the seven years between the studies, many more towns began to fluoridate public water supplies.

Thus, in 1987, 50% of children ages five to 17 had no dental decay. Researchers determined that the primary cause of the striking drop in dental caries incidence was the increased spread of community water fluoridation (Brunelle & Carlos, 1990).

In 2002, a study was published that detailed a water fluoridation experiment in Scotland, the country documented to have the worst dental health in the United Kingdom. After 13 years of natural fluoridation at 1 ppm in three townships, data showed that five and six year old subjects who were lifetime residents had 96% fewer primary dental caries than residents in nearby non-fluoridated townships. In addition, 86% of children in the optimally fluoridated areas were caries free, as opposed to only 32% of children in the non-fluoridated areas (Stephen et. al, 2002).

A study published in 2007 in Australia further reinforced the idea that water fluoridation is a necessary component of solid oral health. This study looked at exposure to fluoridated water in children from birth to three years of age and followed up by checking the prevalence of caries in these children at age six. The researchers found that the group of children with no exposure to fluoridated water from birth to age three had significantly higher prevalence and severity of dental caries at age six compared to children who had been exposed to fluoridated water. They determined that exposure to fluoridated water from birth to age three prevented 34% of cavities at age six. Based on this data, the researchers expressed the opinion that child oral health would deteriorate significantly if water fluoridation were to cease in Australia (Do & Spencer, 2007).

Another study was conducted in 2008 in the cities of Newburgh and Kingston, New York to determine whether or not the prevalence of dental decay had changed since the towns were last studied in 1986. Newburgh has been fluoridated to 1 ppm since 1945 with the exception of a three year interruption between 1978 and 1981. Kingston has naturally occurring fluoride levels

of only 0.3 ppm and is not adjusted. This study looked at caries decline both in general and in terms of different socioeconomic groups. The researchers found that not only did dental caries decline more in fluoridated Newburgh than in non-fluoridated Kingston, but there was also a significant difference in caries prevention among different socioeconomic groups. Kingston showed a large disparity in decay rates between poor and non-poor groups, while fluoridated Newburgh did not. This reinforces the idea that water fluoridation allows significant oral health benefits to be attained by all residents, regardless of socioeconomic status (Kumar et al., 1998).

There has been some debate as to whether or not water fluoridation is still necessary in this age, given the availability of other fluoride sources, such as toothpaste, rinses, and foods grown in fluoridated areas. Risk factors for decay are very high at the present time and include high intake of sugar, poor oral hygiene, exposed root surfaces, and inadequate exposure to fluoride. Because many Americans have one or more risk factors for decay, lots of individuals still experience high caries rates in the absence of water fluoridation (American Dental Association, A, 2005).

A study published in 1995 analyzed lifetime residents of three Indiana communities: Connersville, with a water fluoride concentration of 0.2 ppm, Brownsburg, with an optimal fluoride adjustment to 1.0 ppm, and Lowell, with a naturally high fluoride concentration of 4.0 ppm. Although the towns had differing water fluoride concentrations, all had exposure to other fluoride sources, including fluoridated toothpaste. Using two different scoring methods, the researchers found that decay in optimally fluoridated Brownsburg was 9.2% and 21.2% lower than in non-fluoridated Connersville. In addition, they found that with four times optimally fluoridated water in Lowell, caries rates were 19.8% and 23.1% lower than in the non-fluoridated area (Jackson et al., 1995). This result was reinforced in a 1998 study of fluoridated and non-

fluoridated towns in Illinois. Researchers there found that even with other sources of fluoride available, only 25.2% of children were cavity free in the non-fluoridated town of Broken Bow, while fluoridated Kewanee boasted a 51.9% caries free child population (Selwitz et al., 1998). These considerable differences demonstrate that water fluoridation continues to provide necessary benefits that other fluoride sources cannot provide alone.

In communities where water fluoridation has been discontinued, decay rates haven risen dramatically over time, even with the use of fluoride toothpaste (American Dental Association, A, 2005). After fluoridating its water for 11 years, the town of Antigo, Wisconsin discontinued water fluoridation in 1960. After five years without public water fluoridation, decay data for various age groups was compared to data for those same groups taken before the cessation of water fluoridation. The absence of fluoride resulted in 200% more decay in second graders, 70% more decay in fourth graders, and 91% more decay in sixth graders. Recognizing the drastic deterioration of dental health, Antigo residents began to fluoridate their water supply again in 1965 (Lemke et al., 1970). Though not quite as dramatic, the discontinuation of water fluoridation in Wick, Scotland in 1979 resulted in a 27% decay increase in permanent teeth and a 40% decay increase in primary teeth (Stephen et al., 1987). Additionally, following the termination of water fluoridation in Stanraer, Scotland, residents suffered a 115% increase in the cost of restorative dental treatment to repair decay (Attwood & Blinkhorn, 1991).

There are no observable health differences between people ingesting water with a naturally occurring optimal water fluoride content and those ingesting water adjusted to an optimal fluoride level. Fluoride ions are exactly the same, whether they are picked up by the water naturally as it flows by rocks or added under carefully controlled conditions in a city water plant (American Dental Association, A, 2005). Researchers in Ontario, Canada conducted a

study of three different towns: one optimally fluoridated naturally, one optimally fluoridated by adjustment, and one with deficient levels of fluoride. The data revealed significantly lower dental caries incidence in both the naturally and adjusted optimally fluoridated areas compared to the non-fluoridated town. Between the two optimally fluoridated areas, there was no discernible difference in the effects of naturally occurring fluoridated water compared to the adjusted water supply. This study illustrated that the source of fluoride resulted in no discrepancies in dental benefits (Brown & Poplove, 1965).

Fluoridation for Infants and Children

Given the vast amount of literature which attests to the importance of fluoride in the development of healthy teeth, it is natural to consider at what age fluoride ingestion should commence. Only one prospective, randomized, double blind study has been undertaken to study the effects of prenatal dietary supplementation for pregnant women. Although the study showed no harmful effects from the fluoride on either the mothers or the babies, the authors found that prenatal fluoridation did not have a strong preventative effect on decay of the babies' primary teeth (Leverett et al., 1997). Furthermore, research has shown that permanent teeth do not begin to develop in an infant during pregnancy, so prenatal fluoride supplementation would have no effect on permanent teeth (American Dental Association, 2003). Fluoride supplementation for nursing mothers has also been shown to be unnecessary, as fluoride concentrations in human milk are incredibly low, ranging from 0.007 to 0.011 ppm, and changes in the fluoride concentration of a mother's milk are insensitive to the amount of fluoride ingested by the mother (Institute of Medicine, Food and Nutrition Board, 1997).

On the other hand, babies who are bottle-fed rather than nursed do face a higher risk for primary tooth decay. Known as “baby bottle tooth decay,” the condition is a severe type of childhood dental decay that affects many babies and toddlers (Evans et al., 1996). In 1998, a comprehensive review of methods used to prevent baby bottle tooth decay was undertaken, and the ingestion of fluoridated water was found to be the most effective measure of prevention across the population. In addition, water fluoridation was found to be even more effective in children from low socioeconomic groups, because water fluoridation is the only preventative measure that does not require parental motivation or dental visits (Ismail, 1998).

As previously noted, fluoride ingestion through the water supply is incredibly important in children for the development of optimally resilient teeth. However, in order to strike the correct balance between the attainment of decay prevention and avoiding the development of dental fluorosis (which will be discussed in more detail in a later section), the American Dental Association has recommendations for amount of fluoride intake for each age group. Although water which is optimally fluoridated at around 1 ppm does not pose risks for any age group, the ADA does recommend that children who receive a water supply which is naturally fluoridated to 2 ppm or greater primarily consume an alternative water source, such as bottled or filtered water (American Dental Association, A, 2005).

Bottled Water and Filtering

In recent years, Americans have dramatically increased their consumption of bottled water. The majority of bottled waters on the market are not fluoridated to the optimal level for dental health. Because of this, those who consistently consume bottled water as an alternative to tap water risk missing the benefits of optimally fluoridated water (Lindemeyer et al., 1996; Van

Winkle et al., 1995; Wisconsin Department of Agriculture, Trade and Consumer Protection, 1993; Chan et al., 1994; Johnson & DeBiase, 2003).

Studies have shown significant variation in the fluoride content of different samples of bottled water. A study conducted in 1989 showed that bottled water from nine different sources used by pediatric dental patients ranged in fluoride concentration from 0.04 to 1.4 ppm (Flaitz et al., 1989). A 1991 study of 39 samples of bottled water resulted in 34 of the brands having a fluoride content of less than 0.3 ppm, well below the optimal level for decay prevention (Tate & Chan, 1994). Perhaps most striking, a 2000 study of five national bottled water brands demonstrated significant differences in fluoride content not only among the five brands, but within different batches of the same brand (Bartels et al., 2000).

Although the FDA regulates bottled water, there are no requirements for fluoride content. The FDA has approved the optional addition of fluoride to bottled water, but it does not require fluoride content to be listed on the product label unless it is intentionally added during processing (21 CFR 165; 60 Fed. Reg. 57059, 1995).

In addition to the widespread use of bottled water, many Americans have some type of water treatment or filtration system in their homes. There are several different types of home water treatment systems, including reverse osmosis systems, distillation units, and water softeners. Research on the topic has shown that most reverse osmosis systems and distillation units remove a considerable amount of fluoride from the incoming water supply (Levy et al., 1995; Maier, 1963; American Dental Association Division of Science, 2003), whereas water softeners generally do not greatly alter the water fluoride content (Full and Wefel, 1983; Robinson et al., 1991). Additionally, filters can vary depending on their type, quality, age, and chemical composition (Jobson et al., 2000).

Safety

As previously mentioned, community water fluoridation is endorsed by several national and world health associations, including the American Dental Association, the American Medical Association, the Environmental Protection Agency, and the World Health Organization (American Dental Association, A, 2005). This is because an overwhelming wealth of scientific research has shown that, at the recommended levels, not only is community water fluoridation effective at preventing dental decay, it is safe for the entire body and does not pose risks for any health problems (National Research Council, 1993). As with other nutrients, such as chlorine, sodium, and even water, fluoride is safe and effective when consumed in appropriate amounts (US Department of Health and Human Services, Public Health Service, 1998). The EPA has placed a conservative ceiling of 4 ppm on the fluoridation of water supplies, ensuring protection against undesirable effects with a generous margin of safety (58 Fed. Reg. 68826,68827, 1993). At this level, far above the fluoride content of any adjusted water supply, no accusation against the benefits and safety of water fluoridation has ever been validated by generally accepted scientific knowledge (US Department of Health and Human Services, Public Health Service, 1998).

A ten-year study was conducted on residents of Bartlett, Texas and Cameron, Texas, whose water supplies had fluoride concentrations of 8.0 ppm and 0.4 ppm, respectively. The study examined residents comprehensively, including studying their organs, bones, and other body tissues. Even at a level which is enormously higher than optimal, researchers found no detrimental physiological or functional effects due to fluoride in the Bartlett residents (Leone et al., 1954). In fact, acute fluoride toxicity resulting from the ingestion of fluoridated drinking water is impossible. A human being would have to consume the amount of fluoride present in

10,000 to 20,000 eight ounce glasses of fluoridated water at one time to die of acute fluoride toxicity (American Dental Association, A, 2005).

When fluoride is ingested, it is initially absorbed from the digestive tract into the blood stream. Blood fluoride levels peak within 20-60 minutes, but the concentration declines rapidly due to removal by kidneys and uptake by calcified tissues. Within 24 hours, around 50% of ingested fluoride becomes incorporated in hard tissues, while the remainder is excreted through the urine (Whitford, 1990). This number varies inversely by age, with higher fluoride retention in the bones of younger people than in older people (Whitford, 1990; Whitford, 1994; Levy et al., 1993).

Because of the uptake of fluoride into bones, there is some concern about the effects of fluoride on bone health. One issue is skeletal fluorosis, a crippling bone condition. However, studies have shown that skeletal fluorosis was not present in communities where the water supplies contained up to 20 ppm, a nearly unheard of natural level far above the optimal 1 ppm used in most fluoridated water supplies (Institute of Medicine, Food and Nutrition Board, 1997; Hodge, 1979). It has been determined that crippling skeletal fluorosis is not caused by optimally fluoridated water. In fact, the condition is so rare that only five cases have been documented in the United States within the last 35 years (Institute of Medicine, Food and Nutrition Board, 1997).

Closely related is the concern that fluoridated water causes bone cancer. Since the onset of water fluoridation in 1945, over 50 studies conducted all over the world have failed to show a link between water fluoridation and osteosarcoma (reviewed by US Department of Health and Human Services, Public Health Service, 1991). For example, one study analyzed fluoridated and non-fluoridated populations in New York to determine whether or not data showed any

differences in osteosarcoma rates between the two populations and found none (Mahoney et al., 1991). A 1995 study again found that fluoride did not cause bone cancer and even showed some evidence of a protective effect in males (Gelberg et al., 1995).

Accusations have been made that fluoride inhibits enzyme activity in humans. According to generally accepted scientific knowledge and summarized in a report by the World Health Organization, no evidence has shown that fluoride ingested through optimally fluoridated drinking water has an effect on the metabolism of food, vitamin utilization, or any other hormonal or enzymatic action (Jenkins et al., 1970). Experiments in which enzymes were inhibited by fluoride in human tissues used concentrations hundreds of times higher than concentrations present in the body (Kaminsky et al., 1990). Because of rapid uptake of fluoride into hard tissues and excretion by the kidneys, it is not possible for humans to maintain a fluoride concentration necessary to affect enzymatic activity (American Dental Association, A, 2005).

A small study published in the 1950's in which researchers tried to treat hyperthyroid patients with fluoride raised concern about the effect of water fluoridation on the thyroid gland. However, the researchers in that study had injected patients with massive doses of fluoride, rather than allow them to simply drink fluoridated water (Galletti & Joyet, 1958). In order to resolve whether or not fluoride in drinking water has an effect on the thyroid gland, researchers analyzed thyroid function of two groups of people. Over ten years, one group drank water fluoridated at a level of 3.48 ppm, while the other drank water fluoridated at 0.09 ppm. The study showed no differences in thyroid size or function between the two groups (Leone et al., 1964). Furthermore, two other studies have investigated the connection between fluoride and thyroid cancer. Both concluded that optimally fluoridated water did not cause thyroid cancer (Hoover et al., 1976; Kinlen, 1975).

Research has also shown that fluoride is not genetically hazardous. Unfortunately, no studies directly testing the genetic effects of fluoride on the entire human body have been published, but several comprehensive studies have been done using mice (National Research Council, 1993). Even at fluoride concentrations 100 times that of optimally fluoridated water, these studies failed to demonstrate chromosomal changes to bone marrow or sperm cells (Kram et al., 1978; Li et al., A, 1987; Li et al., B, 1987; Zeiger et al., 1994; Li et al., C, 1987; Dunipace et al., 1989; Li et al., 1989). Another study tested the effects of fluoride on human white blood cells, which are incredibly susceptible to genetic mutations. Fluoride did not have any adverse effects on the white blood cells and actually protected against the effects of a known mutagen (Obe & Slacik-Erben, 1973; Slacik-Erben & Obe, 1976). The safety of water fluoridation with respect to genetics is supported by the National Research Council of the National Academy of Sciences, which states that fluoride concentrations must be 170 times the concentration found in fluoridated water to have a chromosomal effects on mammalian cells (National Research Council, 1993).

One specific chromosomal abnormality which has been inappropriately linked to water fluoridation is Down syndrome. Concern arose because of two articles published in 1953 and 1963 by a psychologist who tried to discover if a relationship exists between the two (Rapaport, 1953; Rapaport, 1963). Researchers from the National Institute of Dental Research and the National Institute of Mental Health discredited those studies after finding serious flaws in their designs, procedures, and validity (Hodge & Smith, 1965). Several studies, including a comprehensive study of 44 U.S. cities, have since been conducted. Researchers have found a consistent incidence of Down syndrome across fluoridated and non-fluoridated communities, demonstrating that the ingestion of optimally fluoridated water by a pregnant woman does not

cause Down syndrome (Berry, 1958; Needleman et al., 1974; Erickson et al., 1976; Knox et al., 1980; Erickson, 1980).

A 1995 study caused some apprehension over whether or not fluoridated water causes attention deficit disorder, other central nervous system disorders, or has any detrimental effect on intelligence, claiming that rats who were fed extremely high levels of fluoride showed cognitive impairment (Mullenix et al., 1995). However, scientists who reviewed the study found that faulty experimental design led the researcher to reach invalid conclusions (Ross & Daston, 1995). In a generally accepted study, researchers examined populations of children from both optimally fluoridated communities and fluoride-deficient communities. Physical health and behavioral characteristics of the children were studied from birth to age six, with medical records and reports from parents and teachers being taken into account as well. The results showed no differences in the mental function of the children who drank optimally fluoridated water compared to those who did not (Shannon et al., 1986).

In addition, a link has been suggested between fluoride and Alzheimer's disease. A study published in 1998 (Varner et al., 1998) raised some alarm, but several inconsistencies in the experimental design prevent any conclusive evidence (American Dental Association, 1998). On the other hand, those that believe aluminum may contribute to the development of Alzheimer's propose that fluoride may be beneficial in Alzheimer's prevention as the two compete for absorption in the body (Kraus & Forbes, 1992; Newbrun, 1986). However, because the cause of Alzheimer's is not fully known, no definitive link can be shown between optimally fluoridated water and Alzheimer's disease at this time.

One group of researchers has claimed that silicofluoride, one of the additives used to fluoridate community water supplies, causes the water to corrode lead pipes and results in

increased blood lead levels for those who drink it (Masters, 2003). Scientists from the Environmental Protection Agency (EPA) have reviewed the studies and found that the methods used were scientifically unjustified. The EPA deduced that “no credible evidence exists to show that water fluoridation has any quantifiable effects on the solubility, bioavailability, bioaccumulation, or reactivity of lead (0) or lead (II) compounds” (Urbansky & Schock, 2000). In actuality, any corrosion of pipes is related to one or more of the following: dissolved oxygen concentration, pH, water temperature, alkalinity, hardness, salt concentration, hydrogen sulfide content, and certain bacteria (US Department of Health and Human Services, 1986). Additionally, the Centers for Disease Control and Prevention have reported that blood lead levels of U.S. children have decreased in recent years due to the discontinuation of leaded gasoline and lead paint (Centers for Disease Control and Prevention, 2003).

Research clearly shows that water fluoridation is not a risk factor for heart disease. One study looked at mortality rates in 473 cities in the United States over 20 years and found no increase in heart disease-related deaths in the fluoridated cities versus the non-fluoridated cities (Rogot et al., 1978). Another study compared the populations of 24 fluoridated cities with the populations of 22 non-fluoridated cities. Those researchers found no evidence of heart disease or any other harmful health effects that could be attributed to water fluoridation (Erickson, 1978). The National Heart and Lung and Blood Institute of the National Institutes of Health and the American Heart Association have both released statements solidifying the safety of public water fluoridation with regard to the cardiovascular system (US Department of Health, Education and Welfare, 1972; American Heart Association, 2005).

The accusation that water fluoridation has a negative effect on kidney function is perhaps one of the most well-known arguments against water fluoridation. This is a sensible idea, since

the kidneys are exposed to more fluoride than most other body tissues because they are responsible for removing excess fluoride from the body. Several large studies have been conducted on this issue, and findings show that long-term exposure to water fluoride concentrations of up to 8 ppm, far above the level water supplies are adjusted to, produce no detrimental effects on kidney function (Leone et al., 1954; Schlesinger et al., 1956; Geever et al., 1958). A 1993 report issued by the Subcommittee on Health Effects of Ingested Fluoride of the National Research Council declared that the threshold fluoridation level which could possibly start to cause impaired kidney function is around 50 ppm. As this level is more than 12 times higher than the maximum level allowed by the EPA, there is a large margin of safety against human kidney toxicity (National Research Council, 1993). The only valid concern is with kidney failure patients on hemodialysis, as that procedure exposes a patient to large amounts of water in a small amount of time. For this procedure, hospitals are directed by the U.S. Public Health Service to use de-ionized water (US Department of Health and Human Services, Public Health Service, 1980; Centers for Disease Control, 1980).

Aside from concern that water fluoridation causes adverse health effects, there are some who raise questions concerning its effect on the environment. Studies have found that optimal levels of fluoride in drinking water cause no adverse effects on the environment and are safe for animals, plants, gardens, and lawns (Tacoma-Pierce County Health Department, 2002; Pollick, 2004). In 1990, a comprehensive literature review was conducted on the impact of fluoride on the environment, and no negative effects were discovered (Osterman, 1990).

Dental Fluorosis

The only justifiable concern with water fluoridation is the fact that a higher than optimal fluoride intake can cause a condition called dental fluorosis. According to the ADA, “dental fluorosis is a change in the appearance of teeth and is caused when higher than optimal amounts of fluoride are ingested in early childhood while tooth enamel is forming.” (American Dental Association, A, 2005, p. 28). Enamel formation of all permanent teeth except for wisdom teeth happens between birth and age five. After tooth enamel finishes formation, fluorosis cannot develop, so older children and adults have no risk of dental fluorosis. Additionally, fluorosis occurs only while teeth are forming below the gum line, so teeth that have already erupted are not at risk for dental fluorosis (American Dental Association, A, 2005).

Although mild cases are not detectable by general perception, severe cases can result in color changes and surface irregularities to the teeth which are typically more obvious. Dental fluorosis is regarded as an aesthetic concern and is not a functional issue. It is also worthwhile to note that several other developmental conditions which are not due to fluoride ingestion can affect the appearance of tooth enamel (American Dental Association, A, 2005). The most recent National Health and Nutrition Examination Survey found that only 2% of school children in the United States have aesthetically displeasing tooth markings which could be attributed to dental fluorosis, and even fewer than that have such markings on the more aesthetically important front teeth (Griffin et al., 2002).

At the recommended level of water fluoridation, studies have shown that only a small number of very mild cases of dental fluorosis have developed, and patients and onlookers are usually not even able to see any differences in tooth appearance (Stephen et al., 2002; Selwitz et al., 1997). The majority of cases can be attributed to consuming a level of fluoride above the

recommended levels (American Dental Association, A, 2005). Studies indicate that fluoride intake from foods, beverages, and water has remained relatively consistent over the last 50 years. Since this is the case, it is highly unlikely that these factors contribute to recent cases of dental fluorosis (Pendrys & Stamm, 1990; Jackson et al., 2002; Whitford et al., 1996). In fact, nearly all cases of dental fluorosis could be prevented by restricting the ingestion of topical fluoride products, like fluoride toothpaste, and avoiding unnecessary supplementation without removing the decay protecting benefits of optimally fluoridated water (American Dental Association, A, 2005).

Since 1992, the ADA has required that toothpaste manufacturers include a warning on their labels cautioning that children under six years of age should only use a pea-sized amount of toothpaste. Before this age, the swallowing reflex is not fully developed, so children are more likely to swallow toothpaste while brushing. In addition, enamel formation is generally complete by age six, so the development of dental fluorosis is not a risk after this age (American Dental Association, A, 2005). Several studies have shown a link between the inadvertent swallowing of toothpaste in young children and the development of dental fluorosis in both fluoridated and non-fluoridated communities (Levy, 1993; Stookey, 1994; Pendrys et al., 1996).

Before 1994, strict protocol was not established for appropriate fluoride supplementation for children. Unfortunately, this led to children taking fluoride supplements inappropriately, which in some cases caused dental fluorosis (Pendrys, 2000). In 1994, the ADA, the American Academy of Pediatrics, and the American Academy of Pediatric Dentistry approved a dietary fluoride supplementation schedule for children living in non-fluoridated areas. These guidelines take into account additional fluoride sources from food and beverages in order to strike the proper balance between the protective effects of fluoride and the development of dental fluorosis

(Preface: Dosage Schedule for Dietary Fluoride Supplements, 1999). Additionally, the Food and Nutrition Board of the Institute of Medicine has approved a table of dietary reference intakes of fluoride per day based on age, weight, and gender (Institute of Medicine, Food and Nutrition Board, 1997). Because of the differences in individual diets and lifestyles, dentists and hygienists should carefully evaluate a child's fluoride history before prescribing fluoride supplements (Margolis et al., 1975; Pendrys, 1995).

It is important to maintain the proper risk-benefit balance in the use of fluoride in order to maximize decay prevention and minimize dental fluorosis. Dental fluorosis causes enamel discoloration, an aesthetic condition, while dental decay is an oral disease which can destroy teeth and impair function (Lennon, 2006). Since proper use of fluoride products combined with the optimal level of water fluoridation clearly produces protective effects against dental caries and zero to very few cases of mild dental fluorosis, the benefits of water fluoridation outweigh the risks (Lennon, 2006; Do and Spencer, 2007; Jackson et al., 1995). That being understood, the situation does require constant monitoring. Recommended dosage levels have been changed in the past when new information has become available. The ADA persistently reviews the latest scientific information in order to determine if its fluoride guidelines are correct and modifies its recommendations as needed (American Dental Association, A, 2005).

Cost Effectiveness

Community water fluoridation has been cited as “one of the very few public health procedures that actually saves more money than it costs.” (Burt, 1989). The cost of fluoridating a public water supply differs slightly among communities based on population and water usage, the number of points where fluoride is added to the water system, the amount and type of

equipment used to add and monitor fluoride, cost of the fluoride additive used, and expertise of the water plant workforce. However, the annual costs to fluoridate a community water supply range from around \$0.50 per person in large cities to \$3 per person in smaller towns. For each person, the cost to fluoridate the water is remarkably less than even one dental filling per year. Treatment of dental disease hurts those directly paying for it and the population as a whole because increased treatment costs result in higher health insurance premiums and increased taxes. For the average U.S. city, every \$1 spent on water fluoridation saves \$38 in dental treatment costs (Griffin et al., 2001).

A 2005 study conducted in Colorado looked specifically at cost savings associated with community water fluoridation programs. After gathering data across the state, the researchers calculated that water fluoridation in Colorado resulted in a \$148.9 million total savings, an average of \$60.78 per person, in 2003. At the time of the study, 52 water systems in Colorado still lacked water fluoridation programs. The researchers estimated that if these remaining cities implemented community water fluoridation as well, the state would save another \$46.6 million per year (O'Connell et al., 2005).

Some opponents of community water fluoridation suggest that we use fluoride supplementation on an individual basis, but that method is not nearly as cost effective. Prescription fluoride supplements cost considerably more than public water fluoridation. That knowledge, combined with the fact that supplements require a high level of compliance over a long time period, results in significant economic and procedural problems for individual fluoride supplementation as opposed to community water fluoridation (American Dental Association, A, 2005).

CENTRAL THEMES TO BE ADDRESSED

Primary Research Question: Should cities fluoridate their public water systems?

Sub-Questions: Because the scientific literature is so strongly in favor of public water fluoridation, I need to answer a few sub-questions in order to fully understand the topic and make the best possible conclusion.

1. Given the support of the scientific literature in favor of water fluoridation, what information is circulating that is causing negative public opinion?
2. Although negative public opinion may not be based on scientific research, is it strong enough to overwhelm the scientific research in favor of public water fluoridation?

METHODOLOGY

Collection of Pseudo-Scientific Literature

There is a lot of literature in circulation that argues against water fluoridation. Critics make a number of claims, ranging from declarations that water fluoridation causes adverse health affects to allegations that it is a means of mind control by the government. This information is not found in reputable scientific journals, but it circulates widely on the Internet. Although the literature may not be based on fact, it is nonetheless in circulation and may therefore be affecting the opinions of Americans on the topic of water fluoridation.

Though there is a wealth of this pseudo-scientific literature in circulation, the main arguments against water fluoridation are fairly consistent. In this section of my methodology, I will present an overview of the arguments against water fluoridation. Many of these arguments have already been refuted by the scientific information presented in my Literature Review.

However, I will also look further into a few examples of each argument and examine the reasoning and tactics used to present each argument.

Claim: Fluoride is not good for teeth.

Perhaps the most startling pseudo-scientific claim against water fluoridation is the allegation that fluoride is not good for teeth. Since benefitting teeth is the purpose of water fluoridation, this is clearly a very serious accusation. Though this claim exists across much of the body of pseudo-scientific literature against water fluoridation, I will analyze a few examples to determine some sources of faulty reasoning.

According to a web page created by Action Pennsylvania, an anti-fluoridation group, “many studies...have shown that the alleged benefits of fluoride are topical and that ingesting fluoride does not help fight cavities.” The group goes on to compare water fluoridation to swallowing suntan lotion (Action Pennsylvania, 2007). The problem with this argument is that although the group claims “many studies” support their allegations, they fail to cite a single one. On the contrary, my literature review does cite several studies that demonstrate the protective effects of fluoride both topically and systemically (Newbrun, 2004; Hargreaves, 1992; Singh et al., 2003; Singh & Spencer, 2004). According to the American Dental Association and reinforced by the cited studies, water fluoridation provides maximum protection against dental decay because it is absorbed systemically prior to tooth eruption to allow incorporation into the teeth during development, and it exposes teeth to topical protection after tooth eruption (American Dental Association, A, 2005).

The only information Action Pennsylvania uses to support their claim is the fact that Pittsburgh and Philadelphia, both of which have had fluoridated water supplies since the 1950’s,

have tooth decay rates above the state average (Law, 2005; Action Pennsylvania, 2007). The group is using a *post hoc* fallacy, which assumes that because A occurs before B, A must be the cause of B. This is incorrect because correlation does not ensure causation (The Nikzor Project, 2009). The group believes that since Pittsburgh and Philadelphia have established water fluoridation programs and high tooth decay, fluoride must be causing tooth decay. Action Pennsylvania does not cite other factors which could be contributing to tooth decay, including the fact that Pittsburgh and Philadelphia have poverty rates far above the state average (Boston, 2008), which may be resulting in inadequate dental care for residents and therefore increasing the level of dental decay.

Similar arguments are made by Paul Connett. Dr. Connett also claims that fluoride is ineffective because fluoride's benefits are more topical than systemic and even cites a few studies in his reasoning (Connett, 2002). However, the studies Dr. Connett cites show that fluoride is beneficial in reducing tooth decay (Featherstone, 2000; Fejerskov et al., 1981). Dr. Connett also claims that fluoride makes only "a minute difference in tooth decay," (Connett, 2002) but studies show that water fluoridation continues to reduce tooth decay by 20-40% (Newbrun, 1989; Brunelle & Carlos, 1990).

Comparable to Action Pennsylvania, Dr. Connett makes a fundamental reasoning error by claiming that because fluoride is not a primary component in breast milk, it must not be necessary for strong teeth. It is worthwhile to note that breast milk also does not contain vitamin D, which is necessary for calcium uptake into the bones. In fact, the University of Michigan's C.S. Mott Children's Hospital recommends both vitamin D and fluoride supplements beginning at two and six months, respectively, for babies who are breastfed (Schmitt, 2006). It is incorrect

for Dr. Connett to assume that just because something is not in breast milk does not mean it is not an important component of good health.

I have discovered countless other web sites making claims similar to those asserted by Dr. Connett and Action Pennsylvania, all of which have either made some type of fundamental reasoning error or have inappropriately used studies to back up their claims. In one rant on a petition web site, a blogger claims he or she has not seen any studies that link fluoride to healthy teeth (True, 2000). In reality, the number of studies demonstrating the protective effects of fluoride against tooth decay is overwhelming (Newbrun, 2004; Hargreaves, 1992; Singh et al., 2003; Singh & Spencer, 2004; Newbrun, 1986; Lambrou et al., 1981; Featherstone, 2000; Backer-Dirks et al., 1978; Silverstone, 1993; Featherstone, 1987; Fejerskov et al., 1981; Silverstone et al., 1981; Newbrun, 1989; Brunelle & Carlos, 1990; Arnold et al., 1962; Ast & Fitzgerald, 1962; Blayney & Hill, 1967; Stephen et. al, 2002; Do & Spencer, 2007; Kumar et al., 1998; Jackson et al., 1995; Selwitz et al., 1998; Lemke et al., 1970; Stephen et al., 1987; Attwood & Blinkhorn, 1991; Brown & Poplove, 1965).

Claim: Fluoride causes adverse health effects.

One of the largest pseudo-scientific claims against water fluoridation is that it has a number of detrimental effects on several aspects of the human physiology. My literature review features extensive research on fluoride's effects on the entire body. I will present a number of these pseudo-scientific claims in this section and assess the use of questionable studies and the reliability of reasoning and highlight peer-reviewed, generally accepted research which refutes these claims.

One claim against water fluoridation is that fluoride is neurotoxic and has detrimental effects on IQ and other brain function. One web page states that a study shows fluoride causes both hyperactivity and hypoactivity in animals (Holistic Medicine Resource Center, n.d.). First of all, a claim that suggests a single substance produces polar opposite effects should raise some concern about its validity. Secondly, after further review, I found that the web site uses the 1995 study by Mullenix to support its claim. As stated in my literature review, that study has been discredited due to faulty experimental design and invalid conclusions (Ross & Daston, 1995).

Noting a specific neurological disorder, multiple sources claim that fluoride causes Alzheimer's disease (Holistic Medicine Resource Center, n.d.; True, 2000), and some suggest that fluoride's affinity to bond with aluminum, which some believe contributes to Alzheimer's, is the problem (True, 2000; Connett, 2002). Both Connett and the Holistic Medicine Resource Center cite a 1998 study by Varner et al., but several inconsistencies in experimental design have been uncovered in that study, resulting in a lack of conclusive evidence (American Dental Association, 1998). On the contrary, generally accepted studies show that fluoride actually competes with aluminum for absorption in the body and does not bond with it, therefore having a potentially preventative effect against aluminum absorption (Kraus & Forbes, 1992; Newbrun, 1986).

Among the most popular claims against water fluoridation is that it has a detrimental effect on bone health (Wikipedia, A, 2009; Connett, 2002; Holistic Medicine Resource Center, n.d.; Action Pennsylvania, 2007). One of the most serious of these claims is that water fluoridation causes bone cancer. Authors of pseudo-scientific literature against water fluoridation claim that bone cancer incidence is higher in fluoridated areas, but even Connett, one of the most tireless opponents of water fluoridation, admits that his concerns are "unproven."

(Connett, 2002). In actuality, several researchers have studied the effects of water fluoridation on bone health, and over 50 studies conducted all over the world have failed to show a link between water fluoridation and osteosarcoma (reviewed by US Department of Health and Human Services, Public Health Service, 1991). The Holistic Medicine Resource Center also claims that another serious bone condition, skeletal fluorosis, is caused by water fluoridation and that drinking fluoridated water over several years can be “expected to cause these symptoms in large numbers of people” (Holistic Medicine Resource Center, n.d.). The web page cites no research to back up its claims. In actuality, studies have shown that skeletal fluorosis was not present in communities whose water supplies contained a natural fluoride level 20 times the level used to fluoridate water supplies (Institute of Medicine, Food and Nutrition Board, 1997; Hodge, 1979). In addition, large numbers of people are not developing skeletal fluorosis under any conditions, as only five cases of the rare condition have been documented in the United States within the last 35 years (Institute of Medicine, Food and Nutrition Board, 1997).

It is clear that the main issue in this category of claims against water fluoridation is using the support of discredited studies. As with the issues already discussed, pseudo-scientific literature asserting that water fluoridation causes Down Syndrome, inhibits enzymatic action in the body, increases lead exposure, and suppresses thyroid function (Holistic Medicine Resource Center, n.d.; Action Pennsylvania, 2007; Wikipedia, 2009; Connett, 2002), are supported by disreputable or inappropriately cited studies (Rapaport, 1953; Rapaport, 1963; Kaminsky et al., 1990; Galletti & Joyet, 1958; Masters, 2003) which used fluoride levels hundreds of times higher than levels present in fluoridated water or which used experimental methods that have been discredited by reviewers and valid studies (Hodge & Smith, 1965; Jenkins et al., 1970; American Dental Association, A, 2005; Leone et al., 1964; Urbansky & Schock, 2000).

As stated in my literature review, an overwhelming wealth of scientific research has shown that, at the recommended levels, fluoride is safe for the entire body and does not pose risks for any health problems (National Research Council, 1993). As with other nutrients, such as chlorine, sodium, and even water, fluoride is safe and effective when consumed in appropriate amounts (US Department of Health and Human Services, Public Health Service, 1998). The EPA has placed a conservative ceiling of 4 ppm on the fluoridation of water supplies, ensuring protection against undesirable effects with a generous margin of safety (58 Fed. Reg. 68826,68827, 1993). At this level, far above the fluoride content of any adjusted water supply, no accusation against the benefits and safety of water fluoridation has ever been validated by the body of generally accepted scientific knowledge (US Department of Health and Human Services, Public Health Service, 1998).

Claim: Water fluoridation programs are costly.

Several sources, including Action Pennsylvania and Dr. Connett, claim that water fluoridation programs are too costly (Connett, 2002; Action Pennsylvania, 2007). The problem with these arguments is that the opponents of water fluoridation are looking at the cost of the programs alone and not taking into account how much money water fluoridation saves in dental costs and health insurance premiums. For example, Action Pennsylvania cites that a water fluoridation program implemented in Salt Lake City, UT had a cost of \$2.6 million (Action Pennsylvania, 2007). However, the Salt Lake City area has a population of 1.2 million (Salt Lake City Demographics). This works out to a cost of \$2.17 per resident, a relatively small cost. In fact, Salt Lake City is a more expensive example, as the annual costs to fluoridate a community water supply range from around \$0.50 per person in large cities to \$3 per person in

smaller towns. For each person, the annual cost to fluoridate the water supply is remarkably less than even one dental filling per year. The average U.S. city saves \$38 in dental treatment costs for every \$1 spent on water fluoridation (Griffin et al., 2001).

Although community water fluoridation has been cited as “one of the very few public health procedures that actually saves more money than it costs,” (Burt, 1989) Dr. Connett suggests that a more cost-effective approach would be to provide fluoridated bottled water free of charge in supermarkets (Connett, 2002). To undertake a measure like that, the provider would not only have to pay for fluoride and to implement a water fluoridation system, just like a city would, but it would also have to pay to bottle the water and distribute it. Not charging for the water would add more costs comparatively, as residents do pay for city water usage. In addition, the extra use of plastic would not be a prudent choice for environmental reasons. Clearly, giving away free bottled water would be much more costly than fluoridating a city’s water supply.

Claim: Water fluoridation is a means for the government to exercise mind control.

Perhaps the most intriguing claim against water fluoridation is the idea that it is a governmental conspiracy designed to exercise mind control over the masses. Countless Internet web sites make this claim (True, 2000; Rense, 2008; Montgomery, 2000), alleging that fluoride was used in Nazi Germany to make humans “stupid, docile, and subservient” (True, 2000). They fail to provide data or cite studies to back up their claims. The most common evidence provided by these sources are quotes from fellow conspiracy theorists and a letter from a chemist written in the 1950’s who toured a German pharmaceutical company and believed the Nazi regime plotted to use fluoride to reduce resistance to their domination (True, 2000; Rense, 2008; Montgomery, 2000). Similarly, during the Red Scare in the 1940’s and 1950’s, conspiracy

theorists declared that fluoridation was a government plot to impose a communist regime on America (Wikipedia, A, 2009).

After an extensive search of multiple scientific databases, I was unable to find any data or medical records from Nazi Germany to either support or refute the claims that the Nazis used fluoride in concentration camp water. However, even if they did use fluoride, we cannot be certain of the amounts used – they could have been hundreds of times the levels currently used to fluoridate public water supplies. We also cannot assume, if fluoride was used, that it was actually effective in making prisoners submissive or that the current U.S. government is exercising a large-scale mind control plot. As previously stated, fluoride levels used in water fluoridation have not been shown to cause any detrimental effects to intelligence or mental function (Shannon et al., 1986).

Claim: Water fluoridation is not ethical.

There are a number of anti-fluoridation advocates who propose that fluoride is unethical, claiming that it is a form of forced mass medication (Action Pennsylvania, 2007; Shattuck, 2001; Connett, 2002; Holistic Medicine Resource Center, n.d.). While I can understand the basis for this assertion, I would argue that there are several reasons why it does not make sense given the scientific support for water fluoridation and the way our country is governed.

Some sources specifically claim that fluoridation infringes upon a person's right to consent to medication (Connett, 2002; Holistic Medicine Resource Center, n.d.; Shattuck, 2001). First of all, because of the American system of government, we *have* consented to fluoridating water in areas where water is fluoridated. We live in a representative democracy, so policies are being implemented either by people we have elected, or, in many cases, by direct vote. If a city

votes to fluoridate its water supply, it is giving consent. Second of all, medicine is defined as “any substance or substances used in treating disease or illness; medicament; remedy” (Dictionary.com, 2009). Fluoride does not fit the definition of medicine since it is a preventative measure, not a treatment for existing illness. It is similar to other public policy measures designed to prevent disease, including chlorinating public water systems or pasteurizing milk to kill disease-causing bacteria.

Another specific argument (Connett, 2002; Cross & Carton, 2003) that challenges the ethics of water fluoridation is the assertion that fluoridating public water supplies is a violation of the Nuremberg Code. The Nuremberg Code is a set of experimental research guidelines developed after the Nuremberg Trials, in which improper experimentation of Nazi doctors on concentration camp prisoners was revealed (U.S. Government Printing Office, 1949; National Institutes of Health Office of Human Subjects Research; Wikipedia, B, 2009). The Nuremberg Code does not even apply to public water fluoridation because fluoridating public water supplies is, in current times, not an experimental procedure. A multitude of studies have been conducted in the past on water fluoridation and have shown it to be safe and effective. At this point in time, water fluoridation is not an experiment – it is a scientifically supported, government approved public health policy.

Case Study of an Un-fluoridated City Water Supply: Prairie du Chien, Wisconsin

The science is very clear: water fluoridation is a safe and effective public health measure that provides important dental health benefits. However, there is also a lot of pseudo-scientific literature opposing water fluoridation. In the face of these conflicting messages, cities often have

a difficult time coming to a conclusion on whether or not their water supply should be fluoridated. One such town is Prairie du Chien, Wisconsin.

Prairie du Chien is located in Crawford County. Crawford and three proximal counties, La Crosse, Monroe, and Vernon, are served by a social service organization called Couleecap. Couleecap is a nonprofit organization which provides resources and opportunities to allow low-income people to satisfy their needs, increase self-confidence, and become self-sufficient. Couleecap advocates on issues in order to help accomplish its mission (Couleecap, 2009).

Couleecap has identified dental care and related cost concerns as one of the top five most serious household issues in the area it serves. Based on the Wisconsin Public Water Supply Fluoridation Census of 2005, only four of the 38 communities in Couleecap's service area have public water supplies. More than 21,000 residents (including 6,500 children) live in poverty and have limited access to regular dental care. Because fluoridation of public water supplies is the most cost-effective oral disease prevention method, implementing the practice would greatly benefit the oral health of residents (McCabe, A, 2009).

Two grants provided by the Wisconsin Partnership Program allowed Couleecap to hire both a health advocate, Martha McCabe, and an academic partner, Dr. James Terman, who has been involved in past successful water fluoridation initiatives. With the help of Dr. Terman, Ms. McCabe facilitated the formation of committees in both Prairie du Chien and Holmen, another Wisconsin town in Couleecap's region. The committees in both towns organized grassroots campaigns to educate the public, using tools such as local print, television, and radio media, distribution of literature to private homes, yard signs, and local health fairs. After voting took place on November 4, 2008, the citizens of Holmen passed a binding fluoridation referendum by

a vote of 2,118 to 1,856. The fluoridation initiative was unsuccessful in Prairie du Chien, losing by a vote of 1,542 to 1,014 (McCabe, A, 2009).

Following the campaign, differences between the two towns were analyzed. The success of the referendum in Holmen is believed to come in large part from more time to educate citizens. For two and a half years prior to the referendum, a dentist in Holmen discussed the safety and effectiveness of water fluoridation with his patients at every visit. His involvement educated the citizens of Holmen far in advance of the referendum. In addition, the communities surrounding Holmen have been fluoridating their water supplies for several years, so many Holmen residents were already familiar with the process (McCabe, A, 2009; McCabe, personal communication, 2009).

Prairie du Chien had only nine months to prepare for its fluoridation referendum. While the committee had support of the local hospital, medical clinics, and dentists, a few other conditions interfered with the committee's efforts (McCabe, A, 2009). First, Prairie du Chien is located in a more rural area than Holmen. Many towns around Prairie du Chien are un-fluoridated as well, so residents are not as familiar with the idea. In addition, the lack of education of many of the residents of Prairie du Chien resulted in higher susceptibility to believing anti-fluoridation propaganda. Second, the local media in Prairie du Chien was largely unsupportive of the fluoridation initiative. Because the local newspaper editor was a fluoridation opponent, there was a bias in newspaper printing with far more coverage of anti-fluoridation pieces than pro-fluoridation pieces, including running two full page anti-fluoridation pieces a few days before the election (McCabe, personal communication, 2009). In addition to the bias of the local newspaper, the local school allowed the school e-mail system to be flooded by anti-fluoridation messages. Finally, the opposition to the fluoridation initiative did not register as a

referendum group, so there may have been campaign violations on the part of the opposition (McCabe, A, 2009).

Because of the current state of the economy, grant funding for the fluoridation initiative in Prairie du Chien has been cut³. The steering committee in Prairie du Chien has been renamed the Crawford County Oral Health Coalition. The committee will continue to focus on oral health issues, and another fluoridation initiative is still of interest (McCabe, A, 2009; McCabe, personal communication, 2009).

Before attempting another fluoridation initiative, McCabe identified two improvements which should be made on a future campaign. First, the fluoridation committee needs to gain at least fair and adequate support of the local newspaper. McCabe suggests that the committee meet with the editor six months to one year ahead of the vote for the referendum with the aid of health professionals to educate him about the fluoridation process and ask for balance of both sides of the issue in print. Second, the success in Holmen has demonstrated that getting local dentists and physicians to speak with patients at every visit starting one and a half to two years ahead of the referendum is invaluable. One-on-one discussion with a trusted health care professional could be very effective in educating the public and combating the scare tactics of anti-fluoridation propaganda (McCabe, personal communication, 2009).

CONCLUSIONS AND DISCUSSION

This paper has provided a comprehensive overview of public water fluoridation and the issues surrounding it. Based on all of my research, I have come to the conclusion that cities should fluoridate their public water systems. The science clearly shows that public water

³ It is worthwhile to note that, under conditions of a normal economy, the committee was successful enough to continue to receive funding. However, the severe economic recession has caused funds to become unavailable.

fluoridation is safe for all parts of the body and has a significant impact on dental health in the way of cavity protection. Tooth decay is the most common and costly oral health problem across the population. Adequate public water fluoridation is the most cost-effective oral disease prevention strategy, and it benefits the entire population, regardless of age, socioeconomic status, education, or social circumstances. While this measure is cost-effective for all citizens and has an especially positive impact on low-income people who may not have regular access to dental care, it is becoming increasingly important for all citizens in our current state of economic distress.

As with nearly all public policy measures, there will be some people who do not agree with public water fluoridation. Martha McCabe, the Health Advocate for Couleecap and an instrumental part of the aforementioned recent fluoridation initiatives, explained the issue by comparing it to seat belt laws. Our country feels it is important to protect public health, so laws and policies are put in place to accomplish that mission. If one does not agree, there are ways to avoid compliance – one can pay a ticket to not wear a seat belt or choose to buy un-fluoridated bottled water. However, the fact that some people do not agree should not stop the majority of the population from enjoying the health benefits of any public health policy, including adequately fluoridated water (McCabe, personal communication, 2009).

Additionally, the disagreement of some segments of the public with public water fluoridation may be mitigated with proper education. Unfortunately, the Internet has the potential to negatively impact movements in favor of water fluoridation. When one simply uses a search engine to attempt to find information about water fluoridation, the majority of the search results are non-scientific anti-fluoridation web sites. Authentic scientific information from peer-reviewed journals is not as readily available to the public (McCabe, B, 2009). Since many

people like to use the Internet for research, it is important to give community members specific sites to visit for factual information (Terman, 2009). The efforts in Holmen and Prairie du Chien demonstrated that an effective tactic to combat unsupported negative information is one-on-one education by health care professionals and grassroots neighborhood canvassing by concerned citizens. Positive education on water fluoridation proved to be much more effective in areas where the citizens were more educated, and therefore less likely to be swayed by negative, emotionally-laden propaganda. Fluoridation initiatives are also more successful in areas where surrounding communities have fluoridated water supplies and can serve as an example that they are not suffering any of the dire consequences proposed by anti-fluoridation advocates (McCabe, B, 2009).

To combat anti-fluoridation propaganda and effectively pass a water fluoridation referendum, Martha McCabe, James W. Terman, M.D., and members of the local committees in Prairie du Chien and Holmen have formulated 13 strategic principles:

1. *Begin the process by recruiting a small core group of workers who can learn the facts, are intimately familiar with their community, have patience, good interpersonal skills, and energy to persevere* (McCabe, B, 2009). Most people do not know a lot about water fluoridation, and credibility is not built in. Because fluoride is a chemical, it can be perceived as threatening. It is necessary to utilize credible people who can spread the word steadily and will be trusted by their fellow citizens (Terman, 2009).
2. *A leader needs to step forth. This could be a health professional if he or she fills the above criteria* (McCabe, B, 2009). Health professionals are often good candidates because they are more familiar with the science (and therefore do not need to be

educated or convinced) and may be passionate about the issue. However, a dedicated leader who is not a health professional can be just as effective. If the leader is a health professional, the group should not assume people will automatically believe him because of his profession. The leader must be willing to work and expect trials along the way (Terman, 2009).

3. *Unless they have excellent grassroots political and public communication skills, dentists and physicians would be better used as resources, consultants, and reviewers* (McCabe, B, 2009). Although dentists and physicians may be experts from a health or science perspective, they may not be familiar with the politics of a referendum. Health professionals can be very effective in educating their patients on the benefits and safety of fluoride, but it is also necessary to involve parties who are able to master the politics of the issue (Terman, 2009).
4. *The core group could expand to a full-fledged steering committee with assigned subdivided tasks. Other committees may work as a committee-of-the-whole* (McCabe, B, 2009). Generally, a group will function most effectively by learning work skills of individual members and dividing up the tasks. However, all groups are different, so it is important for each committee to find out how its members work best (Terman, 2009).
5. *As much literature as possible should be studied, as every possible issue will be raised and challenged* (McCabe, B, 2009). It is critical to have lots of scientific information to use, and the people speaking to the public should be very well informed. The opposition will bring up anything it can think of, and a committee cannot afford to look ignorant (Terman, 2009).

6. *Someone in the group should be very familiar with the community, its demographics, power structure, history, social issues, and decision making methods* (McCabe, B, 2009). This is a critical component, especially if outside facilitators are running the campaign. Each town has its own thought leaders, issues, meeting styles, and networks. It is important to be aware of a town's practices to be able to use them to the committee's advantage and to avoid unnecessary negativity (Terman, 2009).
7. *All preparations should be carried out without publicity until shortly before a public vote. Avoid any links with other contentious issues or politics* (McCabe, B, 2009). Avoid being linked with any other controversial issues. People involved with the water fluoridation initiative should not take a strong, public stance on another hot issue, as this could raise unnecessary controversy for the fluoridation initiative (Terman, 2009).
8. *The "holy grail" would be convening an enlightened city council to make a courageous favorable decision* (McCabe, B, 2009).
9. *It is much more likely that a referendum will be compelled* (McCabe, B, 2009). Once the opposition has created an aura of controversy, most elected officials will not want to take responsibility for making the decision. A referendum will most likely be the only option. The group must be aware of this and be familiar with the legal elements of referendums. It would be very beneficial to have the assistance of a lawyer or city official to aid in this area (Terman, 2009).
10. *Steady, grassroots, neighbor-to-neighbor education must begin, using as many credible thought leaders as possible* (McCabe, 2009). A small percentage of knowledgeable people will be in favor of fluoridation and will not need education.

Another small percentage will be opposed to the initiative no matter what and will not be receptive to education. Most of the citizens, however, will not feel strongly about the issue and will be willing to listen. It is important to know the community and what they will respond to in order to most effectively educate that middle group (Terman, 2009).

11. *Opposition will seek to raise controversy and confrontation. Public pronouncements and letters to the editor should be avoided* (McCabe, B, 2009). Timing is critical! Publicity should not be generated prematurely, or the town may be flooded with anti-fluoridation propaganda. Stay “under the radar” (Terman, 2009) by using a one-on-one or small group approach to educate citizens, and avoid letters to the editor until about two weeks before the vote. This will give the opposition less time to respond and raise controversy (Terman, 2009).
12. *Shortly before a public vote, when the citizens’ attention span is ready, an outpouring of favorable, cheerful, positive publicity should start* (McCabe, B, 2009). Most people do not think about issues until close to a vote, so a big, public campaign should not be carried out until right before the vote. Speak factually and honestly. Educate to oppose arguments of the anti-fluoridation group, but do not actually bring the arguments up – this would only give the opposition free press (Terman, 2009).
13. *It’s not over until it’s over* (Terman, 2009). Do not disband the group until the fluoridation initiative is passed, executed, and people forget about it. The system should run well with no publicity (Terman, 2009).

As these principles and the information presented in this paper suggest, passing water fluoridation initiatives is often a difficult process because of the existence of anti-fluoridation

propaganda and the tendency for populations to be resistant to change. However, with diligent effort and proper education of the public, it is possible to successfully pass a public water fluoridation referendum. Given the large-scale public health impact of water fluoridation, it is in the best interest of cities to provide their residents with the health care benefits offered by adequate fluoridation of their public water supplies.

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