International Academy of Oral Medicine and Toxicology (IAOMT) Position Paper against Fluoride Use in Water, Dental Materials, and Other Products for Dental and Medical Practitioners, Dental and Medical Students, the General Public, and Policy Makers

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Section 1: Summary of the IAOMT's Position against Fluoride

Fluoride exists naturally in our environment and is chemically synthesized for use in community water fluoridation, dental products, fertilizers, pesticides, and an array of other consumer items. The growth in number and popularity of products containing fluoride and fluorine compounds has led to a lifetime of chronic fluoride exposure for consumers. Unfortunately, fluoride products were introduced before the health risks of fluoride and fluorine compounds, safety levels for their use, and appropriate guidelines were adequately researched and established. Current intake estimates are generally reported on a product-by-product basis. However, combining the estimated intake levels of all potential exposure pathways suggests that millions of people are at risk of exceeding safe levels, the first sign of which is dental fluorosis. Risk assessments, recommended intake levels, and regulations must now recognize the overall exposure levels to fluoride and fluorinated compounds from the gamut of sources to adequately protect public health.

In 2006, after compiling an extensive report, the U.S. National Research Council concluded that the maximum contaminant level goals (MCLG) for fluoridated drinking water should be lowered, but the U.S. Environmental Protection Agency has not complied.

Fluoride is not a nutrient and has no essential biological function in the body. Hundreds of research articles published over the past several decades have demonstrated potential harm to humans from fluoride at various levels of exposure, including levels currently deemed safe. Scientific research has shown that fluoride exposure impacts the bones and teeth, as well as the cardiovascular, central nervous, digestive, endocrine, immune, integumentary, renal, and respiratory systems. It has been linked to Alzheimer's disease, cancer, diabetes, heart disease, infertility, osteoarthritis, neurocognitive and neurobehavioral deficits, and many other adverse health outcomes.

Accurate information for either singular or collective sources of fluoride exposure do not exist. Another concern is that fluoride interacts synergistically with other elements, including titanium, arsenic,[1] , iodine........ Allergies to fluoride, nutrient deficiencies, genetic factors, and other variables also interact with, and amplify the impact of fluoride. For example, fluoride exposure can cause greater detrimental effects in susceptible populations such as those with low body weight, including infants and children. It can also cause greater detrimental effects within individuals who consume large amounts of water, such as athletes, military personnel, outdoor laborers, and those with diabetes or kidney dysfunction. Therefore, recommending an optimal level of fluoride or "one dose fits all" level is unacceptable.

Fluoride was added to community water supplies because governments believed that it reduced the incidence and severity of cavities. However, this potential beneficial effect is controversial. Several small underpowered studies and/or studies conducted in specific populations, have shown inconsistent results.[2–4] However, the largest of its kind 10-year retrospective cohort study (2010–2020) using routinely collected National Health System dental treatment claims data was recently conducted in England, consisting of 6.4 million dental patients to assess the cost-effectiveness of water fluoridation, and its clinical effectiveness for preventing decayed, missing and filled (DMFT) teeth. Individuals exposed to drinking water with an optimal fluoride concentration (≥0.7 mg F/L) were matched to non-exposed individuals. There was a 2% reduction in DMFT (costing the consumer ~$1 per year) suggesting that fluoridating the water is not cost-effective. No compelling evidence was found that water fluoridation reduced social inequalities in dental health. The authors concluded that the small positive health effects may not be meaningful, especially when taken in consideration with the potential negative effects of water fluoridation.[5] This compelling study is supported by other studies[6] and WHO data.

As shown in Figure 1, data provided by WHO shows that the downward trend in DMFT over the past several decades has occurred in countries with and without the systemic application of fluoridated water. Note, for

example that Belgium, an unfluoridated country and the fluoridated U.S. had similar declines in tooth decay. The reasons underlying declines in tooth decay, regardless of fluoridation status, have not been examined, but may be related to increased awareness of the importance of dental healthcare and increased access to and use of dental health services. Decreases in tooth decay have also been observed in communities that have discontinued water fluoridation[7], the results of which were minimized in a systematic review conducted by McClaren et al, suggesting pre-existing bias.[8] Indeed, a recent paper published in the same journal as the McClaren article, led by Dr. Christopher Neurath, Research Director of the Fluoride Action Network outlined the flaws in the McClaren article. Importantly, omitted data favor the opposite conclusion: cessation of fluoridation had no effect on decay rates. Other weaknesses, including lack of adequate control for confounding, low participation, inadequate choice of comparison city, among others, further reduce confidence in the conclusion that fluoridation cessation increased decay.[9]

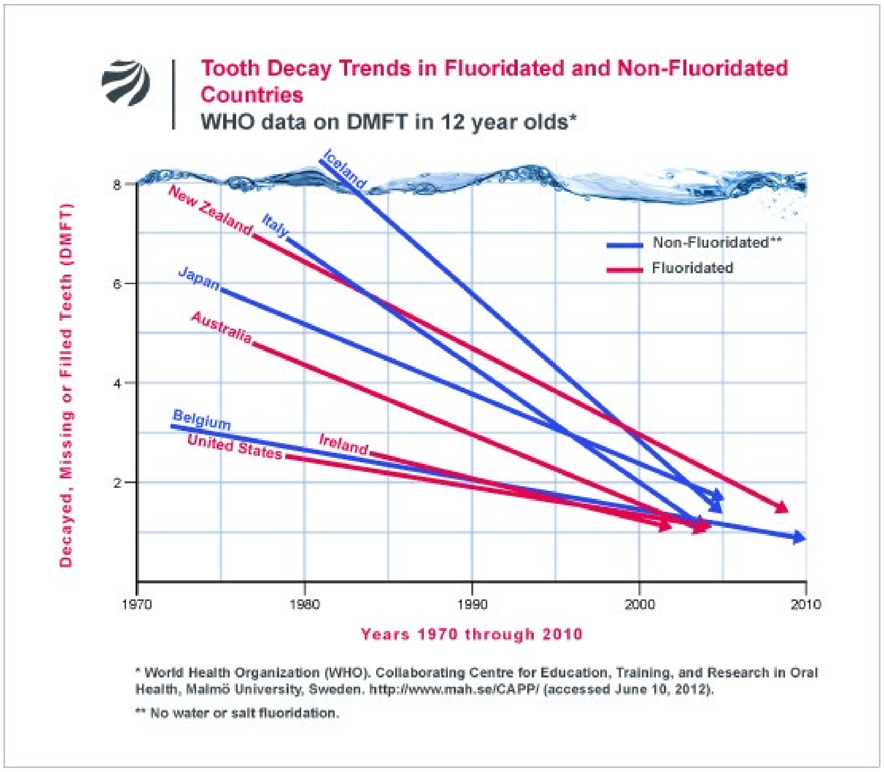


Figure 1 Abbrev: DMFT; Decayed, Missing & Filled teeth

Ethical questions have been raised regarding the use of fluoride, due in part to fluoride's ties to the phosphate fertilizer and dental industries. Researchers have reported difficulties publishing articles that show negative effects of fluoride exposure. Thus, there is an urgent need for an appropriate application of the precautionary principle (i.e. first, do no harm).

The issue of consumer choice is vital to fluoride usage for a variety of reasons. First, consumers have choices when it comes to utilizing fluoride-containing products; however, many over-the-counter products do not provide appropriate labeling. Second, the use of fluoride-containing products at the dental office generally occurs without obtaining informed consent from the patient. Third, the only choice consumers have when fluoride is added to their municipal water is to buy bottled water or costly filters, which is not a choice for the average consumer. Concerns have been raised that fluoride is added only for allegedly preventing tooth decay, while other chemicals added to water serve a purpose of decontamination and elimination of pathogens. In other words, consumers are being 'medicated' without consent.

A scientific understanding of the health effects of fluoride has been limited to promoting its benefits. Therefore, educating medical and dental practitioners, students, consumers, and policy makers about the associated potential health risks of fluoride exposure is essential to improving the dental and overall health of the public. Although informed consumer consent and more informative product labels should contribute to increasing public awareness about fluoride intake, consumers also need to take a more active role in preventing caries. Specifically, a healthier diet, focused on reduced sugar- and processed food-intake, and improved oral health practices would naturally reduce tooth decay.

Finally, policy makers are tasked with the obligation of evaluating the benefits and risks of fluoride. These officials have a responsibility to acknowledge the outdated claims of fluoride's alleged purposes, many of which are based on limited evidence of safety and improperly formulated intake levels that fail to account for multiple exposures, fluoride's interaction with other chemicals, individual variances, and independent (i.e., non-industry sponsored) science. Following evaluation, recommendations and regulations regarding 'safe' fluoride levels should be updated and enforced.

In summary, given the elevated number of fluoride sources and the increased rates of fluoride intake in the American population, which have risen substantially since water fluoridation began in the 1940's, it is necessary to reduce, and work toward eliminating avoidable sources of fluoride exposure, including water fluoridation, fluoride-containing dental materials, and other fluoridated products.

Section 2: Chemical Profile and Mechanisms of Action

Fluorine (F) is the ninth element on the periodic table and is a member of the halogen family. It has an atomic mass unit of 19.0, is the most reactive of all the non-metal elements, forming strong electronegative bonds with other chemicals. It is particularly attracted to the divalent cations of calcium and magnesium. In its free state, fluorine is a highly toxic, pale yellow diatomic gas. However, fluorine is rarely found in its free state in the environment because of its reactive nature. Fluorine commonly occurs as the minerals fluorspar (CaF_2), cryolite (Na_3AlF_6), and fluorapatite $Ca_5(PO_4)_3F$), and it is the 13th most abundant element on earth.[10]

Fluoride (F-) is the chemical ion of fluorine that contains an extra electron, thereby giving it a negative charge. Other than its natural existence in minerals, soil, water, and air, fluoride is also chemically synthesized for use in community water fluoridation, dental products, and other manufactured items. Fluoride is not essential for human growth and development .[11] In fact, it is not required for any physiological process in the human body; consequently, no one will suffer from a lack fluoride. In 2014, Dr. Philippe Grandjean of the Harvard School of Public Health and Dr. Philip J. Landrigan of Icahn School of Medicine at Mount Sinai identified fluoride as one of 12 industrial chemicals known to cause developmental neurotoxicity in humans.[12]

Fluoride readily associates with metals and is highly stable, such that fluoride can often displace the natural metals in the body such as calcium and magnesium. Summarized in a review conducted by Johnston and Strobel, 2020, and available in Table 3, the mechanisms of fluoride toxicity are complex but can be broadly attributed to four categories: inhibition of proteins, organelle disruption, altered pH, and electrolyte imbalance.[13] These four mechanisms occur to varying degrees depending on the concentration of fluoride, its route of administration in multicellular organisms, and each cell's surrounding environment.[13] Fluoride activates virtually all known intracellular signaling pathways including G protein-dependent pathways and mitochondrial processes, and triggers a range of metabolic and transcription alterations, including the expression of several apoptosis-related genes, ultimately leading to cell death.[14]

Another review by Ottappilakkil, et al, found in Table 3, summarizes the mechanisms of fluoride-induced

neurobehavioral, immunological, genetic, and cellular toxic effects.[15] This review includes a table that details the findings of 40 *in vivo* animal studies on the neurotoxic effects of fluoride. It also includes schematic diagrams elucidating the mechanisms of fluoride-induced neurotoxicity.

Section 3: Sources of Fluoride

Natural sources of fluoride include volcanic activity, soil, and water from run-off exposed to fluoride-containing rock. Unnatural sources of fluoride and fluorine compounds have expanded over the past 75 years and are largely due to large-scale industrial emissions and the development of a wide variety of fluoride-containing consumer products. Table 1 provides a list of the most prevalent natural sources of fluoride exposure and Table 2 provides a list of chemically synthesized sources of fluoride and fluorine compounds.

Table 1: Natural sources of fluoride[13,16]

Natural Source	Additional Information
Volcanic activity	Volcanic eruptions emit hydrogen fluoride, which can attach itself to ash particles [17].
Water (including groundwater, streams, rivers, lakes, and some well and drinking water)	This varies by geographic location, when water run-off is exposed to fluoride-containing rock.
Soil	Fluoride in soil can occur naturally, due to erosion/breakdown of fluoride-containing rock.
Food	Negligible levels of fluoride can occur naturally in food grown in regions with fluoride-containing soil.

Table 2: Chemically synthesized sources of fluoride

Source	
Fluoridated municipal drinking water [18]	Water: bottled water that contains fluoride[18]
Perfluorinated compounds[19]	Beverages made with fluoridated water and/or made with water/ingredients exposed to fluoride-containing pesticides[18]
Food: genera [18]	Food containing perfluorinated compounds[20]
Pesticides[18]	Soil: phosphate fertilizers and/or airborne emissions from industrial activities[18]
Air: fluoride releases from industry[18]	Dental product: toothpaste[18]
Dental product: prophy paste[21]	Dental product: mouthwash/rinse[18]
Dental product: dental floss[22,23]	Dental product: fluoridated toothpicks and interdental brushes[24]
Dental product: topical fluoride gel and foam[25]	Dental product: fluoride varnish[25,26]
Dental material for fillings: all glass ionomer cements [26]	Dental material for fillings: all resin-modified glass ionomer cements[26]
Dental material for fillings: all giomers[26]	Dental material for fillings: all polyacid-modified composites (compomers)[26]
Dental material for fillings: some composites[26]	Dental material for fillings: some dental mercury amalgams[26]
Dental material for orthodontics: glass ionomer cement, resin-modified glass ionomer cement, and polyacid-modified composite resin (compomer) cement[27]	Dental material for pit and fissure sealants: resin-based, glass-ionomer, and giomers[28]
Dental material for tooth sensitivity/caries treatment: silver diamine fluoride[29]	Fluoride tablets, drops, lozenges, and rinses[18]

Pharmaceutical/prescription drugs: fluorinated chemicals [18]such as those used in antibiotics, anti-cancer and anti-inflammatory agents [18], drugs used to induce general anesthesia, and psychopharmaceuticals[30]	Other consumer products: perfluorinated chemicals (PFCs) used as protective coatings for carpets and clothing, paints, cosmetics, insecticides, non-stick coatings for cookware, and paper coatings for oil and moisture resistance[19]
Household dust: perfluorinated compounds[31,32]	Occupational sources of exposure[18]
Cigarette smoke[18]	Fluoridated salt and/or milk[33,34]
Aluminofluoride exposure from ingesting a fluoride source *with* an aluminum source[18]	Nuclear reactors and nuclear weapons[35]

Section 4: Brief History of Fluoride

Human knowledge of the mineral fluorspar, from which fluoride originates, dates back centuries.[37] However, the isolation of fluorine from its natural compounds is an essential date in the history of its use in humans. Several scientists who attempted to isolate elemental fluorine were killed during their experimentation and are now known as the "fluorine martyrs".[37] However, in 1886 Dr. Henri Moissan successfully isolated it, eventually earning him the Nobel Prize in Chemistry.[38] This discovery paved the way for human experimentation to begin with fluorine compounds, which were eventually utilized in a number of industrial activities.

Fluoride was not widely used for any dental purposes prior to the mid-1940's, although it was studied for dental effects caused by its natural presence in community water supplies at varying levels in the early 1900's[39]It was shown that high levels of fluoride correlated with increased cases of dental fluorosis (a permanent damage to the enamel of the teeth from overexposure to fluoride). Researchers also demonstrated that reducing the level of fluoride resulted in lower rates of dental fluorosis, while showing a positive effect on caries. This work led H. Trendley Dean, DDS, to research fluoride's minimal threshold of toxicity in the water supply. Dean et al (1942) hypothesized that lower levels of fluoride might result in lower rates of dental caries.[40]

Dean's hypothesis was not widely supported. In fact, an editorial published in the *Journal of the American Dental Association* (JADA;1944) denounced purposeful water fluoridation and warned of its dangers. The authors wrote, "We do know the use of drinking water containing as little as 1.2 to 3.0 parts per million of fluorine will cause such developmental disturbances in bones as osteosclerosis, spondylosis, and osteopetrosis, as well as goiter, and we cannot afford to run the risk of producing such serious systemic disturbances in applying what is at present a doubtful procedure intended to prevent development of dental disfigurements among children". and, "Because of our anxiety to find some therapeutic procedure that will promote mass prevention of caries... the potentialities for harm far outweigh those for good".[41]

Nonetheless, Dean succeeded in his efforts to test his hypothesis and a few months after the ADA warning was issued, on January 25, 1945, Grand Rapids, Michigan, became the first city to be artificially fluoridated. Tooth decay rates were compared in Grand Rapids, the 'test' 'fluoridated' city, with rates in the 'control' non-fluoridated city of Muskegon, Michigan. After a little over five years, the 'control' was dropped and the study only reported the decrease in caries in Grand Rapids.[42] Because the results did not include the control variable from the incomplete Muskegon data, many have stated that the initial studies presented in favor of water fluoridation were invalid. By 1960, fluoridation of drinking water for alleged dental benefits had spread to over 50 million people in communities throughout the United States, regardless of the limited data of its effectiveness.[42]

A Cochran Review conducted in 2015 examined the effects of fluoride added to community water supply on decayed, missing and filled teeth (DMFT) in children.[43] The majority of studies (71%) were conducted prior to 1975 and the widespread introduction of the use of fluoride toothpaste. The results indicated that water

fluoridation significantly reduced caries in children in both deciduous and permanent teeth, while there was insufficient evidence in adults. They also concluded that there was insufficient information to determine that water fluoridation results in a change in disparities in caries across socioeconomic status levels and whether stopping water fluoridation would affect caries development. The results are limited, as is confidence in the results, by the observational nature of the various study designs, the high risk of bias within the studies and, importantly, the applicability of the evidence to conditions after 1975 when all toothpastes contained fluoride and exposure to fluoride through numerous avenues has increased. Dr. Hardy Limeback, PhD, DDS Professor Emeritus and former Head, Preventive Dentistry Faculty of Dentistry, University of Toronto, and a renowned expert on fluoride, served as an external reviewer on this 2015 Review. He criticized the manuscript because of the use of out-of-date studies that did not fit the selection criteria. His criticism fell on deaf ears. Confidence in this report is also diminished by the possibility that fluoride may slow tooth eruption, which would result in fewer observable healthy or carious teeth. However, one retrospective study that used data from the mid-80s in children grouped by fluoride exposure level showed that fluoride did not affect tooth eruption. Unfortunately, due to how the data were analyzed, changes between groups in time to tooth eruption could easily have been missed (i.e., among other methodological concerns, the time frame to examine tooth eruption was over the course of years instead of months).[44] A carefully controlled trial that includes the biological endpoints necessary to determine whether tooth eruption is affected by fluoride has not been conducted.

As of 2020, 73% of U.S. community water systems are fluoridated.[45] Other countries practiced community fluoridation by adding it to salt and or milk for caries management.[46]

Prior to the 1940's, the use of fluoride in American medicine was virtually unknown, with the exception of its rare use as an externally applied antiseptic and antiperiodic. The use of fluoride as a supplement (i.e., drops, tablets and lozenges) and in pharmaceutical drugs began at about the same time as water fluoridation.[47]

The production of perfluorinated carboxylates (PFCAs) and perfluorinated sulfonates (PFSAs) for process aids and surface protection in products also began almost 70 years ago.[48] Perfluorinated compounds (PFCs) are now used in a wide range of items including cookware, extreme weather military uniforms, ink, motor oil, paint, products with water repellant, and sports clothing.[49]

In the late 1960s and early 1970s, fluoridated toothpastes were introduced.[46] By the 1980s, the vast majority of commercially available toothpastes in industrialized countries contained fluoride.[50] Concurrently, fluoridated materials for commercial dental purposes were promoted. Glass ionomer cement materials, used for dental fillings, were invented in 1969,[51] and fluoride-releasing sealants were introduced in the 1970s.[52]

By reviewing the development of fluoride regulations provided in the next section, Section 5, it is apparent that these applications of fluoride were introduced before adequate research established the health risks of fluoride use, safety levels for its use, and what potential restrictions should be put in place.

Section 5: Overview of U.S. Fluoride Regulations

Section 5.1: Regulation of Community Water Fluoridation

Only 3% of community water is fluoridated in western Europe (i.e., Austria, Belgium, France, Germany, Ireland, Luxembourg, the Netherlands, Switzerland, and the United Kingdom), while some governments have openly recognized the hazards of its use. Figure 2 shows the extent of both natural and artificial water fluoridation across the globe as of 2012.[53] Although water fluoridation is not mandated by the federal

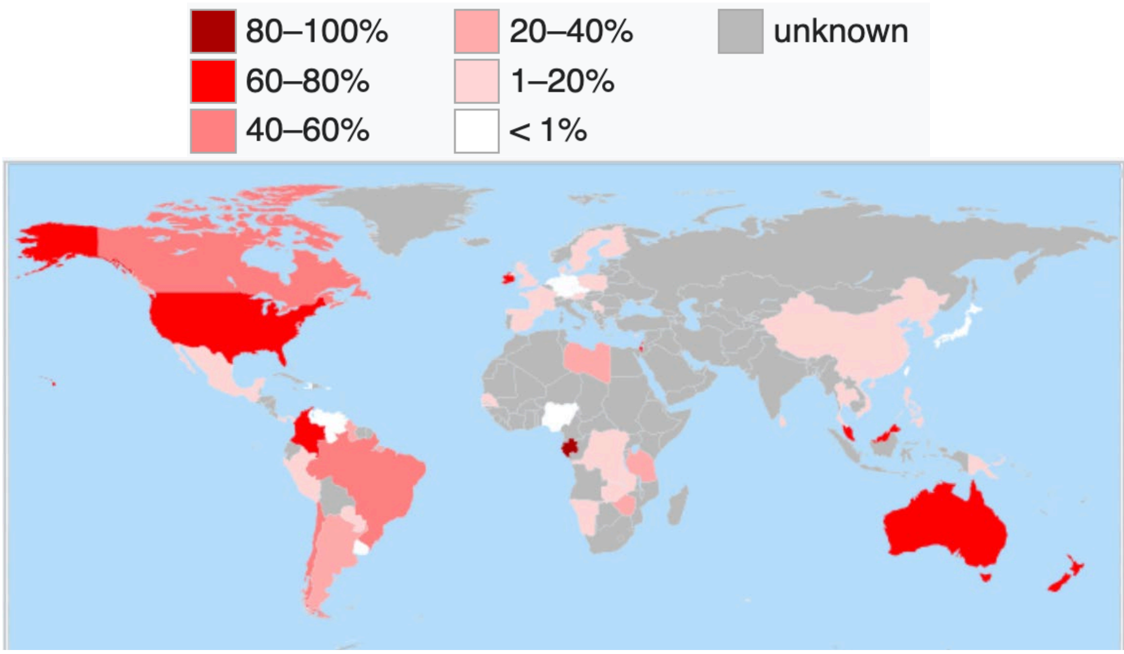


Figure 2 Percentage of population with either artificial or natural fluoridated water (2012). Courtesy Wikipedia

government in the U.S., approximately 73% of Americans live in communities where the water is fluoridated.[54] The decision to fluoridate is made by the state or local municipality. However, the U.S. Public Health Service (PHS) establishes recommended fluoride concentrations in community drinking water for those who choose to fluoridate, and the U.S. Environmental Protection Agency (EPA) sets contaminant levels for public drinking water.

After the first water fluoridation experiment was conducted in Grand Rapids, Michigan in 1945, the practice spread to locales across the country over the next several years. These efforts were encouraged by the U.S. Public Health Service (PHS) in the 1950s, and in 1962, the PHS issued standards for fluoride in drinking water that would stand for 50 years. They stated that fluoride would prevent dental caries and that optimal levels of fluoride added to drinking water should range between 0.7 to 1.2 milligrams per liter.[55] In 2015, the PHS lowered this recommendation to the single level of 0.7 milligrams per liter due to an increase in dental fluorosis (permanent damage to the teeth that can occur from overexposure to fluoride) and to the increase in sources of fluoride exposure to Americans.[56]

In1974, the Safe Drinking Water Act was established to protect the quality of U.S. drinking water, and it authorized the EPA to regulate public drinking water. This legislation allows the EPA to set *enforceable* maximum contaminant levels (MCLs) for drinking water, as well as *non-enforceable* maximum contaminant level goals (MCLGs) and *non-enforceable* drinking water standards of secondary maximum contaminant levels (SMCLs). The EPA specifies that the MCLG is "the maximum level of a contaminant in drinking water at which no known or anticipated adverse effect on the health of persons would occur, allowing an adequate margin of safety." Additionally, the EPA qualifies that community water systems exceeding the MCL for fluoride "must notify persons served by that system as soon as practical, but no later than 30 days after the system learns of the violation."[57]

In 1975, the EPA set a maximum contaminant level (MCL) for fluoride in drinking water at 1.4 to 2.4 milligrams per liter. They established this limit to prevent cases of dental fluorosis. In 1981, South Carolina argued that dental fluorosis is merely cosmetic, and the state petitioned the EPA to eliminate the MCL for fluoride.[58] As a result, in 1985, the EPA changed the endpoint from dental fluorosis to skeletal fluorosis, a bone disease caused

by excess fluoride. They then changed the maximum contaminant level goal (MCLG) for fluoride to 4 milligrams per liter. In 1986, the MCL for fluoride was raised to 4 milligrams per liter, potentially because of the change in endpoint.[58] [It is important to note that a bone biopsy must be performed to diagnose skeletal fluorosis. This procedure is seldom performed in adults and almost never done in children. Thus, the skeletal fluorosis endpoint is basically a non sequitur.] Within the same document, which seems contradictory, the EPA used dental fluorosis as the endpoint to determine the SMCL for fluoride at 2 milligrams per liter.[58]

Controversy ensued over these new regulations and resulted in legal actions against the EPA. South Carolina argued that there was no need for any MCLG for fluoride, while the Natural Resources Defense Council argued that the MCLG should be based on the presence of dental fluorosis, and thus, lowered. A court ruled in the EPA's favor, but in a review of fluoride standards, the EPA enlisted the National Research Council (NRC) of the National Academy of Sciences to re-evaluate the health risks of fluoride.[59]

The report from the National Research Council, released in 2006, concluded that the EPA's MCLG for fluoride should be lowered. In addition to recognizing the potential for risk of fluoride and osteosarcoma (i.e., bone cancer), the report cited concerns about musculoskeletal effects, reproductive and developmental effects, neurotoxicity and neurobehavioral effects, genotoxicity and carcinogenicity, and effects on other organ systems.[16]

As of the date of this IAOMT position paper (2024), the EPA has not lowered the level. In 2016, the Fluoride Action Network (FAN), the IAOMT, and a number of consumer advocacy groups and individuals petitioned the EPA to protect the public, especially susceptible subpopulations, from the neurotoxic risks of fluoride by banning the purposeful addition of fluoride to drinking water.[60] The petition was denied by the EPA in February 2017.[61] However, the lead plaintiff in this case, FAN, and its constituents continued to advocate for EPA protection. In response to a nomination from FAN, another systematic review was conducted by the National Toxicology Program (NTP) of the U.S. Department of Health and Human Services (2019). This was done to evaluate new evidence of the neurocognitive effects of fluoride on children and adults. When synthesizing the evidence from only human studies with low risk of bias and that included the appropriate confounders, the NTP conclude, "There is consistent evidence that exposure to fluoride is associated with cognitive neurodevelopmental effects in children. There is moderate confidence in the human data in children from several well-conducted prospective studies with limited sample sizes, supported by a large number of functionally prospective cross-sectional studies". Further, they conclude, "Integration of these level-of-evidence conclusions supports an initial hazard conclusion of *presumed* to be a cognitive neurodevelopmental hazard to humans because of the extent, consistency, and magnitude of effect in the available data in children".[62]

A series of hurdles initiated by the EPA attempting to quash FAN's efforts met with unfailing vigor that culminated in a trial of FAN versus EPA, of which we await the decision as of May 2024. A timeline of the events leading up to the trial; the flow of the trial, including discussion of emerging evidence by witnesses called by the plaintiffs, and a seemingly unbiased and fair judge; paired with a multitude of new studies, outlined in this position paper, suggest that water fluoridation in the U.S. may soon come to an end.

Section 5.2: Regulation of Bottled Water

The U.S. Food and Drug Administration (FDA) is responsible for making sure that standards for bottled water are consistent with standards for tap water set by the EPA and the recommended levels set by the U.S. Public Health Service (PHS).[63] The FDA permits bottled water that meets its standards to include language claiming that drinking fluoridated water may reduce the risk of tooth decay.[64]

Section 5.3: Regulation of Food

The FDA ruled to limit the addition of fluorine compounds to food in the interest of public health in 1977.[65] However, fluoride is still present in food due to its preparation in fluoridated water and exposure to pesticides and fertilizers (See Table 2, Section 3). In 2004, the U.S. Department of Agriculture (USDA) launched a database of fluoride levels in beverages and food and published the results. While, twenty years old, this report still provides important knowledge regarding the levels of fluoride in food and beverages, even while levels have likely increased due to the use of fluoride in pesticides.[66] Some indirect food additives currently in use also contain fluoride.[65]

Additionally, in 2006, the National Research Council recommended that to "assist in estimating individual fluoride exposure from ingestion, manufacturers and producers should provide information on the fluoride content of commercial foods and beverages."[16] But the FDA has chosen not to heed the recommendations. In 2016, the FDA revised its food labeling requirement for Nutrition and Supplement Facts labels and ruled that declarations of fluoride levels are voluntary both for products with intentionally added fluoride and products with naturally occurring fluoride.[67] At that time, the FDA also did not establish a Daily Reference Value (DRV) for fluoride. However, the FDA did rule to prohibit perfluoroalkyl ethyl containing food-contact substances (PFCSs), which are used as oil and water repellants for paper and paperboard.[68] This action was taken as a result of toxicological data and a petition filed by the Natural Resources Defense Council and other groups.

Other than these considerations for fluoride in food, establishing safe levels of fluoride in food due to pesticides is shared by FDA, EPA, and the Food Safety and Inspection Service of the U.S. Department of Agriculture.

Section 5.4: Regulation of Pesticides

Pesticides sold or distributed in the U.S. must be registered with the EPA, and the EPA can establish tolerances for pesticide residue if exposures from food are deemed to be "safe." In this regard, two fluoride-containing pesticides have been the subject of dispute:

Sulfuryl fluoride: Sulfuryl fluoride was first registered in 1959 for termite control in wood structures and in 2004/2005 for control of insects in processed foods, such as cereal grains, dried fruits, tree nuts, cocoa beans, coffee beans, as well as in food handling and food processing facilities.[69] Cases of human poisoning and even death, while rare, have been associated with sulfuryl fluoride exposure in homes treated with the pesticide.[70] In 2011, due to updated research and concerns raised by the Fluoride Action Network (FAN), the EPA proposed that sulfuryl fluoride no longer meets safety standards and that the tolerances for this pesticide should be withdrawn.[69] In 2013, the pesticide industry mounted a massive lobbying effort to overturn the EPA's proposal to phase-out sulfuryl fluoride, and the EPA proposal was reversed by a provision included in the 2014 Farm Bill.[71]

Cryolite: Cryolite, which contains sodium aluminum fluoride, is an insecticide that was first registered with the EPA in 1957. Cryolite is used on citrus and stone fruits, vegetables, berries, and grapes and is the major fluoride pesticide used in growing food in the U.S.[72] It can leave fluoride residues on food to which it has been applied. In its 2011 proposed order on sulfuryl fluoride, the EPA proposed to withdraw all fluoride tolerances in pesticides.[73]. This would therefore have included cryolite; however, as noted above, this proposal was overturned by industry lobbyers.[71]

Section 5.5: Regulation of Dental Products for Use at Home

The FDA requires labeling for "anticaries drug products" sold over the counter, such as toothpaste and mouthwash. Specific wording for the labeling is designated by the form of the product (i.e. gel or paste and rinse), as well as by the

fluoride concentration (i.e. 850-1,150 ppm, 0.02% sodium fluoride, etc.).[74] Warnings are also divided by age groups (i.e. 2 years and older, under 6, 12 years and older, etc.). Some warnings apply to all products, such as the following:

(1) For all fluoride dentifrice (gel, paste, and powder) products. "Keep out of reach of children under 6 years of age. [highlighted in bold type] If more than used for brushing is accidentally swallowed, get medical help or contact a Poison Control Center right away."

(2) For all fluoride rinse and preventive treatment gel products. "Keep out of reach of children. [highlighted in bold type] If more than used for" (select appropriate word: "brushing" or "rinsing") "is accidentally swallowed, get medical help or contact a Poison Control Center right away."

Although dental floss is categorized by the FDA as a Class I device, dental floss containing fluoride (usually stannous fluoride) is considered a combination product and requires premarket applications.[75] Dental floss can also contain fluoride in the form of perfluorinated compounds[76]: however, no regulatory information about this type of fluoride in dental floss could be located by the authors of this position paper

Section 5.6: Regulation of Dental Products for Use at the Dental Office

A vast majority of the materials used in the dental office that can release fluoride are regulated as medical/dental devices, such as some resin filling materials,[77] some dental cements,[78] and some composite resin materials.[79] More specifically, most of these dental materials are classified by the FDA as Class II Medical Devices,[80] meaning that the FDA provides "reasonable assurance of the device's safety and effectiveness" without subjecting the product to the highest level of regulatory control.[81] Importantly, as part of the FDA's classification procedure, dental devices with fluoride are considered combination products,[76] and fluoride release rate profiles are expected to be provided as part of the pre-market notification for the product. The FDA further states: "Claims of cavity prevention or other therapeutic benefits are permitted if supported by clinical data developed by an IDE (Investigational Device Exemption) investigation."[82] Moreover, while the FDA publicly mentions the fluoride-releasing mechanism of some dental restorative devices, the FDA does not publicly promote them on their website for use in caries prevention.

Similarly, while fluoride varnishes are approved as Class II Medical Devices for use as a cavity liner and/or tooth desensitizer, they are not approved for use in caries prevention.[83] Therefore, when claims of caries prevention are made about a product with fluoride, this is considered by the FDA to be an unapproved, adulterated drug.

In 2014, the FDA permitted the use of silver diamine fluoride for reducing tooth sensitivity.[84] This was done without providing any standardized guidelines, protocols, or consenting procedures, which were subsequently developed and published by an independent research team.[85]

Also essential to note is that fluoride-containing paste used during dental prophylaxis (cleaning) contains much higher levels of fluoride (i.e., 4,000-20,000 ppm) than commercially sold toothpaste (i.e. 850-1,500 ppm).[21] Fluoride paste is not accepted by the FDA or the ADA to prevent dental caries.[21]

Section 5.7: Regulation of Pharmaceutical Drugs (Including Supplements)

Fluoride is intentionally added to pharmaceutical drugs (drops, tablets, and lozenges often called "supplements" or "vitamins") that are routinely prescribed to children, allegedly to prevent cavities. In 1975, the FDA addressed the use of fluoride supplements by withdrawing the new drug application for Ernziflur fluoride. After the FDA's actions on Ernziflur lozenges were published in the *Federal Register*, an article appeared in *Drug Therapy* stating that the FDA approval was withdrawn "because there is no substantial evidence of drug effectiveness as prescribed, recommended, or suggested in its labeling."[86] The article also stated: "The FDA has therefore advised manufacturers of combination fluoride and vitamin preparations that their continued marketing is in violation of

the new drug provisions of the Federal Food, Drug, and Cosmetic Act; they have, therefore, requested that marketing of these products be discontinued." However, this information, which was available at the time of the writing of the 2016 IAOMT position paper, is no longer available on the site. The new information, updated, 2021 states that children 6 months and older should receive oral fluoride supplementation if they live in areas where the water is deficient in fluoride.[87]

In 2016, the FDA sent yet another warning letter out about the same issue of unapproved new drugs in many forms including the fluoride supplements addressed in 1975. A letter, dated January 13, 2016, was sent to Kirkman Laboratories in regard to four different types of pediatric fluoride concoctions labeled as aids in the prevention of dental caries.[88] The FDA warning letter offered the company 15 days to become compliant with law and serves as a yet another example of children hazardously receiving unapproved fluoride preparations, which has now been an issue in the U.S. for over 40 years.

Fluoroquinolones are the class of antibiotics most likely to cause an adverse drug event requiring hospital admission.[89] In 2016 the FDA issued a new warning about fluoroquinolone-associated disabling side effects, years after these drugs were first introduced to the market. The FDA stated that fluoroquinolones are associated with disabling and potentially permanent side effects of the tendons, muscles, joints, nerves, and central nervous system and revised the warning label and the patient Medication Guide. The FDA advised that these drugs should only be used when there is no other treatment option available for patients because the risks outweigh the benefits.[90] At the time of this 2016 FDA announcement, it was estimated that over 26 million Americans were taking these drugs annually, but this number has been substantially reduced, supposedly due to the FDA regulations.[91]

Section 5.8: Regulation of Perfluorinated Compounds

In 2015, over 200 scientists from 38 countries signed on to the "Madrid Statement," a research-based call for action by governments, scientists, and manufacturers to address the signatories' concerns about "production and release into the environment of an increasing number of poly- and perfluoroalkyl substances (PFASs).[32] Products made with PFSAs, also known as perfluorinated chemicals (PFCs), include protective coatings for carpets and clothing (such as stain-resistant or water-proof fabric), paints, cosmetics, insecticides, non-stick coatings for cookware, and food packaging coatings for oil and moisture resistance,[19] as well as, leather, paper, and cardboard,[20] and a wide variety of other consumer items. The signatories urged all parties to be cognizant and concerned over the long-term effects of the use of PFAS, referred to as persistent organic pollutants, on our health and our environment. Parties were asked to actively work on finding safer alternatives.[92]

Efforts have only recently begun to decrease the use of these persistent organic pollutants. For example, in 2016, the EPA issued health advisories for PFASs and PFCs in drinking water, identifying the level at or below which adverse health effects are not anticipated to occur over a lifetime of exposure as 0.07 parts per billion.[93]

Section 5.9: Regulation of Occupational Exposure

Exposure to fluorides in the workplace is regulated by the U. S. Occupational Safety & Health Administration (OSHA). The primary health factor guiding the standards is skeletal fluorosis, and the limit values for occupational exposure to fluorides are 2.5 milligrams/cubic meter.[94] In a 2005 article published in the *International Journal of Occupational and Environmental Health* and presented in part at the American College of Toxicology Symposium, author Phyllis J. Mullenix, PhD, identified the need for better workplace protection from fluorides. Specifically, Dr. Mullenix wrote that while fluoride standards have remained consistent, "...these standards have provided inadequate protection to workers exposed to fluorine and fluorides, but that for decades industry has possessed the information necessary to identify the standards' inadequacy and to set more protective

threshold levels of exposure".[95]

Section 6: Health Effects of Fluoride – See Table 3 for published Reviews (with hyperlinks) of Health Effects

In the 2006 report by the National Research Council (NRC) of the National Academy of Sciences in which the health risks of fluoride were evaluated, concerns were raised about potential associations between fluoride and osteosarcoma (a bone cancer), bone fractures, musculoskeletal effects, reproductive and developmental effects, neurotoxicity and neurobehavioral effects, genotoxicity and carcinogenicity, and effects on other organ systems.[16] Since the NRC report was released, hundreds of additional research studies have identified potential harm to humans from fluoride at various levels of exposure, including levels currently deemed as safe. Although each of these articles merit attention and discussion, doing so is beyond the scope of this position paper. Rather, Section 6 provides an overview based on 33 reviews that have recently been conducted, briefly summarizing the previous works. These reviews are available in Table 3 with hyperlinks to access the articles directly.

It is noteworthy that since the NRC report, 10 National Institutes of Health (NIH)-funded studies have been published on fluoride toxicity (Figure 3). The last one to be published, Malin et al, 2024 showed that children of mothers with higher fluoride exposures, during pregnancy had double the odds of several neurobehavioral problems compared to mothers with lower exposures. These included emotional reactivity, somatic complaints (such as headaches), anxiety, and symptoms linked to autism. An increase in maternal urine fluoride during pregnancy of 0.68 milligrams/liter was associated with a 19% increase in autism spectrum problems.
All of the NIH-funded studies were conducted in populations living in regions with fluoridated water and used excreted urinary fluoride to determine fluoride exposure All of the studies controlled for potential confounders.[96–105]

Figure 3 NIH-funded fluoride studies from 2017-2024
Table 3 Health Effects of Fluoride Reviews

Health Effects of Fluoride (F)	Brief Synopsis	Link
Animal Models of Fluoride Toxicity	This descriptive 2013 review focuses mainly on the animal models of fluorosis and includes detailed tables outlining a significant literature of the effects of F on multiple endpoints. It also includes a section describing studies showing reversibility of the effects of F toxicity upon cessation of F exposure.	Perumal, et al. "A Brief Review on Experimental Fluorosis." *Toxicology Letters* 223, no. 2 (November 25, 2013): 236–51.
Animal: Neuro-behavioral impairments (not in F Science)	This 2022 review of the animal work summarizes the mechanisms of F-induced neurobehavioral, immunological, genetic, and cellular toxic effects.	Ottappilakkil, et al. Fluoride Induced Neurobehavioral Impairments in Experimental Animals: a Brief Review. Biol Trace Elem Res. 2022 Apr 30
Alzheimer's Disease (AD; Dementia)	This detailed review with close to 200 references describes the pathogenesis of AD, and based on the accruing evidence, the plausible role F plays in its etiology.	Goschorska, et al. "Potential Role of Fluoride in the Etiopathogenesis of Alzheimer's Disease." *International Journal of Molecular Sciences* 19, no. 12 (December 2018): 3965.
Attention Deficit Hyperactivity Disorder (ADHD)	This 2023 systematic review found seven studies that investigated the effect of F exposure on ADHD. The authors conclude that early exposure to F may have neurotoxic effects on neurodevelopment affecting behavioral, cognitive and psychosomatic symptoms related to ADHD.	Fiore, et al. Fluoride Exposure and ADHD: A Systematic Review of Epidemiological Studies. Medicina (Kaunas). 2023 Apr 19;59(4):797
Blood pressure/ Hypertension (not in F Science)	This 2020 systematic review and meta-analysis assessed the relationship of F exposure with blood pressure and essential hypertension prevalence. Significant relationships were found between high-F drinking water and essential hypertension, as well as systolic and diastolic blood pressure.	Davoudi, et al. "Relationship of Fluoride in Drinking Water with Blood Pressure and Essential Hypertension Prevalence: A Systematic Review and Meta-Analysis." International Archives of Occupational and Environmental Health 94, no. 6 (August 1, 2021).
Brain damage	This 2022 article reviews the effects of chronic fluorosis on the brain and possible mechanisms	Ren, et al. "Effects of Chronic Fluorosis on the Brain." *Ecotoxicology and Environmental Safety* 244 (October 1, 2022): 114021.
Brain Development	78 out of 87 studies show that F reduces IQ. All of the studies are listed on the link provided by the Fluoride Action Network (updated 2022).	"The 78 Fluoride-IQ Studies - Fluoride Action Network," May 18, 2022.
Brain Development	This 2020 review critically evaluates the evidence of F's effects on neurocognition (IQ) from multiple avenues including human, animal, cellular and molecular studies. One facet of the examination consisted of a literature search (2012-2019) that included 23 epidemiological studies conducted in children. 21 studies concluded that higher F exposure was associated with lower IQ.	Guth, et al. "Toxicity of Fluoride: Critical Evaluation of Evidence for Human Developmental Neurotoxicity in Epidemiological Studies, Animal Experiments and in Vitro Analyses." *Archives of Toxicology* 94, no. 5 (May 1, 2020): 1375–1415.

Health Effects of Fluoride (F)	Brief Synopsis	Link
Brain Development	This recent review of F effects on cognition focuses on literature published post the 2012 NRC meta-analysis. Latest literature shows that neurotoxicity is dose-dependent and currently acceptable levels of F are unsafe.	Grandjean. "Developmental Fluoride Neurotoxicity: An Updated Review." *Environmental Health* 18, no. 1 (December 19, 2019): 110.
Brain Development	27 eligible epidemiological studies conducted in children were identified with high and reference exposures, end points of IQ scores, or related cognitive function measures for the two exposure groups. Children who lived in high-F areas had significantly lower IQ scores than those in low-F areas.	Choi, et al. "Developmental Fluoride Neurotoxicity: A Systematic Review and Meta-Analysis." *Environmental Health Perspectives* 120, no. 10 (October 2012): 1362–68.
Brain Tumors; Neurodegenerative effects	This 2023 review outlines the neurodegenerative effects of F and contains excellent figures. F causes degenerative changes in all parts of the brain. F causes oxidative stress, disruption of multiple cellular pathways, and microglial activation that can underlie brain tumor formation.	Żwierełło, et al."Fluoride in the Central Nervous System and Its Potential Influence on the Development and Invasiveness of Brain Tumours-A Research Hypothesis." *International Journal of Molecular Sciences* 24, no. 2 (January 13, 2023): 1558.
Cognition (general intelligence)	This 2020 review, conducted by the U.S. Environmental Protection Agency (EPA) finds that exposure to F has even more negative impact on children's cognitive ability than lead.	Nilsen, et al. A Meta-Analysis of Stressors from the Total Environment Associated with Children's General Cognitive Ability. Int. J. Environ. Res. Public Health 2020, 17(15), 5451
Cognition (general intelligence)	This well-conducted highly transparent systematic review focused on pregnant women and children. 46 studies that examined IQ and/or other neurobehavioral measures were identified and rated (on quality). Conclusion: High F exposure might be associated with negative cognitive outcomes in children.	Gopu, et al. "The Relationship between Fluoride Exposure and Cognitive Outcomes from Gestation to Adulthood—A Systematic Review." *International Journal of Environmental Research and Public Health* 20, no. 1 (December 20, 2022): 22.
Dental Fluorosis	A previous review suggested publication bias existed when examining the association between F in drinking water and dental fluorosis. Thus, the goal of this 2023 systematic review aimed to examine this construct only in high quality, low bias studies. The findings indicate that even low levels of F lead to dental fluorosis and detrimental effects on human health.	Umer. "A Systematic Review on Water Fluoride Levels Causing Dental Fluorosis." *Sustainability* 15, no. 16 (January 2023): 12227.
Dental Fluorosis	The first sign of F toxicity is dental fluorosis. This Cochrane review (i.e., systematic review of health care and health policy research that uses methods to reduce bias and produce reliable findings) estimates that 12% of children living in fluoridated communities with 0.7 ppm F have aesthetically objectionable dental fluorosis with a total dental fluorosis effect of 40%.	Iheozor-Ejiofor, et al. "Water Fluoridation for the Prevention of Dental Caries." *The Cochrane Database of Systematic Reviews* 2015, no. 6 (June 18, 2015): CD010856.

Health Effects of Fluoride (F)	Brief Synopsis	Link
Endocrine System (hormones and reproductive)	This 2020 review, which contains excellent informative mechanistic diagrams, outlines how F adversely effects the endocrine system (i.e., the pineal gland, hypothalamus, pituitary gland, thyroid with parathyroid glands, thymus, pancreas, adrenal glands, and reproductive organs) by inducing oxidative stress, apoptosis and inflammation.	Skórka-Majewicz et al, Effect of fluoride on endocrine tissues and their secretory functions -- review. Chemosphere, Volume 260, December 2020, 127565
Eye Disease: Cataracts, age-related macular degeneration and glaucoma	This descriptive review (2019) that includes over 300 references summarizes the evidence and mechanisms demonstrating that F exposure contributes to degenerative eye diseases.	Waugh. The Contribution of Fluoride to the Pathogenesis of Eye Diseases: Molecular Mechanisms and Implications for Public Health. Int. J. Environ. Res. Public Health. 2019, 16(5), 856
Gastrointestinal Disorders Not in F Science	All regions of the GI tract are exposed to F. The animal literature indicates that F is detrimental to the gut microbiome however, human research on the effects of F on the GI tract is sparse. This descriptive review concludes that more research is needed in this area.	Moran, et al. "Does Fluoride Exposure Impact on the Human Microbiome?" *Toxicology Letters* 379 (April 15, 2023): 11–19.
Genetic Susceptibilities underlying dental and skeletal fluorosis and other F-induced illness	This short review briefly outlines the mechanisms of F toxicity and synthesizes newer literature on genetic susceptibilities.	Wei, et al. "The Pathogenesis of Endemic Fluorosis: Research Progress in the Last 5 Years." *Journal of Cellular and Molecular Medicine* 23, no. 4 (2019): 2333–42.
Inflammatory Bowel Disease/Crohn's Disease	Epidemiological studies suggest an association between fluoride exposure and IBD. This review presents the evidence that fluoride exposure is associated with gastrointestinal symptoms and suggests the working hypothesis that it does this through its effects on intestinal microbiota. This article is not available freely however, the IAOMT can provide the article to interested parties.	Follin-Arbelet, Benoit, and Bjørn Moum. "Fluoride: A Risk Factor for Inflammatory Bowel Disease?" *Scandinavian Journal of Gastroenterology* 51, no. 9 (September 2016): 1019–24. https://doi.org/10.1080/00365521.2016.1177855.
Intelligence Quotient (IQ)	The aim of this 2023 systematic meta-analysis review was to determine the effect of early or prenatal F exposure on neurodevelopment according to a dose-response relation. Out of 30 studies that were eligible, an inverse association between F exposure and IQ was observed.	Veneri, et al. Fluoride exposure and cognitive neurodevelopment: Systematic review and dose- response meta-analysis. Environ Res. 2023 Mar 15;221:115239.

Health Effects of Fluoride (F)	Brief Synopsis	Link
Iodine deficiency disorders (e.g., hypothyroidism)	In this comprehensive 2019 review the key mechanisms by which F inhibits iodine absorption contributing to iodine deficiency are elucidated. Iodine deficiency causes goiter, hypothyroidism, cretinism, neonatal and infant mortality, and neurologic effects.	Waugh. Fluoride Exposure Induces Inhibition of Sodium/Iodide Symporter (NIS) Contributing to Impaired Iodine Absorption and Iodine Deficiency: Molecular Mechanisms of Inhibition and Implications for Public Health. Int. J. Environ. Res. Public Health 2019.
Kidney (Chronic) Disease	This article describes how exposure to environmental toxicants can damage the kidneys. The literature on the effects of heavy metals and F is summarized.	Lash and Lawrence. "Environmental and Genetic Factors Influencing Kidney Toxicity." *Seminars in Nephrology*, Kidney Safety Science, 39, no. 2 (March 1, 2019): 132–40.
Kidney Disease (not in F Science)	This 2019 review examines nearly 100 years of literature pointing to F toxicity as a key player underlying chronic kidney disease.	Dharmaratne "Exploring the Role of Excess Fluoride in Chronic Kidney Disease: A Review." *Human & Experimental Toxicology* 38, no. 3 (March 1, 2019): 269–79.
Multiple diseases/conditions	This is a comprehensive review published in 2022. One aspect that it covers is F-induced health problems including dental and skeletal fluorosis; arthritis; bone and muscle diseases; chronic fatigue and other joint-related problems; cardiovascular, kidney, liver and endocrine disease. Methods for fluoride detection and measurement are described.	Solanki, et al. "Fluoride Occurrences, Health Problems, Detection, and Remediation Methods for Drinking Water: A Comprehensive Review." *Science of The Total Environment* 807 (February 10, 2022): 150601.
Multiple diseases/conditions	This review, that reads more like a position paper, cites literature on the adverse health consequences of F including, dental and skeletal fluorosis and thyroid disease. This paper includes in depth discussion on 'optimal dose' of F for preventing caries and ethical arguments.	Peckham and Awofeso. "Water Fluoridation: A Critical Review of the Physiological Effects of Ingested Fluoride as a Public Health Intervention." *The Scientific World Journal* 2014 (February 26, 2014).
Multiple diseases/conditions	This report, supported by *the Collaborative on Health and the Environment* provides a database of human studies summarizing potential links between chemical contaminants and ~180 human diseases or conditions. F is identified in 15 diseases/conditions including diseases of the liver, kidney, bone, brain, lung and thyroid.	Janssen, et al. "Chemical Contaminants and human disease: A summary of Evidence." www.HealthandEnvironment.org, 2004.
Multiple diseases/conditions	This 2022 article focuses on the effects of low F on human and animal in bones, cardiovascular system, nervous system, hepatic and renal function, reproductive system, thyroid function, blood glucose homeostasis, and the immune system.	Zhou, et al. Necessity to Pay Attention to the Effects of Low Fluoride on Human Health: an Overview of Skeletal and Non-skeletal Damages in Epidemiologic Investigations and Laboratory Studies. Biol Trace Elem Res. 2022 Jun 6

Health Effects of Fluoride (F)	Brief Synopsis	Link
Multiple diseases/conditions Not in F Science	This 2020 review article's major focus is in describing the mechanisms underlying fluorotoxicity, but it also delves into F's effects in the brain, the endocrine system, skeletal and dental fluorosis, and its potential role in diabetes.	Johnston and Strobel. "Principles of Fluoride Toxicity and the Cellular Response: A Review." *Archives of Toxicology* 94, no. 4 (April 2020): 1051–69.
Pinealgland disorders	F accumulates in the pineal gland leading to mental illness, neurodegenerative disorders, brain tumors, strokes, migraine headaches, aging and sleep disorders. This descriptive 2020 review summarizes the relatively few studies that have been conducted.	Chlubek and Sikora. Fluoride and Pineal Gland. Applied Sciences. 22 April 2020
Reproduction/Fertility	This meta-analysis collates evidence from 53 papers of the effects of F on female reproductive organs. Most animal species studied have decreased fertility when exposed to F. F negatively effects reproductive performance, ovarian function, fetal development, among others. The methods of F toxicity on reproduction are clearly described.	Fishta, et al.Effects of Fluoride Toxicity on Female Reproductive System of Mammals: A Meta-Analysis." *Biological Trace Element Research*, May 6, 2024.
Skeletal Fluorosis	Highly informative article describing the impact of calcium, magnesium, phosphorus, F and heavy metals on bone health.	Ciosek, et al. "The Effects of Calcium, Magnesium, Phosphorus, Fluoride, and Lead on Bone Tissue." *Biomolecules* 11, no. 4 (March 28, 2021): 506.
Thyroid Function	This 2023 systematic review aimed to assess the relationship between F exposure and thyroid function and disease. Bias risk was assessed for all included studies. The authors concluded that exposure to high-F drinking water affects thyroid function and increases the risk of some thyroid diseases.	Iamandi, et al. Does fluoride exposure affect thyroid function? A systematic review and dose-response meta-analysis. Environmental Research 2023 Nov 28

Section 6.1: Skeletal System

Fluoride enters the bloodstream through the digestive tract wherein 50% is excreted via urine,[106] and 99% of what remains is concentrated in the bones and teeth, where it is incorporated into the crystalline structure and accumulates over time.[18] The rest accumulates in the organs, including the liver and the kidneys. Summarized in the paragraphs below, Ciosek et al, 2021 reviewed the effects of fluoride on bone and teeth.[107]

Bones are calcified tissues composed of 50%−70% hydroxyapatite (i.e., calcium phosphate), water and proteins. Bone is classified into two types: Compact bone (also called cortical bone) is dense bone tissue surrounding a medullary cavity, or bone marrow. Cancellous bone (also called trabecular bone) is a less dense spongy material interspersed within the bone marrow. The adult human skeleton is composed of 80% compact and 20% cancellous bone.[108] Bone is continuously remodeled by alternating resorption (degrading) and accretion (growth). Bone is encased in a membrane of blood vessels and nerves called the periosteum.

Fluoride is incorporated into the apatite crystals in the process of ion exchange, which leads to the formation of fluorapatite, replacing one's natural composition of hydroxyapatite. Fluorapatite overstimulates the proliferation of osteoblasts (cells that form bone tissue) while inhibiting the activity of osteoclasts (cells that resorb bone during normal bone remodeling and in pathologic states), increasing bone mass. This was the rationale for the use of fluorine compounds in the treatment of osteoporosis.[109]

And yet, excessive fluoride intake causes skeletal fluorosis, a condition characterized by bone changes ranging from osteoporosis to osteosclerosis.[110] This is a result of the imbalance between bone formation (> osteoblasts) and bone resorption (< osteoclasts). Under the microscope, fluorotic bones have increased numbers of osteoblasts and increased density and thickness of cancellous bone.[107]

The accumulation of fluoride in bones is multi-determined by the duration of exposure, age, sex, and underlying bone diseases.[107] Fluoride retention is greater in children than in adults; children and adults exposed to low doses of fluoride compounds accumulate approximately 50% and 10%, respectively, in tissue. Women accumulate higher fluoride levels than males (could this underlie the higher rates of osteoporosis in women?). Fluoride accumulates in the bone throughout life; greater fluoride levels were observed in people over 60 compared to under 60 years of age. We know that fluoride concentration in the bones is related to drinking fluoridated water and exposure to other fluoridated substances (See Tables 1and 2, Sources of Fluoride). It is possible to reverse fluoride levels by reducing fluoride intake and eating a healthy diet that includes natural nutrients and minerals, but it could take some time; the half-life of fluoride in bone ranges from several- to up to 20 years.[111]

In its 2006 report, the National Research Council (NRC)'s discussion on the danger of bone fractures from excessive fluoride was substantiated with significant research. Specifically, the report stated: "Overall, there was consensus among the committee that there is scientific evidence that under certain conditions fluoride can weaken bone and increase the risk of fractures.[18] A recent report compared fluoride in serum and fluoride in drinking water within 10 patients having osteosarcoma and 10 healthy controls. Both serum and drinking water fluoride levels were significantly higher in patients with osteosarcoma ($P < 0.05$, $P < 0.001$, respectively).[112] There are several reviews in Table 3 clearly describing the role of F in skeletal disorders.

Section 6.1.1: Dental Fluorosis

Figure 3: Dental Fluorosis Ranging from Very Mild to Severe

(Photos courtesy of Dr. David Kennedy and are used with permission from patients with dental fluorosis.)

In some ways similar to bone, the enamel of teeth is composed of 90% hydroxyapatite. Just as with bone, fluoride is incorporated into the apatite crystals, replacing the natural composition of the teeth with fluorapatite.[113] Since the 1940s we have known that the first outward manifestation of fluoride toxicity is dental fluorosis, a condition in which the teeth enamel is irreversibly damaged and discolored, forming brittle teeth that break and stain easily (see Figure 3).[18] According to the Centers for Disease Control and Prevention, 23% of Americans aged 6-49 and 41% of children aged 12-15 exhibit fluorosis to some degree.[114] These high rates of dental fluorosis were a crucial

factor in the Public Health Service's decision to lower its water fluoridation level recommendations in 2015.[115] In case we needed more evidence, a 2023 nation-wide study that specifically explore the association between fluoride levels and dental fluorosis, shows that dental fluorosis is directly related to the fluoride in drinking water and in plasma. After adjusting for covariates both higher water and plasma fluoride concentrations were associated with higher odds of dental fluorosis.[116]

Section 6.1.2: Skeletal Fluorosis

Like dental fluorosis, skeletal fluorosis is an undeniable effect of overexposure to fluoride. Skeletal fluorosis causes denser bones, joint pain, a limited range of joint movement, and in severe cases, a completely rigid spine. Although considered rare in the U.S., the condition does occur, and since the procedure to diagnose it is rarely performed, skeletal fluorosis could be more of a public health issue than recognized.

There is no scientific consensus as to how much and/or for how long (i.e., exposure) fluoride causes skeletal fluorosis. While some authorities have suggested skeletal fluorosis only occurs after 10 years or more of exposure, children can develop the disease in as little as six months, and some adults have developed it in as little as two to seven years. Similarly, while some authorities have suggested that 10 mg/day of fluoride is necessary to develop skeletal fluorosis, much lower levels can also cause the disease. Furthermore, research has confirmed that skeletal tissue response to fluoride varies by individual. Skeletal fluorosis is described in a number of reviews including Ciosek et al, available in Table 3.

Section 6.2: Central Nervous System (i.e., The Brain)

The potential for fluoride to impact the brain has been well-established. In their 2006 report, the NRC explained: "On the basis of information largely 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." Both dementia and Alzheimer's disease are also mentioned in the NRC report for consideration as being potentially linked to fluoride exposure.[18]

These concerns have been substantiated in a multitude of studies. In Table 3, over 40 Reviews are referenced of the effects of fluoride on neurodegenerative disorders, neurodevelopment, brain cancer and cognition.

Prompted by the Fluoride Action Network (FAN), in 2019 the National Toxicology Program (NTP) conducted a systematic review to examine new evidence of fluoride's effects on neurocognition. They identified 13 new studies across multiple populations with risk of low bias that assessed IQ in children in relation to fluoride exposure. All of the studies found associations between fluoride exposure and IQ.[62] Two studies in particular showed a large magnitude of effect. These were well-conducted Canadian and Mexican prospective cohort studies conducted in children during which urinary fluoride levels were assessed during pregnancy. One study, showed that fluoride exposure was associated with a 3.66 lower IQ score in children per 1 milligram/liter maternal urinary fluoride.[99] The other study showed a 2.5-point decrease in IQ per 0.5 milligrams/liter increase in maternal urinary fluoride.[97] These studies are supported by the 11 functionally-prospective cross-sectional studies identified by the NTP, presenting a consistent pattern of evidence that exposure to fluoride is associated with decreased IQ.

Section 6.3: Cardiovascular System

As of 2021, heart disease continues to be the leading cause of death U.S., taking 1 in 5 lives and costing close to $240 billion annually.[117] Thus, recognizing the potential relationship between fluoride and cardiovascular

problems is essential not only for safe measures to be established for fluoride but also for preventative measures to be established for heart disease. Several reviews are listed in Table 3 describing fluoride's role in cardiovascular illness.

Section 6.4: Endocrine System

The endocrine system consists of glands that regulate hormones (i.e., the pineal gland, hypothalamus, pituitary gland, thyroid with parathyroid glands, thymus, pancreas, adrenal glands, and reproductive organs). In the 2006 NRC report, it was stated: "In summary, evidence of several types indicates that fluoride affects normal endocrine function or response; the effects of the fluoride-induced changes vary in degree and kind in different individuals." The 2006 NRC report further included a table demonstrating how extremely low doses of fluoride have been found to disrupt thyroid function, especially when there was a deficiency in iodine present.[18] In more recent years, the impact of fluoride on the endocrine system has been re-emphasized. See Table 3 for a thorough review of the effects of fluoride on the endocrine system, another review of its specific effects on the thyroid gland and yet another review for its specific effects on the pineal gland.

Section 6.5: Renal System

Urine is a major route of excretion for fluoride taken into the body, and the renal system is essential for the regulation of fluoride levels in the body. Urinary excretion of fluoride is influenced by urine pH, diet, presence of drugs, and other factors.

The 2006 NRC report recognized the role of the kidney in fluoride exposures. They noted that it is not surprising for patients with kidney disease to have increased plasma and bone fluoride concentrations. They further stated that human kidneys " concentrate fluoride as much as 50-fold from plasma to urine. Portions of the renal system may therefore be at higher risk of fluoride toxicity than most soft tissues." Two reviews listed in Table 3 specifically address the role of fluoride in kidney disease.

Section 6.6: Gastrointestinal (GI) System

The GI tract consists of the oral cavity, pharynx, esophagus, stomach, small intestine, large intestine, and anal canal. Upon ingestion, including through fluoridated water, fluoride is absorbed by the GI system where it has a half-life of 30 minutes. The amount of fluoride absorbed is dependent upon calcium levels, with higher concentrations of calcium lowering gastrointestinal absorption. Also, fluoride interacts with the hydrochloric acid naturally present in the GI tract resulting in formation of hydrofluoric acid (HF). HF acid is highly corrosive and has the capacity to destroy the microvilli lining of the stomach and intestinal wall. Several related reviews are listed in Table 3.

Section 6.7: Liver

The 2006 NRC report called for more information about fluoride's effect on the liver stating that it is possible that a lifetime ingestion of drinking water containing fluoride at 4 mg/L may have long-term effects on the liver.[18] Several of the reviews listed in Table 3 that cover multiple diseases/conditions address fluoride's effects on the liver.

Section 6.8: Immune System

Based on fluoride's ability to decrease cell proliferation, increase apoptosis, disrupt the immune system and

cause changes in organs in cell-based studies, among other negative effects, it seems plausible that it negatively affects the immune system in humans, especially, when considering that immune cells develop in the bone marrow. Thus far, however very little research has been conducted in this area. The review provided by Zhou et al in Table 3 provides an overview of the molecular and cellular research.

Allergies and hypersensitivities to fluoride are another risk component related to the immune system. A number of case studies have been collated and described briefly by the Fluoride Action Network (FAN).[118] Symptoms include rashes, severe itching, vomiting, and remit when fluoride is not present.

Section 6.9: Acute Fluoride Toxicity

The first large scale case of alleged industrial poisoning from fluorine gas involved a disaster at Meuse Valley in Belgium in the 1930s. Fog and other conditions in this industrialized area were associated with 60 deaths and several thousand people becoming ill. Evidence has since related these casualties to fluorine releases from the nearby factories.[119] Many tragic cases such as this one have been documented in the past, however more recently, acute fluoride toxicity occurs in the home in small children when fluoride-containing products are ingested – and it doesn't take much. Five milligrams/kilogram of ingested fluoride can cause critical or life-threatening systemic effects and that require immediate therapeutic intervention and hospitalization. For example, an 8.2-ounce (232 gram) tube of toothpaste can contain 232 milligrams of fluoride. Ingestion of only 1.76 ounces (50 grams, equivalent to about 2 teaspoons) by a 10-kilogram (22 pounds – about the size of a 2-year old) child provides enough fluoride to reach a dose that is most likely, toxic (toxicity is based on additional factors such as length of time since ingestion).[120] Up until 2005, the CDC received over 30,000 calls per year related to children ingesting fluoride-containing products and the results were publicly available. The CDC no longer makes this information available. In the current era, people are much more aware and concerned about the health of their teeth, but most are not aware that the toothpaste in their cupboard or left out on the counter could be toxic to their children. Further, if the parents did not see the child ingest the toothpaste they cannot aid in a diagnosis. Child-proof caps are required by the FDA, but industry has not complied.

According to the Center for Disease Control, acute fluoride toxicity can occur in the event of natural disasters, when storage facilities are damaged; terrorism; occupational exposure; and some hobbies.[121] Hydrogen fluoride easily passes into the skin and tissues of the body. The extent of poisoning depends on the amount, route and length of time of exposure; and the health status of the person exposed. Hydrogen fluoride gas, even at low levels, can immediately irritate the eyes, nose, and respiratory tract. At higher levels it can cause fluid to accumulate in the lungs and can lead to death. Small amounts of hydrogen fluoride (liquid) products can burn the skin and can even be fatal. Skin contact may not cause immediate pain or visible skin damage but can take up to 24 hours to develop. Long-term effects of acute exposure include chronic lung disease; skin damage with scarring; persistent pain; bone loss; and if it gets into the eyes, permanent visual defects and blindness.[121]

Section 6.10: Chronic Fluoride Toxicity

Chronic fluoride poisoning (low dose, long-term) must also be considered. Chronic fluoride exposure is an occupational hazard within a number of industries. The gas, hydrogen fluoride is used to make refrigerants; herbicides; pharmaceuticals; high-octane gasoline; aluminum; plastics; electrical components including electronic chip manufacturing; etched metal and glass (such as that used in some electronic devices); uranium chemicals production; and quartz purification[121]. Health effects from hydrogen fluoride include damage to the respiratory system. Breathing the chemical can harm lung tissue and cause swelling and fluid accumulation in the lungs (pulmonary edema) and potentially lead to chronic lung disease. High levels of exposure to hydrogen fluoride can cause death from the buildup in the lungs. The aluminum industry has been the subject of investigation into fluoride's impact on the respiratory systems of workers. Studies indicate a correlation

between workers at aluminum plants, exposures to fluoride, and respiratory effects, such as asthma, emphysema, bronchitis, and diminished lung function (Review).[122]

Section 7: Fluoride Exposure Levels

Due to increased rates of dental fluorosis and increased sources of exposure to fluoride, in 2015 the Public Health Service (PHS) lowered its recommended levels of fluoride. However, the need to update previously established fluoride levels again is extremely urgent, as fluoride exposures have surged since then.

Table 2, provided in Section 3 of this document lists sources of fluoride exposure that are relevant to consumers. Similarly, a history of fluoride, as provided in Section 4 of this document, helps firmly demonstrate the number of fluoride-containing products developed over the past 75 years. Furthermore, the health effects of fluoride, as provided in Section 6 of this document, offer details about the damages of fluoride exposures inflicted upon all systems of the human body. When viewed in context with the history, sources, and health effects of fluoride, the uncertainty of exposure levels described in this section provides overwhelming evidence of potential harm to human health.

Section 7.1: Fluoride Exposure Limits and Recommendations

Due to increased rates of dental fluorosis, an early sign of toxicity, and increased sources of exposure to fluoride, in 2015 the U.S. Public Health Service (PHS) lowered its recommended drinking water levels of fluoride, originally set between 0.7 to 1.2 milligrams per liter in 1962,[123] to 0.7 milligrams per liter.[124] Generally, the "optimal" intake of fluoride has been defined as between 0.05 and 0.07 milligrams of fluoride per kilogram of body weight.[125] However, in a longitudinal study of children examining optimal fluoride intake using dental fluorosis and dental caries outcomes, researchers found an overlap among caries/fluorosis groups in mean fluoride intake and extreme variability in individual fluoride intake. They noted a lack of scientific evidence for this intake level and concluded that recommending an 'optimal' fluoride intake is problematic.[125]

Comparing some of the existing guidelines for fluoride intake exemplifies the complexity of establishing and enforcing levels; utilizing them to protect *all* individuals; and applying them to everyday life. To illustrate this point, Table 4 provides a comparison of recommendations from various institutions of the U.S. government. What can be discerned from the table is that limits and recommendations for fluoride in food and water vary tremendously, and, in their current state, would be nearly impossible for consumers to incorporate into daily life. It is also obvious that the recommendations do not consider all avenues of fluoride exposure. Further, the table shows that the enforceable maximum contaminant level (eMCL) far exceeds the recommended fluoride level deemed to be safe. Further, the table makes no recommendations for vulnerable populations such as pregnant women, athletes or health-compromised individuals.

Table 4: Comparison of Recommendations and Regulations for Fluoride (F) Intake

Type of F level	Specific F Recommendation /Regulation	Source/Notes
Recommendation concentration in drinking water for the prevention of dental caries	0.7 mg per liter	U.S. Public Health Service (PHS) [126] *Non-enforceable recommendation.*
Dietary reference intake: Tolerable upper intake level	Infants 0-6 mo. 0.7 mg/d Infants 6-12 mo. 0.9 mg/d Children 1-3 y 1.3 mg/d Children 4-8 y 2.2 mg/d Males 9 - >70 y 10 mg/d Females 9 - >70 y* 10 mg/d	Food and Nutrition Board, Institute of Medicine (IOM), National Academies [127] *Non-enforceable recommendation.*
Dietary reference intake: Recommended dietary allowances and adequate Intakes	Infants 0-6 mo. 0.01 mg/d Infants 6-12 mo. 0.50 mg/d Children 1-3 y 0.7 mg/d Children 4-8 y 1.0 mg/d Males 9-13 y 2.0 mg/d Males 14-18 y 3.0 mg/d Males 19 - >70 y 4.0 mg/d Females 9-13 y 2.0 mg/d Females 14 - >70 y* 3.0 mg/d	Food and Nutrition Board, Institute of Medicine (IOM), National Academies [127] *Non-enforceable recommendation.*
Maximum Contaminant Level (MCL) from Public Water Systems	4.0 mg per liter	U.S. Environmental Protection Agency (EPA) [128] *Enforceable regulation.*
Maximum Contaminant Level Goal (MCLG) from Public Water Systems	4.0 mg per liter	U.S. Environmental Protection Agency (EPA) [128] *Non-enforceable regulation.*
Secondary Standard of Maximum Contaminant Levels (SMCL) from Public Water Systems	2.0 mg per liter	U.S. Environmental Protection Agency (EPA) [128] *Non-enforceable regulation.*

Abbrev: mg, milligrams; d, day; y, years of age; mo., months of age

Section 7.2: Multiple Sources of Exposure

Understanding fluoride exposure levels from *all sources* is crucial because recommended intake levels for fluoride in water and food should be based upon these common multiple exposures. However, clearly these levels are *not* based on collective exposures because the authors of this document could not locate a single study or research article that included estimates of combined exposure levels from all sources identified in Table 2 in Section 3 of this position paper. However, there are several review articles stating that the controlled population-level trials to determine the optimal dose (even if that is zero) have not been conducted and that there is an urgent need to do so.[129,130]

As stated above no literature exists combining all identified exposures, however, there is some literature on the effects of multiple exposures to fluoride. One study evaluated fluoride exposures in children from drinking water, beverages, cow's milk, foods, fluoride supplements, toothpaste swallowing, and soil ingestion. They found that the reasonable maximum exposure estimates exceeded the upper tolerable intake and concluded that some children may be at risk for fluorosis.[131] Another study considered exposures from water, toothpaste, fluoride supplements, and foods. They found considerable individual variation and showed that some children

exceeded the optimal range, suggesting that the concept of an 'optimal' intake amount is inconceivable.[132] Several studies have shown that young children (under two years of age) get most of their fluoride exposure from swallowing toothpaste.[133]

Although the American Dental Association (ADA) is a trade group and not a government entity, it heavily influences government decisions and the dental industry regarding its stance on dental products. The ADA has recommended that collective sources of fluoride exposure should be taken into account. In particular, they have recommended that research should estimate the total fluoride intake from all sources individually, and in combination.[134] Furthermore, in an article about the use of fluoride "supplements" (i.e., prescription drugs given to patients, usually children, that contain fluoride as the active ingredient), the ADA mentioned that all sources of fluoride should be evaluated and that "patient exposure to multiple water sources can make proper prescribing complex."

The concept of evaluating fluoride exposure levels from multiple sources was addressed in the 2006 National Research Council (NRC) report, which acknowledged the difficulties with accounting for all sources and individual variances. Nonetheless, the NRC authors attempted to calculate combined exposures from pesticides/air, food, toothpaste, and drinking water.[16] While these calculations did not include exposures from other dental materials, pharmaceutical drugs, and other consumer products, the NRC still recommended to lower the MCLG for fluoride, which has not yet been accomplished.

Section 7.3: Individualized Responses and Susceptible Subgroups

Setting one universal level of fluoride as a recommended limit is also problematic because it does not consider individualized responses. While age, weight, and sex are *sometimes* considered in recommendations, the current EPA regulations for water prescribe one level that applies to everyone, including infants and children that are known to be at increased risk. For example, infants who are primarily fed formula have fluoride exposure levels that are 2.8-3.4 times greater than that of adults.[16] Further, such a "one dose fits all" level also fails to address allergies to fluoride, genetic factors, nutrient deficiencies, and other individualized factors known to influence the effects of fluoride exposure.[129]

The NRC recognized such individualized responses to fluoride numerous times in their 2006 publication,[16] and further research is confirmatory.[129] For example, urine pH, diet, lifestyle, presence of drugs, and other factors have been identified as variables that affect the amount of fluoride excreted in the urine. As noted in the NRC report, certain subgroups of people have water intakes that are much greater than average and as such, these subgroups are at greater risk (i.e., athletes, workers with physically demanding duties, military personnel, people living in hot/dry climates). People with health conditions that increase water intake are also at greater risk (i.e., pregnant or lactating women, people with diabetes mellitus). Summing all of these subgroups and considering that almost 40 million (12% of the U.S. population) people have diabetes, it is apparent that hundreds of millions of Americans are at risk from the current levels of fluoride added to community drinking water.[135]

The American Dental Association (ADA), a trade-based group that promotes water fluoridation, recognized the issue of individual variance in fluoride intake. They recommended research should be conducted to identify biomarkers (that is, distinct biological indicators) as an alternative to direct fluoride intake measurement.[134] The ADA further recommended that metabolic studies of fluoride be conducted, to determine the influence of environmental, physiological and pathological conditions on the pharmacokinetics, balance and effects of fluoride.[134]

Perhaps most notably, the ADA has acknowledged infants as a susceptible subgroup. The ADA recommends following the American Academy of Pediatrics guideline that breastfeeding should be exclusively practiced until

a child is six months old and continued until 12 months, unless contraindicated.[134] It has been shown that breastfed versus formula-fed infants have lower fluoride intake, exertion and retention.[136] However, in the U.S. only about 56% of babies are breastfed at 6 months, which falls to 36% by 12 months.[137] Thus, millions of infants who are fed formula mixed with fluoridated water, are exceeding the optimal intake levels of fluoride based on their low weight, small size, and developing body. Hardy Limeback, PhD, DDS, a member of a 2006 National Research Council (NRC) panel on fluoride toxicity, and former President of the Canadian Association of Dental Research elaborated: "Newborn babies have undeveloped brains, and exposure to fluoride, a suspected neurotoxin, should be avoided."[138]

Studies show that children experience the greatest negative consequences from fluoride exposure, casting them as potentially, the most vulnerable subgroup. This is because their bodies and brains are still in development. Prenatal exposure carries even greater risks. Evidence indicates that fluoride is found in the maternal plasma and urine, placenta, amniotic fluid and fetus (Review).[139] In one study maternal urinary fluoride concentrations were measured in urine samples obtained during pregnancy in two previously published large cohorts of mother-child pairs. These earlier studies were criticized by pro-fluoridation proponents. One is referred to as the ELEMENT (Early Life Exposures in Mexico to Environmental Toxicants) cohort[140] and the other, the MIREC (Maternal-Infant Research on Environmental Chemicals) cohort.[99] Both of these studies found that greater maternal urine fluoride predicted lower intelligence quotient (IQ) in their offspring. In the combined study, similar effects were observed: Children were assessed for IQ at age 4 in one cohort and age 12 in the other cohort. Overall, maternal urinary fluoride exposure predicted significantly lower IQ scores.[141]. In 2024, this study was expanded by adding a third cohort bringing the total number of mother-child pairs to >1500. The joint analysis of the 3 cohorts showed a significant association between urine-fluoride and IQ.[142] The benchmark concentration that showed effects was 0.45 milligrams/liter, illustrating the need for protection against fluoride toxicity in women of child-bearing age. These studies were all rated as low risk of bias, well-conducted studies that included appropriate confounders by the 2019 NTP report assessing the effects of fluoride on neurocognition.[62] According to the Fluoride Action Network, 78 out of 87 studies report lowered IQ in children associated with exposure to fluoride.[143]

Section 7.4: Exposure from Water and Food

Fluoridated water is generally considered the main source of fluoride exposure for Americans. The PHS estimated that the average dietary intake of fluoride for adults living in areas with 1.0 milligram/liter fluoride in the water as between 0.02-0.048 milligrams/kilogram/day and for children as between 0.03 to 0.06 milligrams/kilogram/day [35]. Additionally, the CDC has shared research reporting that water and processed beverages can comprise 75% of a person's fluoride intake.[21,144]

The 2006 report on fluoride from the U.S. National Research Council (NRC) came to similar conclusions. The authors estimated how much of overall fluoride exposure is attributable to water when compared to pesticides/air, food, and toothpaste, and they stated: "Assuming that all drinking-water sources (tap and non-tap) contain the same fluoride concentration and using the EPA default drinking water intake rates, the drinking water contribution is 67-92% at 1 milligrams/liter, 80-96% at 2 milligrams/liter, and 89-98% at 4 milligrams/liter".[16] The levels of the NRC's estimated fluoridated water intake rates were higher for individuals with higher water requirements such as, athletes, people who work outdoors, and individuals with diabetes.[18]

Drinking fluoridated tap water is not the only source of fluoride received from water. Fluoridated water is also used for growing crops, tending to livestock, food preparation, and bathing. It is also used to create processed foods, cereals and beverages. Disturbingly high levels of fluoride have been recorded in infant formula and commercial beverages, such as juice and soft drinks.[18,145] Significant levels of fluoride have also been recorded in alcoholic beverages, especially wine and beer.[146,147]

Domestic pets and livestock are also at risk for unsafe levels of fluoride exposure in fluoridated areas. Not only are they exposed through fluoridated water, but they also are often fed processed meats that contain high levels of fluoride. Much of the fluoride that is not excreted in the urine is sequestered in bones, and processed meats are prepared by mechanical deboning, which leaves skin and bone particles in the meat, thereby increasing the fluoride levels.[16]

Exposure estimates provided in the 2006 NRC report, illustrate that fluoride in food consistently ranked as the second largest source behind water.[16] Significant Increased levels of fluoride in food can occur with the use of fluoride-containing pesticides and fertilizers and during food preparation.[16] Significant fluoride levels have been recorded in grapes and grape products.[16] Significant Fluoride levels have also been reported in cow's milk due to livestock raised on fluoride-containing water, feed, and soil,[145] as well as processed meat (i.e., chicken patties), likely due to mechanical deboning.[16]

Section 7.5: Exposure from Fertilizers, Pesticides, and Other Industrial Releases

Phosphate fertilizers and certain types of pesticides contain fluoride, and these sources constitute a portion of overall fluoride intake. The levels vary based upon the exact product and the individual's exposure, but in the 2006 NRC report, an examination of dietary fluoride exposure levels from two pesticides found that the contribution from pesticides plus fluoride in the air is within 4% to 10% for all population subgroups at 1 mg/L in tap water, 3-7% at 2 milligrams/liter in tap water, and 1-5% at 4 milligrams/liter in tap water".[16]

Additionally, the environment is contaminated by fluoride releases from industrial sources, and these releases likewise impact water, soil, air, food, and human beings within the surrounding vicinity. Industrial releases of fluoride result from coal combustion by electrical utilities and other industries.[16] Releases also occur from refineries and metal ore smelters,[148] aluminum production plants, phosphate fertilizer plants, chemical production facilities, steel mills, magnesium plants, and brick and structural clay manufacturers,[16] as well as, copper and nickel producers, phosphate ore processors, glass manufacturers, and ceramic manufacturers.[149] Concerns about fluoride exposure from these industrial activities, especially when combined with other sources of exposure, demonstrate the necessity of stricter industrial safety measures to reduce the unethical discharge of fluoride compounds into the environment.[150]

Section 7.6: Exposure from Dental Products for Use at Home

The U.S. Food and Drug Administration (FDA) 'requires' specific wording for the labeling on toothpaste, including strict warnings for children [74]. Yet, in spite of these labels and directions for use, research suggests that toothpaste significantly contributes to daily fluoride intake in children [145]. In February 2019, the CDC released a report with statistics from a study showing that more than 38% of children aged 3–6 years reportedly used a half or full load of toothpaste, exceeding current recommendations for no more than a pea-sized amount (0.25 gram) and putting them in danger of exceeding recommended levels of daily fluoride ingestion.[151] One might conjecture that children and adults who are exceeding the dose are merely responding to the advertisements they have repeatedly been exposed to. Fluoride exposure from dental products used at home likewise contribute to overall exposure levels. These levels are highly significant and occur at rates which vary by person due to the frequency and amount of use, as well as individual response. They also vary not only by the type of product used, but also by the specific brand of the product used. To add to the complexity, these products contain different types of fluoride, and the average consumer is unaware of what the type and concentrations listed on the label means. Additionally, most of the studies that have been done on these products involve children, and even the CDC has explained that research involving adult exposure to fluoridated toothpaste, mouth rinse, and other products is lacking.[21]

Fluoride added to toothpaste can be in the form of sodium fluoride (NaF), sodium monofluorophosphate (Na_2FPO_3), stannous fluoride (tin fluoride, SnF_2), or a variety of amines.[152] Toothpaste used at home generally contains between 850 to 1,500 parts per million (ppm) fluoride,[74] while prophy paste, used in the dental office during a cleaning, generally contains 4,000 to 20,000 ppm fluoride [21]. Brushing with fluoridated toothpaste is known to raise fluoride concentration in saliva by 100 to 1,000 times, with effects lasting one to two hours.[21,153]

Basch et al 2014, examined the marketing strategies and warning labels on children's toothpaste with alarming results. Out of 26 toothpastes marketed towards children, 50% had pictures of appetizing food items (i.e, strawberry, watermelon slice, etc.), while 92.3% stated they were flavored (i.e., berry, bubble fruit, etc.). In direct contradiction to the recommendations of using a pea-sized amount (shown in small font on the back of 85% of the packages), 26.9% of ads showed a toothbrush with a full swirl of toothpaste.[154] Adult toothpastes are also marketed in a similar manner.

A 'pea sized' amount is recommended on the back of some packaging, while advertisements and product packaging often show large quantities of toothpaste on the brush.

Some research has even shown that swallowing toothpaste can result in higher levels of fluoride intake in children than that received from daily water consumption. One study showed that children's ingestion of toothpaste accounted for 74% of total fluoride intake in fluoridated areas and 87% in non-fluoridated areas.[155] In light of the significant fluoride exposure levels in children from toothpaste and other sources, scientists have questioned the continued need for fluoridation in the U.S. municipal water supply.[145]

Mouth rinses (and mouthwash) also contribute to overall fluoride exposure levels. Mouth rinses can contain sodium fluoride (NaF), phosphate fluoride (APF), stannous fluoride (SnF2), sodium monofluorophosphate (SMFP), amine fluoride (AmF), or ammonium fluoride (NH4F).[156] A 0.05% sodium fluoride solution of mouth rinse contains 225 ppm of fluoride.[157] Like toothpaste, accidental swallowing of this dental product can raise fluoride intake levels even higher.

Fluoridated dental floss is yet another product that contributes to overall fluoride exposure. Flosses that have added fluoride have been reported to contain 0.15 milligrams/meter and release fluoride into the tooth enamel[158] at levels greater than mouth rinse.[159] Elevated fluoride in saliva has been documented for at least 30 minutes after flossing,[22] but like other over-the-counter dental products, a variety of factors influence the fluoride release. In one study it was shown that saliva (flow rate and volume), intra- and inter-individual circumstances, and variation between products impact fluoride releases from dental floss, fluoridated toothpicks, and interdental brushes.[24] Additionally, dental floss can contain fluoride in the form of perfluorinated compounds, and 5.81 nanograms/gram of liquid has been identified as the maximum concentration of perfluorinated carboxylic acid (PFCA) in dental floss and plaque removers.[160]

Many consumers utilize toothpaste, mouthwash, and floss in combination on a daily basis, and thus, these multiple routes of fluoride exposure are especially relevant when considering an individual's overall intake levels of fluoride. In addition to these over-the-counter dental products, many materials used during dental office visits

result in even higher fluoride exposure levels for millions of consumers.

Section 7.7: Exposure from Dental Products for Use at the Dental Office

A major void exists in the scientific literature attempting to quantify fluoride releases from procedures and products administered at the dental office as part of estimates of overall fluoride intake. Part of this is likely because researchers evaluating exposure levels from sources in the dental office have found that establishing any type of average release rate for these products is impossible.

A prime example of this scenario is the use of dental "restorative" materials, which are used to fill cavities. Many of the options for filling materials contain fluoride, including *all* glass ionomer cements, *all* resin-modified glass ionomer cements, *all* giomers, *all* polyacid-modified composites (compomers), *certain types of* composites, and *certain types of* dental mercury amalgams.[26] Fluoride-containing glass ionomer cements, resin-modified glass ionomer cements, and polyacid-modified composite resin (compomer) cements are also used in orthodontic band cements.[27]

Glass ionomers and resin-modified glass ionomers release an "initial burst" of fluoride and then give off lower levels of fluoride long-term.[26] The long-term emission also occurs with giomers and compomers, as well as fluoride-containing composites and amalgams.[26] However, composite and amalgam filling materials are known to release much lower levels of fluoride than the glass ionomer-based materials.[161] To put these releases into perspective, one study showed that the fluoride concentration released from glass ionomer cements was approximately 2-3 ppm after 15 minutes, 3-5 ppm after 45 minutes, and 15-21 ppm within twenty-four hours, with a total of 2-12 milligrams of fluoride per milliliter of glass-ionomer cement released during the first 100 days.[162] To complicate matters, these dental materials are designed to "recharge" their fluoride releasing capacity, thereby boosting the amounts of fluoride released. This increase in fluoride release is initiated because the materials are constructed to serve as a fluoride reservoir that can be refilled. Thus, by utilizing another fluoride-containing product, such as a gel, varnish, or mouthwash, more fluoride can be retained by the material and thereafter released over time. Glass ionomers and compomers are most recognized for their recharging effects, but a number of variables influence this mechanism, such as the composition and the age of the material,[161] in addition to the frequency of recharging and the type of agent used for recharging.[163,164]

In spite of the many factors that influence fluoride release rates in dental devices, attempts have been made to establish fluoride release profiles for these products. Vermeersch and colleagues examined fluoride release in 16 types of dental products including glass-ionomers and resin composites. They found that fluoride release was highest within the first 24 hours after placement. They further found that it was not possible to distinguish fluoride release by material type unless products by the same manufacturer were compared.[165]

Other materials used at the dental office likewise fluctuate in fluoride concentration and release levels. Currently, there are dozens of products on the market for fluoride varnish, which, when used, are typically applied to the teeth during two dental visits per year. These products have different compositions and delivery systems[166] that vary by brand.[167] According to the American Dental Association (ADA), fluoride-containing varnishes generally contain 5% sodium fluoride (NaF), which is equivalent to 2.26% or 22,600 ppm fluoride ion.[168] Gels and foams can also be used at the dentist office and sometimes even at home. According to the ADA, some of the most routinely used fluoride gels contain acidulated phosphate fluoride (APF), which consists of 1.23% or 12,300 ppm fluoride ion, and 2% sodium fluoride (NaF), which consists of 0.90% or 9,050 ppm fluoride ion.[168] Brushing and flossing before applying gel can result in higher levels of fluoride retained in the enamel.[169] The ADA has noted that there are few clinical studies on the effectiveness of fluoride foams.[168]

Silver diamine fluoride is also used in dental procedures, and the brand used in the U.S. contains 5.0-5.9%

fluoride.[85] This is a relatively new procedure that received FDA approval in 2014 for treating tooth sensitivity, but not dental caries, which is an off-label use.[85] Concerns have been raised about risks of silver diamine fluoride, which can permanently stain teeth black.[85,170]

Section 7.8: Exposure from Pharmaceutical Drugs (including supplements)

U to 20-30% of pharmaceutical compounds have been estimated to contain fluorine [171]. Some reasons that have been identified for its addition to drugs include claims that it can increase the drug's selectivity, enable it to dissolve in fats, and decrease the speed at which the drug is metabolized, thus allowing it more time to work.[89] Fluorine is used in drugs such as general anesthetics, antibiotics, anti-cancer and anti-inflammatory agents, psychopharmaceuticals [30], and other applications. Some of the most popular fluorine-containing drugs include Prozac and Lipitor [172], as well as the fluoroquinolone family (ciprofloxacin, marketed as Cipro), gemifloxacin (marketed as Factive), levofloxacin (marketed as Levaquin), moxifloxacin (marketed as Avelox), and ofloxacin.[173]

A partial list of commonly prescribed medications, collated by the Fluoride Action Network (FAN) includes Advair Diskus; Atorvastatin; Baycol; Celebrex; Dexamethasone; Diflucan; Flonase; Flovent; Haldol; Lipitor; Luvox; Fluconazole; Fluoroquinolone antibiotics such as Cipro, Levaquin, Penetrex, Tequin, Factive, Raxar, Maxaquin, Avelox, Noroxin, Floxin, Zagam, Omniflox and Trovan; Fluvastatin; Paroxetine; Paxil; Prozac; Redux; Zetia.

The release of elemental fluorine, referred to as defluorination, of any type of fluorinated drug can and does occur, and can lead to osteofluorosis and severe renal insufficiency (Review).[30] These, among a multitude of other health risks, led researchers to conclude that it is impossible to responsibly predict what happens in the human body after administration of fluorinated compounds. In their review, describing the mechanisms of defluorination and the wide-spread use of fluorinated drugs in vulnerable populations, including neonates, infants, children, and ill patients, Strunecká et al, 2004 question whether these groups are being used as clinical research subjects.[30]

Certain drugs generate extremely high levels of fluoride exposure. For example, fluoridated anesthesia is known to increase plasma fluoride levels. In particular, the anesthesia sevoflurane can result in 20 times the total daily dietary fluoride intake than that obtained from sources of food and water combined.[174]

Another prescription drug is likewise essential to consider regarding overall fluoride exposure levels: These are fluoride tablets, drops, lozenges, and rinses, which are often referred to as fluoride supplements or vitamins, and are prescribed by dentists. These products contain 0.25, 0.5, or 1.0 milligram fluoride,[21] and they are not approved as safe and effective for caries prevention by the FDA.[175]

Potential dangers of these fluoride "supplements" have been addressed. The 2006 NRC report showed that all children through age 12 who take fluoride supplements, even while consuming low water fluoride, will reach or exceed 0.05-0.07 mg/kg/day.[18] No data exist regarding adverse effects related to fluoride supplementation in children aged less than 6 years. Thus, the benefit/risk ratio of fluoride supplementation is unknown for young children".[176] Moreover, an analysis of fluoride in toothpaste and fluoride supplements found extremely high levels of fluoride and concluded that more strict control of fluoride content in consumer products for oral hygiene is needed.[152]

Section 7.9: Exposure from Perfluorinated Compounds

In 2012, dietary intake was first identified as the major source of exposure to PFCs.[19] and additional scientific investigation has supported this claim. In one study estimating consumer exposure to fluoride through PFC

exposure, researchers found that contaminated food (including drinking water) is the most common exposure route of perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA).[20] They concluded that North American and European consumers are likely to experience ubiquitous and long-term uptake doses of PFOS and PFOA in the range of 3 to 220 nanograms per kilogram body weight per day (ng/kg(bw)/day) and 1 to 130 ng/kg(bw)/day, respectively.[20] They also concluded that children have increased uptake doses due to their smaller body weight.

Posner, 2012 explored some of the other common sources of PFCs. Results showed that commercial carpet-care liquids, household carpet and fabric-care liquids and foams, and treated floor waxes and stone/wood sealants had higher concentrations of PFCs when compared to other PFC-containing products.[160] The authors also specified that the exact compositions of PFCs in consumer products are often kept confidential and that knowledge about these compositions is "very limited".[160]

Additionally, in 2016, the EPA stated of PFSAs, "Studies indicate that exposure to PFOAs and PFOSs over certain levels may result in adverse health effects, including developmental effects to fetuses during pregnancy or to breast-fed infants (e.g., low birth weight, accelerated puberty, skeletal variations), cancer (e.g., testicular, kidney), liver effects (e.g., tissue damage), immune effects (e.g., antibody production and immunity), and other effects (e.g., cholesterol changes).[177]

Section 7.10: Interactions of Fluoride with Other Chemicals

Although fluoride exposure itself can pose a health threat, when it interacts with other chemicals it has the potential to cause even greater damage. While the majority of these interactions have not been tested we do know of several hazardous combinations.[178]

Aluminofluoride exposure occurs from ingesting a fluoride source in combination with an aluminum source. This dual and synergistic exposure can occur through consumer use of water, tea, food residue, infant formulas, aluminum-containing antacids or medications, deodorants, cosmetics, and glassware.[16] These complexes act as phosphate analogs in the human body, interfering with cell metabolism.[179]

Ingredients in dental products also interact with fluoride. For example, fluoride treatment dramatically increases galvanic corrosion of mercury amalgam fillings and other dental alloys.[180] Some orthodontic wires and brackets also show increased levels of corrosion when exposed to fluoride-containing mouthwash.[181] Essential to note is that galvanic corrosion of dental materials has been linked to other adverse health effects such as potentially malignant oral lesions and local or systemic hypersensitivity that may lead to neurodegenerative and autoimmune disease (Review).[182]

Furthermore, fluoride, in its form of silicofluoride (SiF), which is added to many water supplies to fluoridate the water, attracts manganese and lead, both of which can be present in certain types of plumbing pipes. Likely because of its affinity for lead, fluoride has been linked to higher blood lead levels in children, especially in minority groups.[183,184] Lead exposure causes significant reductions in IQ in children and death due to cardiovascular disease.[185]

Many health issues associated with fluoride are due to displacement of essential iodine. As reviewed by Iamandii et al, 2024, some studies have shown that when iodine status is either low or high, fluoride has greater negative effects (Review). For example, one study examined the impact of chronic low-level fluoride exposure on thyroid function, while considering iodine status. The objective was to determine whether urinary iodine status modified the effect of fluoride exposure on thyroid stimulating hormone (TSH) levels. An increase in urinary fluoride was

significantly associated with a decrease in TSH within individuals who were iodine-deficient, putting these individuals at increased risk for underactive thyroid gland activity.[186]

Section 8: Lack of Efficacy, Lack of Evidence, and Lack of Ethics

The reduction in tooth decay that has occurred in countries with and without fluoridation makes it glaringly obvious that water fluoridation is not necessary to reduce caries. The fact that the water supply of 66% of Americans is fluoridated[187] when there is a lack of efficacy and a lack of evidence for its use, demonstrates a lack of ethics, which may be fueled by the government's ties to industry.

In relation to the lack of efficacy and lack of evidence, the ethics of dental practices are called in to play. A cornerstone of public health policy known as the precautionary principle must be considered. The basic premise of this policy is built upon the centuries-old medical oath to "first, do no harm." Yet, the modern application of the precautionary principle is supported by an international agreement: In January 1998, at an international conference involving scientists, lawyers, policy makers, and environmentalists from the U.S., Canada and Europe, a formalized statement was signed and became known as the Wingspread Conference on the Precautionary Principle. Participants concluded that based on the magnitude and seriousness of damage to humans and the environment from human activity, new principles were needed for conducting human activities. Therefore, they implemented the Precautionary Principle: "When an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause and effect relationships are not fully established scientifically" and "In this context the proponent of an activity, rather than the public, should bear the burden of proof."[188]

Not surprisingly, the need for the appropriate application of the precautionary principle has been associated with fluoride usage. Authors of an article entitled "What Does the Precautionary Principle Mean for Evidence-Based Dentistry?" suggested the need to account for cumulative exposures from all fluoride sources and population variability, while also stating that consumers can reach "optimal" fluoridation levels without ever drinking fluoridated water.[189] Additionally, a review published in 2014 addressed the obligation for the precautionary principle to be applied to fluoride usage, and they took this concept one step further when they suggested that our current understanding of dental caries "diminishes any major future role for fluoride in caries prevention."[190]

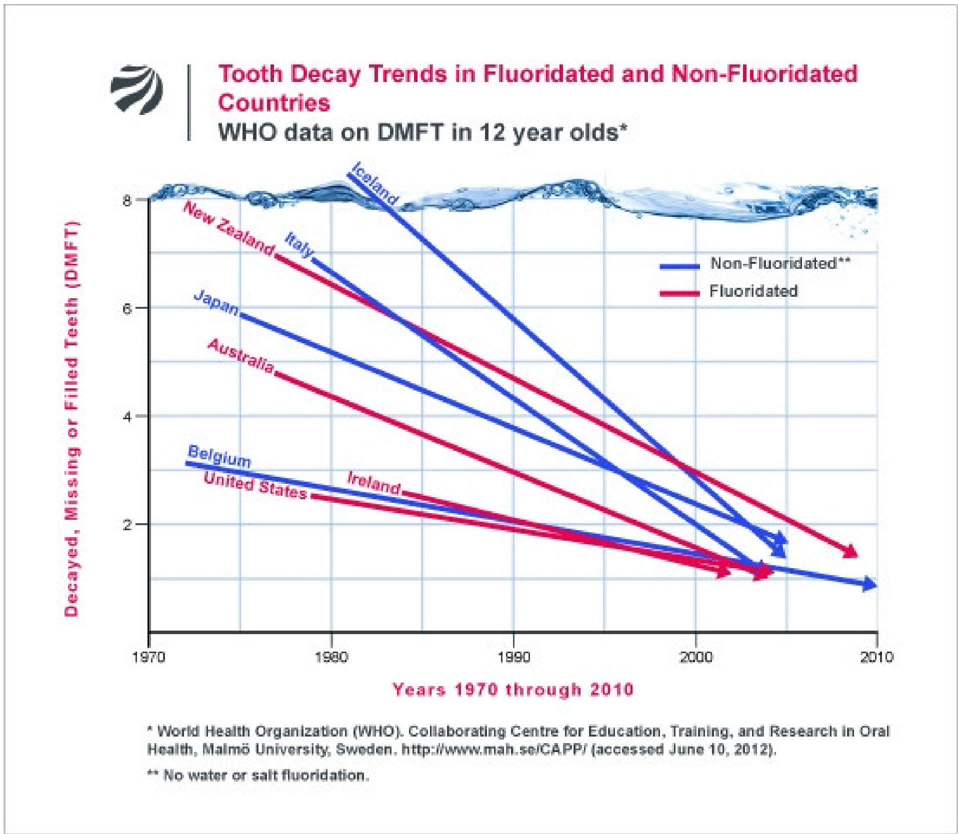
Section 8.1: Lack of Efficacy

Fluoride is added to toothpastes and other dental products because it allegedly reduces dental caries. It does this by inhibiting bacterial respiration of Streptococcus mutans, the bacterium that turns sugar and starches into a sticky acid that dissolves enamel.[191] In particular, the interaction of fluoride with the mineral component of teeth produces fluorohydroxyapatite, and the result of this action is said to be enhanced remineralization and reduced demineralization of teeth. However, some research has shown that it is *topical* application (i.e. scrubbing it directly onto to teeth with a toothbrush), rather than *systemic* (i.e. drinking or ingesting fluoride through water or other means) that provides this result.[16,192] However, doubts to whether topical application has an effect have been recently called into question. A prospective randomized clinical trial compared the effectiveness of two topical fluoride applications versus placebo control (i.e., 3 groups of children) on preventing the development of approximal caries in primary teeth. Following a period of 18 months, and controlling for confounding variables, no differences were observed in caries development between the 3 groups.[193]

Although the topical benefits of fluoride have been shown in scientific literature, although see [193], is it *necessary* to reduce caries? It would seem not, as caries reduction has occurred without such application in many industrialized countries regardless of water fluoridation policies (See Figure 4), and it has continued in countries

that discontinue systemic water fluoridation. In this case, it would be prudent to apply the precautionary principle.[189] It is suggested that increased oral hygiene, access to preventative services, and more awareness of the detrimental effects of sugar are responsible for the decrease in tooth decay, however the reasons for reduced decay have not been systematically examined.

Figure 4: Tooth Decay Trends in Fluoridated and Unfluoridated Countries, 1970-2010



Abbrev: DMFT, Decayed, Missing & Filled teeth

Fluoride's use in preventing tooth decay has been questioned in other research as well. A 2014 review argues that the modest benefits of intentionally ingesting fluoride to prevent caries are "...counterbalanced by its established and potential diverse adverse impacts on human health".[150] Furthermore, a plethora of research cited in the 2006 National Research Council Report on fluoride has shown that *systemic* fluoride exposure has minimal (if any) effect on the teeth.[18] Further, newer studies conducted with rigorous methods indicate that water fluoridation does not reduce caries development.[5,6] Thus, since fluoridating the water causes dental fluorosis (the first sign of fluoride toxicity) application of the precautionary principle, to guide health-protective decision making when facing complex risks, seems appropriate.[189]

Several other considerations are relevant in any decision about the use of fluoride to prevent caries: First, fluoride is not essential for human growth and development, [18] which begs the question, why would we put it in the human body? Second, fluoride is recognized as one of 12 industrial chemicals known to cause developmental neurotoxicity in human beings;[12] and finally, in their executive summary of the updated clinical recommendations and supporting systematic review, the American Dental Association (ADA) called for more research in regard to the mechanism of fluoride action and effects:

> "Research is needed regarding various topical fluorides to determine their mechanism of action and caries-preventive effects when in use at the current level of background fluoride exposure (that is, fluoridated water and fluoride toothpaste) in the United States. Studies regarding strategies for using fluoride to induce arrest or reversal of caries progression, as well as topical fluoride's specific effect on erupting teeth, also are needed".[166]

The research called out for by the ADA has now been conducted and indicates that topical applications have less of an effect than what has previously been shown. A 2023 prospective randomized longitudinal clinical trial compared the effectiveness of two topical fluoride applications or a placebo control on preventing the development caries in the primary teeth of preschool-aged children. Following a period of 18 months, and controlling for confounding variables, no differences were observed in caries development between the 3 groups.[193]

Section 8.2: Lack of Evidence

References to the unpredictability of levels at which fluoride's effects on the human system occur have been made throughout this position paper. However, it is important to reiterate the lack of evidence associated with fluoride use, and thus, Table 5 provides an abbreviated list of stringent warnings from governmental, scientific, and other pertinent authorities about the dangers and uncertainties related to utilizing fluoridated products.

Table 5: Selected Quotes about Fluoride Warnings Categorized by Product/Process and Source

Product/ Process	Quotes	Source of Information
Fluoride for dental uses, including water fluoridation	"The prevalence of dental caries in a population is not inversely related to the concentration of fluoride in enamel, and a higher concentration of enamel fluoride is not necessarily more efficacious in preventing dental caries." "Few studies evaluating the effectiveness of fluoride toothpaste, gel, rinse, and varnish among adult populations are available."	Centers for Disease Control and Prevention (CDC). Kohn WG, Maas WR, Malvitz DM, Presson SM, Shaddik KK. Recommendations for using fluoride to prevent and control dental caries in the United States. *Morbidity and Mortality Weekly Report: Recommendations and Reports*. 2001 Aug 17:i-42.
Fluoride in drinking water	"Overall, there was consensus among the committee that there is scientific evidence that under certain conditions fluoride can weaken bone and increase the risk of fractures."	National Research Council. *Fluoride in Drinking Water: A Scientific Review of EPA's Standards.* The National Academies Press: Washington, D.C. 2006.
Fluoride in drinking water	"The recommended Maximum Contaminant Level Goal (MCLG) for fluoride in drinking water should be zero."	Carton RJ. Review of the 2006 United States National Research Council Report: Fluoride in Drinking Water. *Fluoride.* 2006 Jul 1;39(3):163-72.
Water fluoridation	"Fluoride exposure has a complex relationship in relation to dental caries and may increase dental caries risk in malnourished children due to calcium depletion and enamel hypoplasia..."	Peckham S, Awofeso N. Water fluoridation: a critical review of the physiological effects of ingested fluoride as a public health intervention. *The Scientific World Journal.* 2014 Feb 26; 2014.

Product/ Process	Quotes	Source of Information
Fluoride in dental products, food, and drinking water	"Because the use of fluoridated dental products and the consumption of food and beverages made with fluoridated water have increased since HHS recommended optimal levels for fluoridation, many people now may be exposed to more fluoride than had been anticipated."	Tiemann M. Fluoride in drinking water: a review of fluoridation and regulation issues. *BiblioGov*. 2013 Apr 5. Congressional Research Service Report for Congress.
Fluoride intake in children	"The 'optimal' intake of fluoride has been widely accepted for decades as between 0.05 and 0.07 mg fluoride per kilogram of body weight but is based on limited scientific evidence." "These findings suggest that achieving a caries-free status may have relatively little to do with fluoride intake, while fluorosis is clearly more dependent on fluoride intake."	Warren JJ, Levy SM, Broffitt B, Cavanaugh JE, Kanellis MJ, Weber-Gasparoni K. Considerations on optimal fluoride intake using dental fluorosis and dental caries outcomes–a longitudinal study. *Journal of Public Health Dentistry.* 2009 Mar 1;69(2):111-5.
Fluoride-releasing dental restorative materials (i.e. dental fillings)	"However, it is not proven by prospective clinical studies whether the incidence of secondary caries can be significantly reduced by the fluoride release of restorative materials."	Wiegand A, Buchalla W, Attin T. Review on fluoride-releasing restorative materials—fluoride release and uptake characteristics, antibacterial activity and influence on caries formation. *Dental Materials.* 2007 Mar 31;23(3):343-62.
Dental material: silver diamine fluoride	"Because silver diamine fluoride is new to American dentistry and dental education, there is a need for a standardized guideline, protocol, and consent." "It is unclear what will happen if treatment is stopped after 2-3 years and research is needed."	Horst JA, Ellenikiotis H, Milgrom PM, UCSF Silver Caries Arrest Committee. UCSF Protocol for Caries Arrest Using Silver Diamine Fluoride: Rationale, Indications, and Consent. *Journal of the California Dental Association.* 2016 Jan;44(1):16.
Topical fluoride for dental use	"The panel had a low level of certainty regarding the benefit of 0.5 percent fluoride paste or gel on the permanent teeth of children and on root caries because there were few data on the home use of these products." "Research is needed concerning the effectiveness and risks of specific products in the following areas: self- applied, prescription-strength, home-use fluoride gels, toothpastes or drops; 2 percent professionally applied sodium fluoride gel; alternative delivery systems, such as foam; optimal application frequencies for fluoride varnish and gels; one-minute applications of APF gel; and combinations of products (home-use and professionally applied)."	Weyant RJ, Tracy SL, Anselmo TT, Beltrán-Aguilar ED, Donly KJ, Frese WA, Hujoel PP, Iafolla T, Kohn W, Kumar J, Levy SM. Topical fluoride for caries prevention: Executive summary of the updated clinical recommendations and supporting systematic review. *Journal of the American Dental Association.* 2013;144(11):1279-1291.
Fluoride "supplements" (tablets)	"Evident disagreements among the results show that there's a limited effectiveness on fluoride tablets."	Tomasin L, Pusinanti L, Zerman N. The role of fluoride tablets in the prophylaxis of dental caries. A literature review. *Annali di Stomatologia.* 2015 Jan;6(1):1.

Product/ Process	Quotes	Source of Information
Pharmaceuticals, fluorine in medicine	"No one can responsibly predict what happens in a human body after administration of fluorinated compounds."	Strunecká A, Patočka J, Connett P. Fluorine in medicine. *Journal of Applied Biomedicine.* 2004; 2:141-50.
Drinking water with poly- and perfluoroalkyl substances (PFASs)	"Drinking water contamination with poly- and perfluoroalkyl substances (PFASs) poses risks to the developmental, immune, metabolic, and endocrine health of consumers." "…information about drinking water PFAS exposures is therefore lacking for almost one-third of the U.S. population."	Hu XC, Andrews DQ, Lindstrom AB, Bruton TA, Schaider LA, Grandjean P, Lohmann R, Carignan CC, Blum A, Balan SA, Higgins CP. Detection of Poly-and Perfluoroalkyl Substances (PFASs) in US Drinking Water Linked to Industrial Sites, Military Fire Training Areas, and Wastewater Treatment Plants. *Environmental Science & Technology Letters*. 2016 Oct 11.
Occupational exposures to fluoride and fluoride toxicity	"Review of unpublished information regarding the effects of chronic inhalation of fluoride and fluorine reveals that current occupational standards provide inadequate protection."	Mullenix PJ. Fluoride poisoning: a puzzle with hidden pieces. *International Journal of Occupational and Environmental Health.* 2005 Oct 1;11(4):404-14.
Review of safety standards for exposure to fluorine and fluorides	"If we were to consider only fluoride's affinity for calcium, we would understand fluoride's far-reaching ability to cause damage to cells, organs, glands, and tissues."	Prystupa J. Fluorine—a current literature review. An NRC and ATSDR based review of safety standards for exposure to fluorine and fluorides. *Toxicology Mechanisms and Methods.* 2011 Feb 1;21(2):103-70.

Section 8.3: Lack of Ethics

According to the Centers for Disease Control and Prevention (CDC)[194], three types of fluoride are generally used for community water fluoridation:

- **Fluorosilicic acid** (SiF): a water-based solution also known as hydrofluorosilicate, silicofluoride, FSA, or HFS. 95% of community water systems in the U.S. uses this product to fluoridate their water.
- **Sodium fluorosilicate**: a dry additive, dissolved into a solution before being added to water.
- **Sodium fluoride:** a dry additive, dissolved into a solution before being added to water, typically used in small water systems.

A controversial issue regarding water fluoridation is how the fluoride is obtained; fluoridation products are a byproduct of industry. For example, fluorosilicic acid, hydrofluorosilicic acid, sodium silicofluoride and sodium fluoride are all sourced from phosphate fertilizer manufacturers.[195] Safety advocates for fluoride exposures have questioned if such industrial ties are ethical and if the industrial connection with these chemicals underlies the cover-up of the health effects caused by fluoride exposure.

Ethical concerns arise with such profit-driven industry involvement because they have the funding to produce the "best" evidence-based research. The biased research produced by parties that have interests, such as the

fertilizer industry, is often all the research that exists. And because it exists, unbiased science is then difficult to fund, produce, publish, and publicize. This is because funding a large-scale study is expensive for the federal government and decisions must be made about how to spend the taxpayer's dollars. Industry can also afford to spend time examining different ways of reporting results, such as leaving out certain statistics to obtain a more favorable result, and they can further afford to publicize any aspect of the research that supports their activities. Importantly, they have the resources to lobby for their cause at the federal level. And, finally, corporate entities can and will harass independent scientists if their research results and conclusions are in opposition to their claims.[190]

Ethical concerns also arise with respect to the presence and health impacts of perfluorinated compounds (PFCs) in food. An overview of the available scientific information, by country, showed that there was a paucity of science issuing from the U.S., especially in comparison to other countries.[196] Only one article was found emanating from the U.S.; this study showed that despite bans on the use of PFCs, they were found in food at varying levels.[197]

Conflicts of interest have also been known to infiltrate government agencies involved in toxic chemical regulation. A *Newsweek* article entitled "Does the EPA Favor Industry When Assessing Chemical Dangers?" described the experience of ecologist Michelle Boone, as an expert panelist for the U.S. EPA, on the use of a particular fertilizer and its environmental impacts. Boone was shocked that the EPA blatantly looked the other way and ignored the science she and the other panelists had examined and instead focused on only one industry-sponsored paper. The unanimous agreement among the panelists that the products were damaging wildlife meant nothing to the EPA.[198]

Clearly, the dental industry has a conflict of interest with the use of fluoride. Dental procedures involving fluoride earn profits for dental offices, and ethical claims have been raised about pushing fluoride procedures on patients.

Regarding water fluoridation, concerns have been raised that fluoride is added allegedly to prevent tooth decay, while other chemicals added to water serve a purpose of decontamination and elimination of pathogens. In their critical review of the physiological effects of ingested fluoride as a public health intervention, Peckham and Awofeso (2014) wrote "In addition, community water fluoridation provides policy makers with important questions about medication without consent, the removal of individual choice and whether public water supplies are an appropriate delivery mechanism."[190] Almost all of western Europe (98%) does not use water fluoridation, and governments from this region of the world have identified the issue of consumer consent as one reason for not fluoridating community drinking water.[199]

Thus, the only choice consumers have when fluoride is added to their municipal water is to buy bottled water or costly filters. The EPA has acknowledged that charcoal-based water filtration systems do not remove fluoride and that distillation and reverse osmosis systems, which can remove fluoride, are costly and therefore not available to the average consumer.[128]

A major issue in the U.S. is that consumers are not aware that fluoride is an ingredient in hundreds of products they routinely use; specifying whether fluoride is added to water or food is not a U.S. FDA requirement. While toothpaste and other over-the-counter dental products include disclosure of fluoride contents and warning labels, usually included in small difficult to read font, the average person has no context for what these ingredients or contents mean. Materials used at the dental office provide even less consumer awareness as informed consent is generally not practiced, and the presence and risks of fluoride in dental materials is, in many instances, never mentioned to the patient. Offering information on fluoride content is not enforced and only occurs in a few

states. For example, the U.S. FDA cleared the use of silver diamine fluoride as a caries preventative medication, without providing a standardized guideline, protocol, or human subjects consent.[200]

Section 9: Alternatives to Fluoride Use

Based upon the elevated number of fluoride sources and greater fluoride intake in the American population, which have both risen concurrently since water fluoridation began in the 1940's, lowering exposures to fluoride is crucial. As outlined within this position paper significant levels of fluoride can be obtained from sources other than water, providing us a starting platform.

Tooth decay is a disease caused by specific bacteria called Streptococcus mutans. Streptococcus mutans lives in microscopic colonies on the surface of the teeth and produce concentrated acid waste that can dissolve the tooth enamel on which it resides. In other words, these germs can create holes in teeth, and all they require to do so is a fuel such as sugar, processed foods, and/or other carbohydrates.

Thus, knowing what causes tooth decay is instrumental in developing ways to prevent it without resorting to fluoride. The most crucial, and yet simple method to prevent caries is diet. Eating less sugar containing foods, drinking less sugar containing beverages, improving oral hygiene, and establishing a nutritious diet and lifestyle is the best medicine to strengthen the teeth and bones. Iodine binds strongly with fluoride. Therefore, a diet containing iodine can help eliminate fluoride in the body. Food sources that contain iodine include seaweed, cruciferous vegetables, eggs and potatoes. Calcium is also one of the most effective supplements to help rid the bones and teeth of stored fluoride. Good sources of calcium include seeds, cheese, yogurt, almonds, leafy greens, sardines and salmon. Vitamin D helps with the absorption of calcium and Vitamin C helps heal the body from fluoride's effects.

In support of such strategies to prevent dental caries without fluoride, the trend of decreased decayed, missing, and filled teeth over the past few decades has occurred both in countries *with and without* the systemic application of fluoridated water (See Figure 1 or 4). Furthermore, research has documented decreases of tooth decay in communities that have discontinued water fluoridation.[7] This may suggest that increased access to preventative services, better oral health care and more awareness of the detrimental effects of sugar are responsible for these improvements in dental health.

Hydroxyapatite, composed of calcium and phosphorus, is the major mineral component occurring naturally in teeth and has significant re-mineralizing effects (Review).[201] Hydroxyapatite products are biocompatible, bioactive and durable. Hydroxyapatite chemically bonds to bone, is nontoxic and stimulates bone growth through a direct action on osteoblasts.[201] It's use in oral implantology is established and it is widely used in periodontology and in oral and maxillofacial surgery.

If fluoride it present, it replaces the tooth's natural hydroxyapatite with hydroxyfluorapatite. Fluoride-containing products such as toothpaste and mouthwash can be replaced with toothpastes that contain hydroxyapatite to preserve and strengthen the natural structure of teeth and help to prevent caries formation.

Some countries that do not use fluoridated water make fluoridated salt and milk available to provide consumers a choice on fluoride use.[46] Fluoridated salt is sold in Austria, the Czech Republic, France, Germany, Slovakia, Spain, Switzerland, Colombia, Costa Rica, and Jamaica. Fluoridated milk has been used in programs in Chile, Hungary, Scotland, and Switzerland. But, again, it has been shown that it is topical, not systemic, application of fluoride that may benefit caries reduction and because of multiple routes of exposure to fluoride, and individual variability in response, it is mostly likely, not necessary. Indeed, a recent prospective randomized longitudinal clinical trial suggests that even topical application of fluoride does not result in caries prevention.

This study compared the effectiveness of two topical fluoride applications or a placebo control on preventing the development of approximal caries in primary teeth. Following a period of 18 months, and controlling for confounding variables, no differences were observed in caries development between the 3 groups.[193]

Section 10: Education for Medical/Dental Professionals, Student, Patients, and Policy Makers

Since a scientific understanding of the health effects of fluoride has been limited to promoting its benefits, the reality of its overexposure and potential harms must now be conveyed to medical and dental practitioners, students of medicine and dentistry, patients, and policy makers.

Although informed consumer consent and more informative product labels would contribute to increasing patient awareness about fluoride intake, educating consumers as to the benefits of taking a more active role in preventing caries is crucial. A healthy diet, improved oral health practices, and other measures would assist in reducing tooth decay. This is where biological dentists and their staff can play an active role.

Finally, policymakers are tasked with the obligation of evaluating the benefits and risks of fluoride. However, these officials are often bombarded by dated claims of fluoride's alleged purposes, many of which are constructed upon limited evidence of safety and improperly formulated intake levels that fail to account for multiple exposures, individual variances, fluoride's interaction with other chemicals, and independent (non-industry sponsored) science.

Section 11: Conclusion

The sources of human exposure to fluoride and fluorine compounds have drastically increased since community water fluoridation began in the U.S. in the 1940s. In addition to water, these sources now include food, pesticides, fertilizers, dental products used at home and in the dental office (some of which are implanted in the human body and continually release fluoride), pharmaceutical drugs, carpeting, clothing, cookware, and an array of other items consumed on a routine basis.

Unfortunately, all of these applications were introduced before the health risks of fluoride and fluorine compounds, safety levels for their use, and appropriate guidelines were adequately researched and established. Combining the estimated intake levels of various products establishes that millions of people are at risk of greatly exceeding the levels of fluoride and fluorine compounds associated with systemic injuries and toxicity, the first visible sign of which is dental fluorosis. Susceptible subpopulations, such as infants, children, and individuals with diabetes or renal problems, are known to be more severely impacted by higher intake levels of fluoride.

Data from the World Health Organization (WHO) clearly show that countries with nonfluoridated water such as Italy, Germany, Norway and Japan have significantly reduced rates of tooth decay, potentially even greater rates of reduction than fluoridated countries including the U.S. and Australia, suggesting that fluoridation is not the contributing factor. Risk assessments, recommendations, and regulations that recognize exposure to fluoride and fluorine compounds from collective sources are crucial. Moreover, when the long-term, chronic exposure to these multiple sources is conscientiously considered, the required action is indisputable: Given the current levels of exposure, policies should be implemented that reduce and work toward eliminating avoidable sources of fluoride, including water fluoridation, fluoride-containing dental materials, and other products containing fluoride and fluorine compounds, as a means to promote the health and safety of the public. Consumers are relying upon policy makers to protect them by enacting enforceable regulations based upon accurate data. Is fluoridated water to prevent tooth decay worth the risks? The position of the IAOMT is clearly elucidated here, and the answer is a resounding NO!

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