COMMUNITY WATER FLUORIDATION A COST-BENEFIT-RISK CONSIDERATION

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Abstract

Background For over 70 years the addition of fluoride to public water with intent to prevent dental caries continues to be controversial and risks are seldom included in monetary evaluations. Objectives To estimate an economic cost-benefit-risk of Community Water Fluoridation (CWF) using 2021 USA dollars Per Person Per Year (PPPY), with the inclusion of two risks: dental fluorosis and lower income resulting from developmental neurotoxicity as measured with lower IQ. Methods Published operational costs and benefits of CWF are used. Published and clinical experience treating dental fluorosis are utilized to estimate treatment costs of patient perceived dental fluorosis, and lost wages from lower IQ. Patients of record provided consent for photographs. Results: Published estimated caries averted, less operational costs, were calculated at $8 PPPY and estimates of compensation for functional and cosmetic dental fluorosis were $126 PPPY. Lower earnings from presumed harm of developmental neurotoxicity $438 PPPY. Net loss from CWF is estimated at $556 PPPY. Conclusions Previous economic evaluations of CWF have estimated caries averted and costs of operations. Few evaluations include the costs of treating harm. CWF is not cost effective if the cost of harm is included.

Policy Implications Alternatives for the prevention of dental caries should be promoted and the cessation of CWF is indicated.
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**Results:** Published estimated caries averted, less operational costs, were calculated at $8 PPPY and estimates of compensation for functional and cosmetic dental fluorosis were $126 PPPY. Lower earnings from presumed harm of developmental neurotoxicity $438 PPPY. Net loss from CWF is estimated at $556 PPPY.

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1. **INTRODUCTION:** The aim of this analysis is to incorporate into previous estimates of CWF costs and benefit and include two adverse effects: dental fluorosis and lower income due to developmental neurotoxicity.

See Supplement for list of Assumptions.

Community Water Fluoridation (CWF) is referred to here as the addition of fluoride into public water by authorities with the singular intent to ”prevent or mitigate” dental caries, a disease. Estimates of about 400 million people world-wide have fluoride added to their drinking water, with more than half of those in the United States of America (USA). In contrast, about 97% of Europe is without CWF and has a similar prevalence of dental caries. Endemic fluoride, which is a major health problem in over 20 countries, is not the direct focus of this analysis. Fluoridation is controversial. [1]

Topical fluoride in toothpaste is approved by the US Food and Drug Administration Center for Drug Evaluation and Research with a New Drug Approval (FDA CDER NDA) as a drug with label and dosage. The label is precise and clear, to use a pea, rice or smear size which contains about a quarter milligram of fluoride and the warning, “do not swallow.” Acute toxicity of fluoride is estimated at 5 mg/Kg body weight. In contrast, neither CWF nor fluoride supplements have FDA CDER NDA and are considered unapproved prescription drugs, misbranded and adulterated.

Dental caries is not a fluoride deficiency disease. Fluoride is not an essential nutrient, because a lack of fluoride does not cause dental caries or any disease. Many public health agencies in the USA claim every dollar spent on fluoridation saves $38 of dental treatment [2] and assume negligible harm. However, the public has concerns with the safety of fluoride,[3] and dental caries have significantly declined with or without fluoridation.[4] A national survey [9] reported about 60% of children and adolescents have dental fluorosis, a biomarker of excess fluoride ingestion prior to eight years of age.

A clinician’s error may harm a patient and result in compensation for the specific patient harmed. Public health policy error may harm millions. As public health authorities, it is imperative that we ensure the public water is safe, because water is essential for life. Prior economic evaluations of CWF have almost always omitted potential harm or considering harm to be negligible or discounted as a “side-effect”; however, the public has concern both for safety [3] and cosmetics.[11]
Potential harms are reported by the National Research Council in 2006 [5] to such structures and physiologic functions as cell function, teeth, skeleton, chondrocyte metabolism, arthritis, reproductive and developmental effects, neurotoxicity, neurobehavioral effects, endocrine system, gastrointestinal, renal, hepatic, immune systems, genotoxicity, carcinogenicity, and more recently concerns of potential low birth weight, miscarriage, and increased infant mortality have been raised. Safety should be assured by authorities rather than patients required to prove policy is flawed. Without randomized controlled trials including both benefits and monitoring risks. Without FDA CDER drug regulatory approval, safety, dosage, and label have been neglected.

2. METHODS

A Medline and scholar.google review for costs, benefits and risks of fluoridation resulted in thousands of hits. A search with PubMed of “cost of water fluoridation harm” resulted in 1 report from 1982 and scholar.google with thousands of hits. Although not all were read, the majority appear to suggest CWF is environmentally sustainable, effective and risk to the individual is negligible, perhaps a side effect, but not specifically harm. [6]

COSTS

Published estimated costs Per Person Per Year (PPPY) to fluoridate water and estimated caries treatment costs are used. Costs to treat dental fluorosis and lower wages from lower IQ are estimated.

Discount rates generally vary from 0% to 5%. In this analysis, a discount rate of 0% was chosen for two reasons. First, this evaluation is considering life-time harm rather than potential benefit. Second, assumption is made that patients expect full compensation. Pain, suffering, time, and adverse effects and treatment failure should be included.

UNCERTAINTY

The degree of certainty that ingested fluoride during tooth development causes dental fluorosis is high with strong consensus. The cost for treating dental fluorosis has less certainty as dental fluorosis is often brushed aside as only cosmetic and therefore negligible and functional harm is ignored. The effects of low fluoride exposure on developmental neurotoxicity are rapidly developing and presumed, although less certain.

3. CWF OPERATING COSTS AND BENEFITS:

A MEDLINE review provided a range of net benefit for CWF generally from $8 PPPY [2] to $41 PPPY, and costs of treating harm is omitted or considered negligible. When costs are mentioned, not all costs are included, such as accidental spills and transportation accidents, overfeeds, infrastructure installation and maintenance, costs to avoid CWF, land, reasonable employee wages, benefits and training, supplies, research promoting and opposing CWF, defending against challenges to CWF, and costs to treat and compensate for adverse health effects. If observational studies are dismissed, no evidence of CWF benefit or risk would be available. Randomized controlled trials are lacking.

The main body of evidence for potential dental caries mitigation has numerous limitations and assumptions (See Supplement), yet the body of published evidence suggests CWF may have had and continues to have some mitigating effect on dental caries at 1 ppm for children. [6,8].

DENTAL FLUOROSIS:

CWF is authority controlled but not individual dosage or total individual exposure controlled. Not everyone drinks the same amount of water or has the same amount of fluoride intake from other sources.

A US Environmental Protection Agency (EPA) study [10] (1987)., funded by the EPA with fluoride concentrations between 1.0-4.0 mg/L evaluated the cost of treating dental fluorosis, finding:

“A mean cost for all consultants shows that the estimated costs for restoring function exceeds the cosmetic costs in all categories except the minimum later costs. This represents a new finding and raises an issue that has been overlooked or ignored by previous investigators and the profession, i.e . that repair of the cosmetic discoloration was the only cost involved; or that repair of dysfunction was never considered to be a problem.”
All consultants do not appear to have been cosmetic dentists nor did they estimate life-time costs. Dental insurance companies usually reject payment for the initial cosmetic treatment and consider wear as a “natural-phenomena” usually not covered. “Damage is the cost, not the repair.”

Patient #1 (below) has a normal ideal smile with healthy teeth, no fluorosis detected, and was raised predominantly on mother’s milk and no formula was made with CWF.

For comparison, Patient #2, (below) diagnosed with Dean’s Fluorosis Index of 4, “discrete or confluent pitting,” moderate to severe dental fluorosis and has functional damage with chipped, pitted and warn teeth.

Patient #2 was raised mostly on formula made with fluoridated water. Mom was confident fluoridated toothpaste was not swallowed and no fluoride supplements ingested.

The diagnostic classification of fluorosis has some value to the researcher but seldom to the patient. For patient #2, the top two front teeth are most severely damaged; however, restoring just those two teeth
would emphasize the adjacent moderate and mild fluorosis. Each patient and their dentist need to decide how many teeth have been damaged and should or should not be treated. In this case, 24 teeth had cosmetic and functional dental fluorosis damage.

Professional diagnosis of dental fluorosis is commonly reported at 17.5% to 14.5%. [11,12] However, 52% of patients perceived their dental fluorosis at 0.7 mg/L CWF to be objectionable and 95% of those wished the damage repaired. [12]

This analysis uses an overly conservative 30% of those on CWF will have perceived dental fluorosis they would wish to have removed or receive compensation. Options for treatment vary depending on the extent of damage, patient preference and treating clinician.

The options are divided here into two general groups. An estimated 20% of those on fluoridated water would choose a conservative “Option A” and 10% a comprehensive “Option B.” Costs for treating functional damage have less documentation and are not specifically estimated here, although functional damage may cost more than cosmetic damage.

COSTS TO TREAT COSMETIC DENTAL FLUOROSIS

The EPA study [10] of professional diagnosis rather than patient perception appears to have assumed optimum care would last a lifetime and reported a range between $660 to $12,000 per patient. (All costs in USA dollars converted to 2021 value). Dental fluorosis may be managed by bleaching, micro-abrasion, resin infiltration, veneering or full coverage of the tooth such as crowns.

Treatment Option A: Micro-abrasion grinding away the outer layer of enamel, sealants or resin infiltration (fillings) can improve dental fluorosis appearance and minor functional damage. Bleaching prior to resin infiltration can improve cosmetics but tends to whiten all areas and a contrast in shade is not always considered fully restored. Repeated treatment or “touch up” bleaching and/or minor restorations and re-treatments estimated every 5 years for a conservative $100 PPPY (Per Person Per Year) for 60 years. Depending on case presentation, an estimated 20% on CWF with perceived dental fluorosis and minor functional damage would accept a bleaching/micro-abrasion and/or minor filling treatment. General inflation rate of 3.57% and inflation of dental fees of 4.33% is used (Supplement Table 1). Patients requesting compensation for harm would expect full compensation and a zero-discount rate is used.

Summary of Micro-abrasion Option A. Estimated cost of $100 a year per person X 60 years = $6,000. An additional $1,200 for the difference of general inflation at 3.57% and dental inflation at 4.33% for $7,200. An estimated 20% of the population on CWF is assumed to choose Option A which is $1,440 X 1.46% percent of the population at each age = $21 PPPY.

Comprehensive Treatment Option B: If offered compensation for the damage, many would choose the highest quality treatment. Comprehensive cosmetic and functional treatment are estimated at $1,200 per tooth. [2] Classification of dental fluorosis is based on the two worst teeth, although 1 to 32 teeth can be damaged. If costs are not the controlling factor, a cosmetic patient will want several or all upper and lower teeth treated inclusive of functional damage. An estimate is used here of an average of 10 teeth per person at $1,200 of damage per tooth. This estimate is at the high end of the EPA study [10] and in keeping with another published study on the treatment of dental fluorosis harm [2]. The original treatment is estimated to be replaced an average of four times during a person’s life. Re-treatment often progresses to more complex pathology and more extensive treatment. These additional expenses are not included here.

A dental school clinic reported “average survival time for all crowns (PFM) was 4.4 years. Reports of restoration survival at 95% at 10 years and 75% at 18 years are consistent with clinical experience. Dental insurance companies seldom pay for re-treatment of crowns within 5 years. A twelve-year expectancy is used here.

Summary of Option B: $1,200 X 10 teeth = $12,000 x 5 treatments = $60,000 add $12,000 (Table 4) for difference in inflation rates = $72,000 X 10% on CWF choosing optimal treatment = $7,200 X 1.46% of the
population at each age = $105 \text{ PPPY}$.

Combining Options A of $21 \text{ PPPY}$ and Option B of $105 \text{ PPPY}$ is a conservative estimate of $126 \text{ PPPY}$ for the treatment of dental fluorosis.

**DEVELOPMENTAL NEUROTOXICITY:**

Fluoride was nominated to the USA National Toxicology Program (NTP) in 2015 for review of fluoride’s possible neurodevelopment and cognitive health effects and was accepted. Eight years and several peer reviews later, the Board of Scientific Councilors approved a draft. The current NTP draft review included 159 human studies, 339 non-human studies, 60 in vitro, and many other publications, 95% of the highest quality studies reported lower IQ. The original draft reported a presumed neurodevelopmental hazard. The draft monogram was blocked from release until the court [13] ordered release. The report [14] has been divided into two sections, one called “state of the science” and the second the “meta-analysis.”

Reviewers of the NTP monograph have generally focused on clarity and strengthening the report rather than disagreement with the conclusion. Some reviewers suggested, “that the monograph is not designed to be informative regarding decisions about fluoride concentrations for water fluoridation.” [14] The NTP authors disagreed, confirming they were considering total exposure, not just fluoride from CWF. Evaluation of drugs/medicines is not in the jurisdiction of the NTP and CWF is only one source of fluoride exposure, not an individual dosage. And water consumption varies from little to over 10 liters per day. [15]

Subsequent to the NTP cut-off date, research is reasonably consistent, “0.5 mg increase in fluoride intake from infant formula corresponded to an 8.8-point decrement in Performance IQ” and a “4.4 FSIQ (Full Scale IQ) points among preschool children who were formula-fed in the first six months of life for each 0.5 mg/L increase in water fluoride concentration.” [16]

The fluoride concentration set by authorities in CWF is a concentration and not a dosage. An intraspecies uncertainty factor and margin of error of at least 10 should be used for differences in water consumption.

Nine mother-child neurotoxicity studies have been published [17]. Eight of the studies (the first of USA/Canadian cohorts in 2020) report neurotoxicity at low concentrations. One outlier [18] reported an increase of +15 IQ points per 1 mg/g increase in MUFCr (Mother’s Urinary Fluoride Creatinine) for boys, not girls. An impossible boost to IQ that has never been found for any other chemical, nutrient, or diet. Even more impossible is the finding that in the non-fluoridated zone where the water F concentration was 0.05 mg/L, the increase in IQ for those in the low fluoride communities was +28 IQ points per 1 mg/g MUFCr and when corrected for creatinine increased IQ to an impossible 38 points. If true, most boys would be gifted, geniuses, and fluoridated communities would have few if any boys in the special education classes. A delay in effect, huge increase for boys not girls, and without supporting research indicates this study needs the laboratory work redone. The study is an outlier because it is the only study out of 72 identified by NTP that has ever found a statistically significant benefit from the ingestion of fluoride.

Over 90% of the higher quality fluoride studies reported by the NTP at exposure levels of < 1.5 mg/L fluoride in water or urine, reported significant adverse neurotoxic effects [19]. A recent meta-analysis of 8 studies from non-endemic fluoride communities [20] reported no effect on IQ scores. The study has limitations such as including the outlier mentioned above.

There is reasonable agreement and consistency that fluoride is a developmental neurotoxin. This study is consistent with the NTP report and the majority of published research and uses a conservative 3 IQ loss for those on CWF.

**IQ AND WAGES**: A search at scholar.google of “IQ effect on wages,” resulted in 59,800 articles. Although lacking consensus, 1 IQ point increase appears to predict about 1% higher wages, about $500/IQ point [21], at the population level rather than individual.

**Lower Wages Results**
Summary: 3 IQ loss $500/year/IQ loss = $1,500 lower income/year. 40 work years $1,500 lower income/year = $60,000 and assuming only 50% drink a significant amount of the CWF = $30,000 x 1.46% of population at each age = $438 PPPY lower wages. (Supplement Table 2)

4. DISCUSSION

Dental fluorosis is a known risk of excess fluoride ingestion prior to 6-8 years of age. Given the cost of treating cosmetic dental fluorosis and lower wages due to lower IQ, fluoridation is not cost effective. When reviewing the populations at large, fluoride exposure appears dose related. However, some children get severe dental fluorosis with apparently low fluoride concentrations and diet, genetics, elevation, chemical sensitivity, other toxins such as lead and kidney function can be confounders.

Some have suggested mild fluorosis is not a cosmetic concern. However, clinicians placing ugly black mercury fillings and bright gold crowns may not have been cosmetically as sensitive to our patients' opinions. For example, a scratch on a car is undisputed cosmetic damage. If patients find dental fluorosis has harmed their smile, those in authority contributing or causing the damage must respect the patient's opinion.

A National Productivity (GDP) and national IQ (the “Hive Mind”) affecting savings, cooperation, high-value technologies, and market-oriented policies appear to have a greater impact than individual IQ on individual wages. A negative effect on the “Hive Mind” is not included here, nor risks to bones, thyroid, cells, endocrine system, cancer, kidneys, and other risks from excess fluoride exposure. A benchmark dose analysis to consider a safe fluoride exposure reported about 0.2 mg/L maternal urine-fluoride exposure (similar concentration for water) would be safe [22].

ALTERNATIVES TO CWF

Comparing five preventative procedures, toothbrushing with toothpaste was the most effective preventative procedure, followed by fluoride varnish. CWF with dental sealants and initial exams are considered less effective. Additionally, individual health education with oral hygiene and nutrition would not only reduces dental caries but also periodontal disease and other adverse health risks. Money from a tax on carbonated beverages could be used for preventive education. For those wanting to ingest fluoride, a doctor’s prescription is an option.

CONCLUSION:

After almost 80 years of adding fluoride to community water, the controversy continues due to current efficacy, lack of individual choice, authority administered, risks, desired dosage, total exposure, jurisdiction, research quality, environmental justice, ethics, alternatives, and cost-benefit. All streams of evidence should be considered for policy evaluation.

Excess fluoride exposure and the harm caused is one of the easiest public health risks to mitigate, simply turn off the fluoridation pumps. Public health policy should be reviewed inclusive of stakeholders with concerns and streams of evidence such as costs, benefits, risks, total exposure, patient consent, margin of error, laws, safety factors and alternatives. The estimate here is:

caries averted, less operational costs at $8 PPPY.

dental fluorosis treatment -$126 PPPY.

developmental neurotoxicity lower wages -$438 PPPY .

Net loss from CWF -$556 Per Person Per Year

Citations


5. Fluoride in Drinking Water A scientific Review of EPA’s Standards, National Research Council of the National Academies. [Link]


