WASHINGTON STATE DEPARTMENT OF HEALTH

Report of the Fluoride Science Review Panel, August 2025

Washington State Department of HEALTH

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Executive Summary

Situation

In 2024, the State Board of Health received multiple petitions for rulemaking regarding fluoride exposure for pregnant people, infants, and children. Included were recommendations against adding chemicals such as fluoride to drinking water to treat or prevent disease in humans or animals. The petitions cited findings from the National Toxicology Program (NTP) showing an association between high levels of fluoride exposure and lowered IQ in children. The Department of Health convened a panel of public health staff to review the science and advise the State Board of Health.

Background

The panel's job was to summarize their learnings and interpret the science so that the State Board of Health could consider it in potential policy action. The panel narrowly focused on the risks and benefits of community water fluoridation. We did not assess the evidence around prevention of tooth decay, other forms of fluoride use or exposure, or healthy brain development.

Assessment

Department of Health staff presented the National Toxicology Program monograph, a recent court finding involving the Environmental Protection Agency (EPA) and the Toxic Substances Control Act (TSCA), a Cochrane review, and several additional studies. Additionally, the panel heard from a Department of Health economist, the author of several of the studies reviewed by the NTP, the Arcora Foundation, and other expert and volunteer community members.

Community water fluoridation was very effective when it began in 1945. Many health organizations continue to recommend it. The Cochrane Review raises questions about the added value of community water fluoridation today, given other modern fluoride sources. The NTP reported with moderate confidence that higher estimated fluoride exposures are consistently associated with lower IQ in children. High concentrations of fluoride are also toxic to bones to tooth enamel.

For many people, the oral health benefits of community water fluoridation at current levels may outweigh the risks. However, pregnant people and infants should be considered separately for two reasons. Firstly, they tend to drink more water for their body size than other demographic and age groups. Additionally, developing fetuses, infants and young children are particularly vulnerable to neurodevelopmental hazards.

Recommendations

The State Board of Health should:

- Keep the current optimal level of fluoride concentration for now. Community water fluoridation should remain a local decision. Communities should carefully weigh the benefits and risks of water fluoridation.
- Begin the rulemaking process to consider adopting a State Action Level of 1.5 mg/L for fluoride.
- Coordinate with the Department of Health and public health partners to update messaging on fluoride to include guidance to limit fluoride exposure for pregnant people, fetuses, and infants.

Context

Current Situation

In Washington, the State Board of Health sets an optimal level of fluoridation for water systems that choose to provide fluoridated water. In 2016, the State Board of Health set the optimal level of fluoride at 0.7 mg/L.

Washington state law (RCW 57.08.012) allows, but does not require, community water fluoridation. Local governments make the decision of whether to provide optimally fluoridated water to their communities. Who the local government decision-making authority is varies depending on local governance structure and whether the water system is publicly or privately operated. The decision to optimally fluoridate community water can be controversial.

In 2024, the State Board of Health received multiple petitions for rulemaking regarding fluoride exposure for pregnant people, infants, and children, and recommendations against adding chemicals such as fluoride to drinking water to treat or prevent disease in humans or animals. The petitions cited findings reported by the National Toxicology Program. The Department of Health (DOH) convened a panel to review the science and advise the State Board of Health.

Background

Fluoride is a naturally occurring mineral. Today it is present in drinking water, food, and consumer products. Fluoride has been widely promoted for oral health benefits. Oral health interventions include community water fluoridation, fluoridated toothpaste, and fluoride varnishes. At high concentrations in water, fluoride is toxic to bones (4 mg/L) and tooth enamel (2 mg/L). There are also emerging concerns that fluoride may negatively impact neurodevelopment.

Community water fluoridation began in 1945 in Grand Rapids, Michigan. It resulted in dramatic declines in dental decay in school children. Since then, community water fluoridation has been adopted by communities across the country. Before community water fluoridation, tooth decay was widespread and severe. After fluoride was added to the water supply in many places in the U.S., tooth decay declined in both children and adults. Complete tooth loss in older adults became rarer. In 2000, the Centers for Disease Control and Prevention (CDC) named community water fluoridation as one of the top ten public health successes of the 1900s. Indeed, there is little debate that community water fluoridation was very effective at preventing dental decay prior to about 1975, when fluoride became more common in consumer products like toothpaste.

In Washington, 64% of the population drinks optimally fluoridated water provided by a public water system.

DOH works on health issues relating to water fluoridation and the health of pregnant people, infants, and children in the following ways:

Office of Drinking Water:

- Provides technical assistance to water systems that decide to optimally fluoridate their water.
- Ensures that naturally occurring fluoride in the water stays below the EPA's maximum contaminant level (MCL).

Office of Healthy and Safe Communities, State Oral Health Program:

- This program works to promote and facilitate policies, systems, and partnerships that:
    - Increase the awareness of relationships between oral health and systemic health.
    - Prevent or reduce oral/craniofacial disease and injuries of the head, neck, and oral cavity.
    - Improve access/reduce barriers to preventive oral health services and dental care.
- Promotes strategies that protect oral health, including the benefits of fluoride for the prevention and management of dental decay.
- Occasionally provides technical assistance to communities about community water fluoridation.

Prevention and Community Health Division:

- Works to prevent disease and promote a healthy start, healthy choices, and access to services for children and families, including during pregnancy.
- Provides nutrition education and programs, including the Special Supplemental Nutrition Program for Women and Infants, also known as WIC.

Controversy

Community water fluoridation has been controversial since it began. Some residents of Grand Rapids complained of adverse health effects due to fluoride before the intervention even started.

People who oppose community water fluoridation generally do so based on:

- Concerns for public safety
- The value for bodily autonomy
- Concerns about the proper role of government.

People who support community water fluoridation generally do so based on:

- The long history of apparently safe water fluoridation in the U.S.
- The belief that community water fluoridation prevents dental decay
- The value for equitable public health approaches to disease prevention that do not depend on access to care or other resources.

Science Review Panel

Participants

Panel participants represented the State Board of Health, the State Department of Health, Local Health Jurisdictions, and Tribal Health Organizations. Staff of these agencies were invited to listen to the panel proceedings. They also provided technical information to the panel.

A community member expressed concern to the board that the panelists would have pre-formed opinions about community water fluoridation and would be unwilling to fully review the evidence. This community member was invited to observe the panel's work and participate in the panel's Community Input session. As the meetings went on, other observers also joined.

Panel co-chairs:

Lauren Jenks, Assistant Secretary for Environmental Public Health
Dr. Tao Sheng Kwan-Gett, State Health Officer at the Department of Health

Panel participants:

Amber Arndt, Department of Health, Tribal Policy Director
Dr. Allison Berry, Local Health Officer
Shay Bauman, State Board of Health
Dr. Emerson Christie, Department of Health, Toxicologist
Derrick Dennis, Department of Health, Drinking Water
Molly Dinardo, State Board of Health
Dr. Herbie Duber, Department of Health, Regional Medical Officer
Phuc Ha, Local Public Health
Lindsay Herendeen, State Board of Health
Lauren Jenks, Department of Health, Environmental Public Health
Dr. Tao Sheng Kwan-Gett, Department of Health, State Health Officer
Dr. Tom Locke, Tribal Health Officer
Dr. Bob Lutz, Local Health Officer
Shawn Magee, Local Public Health
Dr. Jessica Marcinkevage, Department of Health, State Epidemiologist for Policy and Practice
Dr. Kari Mentzer, Department of Health, Epidemiologist
Michele Roberts, Department of Health, Prevention and Community Health

Charge to the Panel

The panel was charged with listening, learning, and considering all relevant science in its discussions of community water fluoridation. It was further charged with summarizing its learnings and interpreting the science so that the State Board of Health could consider it for potential policy action.

As the panel worked together, its discussion began to center around how best to get the benefits of community water fluoridation while minimizing the risk of fluoride exposure to fetuses and infants.

Process

The panel met 10 times from January through June 2025. The meetings were held over Zoom and generally lasted about 2 hours. The meeting format was approximately 1 to 1.5 hours of presentation followed by discussion and questions. When possible, questions were answered during the same meeting. If more research was required, questions were answered in the next meeting. The slides presented at the meetings are available in Attachment A.

Based on the science and panel discussions, DOH staff drafted potential consensus statements ahead of the meeting. The panel reviewed the draft consensus statements and edited them during the meetings. When it looked like we might have gotten the statements to a point of consensus, we voted by putting a number from 1 (completely disagree) to 5 (wholeheartedly agree) in the meeting chat. Fours and fives were generally considered approval of the statements. Anyone who voted lower was asked to explain their concerns. More discussion and another vote would follow. A similar process was followed to develop the conclusions and recommendations. Not all panelists attended all voting sessions, and an individual panelist's views may differ from this report.

Limitations

The panel narrowly focused on the risks and benefits of community water fluoridation. We did not assess the evidence around other strategies for the prevention of tooth decay. We also did not assess the evidence around healthy brain development or measurement of IQ in children. Occasionally, we heard information related to potentially less risky methods of getting the benefits of fluoride and other health behaviors that improve oral health. We did not review the evidence around these interventions. Changes to the health care system or dental care system were also out of the panel's scope.

Summary of Information Reviewed at Each Meeting

This is a summary of the information that was reviewed at the meetings. This summary is not a comprehensive review of the literature or a critical review of what was presented.

Pre-work	Review Dr. Kyla Taylor's explanation of the NTP monograph on a Collaborative for Health and the Environment webinar.

Meeting 1
January 9
	Dr. Emerson Christie, Department of Health, summarized *Fluoride, Neurodevelopment, and Cognition: A National Toxicology Program Monograph*.
	• Moderate confidence that higher estimated fluoride exposures are consistently associated with lower IQ in children.
	• Unsure: whether low fluoride level of 0.7 mg/L currently recommended for US community water has a negative effect on children's IQ.
	• No evidence: that fluoride exposure has adverse effects on adult cognition.
	• Strengths: The National Toxicology Program (NTP) Monograph on Fluoride Exposure and Neurodevelopment (August 2024) is a comprehensive assessment of the scientific literature.
	    ○ The monograph identified a large body of evidence (72 epidemiologic studies) evaluating associations between fluoride exposure and IQ in children. Of the 19 high-quality studies, 18 found a relationship between higher fluoride and lower IQ in children.
	    ○ The high-quality studies included 3 prospective cohort studies and 15 cross-sectional studies spanning 5 different countries (none in the U.S.). Of the remaining 53 studies,

	46 also provided evidence of inverse associations between fluoride exposure and IQ. • NTP also reviewed studies of other neurodevelopmental conditions (e.g. memory, ADHD) and identified 8 out of 9 high-quality studies observed inverse associations with fluoride exposure. • Limitations: The database on toxicity is not complete (EPA 2024).
Meeting 2 January 28	Dr. Emerson Christie, Dr. Holly Davies, and Michael Ellsworth, JD, Department of Health, summarized the 2024 EPA court judgement on fluoride and the Toxic Substances Control Act. • In November 2016, a group of organizations and individuals petitioned the EPA under Section 21 of Amended Toxic Substances Controlled Act to regulate the fluoridation of drinking water supplies under Section 6(a). • They alleged that fluoridation at levels occurring throughout the country presented an unreasonable risk of injury to health under the Toxic Substances Control Act ("TSCA"), 15 U.S.C. § 2620(b)(4)(B). • After the EPA denied the petition, in April 2017, the organizations and individuals filed suit seeking judicial review of the EPA's denial pursuant to 15 U.S.C. § 2620. • For a risk to be present, the court must find that some segment of the United States population is exposed to fluoride in drinking water at levels that either exceed or are too close to the dosage at which fluoride presents a hazard. • The Court found that fluoridation of water at 0.7 mg/L poses an unreasonable risk of reduced IQ in children. • This does not mean that the court found that fluoridated water is definitely harmful. Rather, the court found an unreasonable risk of harm, which is a toxicological standard used by EPA under TSCA. • EPA argued that there is uncertainty around the hazard level and the precise relationship between dosage and response at lower levels. The court found these arguments "not persuasive" because of the requirement for a margin of safety between the hazard level and the dose. Even accounting for the uncertainty, that margin of safety was not currently met. • EPA argued that maternal urinary fluoride is not a good way to measure effects of community water fluoridation because it will include all exposures to fluoride—including toothpaste, mouthwash, etc. The court found that EPA must consider the additive effect of all exposures to fluoride to adequately assess safety. • The court did not consider the benefits of fluoride in their review. • A court finding is not a scientific finding. It is an interpretation of the science that exists in reference to current federal law.

<table>
<tr><td>Meeting 3
February 11</td><td>Shelley Guinn, Department of Health, reviewed the causes of tooth decay, the burden of disease and inequities, relative efficacy and mechanism of action of different fluoride applications, the modes of fluoride intake, and public health and economic considerations of community water fluoridation. Arcora and Health Care Authority discussed access to dental health care in Washington.

Oral health impacts physical and mental health, school and work attendance, and many aspects of quality of life.
Exposure to fluoride hardens the tooth enamel and is protective against tooth decay in children and adults.
Community water fluoridation is a long-standing intervention intended to provide the benefits of fluoride and good oral health to large portions of the community, regardless of access to dental care or fluoride-containing hygiene products.
Access to dental care varies by employment and income and location in the state. Many children and adults in the state lack adequate access to dental care.
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<tr><td>Meeting 4
March 11</td><td>Claire Nitcshe and Dr. Kyle Yomogida, Department of Health, reviewed the 2024 Cochrane Review, Water fluoridation for the prevention of dental caries.

Studies conducted in 1975 and earlier showed a clear and beneficial effect of community water fluoridation on prevention of tooth decay in children. However, due to the increased availability of fluoride in toothpaste since 1975, we do not see the same size effect at a population level today.
Studies conducted after 1975 showed that adding fluoride to water may lead to slightly less tooth decay in children's baby teeth.
Adding fluoride to water may slightly increase the number of children who have no tooth decay in either their baby teeth or permanent teeth. However, these results also included the possibility of little or no difference in tooth decay.
Unsure: whether adding fluoride to water reduced tooth decay in children's permanent teeth.
Unsure: whether there are any effects on tooth decay when fluoride is removed from a water supply.
Unsure: whether fluoride reduces differences in tooth decay between people with higher incomes and people with lower incomes.
The authors point out that a finding of insufficient evidence of an effect is not the same as evidence of no effect.
The panel hypothesized that additional studies on the effects of community water fluoridation on health disparities may find that community water fluoridation reduces oral health disparities.
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<tr><td>Meeting 5
March 25</td><td>Dr. Herbie Duber, Department of Health, reviewed additional information on tooth decay: burden of the disease, cumulative all-cause mortality as related to tooth decay, and oral disorders costs. Dr. Duber reviewed two</td></tr>
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	case studies: Calgary, Alberta, (“Community water fluoride cessation and rate of caries-related pediatric dental treatments under general anesthesia in Alberta, Canada” and “Equity in children’s dental caries before and after cessation of community water fluoridation”) and Juneau, Alaska (“Consequences of community water fluoridation cessation for Medicaid-eligible children and adolescents in Juneau, Alaska”). • There are strong associations between dental caries and stroke and all-cause mortality. • Oral disorder costs make up about 3.8% of US health care spending, with an estimated cost of $93 billion. • Community water fluoridation was very effective for the prevention of tooth decay when it began in 1945, and it continues to be recommended by many health organizations including the American Dental Association and the American Academy of Pediatrics. • Cochrane Review raises questions about the added value of community water fluoridation given alternative fluoride sources in modern society. • Calgary, Canada: Fluoride was introduced to drinking water in 1991, removed in 2011, and reintroduced in 2021. Discontinuing community water fluoridation was associated with increased dental treatment under general anesthesia, especially among children 0-5 years old. • Calgary, Canada: Odds of untreated dental decay increased more among those without dental insurance from 2009/2010 to 2013/2014, showing an increase in disparity. The authors present multiple possible causes, one of which is the end of community water fluoridation. • Juneau, Alaska: After stopping community water fluoridation, they found significant differences in the mean number of Medicaid eligible dental procedures among 0-6, 0-7, and 0-18 groups, but not significant in ages 7-13 or 13-18. This indicates a significant difference in treatment of primary teeth but not permanent teeth. • Increased dental care costs were correlated with the stopping of community water fluoridation. Anna Hidle, Department of Health, reviewed and presented learnings from economic evidence about community water fluoridation. • Even with the decline of benefits from community water fluoridation, literature continues to report it as a cost-effective intervention. • However, two recent papers call for inclusion of the costs of treating fluorosis and/or lost IQ points which demonstrate a reduction in the historical return on investment.

	• Future economic modeling should consider learnings from lost IQ points due to elevated blood lead levels, including level of impact from exposure and racial disparities.
Meeting 6 April 8	Dr. Charlotte Lewis, Dr. Donald Chi, Dr. Bill Osmunson, Dr. Scott Tomar, and Lauren Johnson provided perspective and comment. • Summarized below under "Community Input"
Meeting 7 April 22	Panel created consensus statements. (See below.)
Meeting 8 May 6	Dr. Christine Till, York University, Toronto, presented an overview of the emerging science on fluoride toxicology and her findings and conclusions from several studies included in the NTP report. • In addition to dental fluorosis, evidence is strong for reduction in IQ scores in children, moderate for thyroid dysfunction, weak for kidney dysfunction, and limited for sex hormone disruptions. • A 1 mg/L increase in fluoride intake was associated with a 3.66 (95% CI,-7.16 to -0.15; p=.04) lower IQ score in boys and girls. • Formula-fed babies are at risk of lower IQ if their formula is made with fluoridated water. • IQ decreases with increasing levels of fluoride in water and urine. There is no obvious threshold. • Evidence of fluoride neurotoxicity at urine fluoride levels <1.5 mg/L is relevant to community water fluoridation because pregnant women and children can exceed an equivalent dose of fluoride even when drinking optimally fluoridated water depending on amount of fluoridated water they ingest and their exposure to other sources of fluoride. • Iodine deficiency may increase the risk of fluoride neurotoxicity. • Certain genetic factors may increase sensitivity to fluoride exposure. • Higher water fluoride, urine fluoride, and serum fluoride concentrations were associated with higher Thyroid Stimulating Hormone (TSH) in children. • Till stated, "Given that fluoride offers little benefit to the fetus and young infant, community-wide administration of systemic fluoride may pose an unfavorable risk-benefit ratio for the pregnant woman, fetus, and infant."
Meeting 9 May 20	Panel created consensus statements and recommendations. (See below.)
Meeting 10 June 17	Panel finalized recommendations to the Board. (See below.)

Summary of Information Reviewed

This section summarizes the information reviewed in the panel meetings. It draws from the meeting summaries above but is organized by topic instead of by date. It is not a comprehensive review of the literature or a critical review of the information presented.

Evidence of Benefits

Fluoride was first added to drinking water in 1945 to help prevent cavities at a population level. At that time, it was very effective. Many health organizations continue to recommend it.

Studies done in 1975 and earlier showed a clear effect of community water fluoridation on prevention of tooth decay in children. After 1975, the benefits may be smaller because fluoride is now found in toothpaste and other products.

In Calgary, Canada, fluoride was added to drinking water in 1991, removed in 2011, and added again in 2021. When fluoride was stopped, more people needed dental surgery under general anesthesia. This was especially true for children 0-5 years old. In the period without fluoridation, the odds of having untreated dental decay increased, with a sharper increase among people without dental insurance.

In Juneau, Alaska, after fluoridation was stopped, young children on Medicaid suffered a significant increase in their average (mean) number of dental decay procedures. Children born after fluoridation ended had the most procedures and the highest treatment costs.

Using the Cochrane method for systematic reviews, Iheozor-Ejiofor, et al., identified 157 studies on fluoridation. They evaluated the effects of starting or stopping community water fluoridation. They also looked at the association of fluoride in drinking water with fluorosis. Twenty-one studies looked at starting water fluoridation. One looked at stopping water fluoridation. All the studies used non-randomized designs. Studies done after 1975 showed that adding fluoride to water may lead to less tooth decay in children's baby teeth and a increase in the number of children who have no tooth decay in either their baby teeth or permanent teeth. However, these results also included the possibility of little or no difference in tooth decay.

This review raises questions about the added value of community water fluoridation given alternative fluoride sources in modern society.

Four dentists spoke to the panel. Several of the dentists reminded the panel that community water fluoridation prevents tooth decay and is endorsed by:

- The Centers for Disease Control and Prevention
- American Medical Association
- American Academy of Pediatrics
- American Dental Association
- American Academy of Pediatric Dentistry
- American Association for Dental, Oral, and Craniofacial Research.

Several of the dentists stated that community water fluoridation remains a safe, cost-effective, and equitable strategy for preventing dental decay in all age groups. More of the dentists' comments can be found in the community input section of this report.

Evidence of Harms

High levels of naturally occurring fluoride can cause skeletal and dental fluorosis. Optimal fluoride levels used in community water are lower and usually cause at most mild, cosmetic dental fluorosis.

A recent systematic review of international studies has shown that higher levels of fluoride in drinking water may be linked to reduced IQ scores in children. There is limited evidence for association with thyroid dysfunction, kidney dysfunction, and sex hormone disruptions. The authors suggest 1.56mg/L of fluoride as a starting point for setting a health-based limit for fluoride in drinking water.

Other studies (mostly in Asia) found that higher water fluoride, maternal urine fluoride, and maternal serum fluoride concentrations are associated with impacts on thyroid function and an increased risk of some thyroid diseases.

A Canadian study found that higher levels of fluoride exposure during pregnancy were associated with lower IQ scores in children when they were 3-4 years old. A systematic review and meta-analysis found a dose-response associate between increasing levels of fluoride in water and urine and lower IQ in children. Another Canadian study found that babies who drink formula mixed with fluoridated water may also be at risk of lower IQ.

Many studies of IQ and fluoride have been done with water at high levels of fluoride (about 1.5 mg/L). This is higher than what is normally found in U.S. drinking water. However, some studies have been done with water fluoride concentrations or maternal urinary fluoride concentrations comparable to those in the U.S. Additionally, because pregnant women and children drink more water for their size, they can end up having exposures similar to people in places with higher levels of water fluoridation. Factors like iodine deficiency and certain genes may also make some people more sensitive to fluoride.

Till et all stated, “Given that fluoride offers little benefit to the fetus and young infant, community-wide administration of systemic fluoride may pose an unfavorable risk-benefit ratio for the pregnant woman, fetus, and infant.”

In 2024, the National Toxicology Program looked at 72 studies about fluoride and IQ. Of the 19 high-quality studies, 18 found a relationship between higher fluoride and lower IQ in children. The high-quality studies included 3 prospective cohort studies and 15 cross-sectional studies spanning 5 different countries (none in the U.S.). Of the remaining 53 studies, 46 also provide evidence of inverse associations between fluoride exposure and IQ. They also reviewed studies of other neurodevelopmental conditions (e.g. memory, ADHD). Eight out of 9 high-quality studies observed inverse associations with fluoride exposure.

The National Toxicology Program concluded with moderate confidence that higher estimated fluoride exposures are consistently associated with lower IQ in children. These levels of exposure are approximately equivalent to 1.5 mg/L of fluoride or more in drinking water. However, there wasn’t enough evidence to say whether lower levels, like the 0.7 mg/L used in the U.S., have the same effect. They found no evidence that fluoride exposure harms adult brain function. The EPA has noted that we are still learning about fluoride toxicity.

Economic Analysis

Most studies about fluoride and economic costs focus on:

- Saving on dental care costs.
- Avoiding lost work time.
- How much it costs water systems to add fluoride.

Most studies do not count the cost of treating fluorosis or possible IQ loss.

Authors of a cost-effectiveness analysis , used data for 8484 children (mean age 9.6 years) from the 2013-2016 NHANES to create a model that they then used to simulate the impacts of stopping community water fluoridation. The model projected that stopping community water fluoridation in the U.S. could cause a 7.5% increase in tooth decay and cost approximately $9.8 billion over 5 years. Children who are uninsured or publicly insured would be disproportionately affected compared to those with private dental insurance. Sensitivity analyses using lower efficacy estimates from fluoridation found lower, but still substantial, harms.

Recent literature continues to report community water fluoridation is a cost-effective intervention, though its return on investment is lower than it used to be.

Community Input

Dentists, advocates, researchers, and concerned members of the public volunteered to share their views with the panel. We heard summaries of fluoride toxicity and the efficacy of community water fluoridation. Different people reached different conclusions based on the science. Some told painful personal stories of sensitivity to fluoride. We also heard powerful endorsements of community water fluoridation. People passionately expressed deeply held values that inform their opinion on community water fluoridation.

Comments regarding the benefits of community water fluoridation included:

- Community water fluoridation prevents tooth decay (Cochrane reported this with Low Certainty). Does not prevent tooth decay as much as before 1975, but it still prevents some.
- Mistrust of NTP report because of lack of awareness of any reliable study of IQ in 3-4 year-olds
- US Preventive Services Task Force gives fluoride supplements for children 6 months to 5 years old a B rating.
- Community water fluoridation is endorsed by CDC, American Medical Association, American Academy of Pediatrics, American Dental Association, American Academy of Pediatric Dentistry, American Association for Dental, Oral, and Craniofacial Research
- Community water fluoridation is a population-based intervention that helps everyone, especially people at high risk for tooth decay.
- If sugar wasn't a problem, community water fluoridation wouldn't be as important.
- Fluoride is not a chemical, it's a natural substance.
- Hardwick, 1982: community water fluoridation resulted in 26.8% fewer cavities
- Blinkhorn, 2015: community water fluoridation resulted in 32.3% fewer cavities
- Goodwin, 2022: community water fluoridation resulted in 26% fewer cavities in primary teeth and 13% in permanent teeth
- There is no association between community water fluoridation and changes in IQ.

- Community water fluoridation still prevents dental decay even with widespread use of fluoride toothpaste, though smaller absolute effect than we once saw.
- Recent studies suggest cessation of community water fluoridation increases dental decay and costs in children
- No other developed country has changed fluoridation policy due to NTP report or EPA court case, and UK recently announced plan to expand fluoridation.
- Cross-sectional studies consistently show fewer cavities in fluoridated communities, although less so than in the 1950's.
- As feds cut Medicaid, community water fluoridation will be more important for high-risk communities.
- 2020 North Carolina study found that lifetime community water fluoridation exposure (through age 19) virtually eliminated oral health socioeconomic disparities.
- Despite the influence of political forces, community water fluoridation remains a safe, cost-effective, and equitable strategy for prevention of dental decay for individuals of all ages.
- Epidemiologic evidence informs our understanding that fluoride is beneficial throughout the lifespan.

Comments bringing concerns about community water fluoridation included:

- The State Board of Health has a key responsibility to ensure safe drinking water. This responsibility is more important than providing for the marginal benefits to health from community water fluoridation.
- Fluoride is not good for everyone. Some people experience unique toxic effects. Some people are extremely sensitive to exposure to fluoride.
- Putting fluoride in water for a specific health effect is treating fluoride like a drug, but it has not been approved as a drug. Not everyone has consented to receiving this drug.
- Fluoride in the water is not effective at preventing cavities, but it does present an unacceptable neurodevelopmental risk.
- We should make decisions following the precautionary principle and not expose people to a chemical we cannot prove is safe for everyone.
- Washington's code regarding community water fluoridation has not kept up with the science and must be updated.
- Other states are beginning to question or ban community water fluoridation.
- IQ impacts are more important to consider than oral health impacts because a cavity can be filled but a loss of IQ points are forever.
- People should be able to choose whether they have fluoride in their water. People should be able to opt out of fluoride if they don't want it.
- Disease prevalence rates are dynamic. We may be inappropriately attributing changes in the rates of dental decay to community water fluoridation.
- Too much exposure to fluoride also exposes teeth to risk of decay through fluorosis.
- The certainty with which presenters state "community water fluoridation prevents tooth decay" is more marketing than science.
- There is no reason for babies under 6 months of age to get any fluoride. This is consistent with the US Preventive Services Task Force recommendations.

- Endorsements are not science.
- Community Water Fluoridation takes away freedom
- Concentration in drinking water is not the same as dose—dose may be too high for fetuses and infants.
- Most European dental associations no longer recommend fluoride supplements.
- Comparing 50 states, fluoridation is not associated with better dental health.
- Effectiveness of community water fluoridation has declined over time.

Consensus Statements

The following are consensus statements agreed upon by the panel after reviewing and discussing the scientific and community input.

Oral Health and Fluoride

1. Oral Health is essential for overall health and well-being, with connections to quality of life, self-esteem, employment, and school and learning.
2. Fluoride is an effective tool in preventing tooth decay.
3. Dental decay is a preventable disease. Health behaviors related to a combination of diet, oral hygiene, use of fluorides, and regular dental care are key factors. Health education and other public health interventions designed to improve these health behaviors are important for good oral health.
4. When properly used, topical application of fluoride to teeth, including at low levels in saliva, and at higher levels from fluoridated toothpaste, varnishes, and professional fluoride treatments is clearly beneficial to teeth and helps to prevent dental decay.
5. Systemic effects of fluoride include both dose-dependent benefits and harms.
6. The burden of dental decay is inequitably distributed due to economic and social inequities and lack of access to dental care.

Community Water Fluoridation Benefits

1. Community Water Fluoridation began in the US in 1945 in Grand Rapids, Michigan. Dental decay among school aged children was greatly reduced in the fluoridated area. This led to the expansion of community water fluoridation throughout most of the U.S. As a result, in 2000, the Centers for Disease Control and Prevention named community water fluoridation as one of the top ten greatest public health interventions from the twentieth century.
2. Community Water Fluoridation is an effective tool in the prevention of tooth decay.
3. Since about 1975, access to fluoride in consumer dental products such as toothpastes and rinses has become more widespread.
4. As more of the population has access to fluoride in consumer dental products, the magnitude of the added preventive benefit of community water fluoridation for dental decay is lower, as compared to before 1975 when community water fluoridation was the primary way for most people to be exposed to fluoride.
5. Some communities that have stopped community water fluoridation have seen increases in dental decay in their communities. The way researchers have measured those increases and the magnitude of these increases has varied.
6. The issue of the added benefits of community water fluoridation to reducing oral health inequities is unresolved. Worsening oral health inequities should community water fluoridation be discontinued would be a concern.

Community Water Fluoridation Risks

1. In risk assessment, it is typical to have a margin of safety between the level we know to be harmful and the level people are exposed to. This margin accounts for uncertainties and is usually protective of susceptible or vulnerable populations.
2. Optimally fluoridated drinking water can increase the risk of mild, cosmetic dental fluorosis.

3. In 2024, the National Toxicology Program found with moderate confidence, that higher estimated fluoride exposures (e.g., as in approximations of exposure such as drinking water fluoride concentrations that exceed the World Health Organization Guidelines for Drinking-water Quality of 1.5 mg/L of fluoride) are consistently associated with lower IQ in children.
4. The primary populations of concern for neurodevelopmental risk from fluoride exposure are pregnant people and infants. Developing fetuses and infants are known to be particularly vulnerable to neurodevelopmental hazards.
5. Higher fluoride exposure results in more serious health effects. The science is not clear on whether there is a threshold, below which there are no neurodevelopmental risks in vulnerable populations.
6. Some people may be getting too much fluoride. The risks of fluoride come from the total amount consumed from a combination of sources, including water, food, black tea and fluoridated dental products.

Maximum Contaminant Level

1. Naturally occurring high levels of fluoride in drinking water have been linked to skeletal and dental fluorosis.
2. Under the federal Safe Drinking Water Act, a Maximum Contaminant Level (MCL) is the highest allowable concentration of a contaminant in drinking water.
3. Two health hazards are the basis for the primary and secondary maximum contaminant levels (MCL) for fluoride recognized by the Environmental Protection Agency: the primary MCL of 4 mg/L was established to protect against skeletal fluorosis and the secondary MCL of 2 mg/L protects against dental fluorosis.
4. Neurodevelopmental effects are associated with fluoride drinking water levels between 1.5 mg/L and the current MCLs of 4 mg/L and 2 mg/L
5. In February 2024, the EPA Office of Water calculated a new potential MCL (Goal) of 0.9 mg/L to protect against dental fluorosis. They used revised exposure metrics for 1 to <11 years of age because that life stage was identified as a potential critical window of exposure in the development of primary and secondary teeth. This MCLG has not yet been formally proposed.

Next Steps

1. Future risk/benefit analyses on community water fluoridation should carefully weigh potential neurodevelopmental hazards to vulnerable populations alongside the oral health benefit attributed to the intervention.
2. More research is needed to better understand potential neurodevelopmental risks from community water fluoridation at current recommended levels, 0.7 mg/L.
3. Additional research on the contribution of community water fluoridation to reducing oral health inequities is needed.
4. The science surrounding fluoride and toxicity continues to evolve and should be monitored.

Conclusions

- Community water fluoridation is an effective tool to prevent tooth decay.
- As more of the population has access to fluoride in consumer dental products, the benefit of community water fluoridation for dental decay is smaller. Before 1975, community water fluoridation was the primary way people were exposed to fluoride.
- Some communities that have stopped community water fluoridation have seen increases in dental decay.
- More research is needed on the impact of community water fluoridation on reducing oral health inequities.
- In 2024, the National Toxicology Program found with moderate confidence, that higher estimated fluoride exposures (exposures equivalent to drinking water fluoride concentrations of 1.5 mg/L or higher) are consistently associated with lower IQ in children.
- Pregnant people and infants are the primary populations of concern for neurodevelopmental risk from fluoride exposure. Developing fetuses, and infants are particularly vulnerable to neurodevelopmental hazards.
- More research is needed on the potential neurodevelopmental risks from community water fluoridation at current recommended levels (0.7 mg/L).

Summary and Recommendations

The panel summarized their assessment of the science in this way.

We are:

> **SURE** that fluoride prevents tooth decay.
>
> **LESS SURE** that community water fluoridation contributes a significant added oral health benefit beyond other common exposures to fluoride.
>
> **LESS SURE** that community water fluoridation has an impact on oral health inequities.
>
> **MODERATELY SURE** that exposure to higher levels of fluoride coming from a combination of sources poses an IQ risk to developing fetuses and babies.
>
> **LESS SURE** that optimally fluoridated water poses an IQ risk for developing fetuses and babies in today's environment that has additional sources of fluoride.

The panel recognized that the State Board of Health is in the difficult position of considering science-based policy options at a time when the scientific data is inadequate and emerging. There are multiple reasonable pathways available to the Board. Of the available options, the panel recommended that The State Board of Health should:

- Keep the current optimal level of fluoride concentration for now. Community water fluoridation should remain a local decision. Communities should carefully weigh the benefits and risks of water fluoridation.
- Begin the rulemaking process to consider adopting a State Action Level of 1.5 mg/L for fluoride.
- Coordinate with the Department of Health and public health partners to update messaging on fluoride to include guidance to limit fluoride exposure for pregnant people, fetuses, and infants.

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Attachment A: Report from Department of Health Toxicologists

The Washington State Department of Health Site Assessment and Toxicology (SAT) were tasked with evaluating the National Toxicology Program's (NTP) Monograph on Fluoride Exposure and Neurodevelopment and other research related to fluoride and neurodevelopmental toxicity. The summary of key findings below is not intended as a formal risk assessment of fluoride exposure and this work does not represent the derivation of a protective value. However, a risk framework for the information may aid in decision-making.

Hazard Assessment

Several hazards of fluoride ingestion have been identified. The strength of association with fluoride exposure varies for several different hazards. Two health hazards are the basis for the primary and secondary maximum contaminant levels (MCL) recognized by the Environmental Protection Agency (EPA 1986): the primary MCL of 4 mg/L was established to protect against skeletal fluorosis (4 mg/L) and the secondary MCL of 2 mg/L protects against dental fluorosis. Skeletal fluorosis is characterized by pain in the bones and joints and by a weakening of bones resulting in an increase in fractures (NRC 2006). Dental fluorosis is characterized by the discoloration and pitting of the dental enamel (NRC 2006). Less severe dental fluorosis is considered a cosmetic issue (i.e. discoloration), however, more severe forms cause enamel loss (i.e. pitting), which may make teeth more susceptible to decay.

The evidence for fluoride hazards has expanded beyond the effects of skeletal and dental fluorosis to include neurodevelopmental impacts, particularly on children's intelligence quotient (IQ). Over the past two decades, research has increasingly focused on fluoride's potential neurotoxic effects, with IQ being the primary endpoint considered in most studies. IQ is a common metric for evaluating population-level effects of environmental contaminants on cognition (Grandjean and Landrigan 2006, Grandjean and Landrigan 2014) and has proved a useful indicator of adverse effects for many contaminants including lead (ATSDR 2020) and mercury (Grandjean et al 1997, EPA 2001).

The National Toxicology Program (NTP) Monograph on Fluoride Exposure and Neurodevelopment (August 2024) is a comprehensive assessment of the scientific literature. The monograph identified a large body of evidence (72 epidemiologic studies) evaluating associations between fluoride exposure and IQ in children. Of those, 19 studies were identified as high-quality 18 of which reported inverse associations between fluoride exposure and children's IQ. The high-quality studies included three prospective cohort studies and 15 cross-sectional studies spanning five different countries (none in the U.S.). Of the remaining 53 studies 46 also provide evidence of inverse associations between fluoride exposure and IQ. NTP also reviewed studies with other neurodevelopmental endpoints (e.g. memory, ADHD) and identified eight out of nine high-quality studies that observed inverse associations between fluoride exposure and other neurodevelopmental outcomes.

The NTP monograph also identified and reviewed several meta-analyses, which consistently reported inverse associations between fluoride exposure and children's IQ. Meta-analyses are an approach to combine findings from multiple studies to address a research question. The meta-analyses identified by the NTP incorporated many of the IQ studies evaluated above and had variability in methodologies and effect sizes. One meta-analysis, Kumar et al. (2023) found significant inverse associations at higher drinking water concentrations (average 3.7 mg/L) but not at lower concentrations (average 0.9 mg/L).

The ultimate finding from the NTP monograph was that with moderate confidence water fluoride concentrations of 1.5 mg/L or greater are consistently associated with lower IQ in children. They acknowledge that more studies are needed, particularly at lower fluoride concentrations to upgrade the moderate confidence conclusion to high confidence.

Most recently, the NTP authors conducted a meta-analysis (Taylor et al. 2025) that serves as a companion hazard assessment to the NTP report. When restricted to high-quality studies, a significant inverse dose-response relationship was identified between IQ in children and group-level fluoride exposure at drinking water concentrations of 4 mg/L, 2 mg/L, and 1.5 mg/L. A dose-response relationship was also noted when urinary fluoride, rather than drinking water intake, was the exposure metric. Thirteen high-quality studies, each using individual-level measures, revealed a decrease of 1.1 IQ points for every 1 mg/L increase in maternal urinary fluoride.

The results of the NTP monograph and the NTP authors meta-analyses provide evidence that neurodevelopmental effects can occur at fluoride drinking water levels below the current MCLs of 4 mg/L and 2 mg/L. It is important to note that these MCLs were set with no uncertainty factors applied with the rationale at the time provided briefly as follows: no uncertainty due to the oral health benefit, the dental fluorosis endpoint was modeled using epidemiologic data from children and therefore no uncertainty regarding different populations was necessary, and the EPA considered the database for fluoride toxicity to be complete (EPA 2010a). In February of 2024 the EPA Office of Water released a review of health effects for primary drinking water standards where they evaluated recent data for fluoride on dental health effects and exposure. In that report they calculated a new potential MCLG of 0.9 mg/L using revised exposure metrics for 1 to <11 years of age because that life stage was identified as a potential critical window of exposure in the development of primary and secondary teeth (EPA 2024). In the same report they also stated that they are aware of studies reporting an association between fluoride exposure and neurodevelopmental effects in the published literature acknowledging that the database on toxicity is not complete (EPA 2024). Additionally, the EPA has recently announced they intend to perform an updated evaluation of fluoride hazards (EPA 2025).

Exposure Assessment

In risk, exposure is evaluated by both the population exposed and the magnitude. As the neurodevelopment hazard has been related to maternal urinary fluoride concentrations, child urinary fluoride concentrations, drinking water concentration, and infant formula concentrations (NTP 2024) the primary populations of concern are pregnant people, infants, and children. Emphasis is given to pregnant people (i.e. the developing fetus) and infants as these life stages have historically shown vulnerability to neurodevelopmental hazards.

Drinking water concentration has traditionally been used as the primary metric for fluoride exposure in regulatory contexts. Drinking water is generally considered a direct, frequent, and indiscriminate exposure pathway for most populations but the magnitude can be variable depending on consumption. As described above drinking water fluoride concentrations and reduced IQ are associated at concentrations of 1.5 mg/L or greater, although it should be noted that individual studies from Canada have assessed reduced IQ in populations with drinking water at concentrations below 1.5 mg/L (Green et al 2019).

However, drinking water as an exposure metric has several important limitations. Water concentration is not a direct measure of dose but rather requires estimation to determine actual intake as individual water consumption varies significantly. According to EPA estimates, drinking water accounts for 40-70% of total fluoride exposure for most individuals (EPA 2010b). This highlights two important things: 1) drinking water is in most cases the primary route of exposure to fluoride in the U.S. and 2) drinking water, although often the primary route of exposure, is not the only exposure to consider. Integration across all exposure sources and routes provides more useful risk characterization.

Urinary fluoride concentration is more commonly used as a biomarker as it provides an integrated measure of total fluoride exposure across all sources including water, food, and dental products. It has been validated in multiple cohort studies as reliably associated with neurodevelopmental outcomes (Green et al 2019, Bashash et al 2017, Malin et al 2024). Recent research has provided data on fluoride exposure in several areas throughout the U.S. and neighboring countries based upon urinary fluoride. Malin et al. (2024) identified median maternal urinary fluoride levels (MUF) in Los Angeles California of 0.76 mg/L. Griebel-Thompson et al. (2025) performed a multi-state evaluation (IN, KS, KY, MO, and OH) that found baseline median MUF of 1.0 mg/L in fluoridated areas and 0.80 mg/L in non-fluoridated areas.

These US-based findings are corroborated by data from international cohort studies. A Canadian cohort reported mean MUF of 0.51 mg/L, with significantly higher levels (0.69 mg/L) among women living in areas with fluoridated water compared to those in non-fluoridated areas (0.40 mg/L) (Green et al 2019). Also, a Mexican cohort study found mean MUF of 0.9 mg/L, however associated water fluoride levels were not available (Bashash et al 2017). These data suggest that the MUF in the U.S. are comparable to those in neighboring countries, that MUF may be associated with water fluoridation, and that U.S. MUF are at or near those that have been identified by the NTP authors for inverse impact to IQ and exceed the level (0.28 mg/L) put forward by Grandjean et al 2024.

Risk Evaluation

A fundamental tenet of risk assessment is adequately capturing the uncertainty when establishing protective levels. Using the lowest level where an adverse effect was observed or the level where no adverse effect was observed is not necessarily a level that will be protective of public health. Protective levels should provide a buffer against uncertainties in the data and variability in human susceptibility.

Uncertainty factors (UFs) provide a systematic approach to weighing various types of uncertainty in the data. UFs may be assigned for the following sources of uncertainty and variability in the data that are being used to define a protective exposure level: using a lowest observed adverse effect level (LOAEL) instead of a no observed adverse effect level (NOAEL), intraspecies variability, interspecies variability, database uncertainty, and using sub-chronic data in place of chronic data. UFs are typically valued at 3 (half order of magnitude rounded down) and 10 (full order of magnitude) depending on the nature and quality of available data. Multiple UFs may be multiplied together to establish the total margin between observed effect levels and acceptable exposure limits.

As discussed above, the EPA when setting the MCLs elected to set the UF = 1. While this may have been defensible, it does illustrate an example for how uncertainty is typically intended to capture unknowns such as neurodevelopmental hazards. In this risk framework, SAT has identified the following UF as appropriate to consider either individually or combined:

- UF = 10 for estimating a no effect level from an effect level.
- UF = 3 or 10 for human variability in susceptibility which addresses variations among the susceptible population.
- UF = 3 or 10 for database uncertainty which addresses limitations in the available evidence and future unknowns.

As an example, we can take a drinking water fluoride concentration of 4 mg/L, which was the highest effect level observed between fluoride drinking water concentrations and neurodevelopment (Taylor et al 2025), apply a single UF = 10, and arrive at 0.4 mg/L fluoride in drinking water as an example protective value against neurodevelopmental effects.

Considerations

Based on the risk framework above and recognizing that the risks detailed above are associated with ingestion of fluoride; SAT provides the following considerations to carry forward to reduce the risk of neurodevelopmental impacts of fluoride:

- The consistency of the findings for effects on IQ across a large body of evidence, the proximity between the current recommended benefit levels (0.7 mg/L, U.S. Health and Human Services 2015) and the new hazard levels, and the seriousness of IQ decrements warrant careful consideration of this new risk in public health decision-making. Future risk/benefit analyses on fluoride should carefully weigh neurodevelopmental hazards alongside the oral health benefit attributed to the intervention when establishing appropriate exposure limits for fluoride in drinking water and other sources.
- It is best practice to incorporate uncertainty in risk. While the oral health benefits of fluoride may make the selection of an uncertainty factor of one defensible (i.e. UF = 1), it imparts no buffer to account for variability and future unknowns.
- It is not within the scope of this risk framework to discuss the benefits of water fluoridation. However, this is an important decision point that requires a clear and robust understanding of the benefits, especially as the benefit is primarily for the susceptible population at risk of neurodevelopmental effects (e.g. developing fetus, infants, and children).
- An additional burden for pregnant people and caregivers may occur based on fluoridation status if recommendations are made to purchase and use alternate water during pregnancy and for mixing formula.
- Should a source of fluoride be removed from the population it is possible an increase in caries may occur, particularly in children. It will be important for communities to consider how to improve access to oral health care.
- The science surrounding fluoride and toxicity continues to grow and should be monitored. As our ability to measure endpoints with greater sensitivity improves, so does our ability to learn more about and identify additional modes of toxicity. It is likely in the future that existing modes of toxicity (skeletal and dental fluorosis and neurodevelopmental effects) are further defined and that new modes may be better identified (e.g. endocrine disruption via thyroid) through research.
- The federal landscape surrounding fluoride appears to be shifting and changes in guidance could occur that may have implications for the way fluoride is used in oral health.

Potential Recommendations

For Pregnant Individuals

- Minimize fluoride ingestion to protect fetal neurodevelopment. This includes avoiding swallowing fluoridated toothpaste during brushing and limiting consumption of foods and beverages high in fluoride content.
- Consider using alternative water sources for drinking and cooking if living in areas with naturally high fluoride levels or fluoridated water.
- Continue to maintain good oral hygiene through proper brushing techniques and regular dental check-ups throughout pregnancy.

For Formula-Fed Infants

- Avoid using fluoridated water for reconstituting infant formula. It is worth noting that breast milk naturally contains minimal fluoride.
- Caregivers might consider ready-to-feed formula options that do not require reconstitution.
- Parents should consult with pediatricians and pediatric dentists about appropriate fluoride exposure for infants.

For Young Children

- Parents should consult pediatricians and pediatric dentists about appropriate usage of fluoridated products and supplements.
- Parents should supervise young children during brushing to ensure they do not swallow toothpaste.

For Older Children and Adults

- When using fluoridated products, follow all instructions on product labels. Do not swallow fluoridated products.
- Consult with their doctor and/or dentist for any specific concerns.

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Attachment B: Summary of Responses of Other States and Organizations

There are 14 states that require fluoridation in some form:

Arkansas, California, Connecticut, Delaware, Georgia, Illinois, Kentucky, Louisiana, Minnesota, Mississippi, Nebraska, Nevada, Ohio, and South Dakota.

Nevada state law only requires water suppliers to add fluoride if they serve more than 100,000 people in a county with a population of more than 700,000. This criteria includes only Clark County.

Almost all state requirements include exceptions. The most common are for water suppliers serving less than a designated amount of people, like 10,000 in California or 500 in South Dakota.

Other exceptions include allowing local jurisdictions to vote not to add fluoride, like in Georgia or Nebraska, or making it contingent on state funding as in Mississippi or Louisiana. In Louisiana's case, state funding has not been provided since federal grant funding ended in 2015.

As of August 2025, 2 states have banned fluoridation:

- Utah became the first state to ban water fluoridation with HB 81, which prohibits the addition of fluoride to a public water system. It took effect May 7, 2025.
- Florida's SB 700 took effect on July 1, 2025, and prevents local governments from using any "water quality additive", including fluoride, that is not used to improve water quality or remove contaminants.

Some other common state requirements around fluoride and water fluoridation include:

- Setting fluoride concentrations for water suppliers who do add fluoride (typically at or around 0.7 mg/L).
- Requiring water suppliers to conduct regular fluoride concentration tests (ranging from daily to monthly).
- Requiring water suppliers who cease or begin adding fluoride, or who exceed a certain fluoride concentration limit, to issue public notices.
- Placing limits on what state entities are allowed to enforce.
    - For instance, Michigan state entities cannot require fluoridation, and Missouri's Dept. of Natural Resources cannot require or prohibit fluoridation.
- Requiring jurisdictions to hold votes on fluoridation, as in New Hampshire.
- Setting up fluoridation grant programs to support water suppliers' fluoridation efforts, such as in New York or South Carolina.

Many bills have been introduced around fluoridation in recent years. This includes at least 2 states, Hawaii and New Jersey, which introduced bills to require fluoridation.

At least 16 states have introduced bills to ban fluoridation similar to Utah and Florida: Alaska, Arkansas, Hawaii, Louisiana, Maine, Massachusetts, Minnesota, Montana, New Hampshire, North Carolina, North Dakota, Ohio, Pennsylvania, South Carolina, Tennessee, and Texas.

In Texas, the Agriculture Commissioner has recently called on the governor and legislature to ban fluoridation.

Lastly, at least 3 states with fluoride requirements saw bills introduced to make fluoridation optional: Kentucky, Nebraska, and South Dakota.

In addition to the recent bans in Utah and Florida, some states have updated rules around fluoridation in recent years.

In Iowa, the Public Health Department rescinded its community water fluoridation grant program in May 2025 due to its being unfunded by the federal government for several years.

In Nebraska, the Department of Health and Human Services adjusted the required fluoride concentration in its rules, lowering the optimal range of 1 to 1.3 parts per million to a concentration of 0.7 mg/L.

In Virginia, Board of Health rules previously allowed the Board to *require* fluoridation where practicable and feasible, but in 2021 this was amended to a recommendation.

At least 8 states have released some sort of publication in the past 5 years reaffirming support for fluoridation: Alabama, Colorado, Hawaii, Maine, New Hampshire, New York, Oklahoma, and Vermont. 2 others, Ohio and North Carolina, are in the process of reviewing documents related to fluoridation.

At least 2 states, Texas and Florida, have seen state officials come out against fluoridation in recent years. Florida's Surgeon General issued guidance in 2024 against fluoridation, citing a number of studies which have since been criticized by experts. Texas' Agriculture Commissioner issued a statement calling on the governor and legislature to ban fluoridation. The statement voiced support for HHS Secretary Robert Kennedy's anti-fluoridation stance but did not cite specific studies.

As of August 2025, we are not aware of any state or national organization that has changed its fluoride policy or recommendation as a result of updated science regarding potential harms of fluoride.

Attachment C: Information presented in the panel sessions

Slides, as available, from presentations

January 9; Emerson Christie; Review of the NTP Monograph

Slide 1

Washington State Department of HEALTH

NTP MONOGRAPH FLUORIDE TOX REVIEW

Emerson Christie, PhD
Toxicologist

Slide 2

Fluoride

- Naturally occurring mineral
- Present in drinking water, food, and consumer products
- Widely promoted for oral health benefits
  - Community water fluoridation, fluoridated toothpaste, fluoride varnishes
- In Washington:
  - Do not require water fluoridation
  - "Where fluoridation is practiced, the optimal fluoride concentration is 0.7 mg/L."
- At sufficient concentrations toxic to bones and tooth enamel
- Emerging concerns as neurodevelopmental toxicant

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Slide 3

National Toxicology Program

- National Toxicology Program (NTP)
  - Federal Toxicology Program - interagency program within the U.S. Department of Health and Human Services
  - Tasked with identifying compounds with toxic and biological effects and providing information for public health decisions
  - Performed studies on many contaminants including lead and PFAS
  - NTP PFAS study serves as the basis for WA SAL for PFHxS

Slide 4

The NTP Monograph: History

- 2006 National Research Council
  - Association between high levels of fluoride in drinking water and adverse neurological effects in humans
- 2016 NTP Review of Animal Studies
  - Low to moderate confidence fluoride impacts learning and memory
- August 2024 Fluoride Monograph:
  - State of the science – Review
  - Moderate confidence, that higher estimated fluoride exposures (e.g., >1.5 mg/L in drinking water) are consistently associated with lower IQ in children

Slide 5

What this report does not say

- It does not address whether the sole exposure to fluoride at 0.7 mg/L is associated with a measurable effect on IQ
- The monograph does not advocate for discontinuing CWF
- It does not provide a risk assessment
- It does not provide a oral health benefit assessment
- It does not provide a risk/benefit analysis

This is not bad news – this is good news

Slide 6

OHAT Approach

Systematic Review

- Planning and protocol development
- Identify evidence
  - Comprehensive literature search
  - Literature screening
- Evaluate evidence
  - Extract data
  - Risk of bias assessment

Evidence Integration

- Rate confidence in association between exposure and outcome

Slide 7

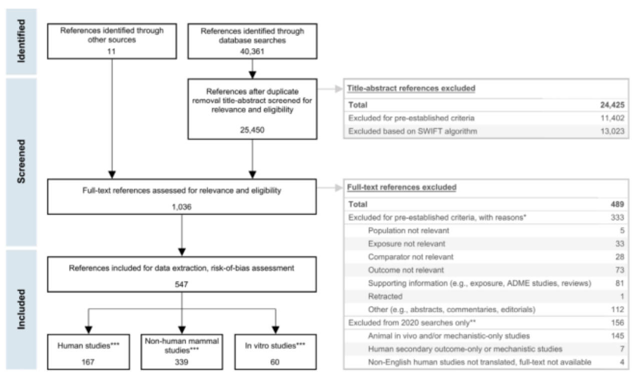


Figure 2. Study Selection Diagram[a]

Figure credit: NTP 2024

Slide 8

What makes a study low (or high) risk of bias

- OHAT approach, some risk-of-bias questions or elements are considered potentially more important when assessing studies
- Key questions
  - Confounding
    - Required - age, sex, and socioeconomic status
    - Required where applicable - co-exposures (lead and arsenic), other covariates considered important for population and outcome
    - Not required to address every covariate
  - Exposure characterization
    - Assessed in a variety of ways – satisfied as long as efforts to reduce bias were included
  - Outcome assessment
    - IQ –appropriate for population and standardized, assessors blind

Slide 9

The NTP Monograph: IQ Association

Monograph (1989 – May 2020)

- 19 low risk of bias studies
  - None from the U.S. (2 Canada)
  - 18 showed inverse association
  - Overall 95% inverse
- 53 medium to high risk of bias studies
  - 46 showed inverse association
  - Overall 86% inverse

Addendum (May 2020 – Oct 2023)

- 12 additional low risk of bias studies
  - 12 inverse associations
  - Overall 97% inverse
- 16 additional medium to high risk of bias studies
  - 13 showed inverse association
  - Overall 86% inverse

Slide 10

The NTP Monograph: IQ Association

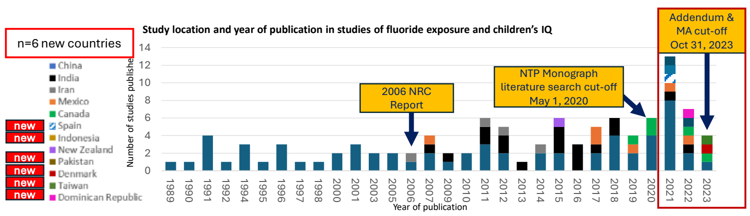


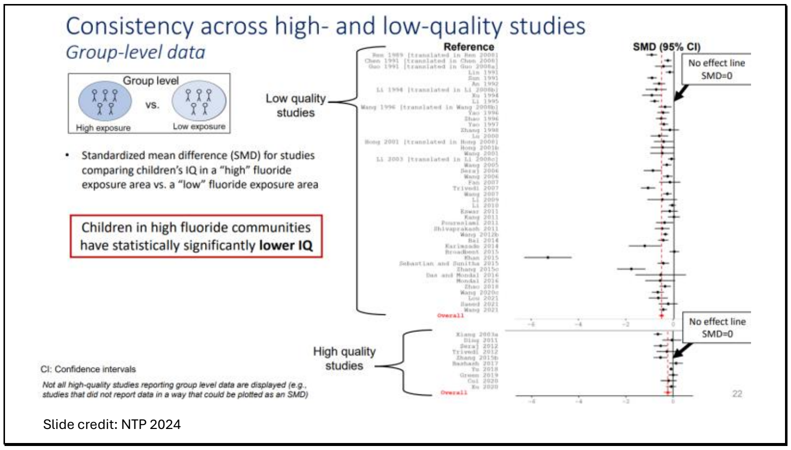
Figure credit: NTP 2024

Slide 11

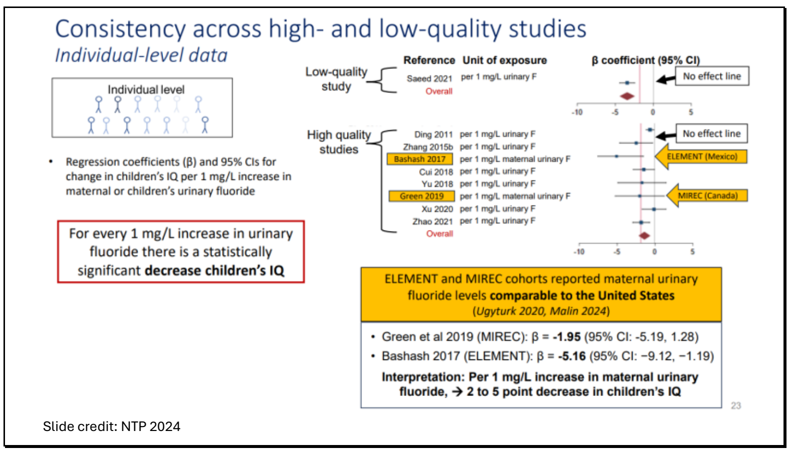
NOTE

- The next 4 slides are from the NTP slide deck: Fluoride, Neurodevelopment, and Cognition: A National Toxicology Program Monograph. https://www.healthandenvironment.org/assets/images/taylor-slides-dec-3-2024.pdf
- This presentation was put on by the Collaborative for Health and Environment on 3 December 2024.
- Slides have been stripped of WA DOH branding and attribution is on each slide.

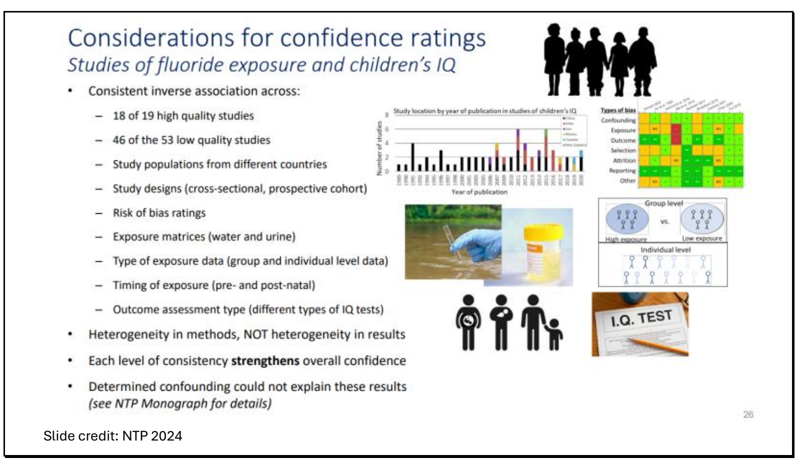
Slide 12



Slide 13



Slide 14



Slide 15

Of note…

- Final confidence conclusions based primarily on high-quality studies (i.e., the best evidence)
  - Consideration of low-quality studies does not decrease confidence in overall body of evidence
- Conclusions based primarily on non-US studies where total fluoride exposure approximated *>1.5 mg/L fluoride in drinking water
  - Several high-quality prospective birth cohort studies with maternal urinary fluoride levels comparable to the United States

  **>1.5 mg/L refers to WHO Drinking Water Guideline of 1.5 mg/L; chosen to describe "higher" fluoride exposure in the NTP Monograph based on an overall assessment of the epidemiology literature; represents a useful total fluoride exposure equivalent metric (no alternative safety guidelines for total fluoride exist)*
- Review ***does not***
  - Evaluate benefits of fluoride or provide a risk/benefit analysis
  - Address whether ***sole exposure*** to fluoride at 0.7 mg/L in drinking water is associated with neurodevelopment and cognitive effects
- Targeted research that prospectively examines the association between fluoride exposure and children's IQ in optimally fluoridated areas of the United States would add clarity to the existing data at lower levels

29

Slide credit: NTP 2024

Slide 16

Meta Analyses Summary

- All meta analyses in the NTP report showed an inverse association between fluoride and IQ
- Kumar et al 2023 – Split studies into high and low fluoride exposure – high showed an inverse, low did not

Addendum Table 2. Previous Meta-analyses on Exposures to Fluoride and Children's IQ

Analysis	Number of Studies	Pooled Effect Type, Estimate (95% CI)	Heterogeneity	
			p-value	I^2
Tang et al. (2008)	16	WMD, −5.03 (−6.51, −3.55)	NR	NR
Choi et al. (2012)	27	SMD, −0.45 (−0.56, −0.34)	<0.001	80%
Duan et al. (2018)	26	SMD, −0.52 (−0.62, −0.42)	<0.001	69.1%
Miranda et al. (2021)	10	OR, 3.88 (2.41, 6.23)	<0.0001	77%
Veneri et al. (2023)	30 (38 results)	WMD, −4.68 (−6.45, −2.92)	NR	98.75%
Kumar et al. (2023)	28 (31 results)	SMD, −0.33 (−0.44, −0.22)	<0.001	83%
DTT Meta-analysis, Taylor et al. (2024, in press)[a]	59	SMD, −0.45 (−0.57, −0.33)	<0.001	94%

CI = confidence interval; NR = not reported; SMD = standardized weighted mean difference; OR = odds ratio of low IQ in the high fluoride versus low fluoride groups; WMD = weighted mean difference.
[a]The NTP authors of this monograph conducted a companion systematic review and meta-analysis of fluoride exposure and children's IQ (DTT Meta-analysis, Taylor et al. 2024, in press).

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Slide 17

Is maternal urinary fluoride an acceptable measurement?

- Maternal Urinary Fluoride is acceptable
  - Measures total fluoride exposure – desired from a risk and hazard perspective
  - Practicality – easy to obtain
  - Temporality
    - Pro – measures during specific time periods
    - Con – subject to bias but can be controlled

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Slide 18

Why IQ?

- Measures population-based shifts in various cognitive parameters
- Important toxicological measurement
  - Lead, arsenic, mercury, and PCBs are neurotoxicants as measured by IQ
  - Exposure relationship often dose-dependent and well-characterized
- Shifts in population IQ associated with societal impacts
  - Educational outcomes
  - Health outcomes
  - Income (when controlling for socioeconomic factors)
  - Crime

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Slide 19

What is the magnitude of impact?

- For every 1 mg/L in increased maternal urinary fluoride (MUF) => 1.14 – 1.63 IQ points (Taylor et. al. 2025)
- MUF third trimester Los Angeles CA cohort median 0.8 mg/L and 95 C.I. of 1.89 mg/L (Malin et. al. 2023)
- ~1 IQ point at median and 2-3 IQ points at 95th C.I. (typical protection level)
- For context - estimated average impact of lead is 2.6 IQ points (McFarland 2022)
- Any contributing shift leftward from a population perspective is of note

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Slide 20

What is the window of exposure?

- Most studies are childhood
  - Of 19 low risk of bias studies
    - Three with maternal urine
    - One breastfeeding and formula
    - Others are either urine or drinking water

Outcome Category	Child	Adult	Child/Adult Combined	Infant	Fetus
Intelligence (IQ)	72	3			
Learning/Memory	5	3		1	
Cognitive Development	3			1	
Cognitive Impairment		6			
Attention/Hyperactivity/Behavioral Issues	7				
Motor/Sensory Function or Development	2	4		1	
Mood/Affect	1	1			
Visual-Spatial/Visual-Motor Function	2	2			
Brain Activity		1			
Brain Structure					2
Neurological Biochemical	3	1	1		1
Neurological Complications of Fluorosis		3			
Neurological Symptoms	1	3			
Birth Defects				3	
Thyroid Gland Function	14	5	2		
Thyroid Disease		2			

Figure 3. Number of Epidemiological Studies by Outcome and Age Categories[a]

[a]Interactive figure and additional study details are available at https://public.tableau.com/app/profile/ntp.visuals/viz/FluorideTableauDashboards/ReadMe.
Choi et al. (2015) used subtests of the omnibus IQ test reported by the authors as Wechsler Intelligence Scale for Children-Revised (WISC-IV) to evaluate visuospatial abilities (using block design) and executive function (using digit span). These endpoints are included in the intelligence (IQ) outcome category as they are subsets of the IQ tests.
Three additional publications based on subsamples (i.e., 50–60 children) of the larger Yu et al. (2018) cohort were identified (Zhao et al. 2019; Zhao et al. 2020; Zhou et al. 2019) and are not included in the counts of this figure.

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Slide 21

Why might this matter for CWF?

- Risk
  - There must exist a margin between the exposure and the level at which a hazard is present.
- Reality

Total fluoride = 1.5 mg/$L_{\text{drinking water}}$ + $0_{\text{other sources}}$ => expect lower IQ

However, reality is

Total fluoride = 0.7 mg/ $L_{\text{drinking water}}$ + $X_{\text{other sources}}$ => ?

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Slide 22

Why might this matter for CWF? Risk

- Risk
  - Conventional risk assessment methods

$$Safe\ level = \frac{LOAEL/NOAEL}{[UF]}$$

  - Fluoride NTP = 1.5 mg/L (LOAEL)
  - Uncertainty Factors (UF) => 10 for LOAEL to NOAEL and 3 for intraspecies

$$Safe\ level = \frac{1.5\ mg/L}{10 * 3} = 0.05\ mg/L$$

  - Fluoride MCL = 4 mg/L (LOAEL)

$$Safe\ level = \frac{4\ mg/L}{10 * 3} = 0.13\ mg/L$$

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Slide 23

Why might this matter for CWF? Reality

- Reality
  - 0.7 mg/ $L_{\text{drinking water}}$ + $X_{\text{other sources}}$ => ?
  - Many sources of fluoride including fluoridated products
  - Potential for exposure at a hazardous level
- Recent data indicate potential risk at current exposures:
  - For every 1 mg/L in increased MUF => 1.14 – 1.63 IQ points (Taylor et. al. 2025)
  - MUF third trimester Los Angeles CA cohort median 0.8 mg/L and 95 C.I. of 1.89 mg/L (Malin et. al. 2023)
  - ~1 IQ point at median and 2-3 IQ points at 95^{th} C.I. (typical protection level)
  - Where water fluoridation occurs ~50% of maternal urinary fluoride (MUF) is attributable to water consumption (Till et. al. 2018)

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Slide 24

Questions

January 28; Holly Davies, Emerson Christie, Mike Ellsworth; TSCA and EPA Court Decision

Slide 1

TOXIC SUBSTANCES CONTROL ACT (TSCA)

Holly Davies, PhD
Environmental Public Health
Fluoride Science Review
Jan. 28, 2025

Slide 2

Toxics Substances Control Act (1976)

- Major federal law that regulates toxic chemical manufacturing, processing, distribution, use, and disposal.
- No unreasonable risk for the intended or foreseen uses.
- Certain substances are generally excluded from TSCA (Sec. 3(2)(B)), including tobacco, pesticide, food, drugs, cosmetics
  - any article subject to the tax imposed by section 4181 of the Internal Revenue Code of 1954
- There are other federal laws within EPA to protect human health and the environment

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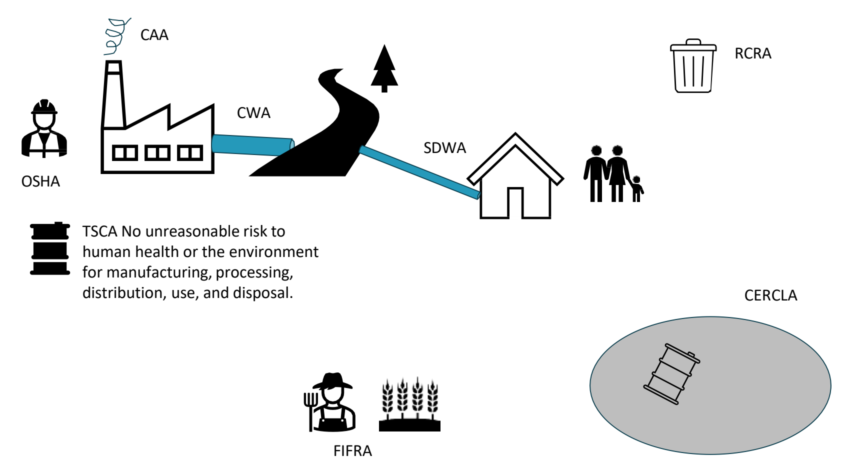
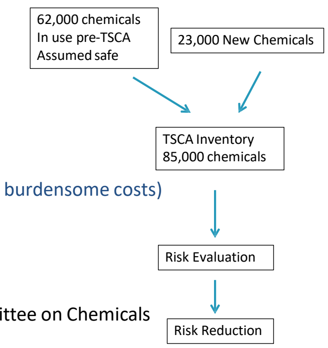
Slide 3



Slide 4

TSCA selected sections with 2016 changes

- Sec. 4 Testing
  - Easier to require testing by order
  - Direction to phase out the use of animals in testing
- Sec. 5 New Chemical review
  - Deadlines for EPA review
- Sec. 6 Management of existing chemicals, ban on PCBs
  - Risk evaluation without consideration of costs (not least burdensome costs)
- Sec. 8 Inventory, reporting, and record keeping
- Sec. 18 Preemption- almost entirely changed in 2016
- Sec. 21 Citizens petitions under sections 4, 5, 6 or 8.
- Sec. 26 Administration, evidence, Science Advisory Committee on Chemicals



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Slide 5

Sec. 6 Prioritization, Risk Evaluation, and Regulation of Chemical Substances and Mixtures

(a) If the Administrator determines that the **manufacture, processing, distribution, use, or disposal** presents an **unreasonable risk**, they **shall by rule** remove such risk.

Prohibit, limit use, warning label, notifications, record keeping

(b) Risk Evaluations- Prioritization, requirements of the evaluations

Not consider costs or other nonrisk factors

Deadlines

(c) Rulemaking

Shall publish … a final rule … **not later than 2 years after**

Consider costs and benefits, feasible alternatives

(g) Exceptions for specific conditions of use, time limited

Essential with no alternative, **significantly disrupt** the economy, etc.

provides a substantial benefit to health, the environment, or public safety

(i) Final Agency Actions and state preemption (Sec. 18)

No unreasonable risk (b) means states are preempted

Unreasonable risk (b) and final rule (a) states are preempted

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Slide 6

Fluoride Sec. 21 Petition

- 2016 A group of NGOs petitioned EPA under Sec.21 to ban fluoridation of drinking water under Sec. 6
- 2017 EPA denied the petition saying the petition had to include a risk evaluation as in Sec. 6(b) and weight of scientific evidence as in Sec. 26
- NGOs appealed under Sec. 21 to a federal district court and bench trial in 2020 and 2024
- 2024 Judged ordered EPA must take actions under Sec. 6 to eliminate the unreasonable risk

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Slide 1

FOOD AND WATER WATCH VS EPA TOX REVIEW

Emerson Christie, PhD
Toxicologist

Washington State Department of HEALTH

Slide 2

Issue

The issue before this Court is whether the Plaintiffs have established by a preponderance of the evidence that the fluoridation of drinking water at levels typical in the United States poses an unreasonable risk of injury to health of the public within the meaning of Amended TSCA. For

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Slide 3

Risk Assessment & Determination

- Hazard Assessment
  - Hazard identification, weight of evidence
  - Dose response analysis – point of departure (POD)
- Exposure Assessment
  - Level of exposure
  - Populations
- Risk Characterization
  - Uncertainty
  - Margin of exposure

} Risk Assessment

- Risk Determination
  - Summary of assessment
  - Identification of "unreasonable risk"

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Slide 4

Hazard Assessment

- Hazard Identification
  - Causation **not** a requirement to establish neurotoxicity hazard
- Weight of the evidence
  - Directional and consistent
- Dose response assessment and point of departure
  - Benchmark

Slide 5

Hazard Assessment

- Hazard Identification:
  - Causation **not** a requirement to establish neurotoxicity hazard

40. EPA experts agreed, in line with the NTP Monograph's conclusion, that fluoride is associated with adverse IQ in children at "higher" levels of exposure. Namely, Dr. Barone testified that he agreed that there is "something going on" at higher-dose levels, though unclear about where the threshold is. Dkt. No. 415, Feb. 12, 2024, Trial Tr. at 1372:9-1373:9 (Barone). Dr. Barone agreed that, at 4 mg/L of fluoride exposure and above, there is more data to support a finding of an adverse effect associated with fluoride. *Id.* at 1373:1-9 (Barone). Dr. Barone further

Slide 6

Hazard Assessment

- ✓ Hazard Identification:
  - Causation **not** a requirement to establish neurotoxicity hazard
- Weight of the evidence
  - Directional and consistent

EPA's expert, Dr. Barone agreed that the NTP Monograph is a "high quality review." Dkt. No. 440, Feb. 13, 2024, Trial Tr. at 1427:2-4 (Barone). Accordingly, the Court finds that the NTP Monograph is probative and afforded significant weight in the risk evaluation analysis.

55. In conclusion, this evidence is sufficient to proceed to the dose-response assessment of the analysis. *Cf.* Methylene Risk Evaluation at 262 (conducting dose-response analysis for Methylene under Amended TSCA based upon one animal study).

Slide 7

Hazard Assessment

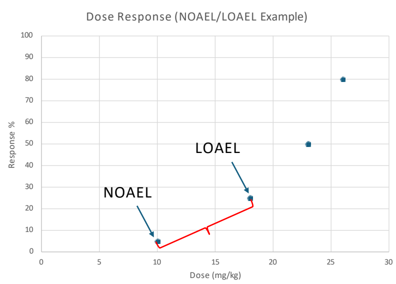
- Hazard Identification:
  - Causation **not** a requirement to establish neurotoxicity hazard
- Weight of the evidence
  - Directional and consistent
- Dose response assessment and point of departure

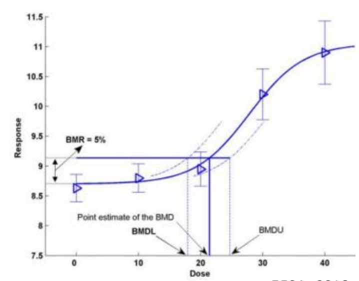
60. 0.28 mg/L, or alternatively, 0.768 and/or 1.536 mg/L measured in maternal urinary fluoride is associated with a 1-point decrease in IQ of girls and boys and is a legitimate point of departure (BMCL) to use in this risk evaluation.

61. Alternatively, 4 mg/L measured in either urinary fluoride or water fluoride, is a legitimate, conservative point of departure (LOAEL) to use in the risk evaluation.

Slide 8

Hazard Assessment: Point of Departure (POD)





EFSA. 2016

Slide 9

Hazard Assessment: Benchmark Dose

- Where did these numbers come from?

60. 0.28 mg/L, or alternatively, 0.768 and/or 1.536 mg/L measured in maternal urinary fluoride is associated with a 1-point decrease in IQ of girls and boys and is a legitimate point of departure (BMCL) to use in this risk evaluation.

61. Alternatively, 4 mg/L measured in either urinary fluoride or water fluoride, is a legitimate, conservative point of departure (LOAEL) to use in the risk evaluation.

Slide 10

Hazard Assessment: Benchmark Dose

- Court considered two publications
  - Phillipe Grandjean (2022 & 2023)
  - Include "lower" exposure levels measured in maternal urinary fluoride
    - 0.9 mg/L in ELEMENT (Mexico)
    - 0.42 mg/L in MIREC (Canada)
    - 0.58 mg/L in OCC (Denmark)
  - These values are consistent with an LA cohort
  - Dr. Grandjean well respected in environmental neurotoxicants and benchmark dose modeling
    - Literal EPA textbook example
    - EPA has used Grandjean BMDs in other decisions

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Slide 11

Hazard Assessment: Benchmark Dose

- Benchmark dose analysis to determine level of maternal urinary fluoride (MUF) associated with 1 point drop in IQ in offspring
- Grandjean 2023
  - ELEMENT, MIREC, and OCC (Canada, Mexico, and Denmark)
  - BMCL (Benchmark Concentration Lower Bound) = **0.28 mg/L MUF**
  - Did not publish a squared model
- Grandjean 2022
  - ELEMENT and MIREC (Canada and Mexico)
  - BMCL = 0.20 mg/L MUF
  - Linear model identified as best overall; split linear and a squared model
  - Squared model: BMCL = **0.768 mg/L MUF**
  - With an uncertainty factor of 2 for not having the OCC data: BMCL = **1.536 mg/L**

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Slide 12

Hazard Assessment: LOAEL

establishes with consistency an association with reduced IQ at that level. Specifically, the NTP Meta-analysis observed a statistically significant inverse association between fluoride and reduced IQ at 4 mg/L measured in water fluoride, based on low-risk-of-bias/high quality studies (*i.e.*, 6

- 4 mg/L in drinking water is also the MCL for skeletal fluorosis
- 2 mg/L in drinking water secondary (non-enforceable) MCL dental fluorosis

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Slide 13

Hazard Assessment: LOAEL

Dr. Barone agreed that, at 4 mg/L of fluoride exposure and above, there is more data to support a finding of an adverse effect associated with fluoride. *Id.* at 1373:1-9 (Barone). Dr. Barone further

81. The EPA has identified a LOAEL based upon far less evidence than that in the record before this Court. In the EPA's risk evaluation of Methylene, conducted pursuant to Amended TSCA, it used a LOAEL for developmental neurotoxicity, derived from the analysis of ***one study conducted upon mouse pups*** (Fredriksson et al., 1992). *See* Methylene Risk Evaluation at 262.

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Slide 14

Hazard Assessment

- ✓ Hazard Identification:
  - Causation **not** a requirement to establish neurotoxicity hazard
- ✓ Weight of the evidence
  - Directional and consistent
- ✓ Dose response assessment and point of departure

Fluoride is a neurotoxicity hazard

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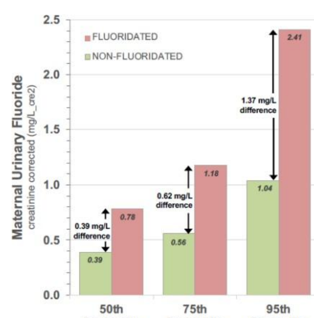
Slide 15

Exposure Assessment

- What is the exposure level at the condition of use?
  - Till et al 2018 – 0.56 mg/L water fluoride
  - Malin et al 2023 – community water fluoridation Los Angeles (~0.7 mg/L)
- Third trimester (Malin et al 2023)
  - Median MUF = 0.8 mg/L
  - 95 CI MUF = 1.89 mg/L
- ~50% MUF attributed to drinking water
- Default RSC for contaminant in drinking water would be 20%



Till et al 2018

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Slide 16

Exposure Assessment: Maternal Urinary Fluoride

- Maternal Urinary Fluoride is acceptable
  - Measures total fluoride exposure
    - Desired from a risk and hazard perspective
    - TSCA specifically allows for consideration of aggregate exposures
  - Water fluoride concentrations:
    - Consistently associated with urinary fluoride
    - Represent ~50% of observed maternal urinary fluoride
  - Temporality
    - Measures during specific time periods

And the EPA's expert witness agreed that the increase in maternal urinary fluoride levels can largely be attributed to intake of fluoridated water. Dkt. No. 416, Feb. 13, 2024, Trial Tr. at

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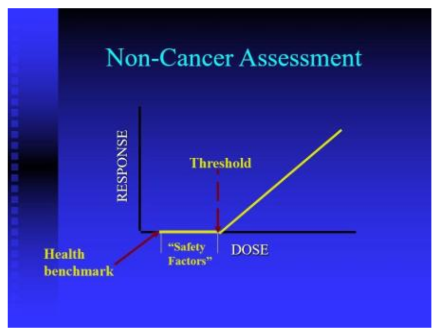
Slide 17

Risk Characterization

- Point of departure (i.e. hazard level) compared to exposure level
- Point of departure is inadequate for protection – a margin must exist



O'Garro 2025

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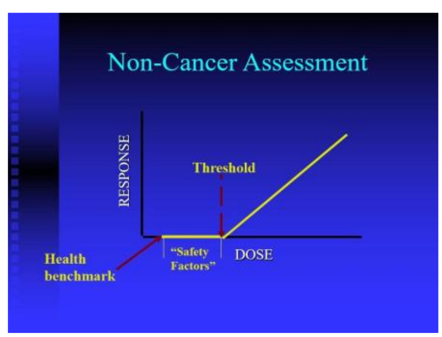
Slide 18

Risk Characterization: Uncertainty Factors

- Intraspecies variability
- Interspecies variability
- LOAEL to NOAEL
- Database uncertainty
- Subchronic to chronic

- Typically single order of magnitude (i.e. 10 fold)
  - Can be ½ power (i.e. 3 fold)
- Total UF should not exceed 3000



O'Garro 2025

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Risk Characterization: Conventional Methods

- Conventional risk assessment methods

$$Safe\ level = \frac{POD}{[UF]}$$

  - POD = Point of departure => BMCL, NOAEL, LOAEL
  - UF = Uncertainty Factors
- Determined risk was present at all identified PODs:
  - BMCL = 0.28 mg/L MUF
  - BMCL = 0.768 mg/L MUF
  - BMCL = 1.536 mg/L MUF
  - LOAEL = 4 mg/L water fluoride

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Risk Characterization: Conventional Methods

- Conventional risk assessment methods
  - POD = 0.28 mg/L MUF (Grandjean 2023 – linear model)
  - UF = 10 for intraspecies variability

$$Safe\ level = \frac{0.28\ mg/L}{10} = 0.028\ mg/L$$

- 0.028 mg/L is:
  - Less than the median MUF of 0.8 mg/L
  - Less than the 95 CI MUF of 1.89 mg/L
  - Less than the median MUF_{water} of 0.4 mg/L (i.e. 50% of the total MUF)
  - Less than the 95 CI MUF_{water} of 0.945 mg/L (i.e. 50% of the total MUF)

  - Risk is present

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Slide 21

Risk Characterization: Conventional Methods

- Conventional risk assessment methods
  - POD = 0.768 mg/L MUF (Grandjean 2022 – squared model)
  - UF = 10 for intraspecies variability

$$Safe\ level = \frac{0.768\ mg/L}{10} = 0.0768\ mg/L$$

- 0.0768 mg/L is:
  - Less than the median MUF of 0.8 mg/L
  - Less than the 95 CI MUF of 1.89 mg/L
  - Less than the median MUF_{water} of 0.4 mg/L (i.e. 50% of the total MUF)
  - Less than the 95 CI MUF_{water} of 0.945 mg/L (i.e. 50% of the total MUF)

  - Risk is present

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Risk Characterization: Conventional Methods

- Conventional risk assessment methods
  - POD = 1.536 mg/L MUF (Grandjean 2022 – squared model x2 for uncertainty)
  - UF = 10 for intraspecies variability

$$Safe\ level = \frac{1.536\ mg/L}{10} = 0.1536\ mg/L$$

- 0.1536 mg/L is:
  - Less than the median MUF of 0.8 mg/L
  - Less than the 95 CI MUF of 1.89 mg/L
  - Less than the median MUF_{water} of 0.4 mg/L (i.e. 50% of the total MUF)
  - Less than the 95 CI MUF_{water} of 0.945 mg/L (i.e. 50% of the total MUF)

  - Risk is present

Slide 23

Risk Characterization: Conventional Methods

- Conventional risk assessment methods
  - POD = 4 mg/L water fluoride (NTP meta analysis)
  - UF = 10 for intraspecies variability
  - UF = 10 for LOAEL to NOAEL

$$Safe\ level = \frac{4\ mg/L}{10\ x\ 10} = 0.04\ mg/L$$

- 0.04 mg/L is:
  - Less than the community water fluoridation level of 0.7 mg/L

  - Risk is present

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Risk Determination

- "Unreasonable" risk
  - Severity of the hazard
  - Exposure-related considerations
    - Duration
    - Magnitude
    - Population size
  - Population characteristics
  - Confidence in the information used for hazard and exposure
  - Confidence in uncertainties and assumptions

Slide 25

Risk Determination

- "Unreasonable" risk
  - Severity of the hazard
    - IQ loss
  - Exposure-related considerations
    - 2,000,000 pregnant people
    - over 300,000 exclusively formula-fed babies
  - Population characteristics
    - Very susceptible populations - pregnant people and infants
  - Confidence in the information used for hazard and exposure
    - High level of certainty of hazard between fluoride and IQ
    - Some uncertainty in which POD to use
  - Confidence in uncertainties and assumptions
    - Uncertainty in mechanism of action

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Finding

IV. CONCLUSIONS OF LAW

121. Plaintiffs have proven, by a preponderance of the evidence, that water fluoridation at the level of 0.7 mg/L – the prescribed optimal level of fluoridation in the United States – presents an "unreasonable risk of injury to health or the environment, without consideration of costs or other non-risk factors, including an unreasonable risk to a potentially exposed or susceptible subpopulation under the conditions of use." 15 U.S.C. § 2620(b)(4)(B)(ii).

122. The Court thus orders the Administrator to initiate rulemaking pursuant to Subsection 6(a) of TSCA. *See id.* §§ 2605(a), 2620(a).

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Final Thoughts on Risk

- Similar assessments could be done with other PODs for fluoride
- This assessment did not consider benefits
- Did not identify what action may be taken

This is not bad news – this is good news

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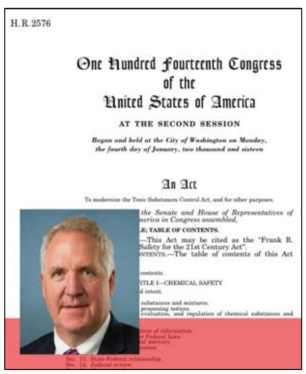
Slide 1

Food & Water Watch, Inc.
v.
U.S. Environmental Protection Agency (EPA)

US District Court Northern District of California
Case No. 17-cv-02162-EMC

Slide 2

Background



Slide 3

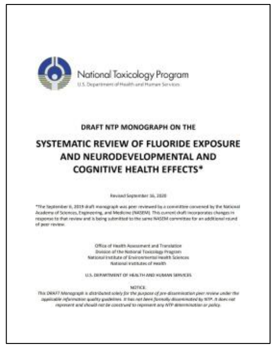
Procedural History

- June 2016, US Congress passes law to amend TSCA
- November 2016, citizens petition, including Food & Water Watch, to EPA to regulate fluoridation
- February 2017, EPA denied Plaintiffs
- April 2017, Plaintiff filed suit in 9th Circuit

Slide 4

Trial Phase 1

- June 2020, 7-day bench trial
- August 2020, Court stayed to allow EPA to consider NTP Systematic Review
- Plaintiffs filed supplemental petition for EPA TSCA reconsideration
- EPA denied petition


National Toxicology Program
DRAFT NTP MONOGRAPH ON THE
SYSTEMATIC REVIEW OF FLUORIDE EXPOSURE AND NEURODEVELOPMENTAL AND COGNITIVE HEALTH EFFECTS*

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Slide 5

Trial Phase 2

- October 2022, Court took case out of abeyance
- January - February 2024, 10-day bench trial
- September 2024, Court issued order finding Plaintiffs met burden that community water fluoridation at 0.7 mg/L presents unreasonable risk of injury to health
- January 2025, EPA appealed decision


UNITED STATES DISTRICT COURT
NORTHERN DISTRICT OF CALIFORNIA
FOOD & WATER WATCH, INC., et al., Plaintiffs, v. UNITED STATES ENVIRONMENTAL PROTECTION AGENCY, et al., Defendants.
FINDINGS OF FACT AND CONCLUSIONS OF LAW
I. INTRODUCTION

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Slide 6

TSCA Risk Evaluation

TSCA risk evaluation is comprised of the following steps:

Step 1: Hazard assessment (including hazard identification and quantitative dose response analysis);

Step 2: Exposure assessment;

Step 3:Rrisk characterization. A risk evaluation under the Amended TSCA includes the three aforementioned steps of a risk assessment, as well as a fourth and final step:

Step 4: Risk determination. The “risk assessment” is the scientific technical evaluation, encompassing the first three parts of this process, resulting in an unbiased, transparent, and reproducible description of the risk.

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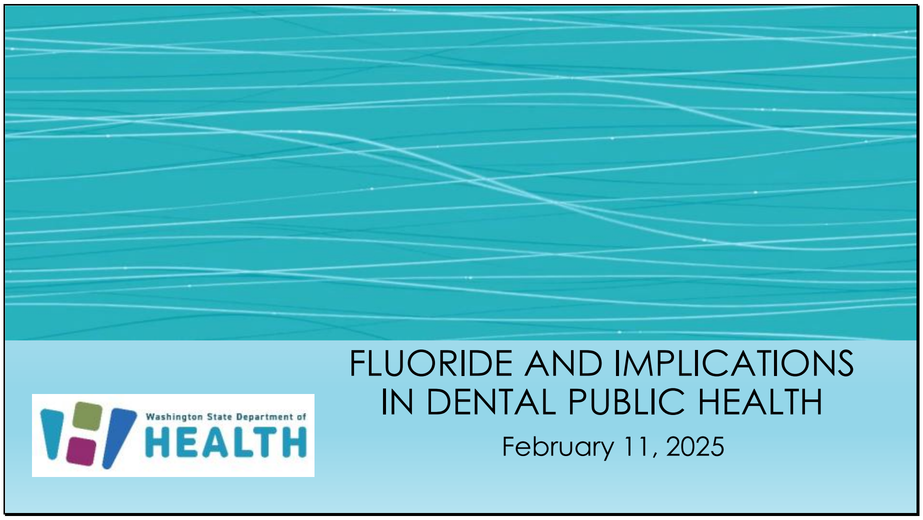
February 11; Shelley Guinn; Oral health and fluoride

Slide 1



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Slide 3

Outline:

1. Dental Health: Tooth Development and Mineralization
2. Dental Caries - Cariology
   1. Etiology of tooth decay
   2. Burden of the Disease and Disparities
3. Fluorides and Fluoridation – Mechanisms of Action and Efficacy
   1. Systemic/Topical Considerations
   2. Fluoride intake
4. Public Health Considerations

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Slide 4

ORAL HEALTH: THE DENTITION

Slide 5

Oral Health is Essential to Health and Well-Being

For the individual, for the family, for the community, and the broader economy

- Function
- QoL
- Self Esteem/mental health
- Employment
- Sleep
- School/Learning
- Systemic/Chronic Disease Connections
- National Security – Recruits must have functioning, disease-free dentition

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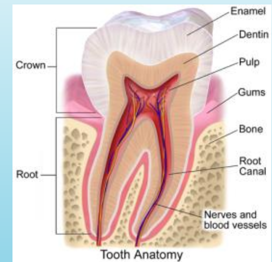
Slide 6

Tooth Histology

Tooth Enamel = Covers the crown of the tooth;
Hardest substance in the body
Dentin: Lies beneath the enamel, more porous
Cementum: covers the root surfaces, less "hard," more easily demineralized

Enamel and Dentin:
Primary mineral is Hydroxyapatite, which is a crystalline calcium phosphate:
$Ca_{10}(PO_4)_6(OH)_2$



Slide 7

DENTAL CARIES: A MULTI FACTORIAL DISEASE

Slide 8

Caries Initiation and Development

Four Factors Required
1. Susceptible tooth surface
2. Caries-causing bacteria
3. Suitable carbohydrate source
4. Time

Modifying Factors
1. Saliva
2. Fluoride

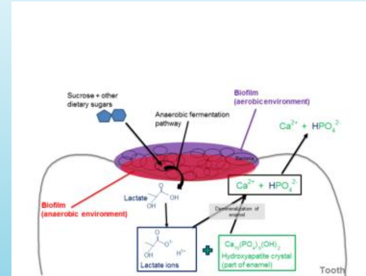
Slide 9

Etiology of Tooth Decay

Tooth enamel = Crystalline Calcium Phosphate $Ca_{10}(PO_4)_6(OH)_2$

- Bacteria metabolize carbohydrates and produce destructive acids which sit undisturbed on the tooth surfaces, in grooves and pits

- Acids cause degradation of the mineral bonds, breaking down tooth surface and releasing **free-floating positive Ca^{2+} ions** into the oral environment.

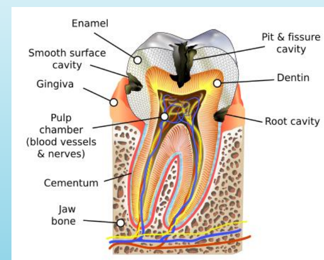


Slide 10

Progression of Tooth Decay

1. Holes (cavities) develop in the tooth surfaces
2. Bacteria and acids may invade the nerve center
3. Pain, inflammation, infection

   Loss of function



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Dental Caries: Burden of the Disease

One of the most common non-communicable diseases affecting both adults and children globally

- Disproportionately affects the poor, the young, minority populations, and children living below 100% of the poverty level.

- Children with poor oral health are more likely to miss school and suffer academically
- US: 25% of young poor and minority children experience 80% of the disease burden
- WA: 45% of Head Start/ECEAP pre K were affected in 2016; with nearly half having rampant decay (6+ teeth)

- Early childhood caries is the single greatest risk factor for caries in the permanent dentition

(Sources: IADR, 2022; Ran, 2016; Smile Survey, 2017)

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Dental Caries: Burden of Disease

- U.S. Economic Impact of dental caries on individuals and society in 2013:
  - $111 billion
- Emergency Departments
  - WHA, 2011: Dental Pain #1 CC among uninsured
- Socioeconomic inequalities that exist in oral health at global and regional levels are detrimental to improving population oral health
  - Dentistry is inadequate for reducing the global or regional disease burden

Investment into upstream, integrated, population-wide policies would maximize oral health improvement

Slide 13

Dental Caries: A Preventable Disease

Dental caries is a chronic disease that can be prevented, but once it begins, can only be *managed*. A filling does not cure the disease.

Prevention and management of disease includes three levels:

I. Primary prevention:

- Behavior modifications: diet, personal hygiene, use of fluorides

II. Secondary prevention:

- Dental sealants, fluoride varnish, more frequent dental visits

III. Tertiary prevention: Control/Management of the Disease:

Silver Diamine Fluoride (SDF) – Complex Restorative procedures

Slide 14

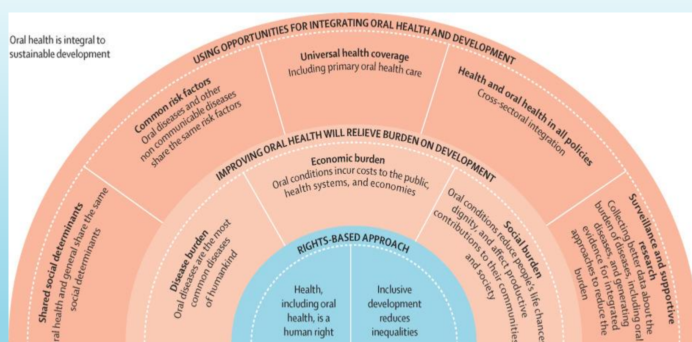

Image: Benzian and Williams, Oral Health Atlas, 2019

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FLUORIDES AND FLUORIDATION

Slide 16

Fluorides: 2 Main Mechanisms of Action

1. Reduced enamel solubility

2. Reversal of (early) caries process

The mechanisms of fluoride action are both topical and systemic

Slide 17

Systemic VS Topical Fluorides: Mechanism of Action

Systemic

Incorporates into dental apatite crystals during tooth development, reducing solubility of enamel: $Ca_{10}(PO_4)_6(F)_2$

- Rx Fluoride Drops/Tabs
- CWF
- Foods and beverage consumption

(These also provide a topical benefit)

Topical

Provides temporary ambient fluoride to the oral environment to assist with acid challenges (CaF_2)

- Toothpaste (1000-1100 mg/L, 1.3 mg/quarter teaspoon)
- Mouthrinse
- Dental Provider Applications
  - FL Varnish, gels
  - *Silver Diamine Fl (SDF)

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Anti-caries effect: Pre-eruptive or Post-eruptive?

Pre-Eruptive:

- Important and effective for pits and fissure morphology (1970s)
- Singh, et. al: Maximum caries preventive effects of CWF were achieved with both "high" pre-and post-eruption exposures
- Cho, et.al, found the effect of ceased CWF in South Korea indicated that 11-year old children with approx. 4 years of CWF since birth, before CWF cessation had significantly lower DMFT ratios relative to those children who grew up in the non-fl community
- Iida and Kumar: Large national dataset of US school children, using fluorosis as a biomarker for pre-eruptive fl exposure and dental caries in first permanent molars. Findings: teeth with fluorosis consistently had lower caries experience than molars without fluorosis in both fluoridated and non-fluoridated communities

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Anti-caries effect: Pre-eruptive or Post-eruptive?

The effects of pre- and post-eruptive fluoride complement each other

- Lifespan consideration:
  - Fluoride incorporated into developing enamel mineral may offer initial resistance to caries initiation or delay the formation of clinically detectable caries, especially at surfaces where post-eruptive fluoride is less than effective (pits, fissures, grooves)
  - Daily lower levels of topical fluoride helps to keep free fluoride available ongoing in the oral environment during times of lowered pH

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Fluoride Intake

- Children ages 6 months to 14 years: Drinking water accounts for 40% to 70% of total fluoride intake (Public Health Reports, 2015)
- Accidentally swallowing toothpaste accounts for ~20% of total fluoride intake in very young children 1 to 3 years old.
- Adults: Drinking water provides 60% of total fluoride intake
- Other major contributors are commercial beverages and solid foods
- Most toothpastes in US contain fluoride in the form of sodium fluoride or monofluorophosphate.
- Drinking Fl water keeps a low level of fluoride (0.7 mg/L) in the mouth all day.
- FL toothpastes provide much higher concentration at important times of the day such as bedtime
- Gels used by dentists: applied 1-4 times/year and can lead to ingestions of 1.3 to 31.2 mg of fluoride each time.

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Public Health Perspective

Communities that cease water fluoridation generally see more cavities in kids, with higher dental bills (Medicaid):

Israel halted CWF in 2014: Kids age 3 – 5 required twice as many dental procedures compared with before.

Canada: Compared Calgary and Edmonton after fluoridation cessation in Calgary, capturing children born after cessation. Findings: Decay rates increased significantly, well above Edmonton's rates. Calgary City Council voted to restart CWF

Alaska: Retrospective comparison: Juneau (stopped fl in 2007) and Anchorage. Findings: Before Juneau stopped CWF, the avg cost to treat tooth decay was similar to Anchorage. After, costs in Juneau jumped by 47%, while treatment costs in CWF Anchorage increased only 5%

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Public Health Perspective

Slade, et. al (JDR, 2018): Cross-sectional study: For every 100 children with access to fluoridated water, there are 130 fewer decayed surfaces of primary teeth and 30 fewer decayed surfaces of permanent teeth.

Public health researchers expect the brunt of fluoride removal to fall on people with low incomes, pre-existing dental conditions, or physical or cognitive disabilities. Marginalized people tend to have fewer prevention and treatment options for tooth decay. Socioeconomic barriers can make it difficult for a person to regularly brush and floss their teeth, maintain a healthy diet or access dental care.

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CWF is Equitable Disease Prevention

- Higher caries experience is found in populations from lower SES backgrounds, and are less likely to be treated for the disease
- CWF allows fluoride to be passively delivered to community residents regardless of SES status of ability to access dental services.
- Prescription fluorides need to be ordered, monitored closely, parents forget to administer, need to be refilled monthly, may have barriers.
- Fluoride products are not always readily available to everyone in the community due to costs or availability

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CWF: Narrowing the Disparity Gap

Research is mixed and still emerging on evidence for CWF reducing inequalities.

- The York review: Some evidence for reduced SES inequalities in caries levels in children
- Cochrane review found insufficient evidence
- National Health and Medical Research Council Review: 'found that water fluoridation reduces tooth decay by 26-44% in children, teenagers and adults' and concluded that there was limited evidence that fluoridation reduced SES inequalities and called for further high-quality research

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Slide 25

CWF: Narrowing the Disparity Gap

More recent studies from different countries report evidence that fluoridation reduced SES inequalities:

- **Neidell, et. al**: *Association between community water fluoridation and adult tooth loss.* Am J Public Health (2010).
- **Kumar, et. al**: *Geographic variation in Medicaid claims for dental procedures in New York State: Role of fluoridation under contemporary conditions.* Public Health Reports (2010).
- **Elmer, et. al**: *An alternative marker for the effectiveness of water fluoridation: hospital extraction rates for dental decay, a two-region study.* Br Dent J. (2014)

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Questions?

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March 11; Claire Nitsche; Cochrane Review

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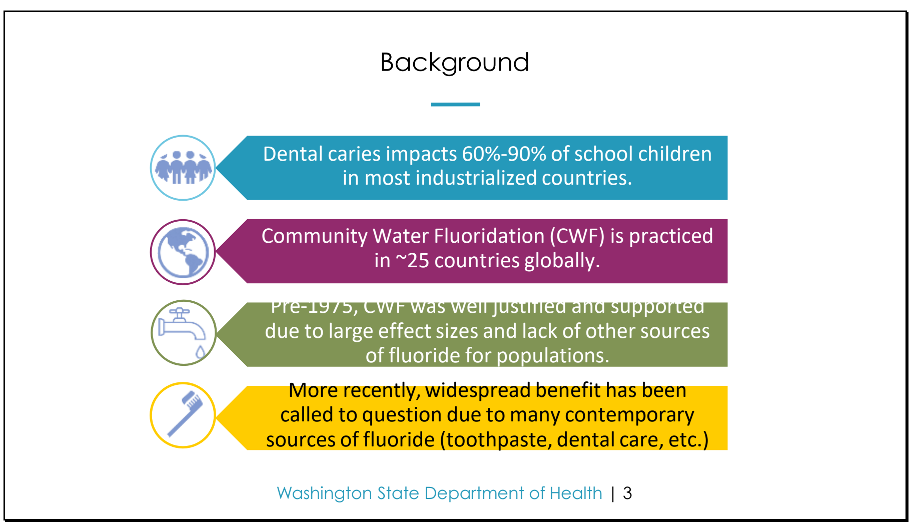
Slide 3



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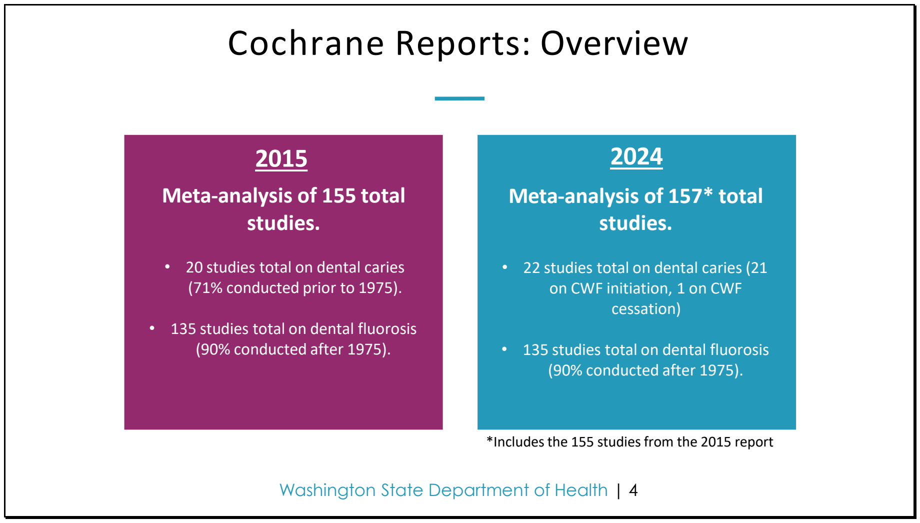

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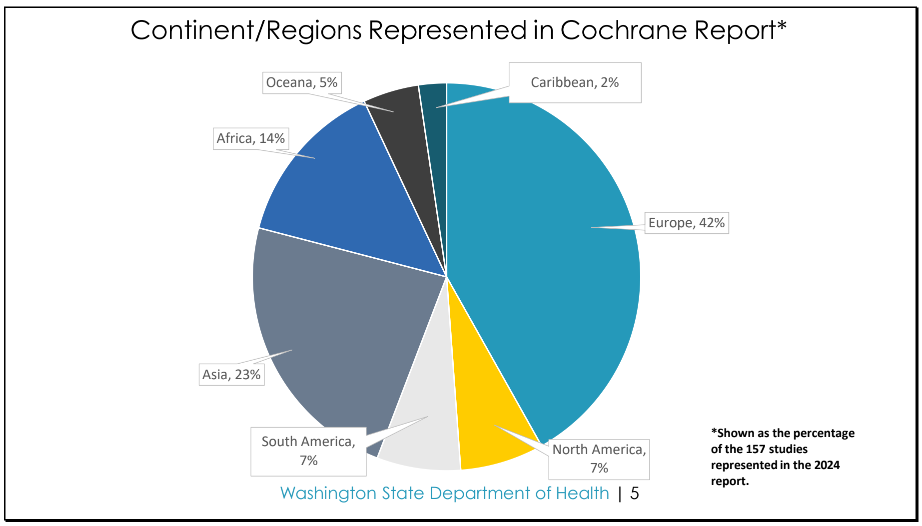

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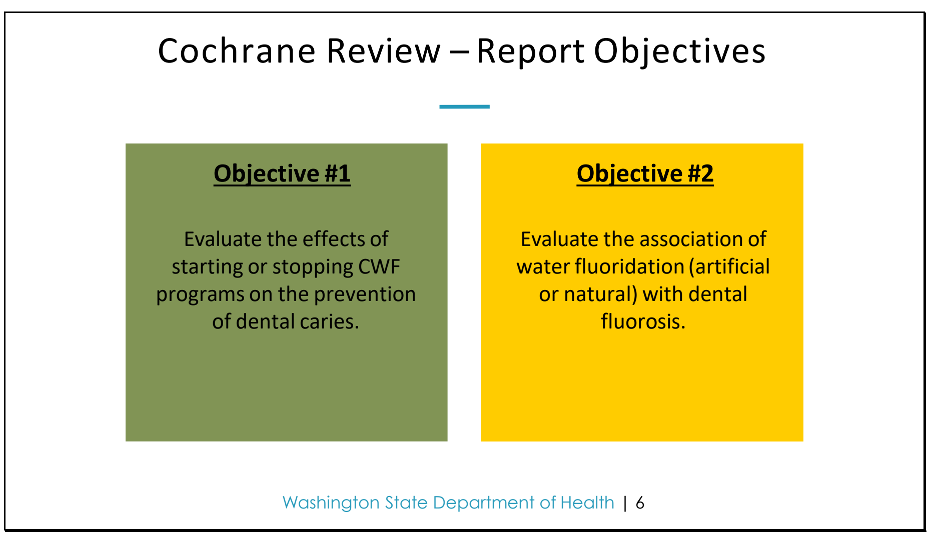


Slide 7

Cochrane Review: Search Methodology and Inclusion Criteria

Study Search Methodology

- CENTRAL, MEDLINE, Embase, Cochrane Oral Health's Trials Register, ProQuest, Web of Science Conference Proceedings, ZETOC Conference Proceedings, US NIH Ongoing Trials Register, WHO Clinical Trials Registry Platform.
- No language, publication year, or publication status restrictions.

Inclusion Criteria – Objective #1 (Dental Caries)

- **Prospective** controlled studies comparing populations receiving water fluoridation to those receiving non-fluoridated OR naturally low-fluoridated water.
- Populations of all ages included, but the 21 studies on CWF initiation only measured caries in children (age 3-18).
- Selected studies that measured caries both within **3 years** of change in fluoridation status, and at end of study follow up.

Inclusion Criteria – Objective #2 (Dental Fluorosis)

- Any study design with concurrent control groups comparing populations exposed to different water fluoridation concentrations.
- Did not look for or include new dental fluorosis data in 2024 report.

All 157 studies in the 2024 report used non-randomized designs.

Slide 8

Fluorosis

Slide 9

Dental fluorosis outcomes measured

- Dental fluorosis of aesthetic concern
  - Dean's Fluorosis Index
  - Tooth Surface Index of Fluorosis (TSIF)
  - Thylstrup and Fejerskov Index (TFI)
  - Developmental Defects of Enamel (DDE)
- Any level of dental fluorosis
- Other possible adverse effects*
- Reported fluorosis outcome data two ways:
  - All fluoride levels
  - Fluoride levels below 5 ppm

Slide 10

Dental fluorosis findings

Findings the same as 2015 Cochrane Review; no new studies added

- No new studies were added
- 2015 review is an update of the McDonagh 2000 review

Adding fluoride to water supplies increases number of people with any dental fluorosis*

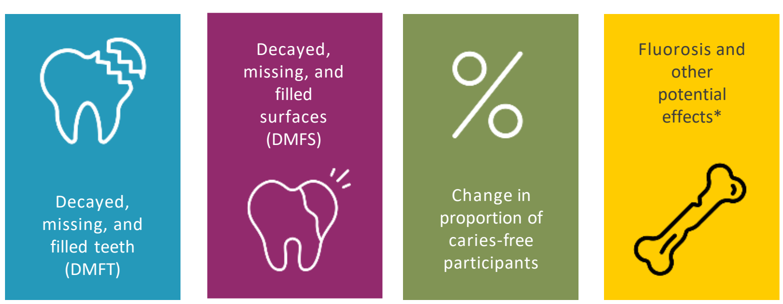
- 9% estimated prevalence of dental fluorosis of aesthetic concern (McDonagh 2000)
- 12% dental fluorosis of aesthetic concern (Cochrane 2015)

Slide 11

Dental Caries and Tooth Decay

Slide 12

Dental caries outcomes measured



Slide 13

Main findings: dental caries/decay

Adding fluoride to water associated with slightly less tooth decay in children's baby teeth.

- Based on studies conducted after 1975
- Children only in studies
- Could not differentiate whether CWF reduced tooth decay in permanent teeth (DMFT) or decay on the surface of teeth (DMFS)
- Effect sizes varied for different populations

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Inconclusive results: dental caries/decay

Could not evaluate the effect of CWF cessation on a community

- Only 1 CWF cessation study included

Could not evaluate differences in CWF effect between richer and poorer people

- Studies after 1975 were not designed to measure this relationship
- "Lack of evidence to demonstrate an effect does not equate to lack of effect."

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Limitations and Considerations

- CWF concentrations in other countries are generally higher than in the U.S. (0.7 mg/L)
- Objective was not to compare fluoride sources efficacy
  - Modes of exposure and reported benefits differ between pre-eruptive/systemic fluoride intake and post-eruptive/contact use
- Pre-eruptive benefits were not evaluated
- The inclusion criteria are strict
  - Review contains most robust study designs but is a subset of all literature
- The included studies measured caries at baseline, prior to CWF initiation or cessation, and at the end of the study period

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Some notable cessation studies were not included


Fluoridation cessation and children's dental caries: A 7-year follow-up evaluation of Grade 2 schoolchildren in Calgary and Edmonton, Canada


Consequences of community water fluoridation cessation for Medicaid-eligible children and adolescents in Juneau, Alaska


Systemic effect of water fluoridation on dental caries prevalence

Slide 17

2024 Cochrane Key Takeaways

Dental fluorosis

- The authors estimate that about 40% of people may have fluorosis of any level
- At 0.7 mg/L, estimate about 12% of people have fluorosis of cosmetic concern

Tooth decay and caries

- Contemporary evidence (post-1975) do not show as clear and important effect of CWF for prevention of tooth decay in children
- Benefits are likely community- or population-specific
- CWF may still be highly effective to populations in which tooth decay is very high

Slide 18

"Any initiation or cessation of a community water fluoridation programme should be fully evaluated using robust methods to address confounding, and should collect cost data to inform economic evaluation…"

"… If one of the key aims of community water fluoridation is to reduce oral health disparities, then full evaluations of the effects of community water fluoridation by socioeconomic status should be undertaken and fully reported whenever schemes are introduced or removed"

Slide 19

Broader Discussion

Slide 20

Questions Not Addressed By Report:
Health Promotion and Behavior Interventions

- Where else (and how often) are populations accessing fluoride in their day-to-day movements?
- What other health promotion programs are available for fluoride that may be impacting findings?
- Were other programs on alternative fluoride access run utilizing the best health education and health behavior change theory applications?
- There is no such thing as "the general public" – how does CWF compare to other interventions at a community-specific level?

Slide 21

Remaining Epidemiological Questions

- Characterize the total fluoride intake across populations
- Study fluoride dose-response relationship to various outcomes by age and route of exposure
- Community-specific evaluation of dental care access
- Population-level risk/benefit analysis (costs, outcomes, knock-on effects)

Slide 22

Examples of Informative Future Studies

Total fluoride consumption relationship to specific health outcomes

- Prospective cohort design
- Characterize fluoride intake from different sources
- Urinalysis to verify total intake
- Could separate groups by CWF initiation/cessation

Water district-specific risk/benefit analysis

- Account for demographics (e.g., age)
- Include covariates like dental care access and insurance coverage coverage
- Cost of care
- Cost of CWF
- Predictive model potential health effects (positive or negative)

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Thank you!

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SUPPLEMENTAL SLIDES

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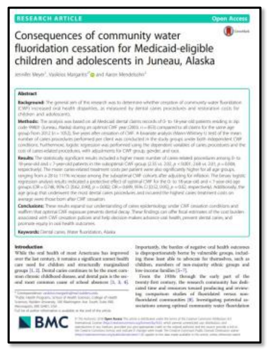
Why the defined follow up period matters


ORIGINAL ARTICLE

WILEY

Fluoridation cessation and children's dental caries: A 7-year follow-up evaluation of Grade 2 schoolchildren in Calgary and Edmonton, Canada


RESEARCH ARTICLE

Open Access

Consequences of community water fluoridation cessation for Medicaid-eligible children and adolescents in Juneau, Alaska

BMC


Systemic effect of water fluoridation on dental caries prevalence

Slide 27

Dental caries outcomes measured

- Change in number of decay, missing, and filled primary and permanent teeth (DMFT)
- Change in the number of decay, missing, and filled primary and permanent tooth surfaces (DMFS)
- Change in the proportion of caries-free participants
- Adverse effects including fluorosis and potential effects* like skeletal fluorosis, hip fractures, cancer, congenital malformations, mortality

**There is lack of evidence for these harms, but authors chose to include in acknowledgement of growing interest (See McDonagh 2000, NHMRC 2017)*

Slide 28

Inconclusive results: dental caries/decay

Could not evaluate the effect of CWF cessation on a community

- Only 1 CWF cessation study included

Could not evaluate differences in CWF effect between richer and poorer people

- Studies after 1975 were not designed to measure this relationship

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Remaining Epidemiological Questions

- Characterize the cumulative F- intake across populations
- Fluoride dose-response relationship to various outcomes; need better exposure contrast rather than high/low water systems
- Community-specific evaluation of dental care access
- Quantifying the risk of one population versus the benefits to another
  - Community-specific risk (e.g., age of population)
  - Consider dental care access and affordability (e.g., many dentists do not accept Medicaid and Medicare)
  - Consider systemic costs

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Dental fluorosis findings

- Findings the same as 2015 Cochrane Review; no new studies added
- Adding fluoride to water supplies increases number of people with dental fluorosis

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Pre-eruption CWF studies

- The Pre-and Posteruptive Effects of Fluoride in the Caries Decline (Beltran 1988)
- Clinical Evidence of the Role of Pre-eruptive Fluoride in Caries Prevention (Thylstrup 1990)
- Systemic versus topical fluoride (Hellwig 2004)
- Fluoride in Caries Prevention: Is the Effect Pre- or Post-eruptive? (Groeneveld 1990)
- Relative Effects of Pre- and Posteruption Water Fluoride on Caries Experience of Permanent First Molars (Singh 2002)
- Effects of water fluoride exposure at crown completion and maturation on caries of permanent first molars (Singh 2007)

March 25; Herbie Duber; Case Studies

Slide 1

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COMMUNITY WATER FLUORIDATION - CASE STUDIES

Slide 2

Overview

Brief overview of BoD and CWF

CWF and the Cochrane Review

Calgary, AB

Juneau, AK

Conclusions

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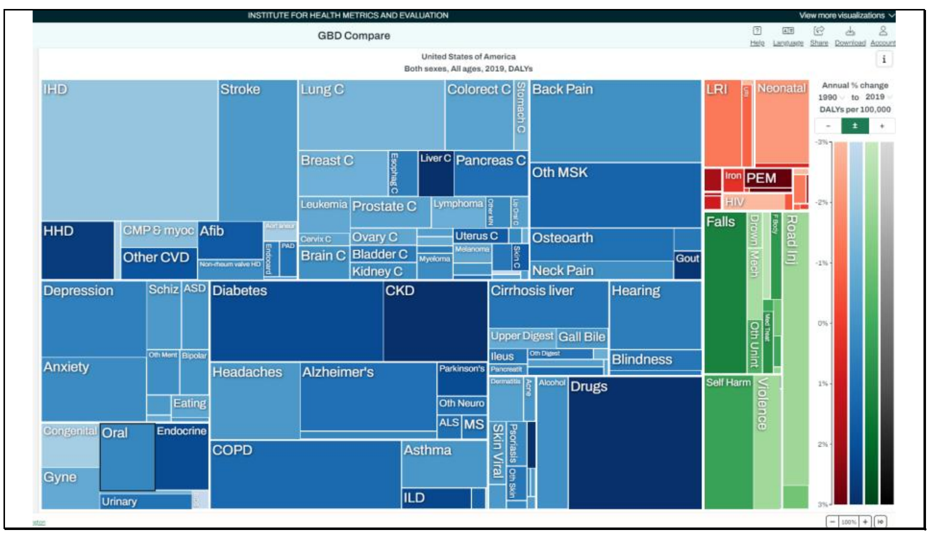

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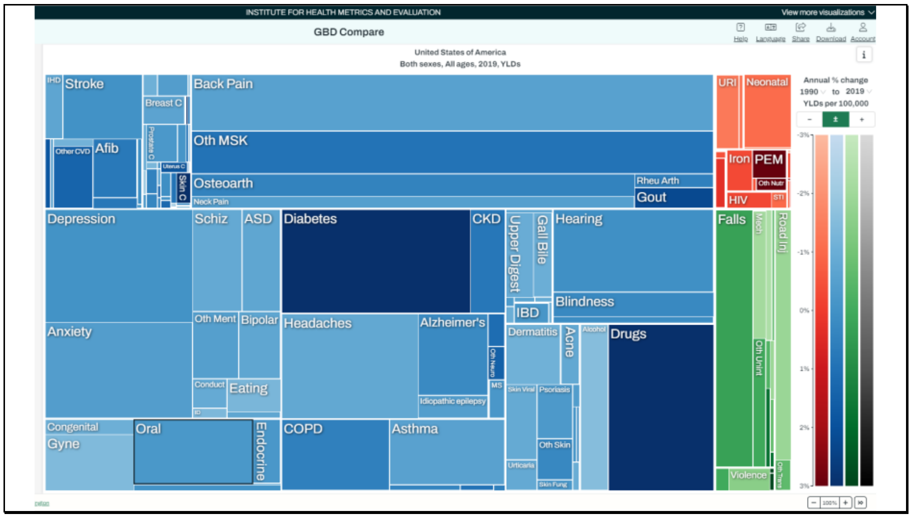

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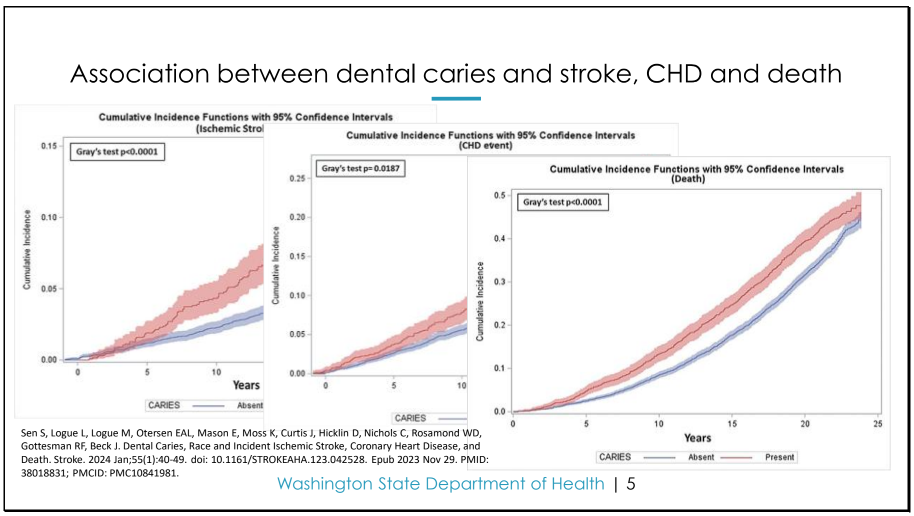

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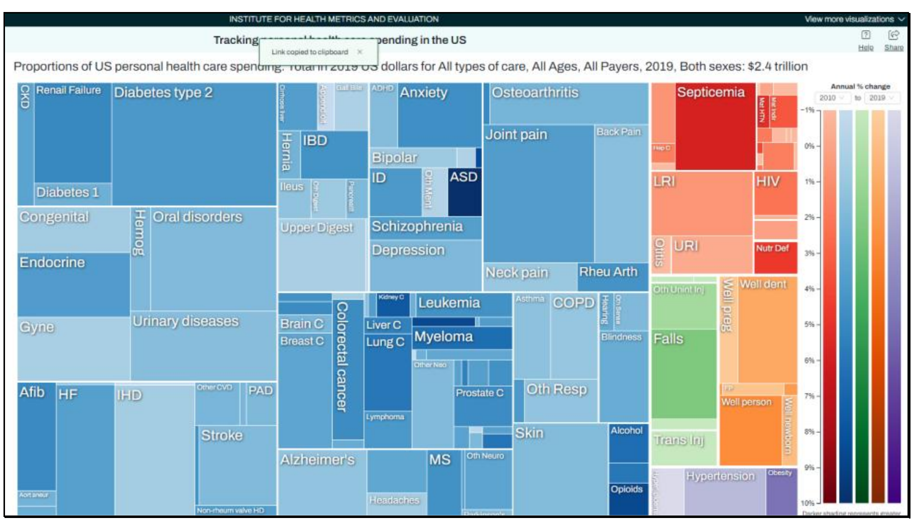

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Community Water Fluoridation

Tenth Year of the Grand Rapids-Muskegon Study

Effect of Fluoridated Public Water Supplies on Dental Caries Prevalence

By FRANCIS A. ARNOLD, Jr., D.D.S., H. TRENDLEY DEAN, D.D.S., PHILIP JAY, D.D.S., and JOHN W. KNUTSON, D.D.S., Dr.P.H.

- Introduced in 1945 in Grand Rapids, MI
  - 10yr follow-up study that compared Grand Rapids to Muskegon, MI
  - 60% reduction in rate of caries (primary and permanent) among children born after introduction of CWF
  - "the percentage of children classed as having fluorosis has increased, but, as anticipated, this increase is confined to the milder forms. As pointed out previously (7), the signs of the milder forms of fluorosis caused by ingestion of water containing 1 p.p.m. fluoride as a rule do not appear on the anterior teeth. "

Slide 8

Community Water Fluoridation

Table 2. Average number of def [1] deciduous teeth per child [2] in Grand Rapids and Muskegon, Mich., by year of examination

Age last birthday	Basic examinations, 1944–45	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954
	Grand Rapids, Mich.										
4	4.19	5.40	3.43	3.19	3.02	2.75	2.46	2.13	2.17	2.06	2.12
5	5.37	6.15	5.08	3.89	4.03	3.27	2.50	2.27	2.32	2.29	2.50
6	6.43	6.98	5.73	5.38	4.78	4.59	3.73	2.98	2.93	2.92	2.95
7	6.29	7.66	6.11	5.84	5.20	4.83	5.72	4.03	3.48	3.10	3.26
8	5.78	8.00	5.10	5.07	4.88	4.75	4.91	4.12	3.89	3.48	3.31
9	4.59	------	4.45	4.11	4.43	4.41	4.23	3.86	3.66	3.35	3.00
10	2.84	------	2.84	3.16	3.06	2.86	2.36	2.43	2.61	2.38	2.35
11	1.35	------	2.12	2.78	1.77	1.19	1.16	1.35	1.51	1.90	1.32
12	.47	.28	.13	.11	.25	.35	.25	.30	.34	.44	.44
13	.18	.13	.14	.14	.17	.10	.15	.12	.17	.19	.18
	Muskegon, Mich. [3]										
4	5.05	------	3.44	4.67	4.39	4.41	5.32	4.46	4.35	3.44	3.03
5	6.82	------	5.86	5.05	5.55	5.56	5.65	5.25	5.39	4.42	3.98
6	7.17	------	6.24	6.18	6.06	5.99	6.02	5.67	5.75	5.71	4.85
7	6.66	------	6.83	5.95	6.92	6.33	5.83	5.77	5.67	5.46	5.35
8	6.06	------	4.83	3.85	4.80	6.08	5.06	5.32	5.28	4.95	4.98
9	4.89	------	4.32	4.34	4.71	4.48	4.09	4.17	4.36	4.29	3.81
10	3.08	------	3.15	3.67	2.79	2.77	3.49	2.86	2.69	2.96	2.75
11	1.33	------	1.67	2.90	.64	1.21	1.09	1.46	1.20	1.38	1.42
12	.42	------	.14	.37	.64	.68	.61	.31	.54	.32	.61
13	.23	------	.29	.17	.11	.11	.13	.15	.08	.21	.12

[1] Decayed, extraction indicated, or filled deciduous teeth. A decayed and filled tooth is counted only once.
[2] See table 1 for small numbers involved in some instances.
[3] The basic examinations in Muskegon were not done until late spring of 1945; therefore, no examinations were made in the fall of 1945.

Table 3. Average number of DMF [1] permanent teeth per child [2] in Grand Rapids and Muskegon, Mich., by year of examination

Age last birthday	Basic examinations, 1944–45	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954
	Grand Rapids, Mich.										
6	0.78	0.56	0.23	0.37	0.26	0.38	0.26	0.26	0.23	0.12	0.19
7	1.89	1.72	1.11	1.09	1.04	.76	1.03	.84	.90	.71	.69
8	2.95	3.27	2.54	2.62	2.30	2.16	1.77	1.58	1.50	1.41	1.27
9	3.90	------	2.98	3.12	2.67	2.48	2.38	2.04	2.02	1.83	1.97
10	4.92	------	3.70	3.56	3.51	3.56	3.17	2.93	2.71	2.41	2.34
11	6.41	------	4.24	3.56	4.32	4.69	4.36	3.67	3.49	3.12	2.98
12	8.07	9.53	7.62	7.03	8.32	7.02	7.10	5.89	5.04	4.76	3.87
13	9.73	10.76	8.92	8.47	8.34	8.11	7.21	6.60	5.87	5.12	5.05
14	10.95	11.90	9.41	9.50	9.41	8.90	8.55	8.21	7.23	5.92	6.78
15	12.48	12.68	11.26	11.94	10.61	11.80	10.12	8.91	9.04	9.75	8.07
16	13.50	13.00	9.33	12.47	13.50	11.83	11.35	11.06	10.14	9.53	9.95
	Muskegon, Mich. [3]										
6	0.81	------	0.48	0.66	0.79	0.63	0.75	0.80	0.52	0.35	0.45
7	1.99	------	1.33	1.05	2.19	1.43	2.01	1.88	1.66	1.24	1.14
8	2.81	------	2.83	2.15	3.50	2.58	2.96	2.63	2.49	2.66	2.18
9	3.81	------	3.29	3.54	3.58	3.88	3.89	3.52	3.05	3.22	3.16
10	4.91	------	4.27	3.60	4.87	4.44	4.53	4.32	3.90	3.64	3.72
11	6.32	------	4.25	4.70	4.71	5.93	5.67	5.34	5.04	4.70	4.58
12	8.66	------	8.43	6.79	7.82	7.21	6.88	7.71	7.00	6.53	6.12
13	9.98	------	9.02	9.23	10.52	9.52	9.58	9.36	8.71	8.20	7.98
14	12.00	------	11.09	12.00	12.27	11.08	12.11	11.36	10.06	10.35	10.74
15	12.86	------	11.17	12.89	12.66	10.32	10.94	12.38	11.57	11.69	11.19
16	14.07	------	19.00	12.77	14.31	12.51	13.91	13.16	12.36	11.48	12.55

[1] Decayed, missing, or filled permanent teeth. A decayed and filled tooth is counted only once.
[2] See table 1 for small numbers involved in some instances.
[3] The basic examinations in Muskegon were not done until the late spring of 1945; therefore, no examinations were done in the fall of 1945.

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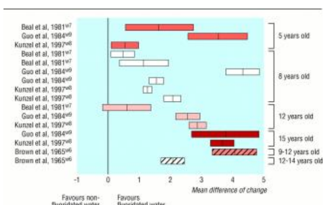
Community Water Fluoridation

- MANY studies since conducted demonstrating the effectiveness of CWF
  - 26-44% reduction in tooth decay in children and 27% in adults in Australia (Slade et al 2013)
  - Children in England found to have significant improvement in decayed, missing and filled teeth for primary/permanent teeth (BMJ Systematic Review 2000)



Change in decayed, missing, and filled teeth for primary/permanent teeth (mean difference and 95% confidence interval)

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Community Water Fluoridation

In 2022, More than 209 million Americans (>70% of the population) had access to community water fluoridation (https://www.cdc.gov/fluoridation/php/statistics/2022-water-fluoridation-statistics.html)

CDC Scientific Statement on Community Water Fluoridation

WHAT TO KNOW

CDC promotes the safety and benefits of community water fluoridation as an effective, cost-efficient method for preventing tooth decay and improving overall oral health.

The U.S. Community Preventive Services Task Force, on the basis of systematic reviews of scientific literature, issued a strong recommendation in 2001 and again in 2013, for community water fluoridation for the prevention and control of tooth decay.

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Community Water Fluoridation – Cochrane Review

- Affirms that fluoride reduces tooth decay in children and adults.
- Cochrane review does NOT suggest that CWF is ineffective
  - Raises important questions about where people receive fluoride since 1970 and the ADDED VALUE of CWF at a population level
- The review was NOT designed to evaluate CWF and its impact on dental health inequities

Slide 12

Calgary, AB

- Fluoride was introduced in Calgary's drinking water in 1991
- Fluoridation was stopped in 2011
- Fluoride was reintroduced in 2021
  - Naturally occurring fluoride at concentrations from 0.1 to 0.4 mg/L
  - City adjusts fluoride to maintain a concentration of 0.7mg/L
- *The infrastructure costs to reintroduce fluoride at Calgary's two water treatment plants was $28.1M with additional annual costs of $1M for operating and maintenance at both plants. This translates into less than 10 cents per person, per month. (*https://www.calgary.ca/water/drinking-water/fluoride.html)

Slide 13

Calgary, AB – Dental caries in children

- Retrospective, population-based study including children <12 undergoing GA for caries related treatment in Calgary and Edmonton
- 2659 children
- 2010-2019
- Variables collected: age, sex, dental diagnosis, neighborhood income level (three levels), facility type
- Calculated per capita rate of children requiring caries related dental treatments under GA per 10,000

Canadian Journal of Public Health (2024) 115:305–314
https://doi.org/10.17269/s41997-024-00858-w

ORIGINAL ARTICLE

Check for updates

Community water fluoride cessation and rate of caries-related pediatric dental treatments under general anesthesia in Alberta, Canada

Elnaz Yazdanbakhsh[1] · Babak Bohlouli[1] · Steven Patterson[1] · Maryam Amin[1]

Received: 18 May 2023 / Accepted: 19 January 2024 / Published online: 22 February 2024

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Calgary, AB - Dental caries in children

Table 2 Rate of caries-related dental treatments under GA among children aged 0–11 years per 10,000 children, stratified by year and fluoridation status

Age groups	Year	Fluoridation status		Per-capita difference
		Non-fluoridated area	Fluoridated area	
Total	2010/11	18	15	3
	2014/15	27	14	13
	2018/19	32	17	15
0–5 years	2010/11	22	18	4
	2014/15	38	17	21
	2018/19	45	24	21
6–11 years	2010/11	14	11	3
	2014/15	15	10	5
	2018/19	19	11	8

Table 3 Risk of caries-related dental treatments under GA per 10,000 children in the population, stratified by age group

	All pediatric patients OR (95% CI)	0–5-year-olds OR (95% CI)	6–11-year-olds OR (95% CI)
2010/11	1.20 (1.03–1.41)	1.21 (0.99–1.48)*	1.17 (0.89–1.53)*
2014/15	1.96 (1.70–1.26)	2.28 (1.91–2.71)	1.45 (1.13–1.86)
2018/19	1.84 (1.62–2.08)	1.93 (1.66–2.39)	1.74 (1.40–2.17)

*Statistically non-significant
Reference category: fluoridated area's per-capita rate
OR, odds ratio; *CI*, confidence interval

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Calgary. AB - Dental caries in children

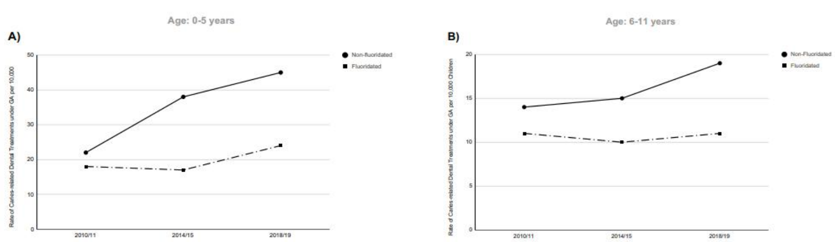

Fig. 2 Trend of caries-related dental treatments under general anesthesia per 10,000 children in fluoridated (Edmonton) and non-fluoridated (Calgary) areas, stratified by age groups: (**A**) 0–5 years and (**B**) 6–11 years

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Calgary, AB – CWF and social inequities

Canadian Journal of Public Health (2022) 113:955–968
https://doi.org/10.17269/s41997-022-00654-4

QUANTITATIVE RESEARCH

Fluoridation cessation and oral health equity: a 7-year post-cessation study of Grade 2 schoolchildren in Alberta, Canada

Lindsay McLaren[1] · Steven K. Patterson[2] · Peter Faris[3] · Guanmin Chen[1,3] · Salima Thawer[1,4] · Rafael Figueiredo[2,5] · Cynthia Weijs[1,6] · Deborah A. McNeil[1,7] · Arianna Waye[8] · Melissa L. Potestio[1]

Received: 21 June 2021 / Accepted: 16 May 2022 / Published online: 7 July 2022

- Cross sectional population-based survey of children in Grade 2 in Calgary and Edmonton in 2009/2010, 2013/2014, 2018/2019
- Estimated association between socioeconomic indicators and dental caries indicators/untreated decay in two or more teeth
- Compared associations over time and between cities post-CWF cessation

Slide 17

Calgary, AB – CWF and social inequities

- Social inequities existed in BOTH cities.
  - Odds of *untreated decay* higher among those without dental insurance in 2018/19 (Calgary OR 3.34; Edmonton OR 2.31)
  - Higher levels of *deft*, *DMFT* and *untreated decay* in lowest material deprivation tercile
- Widening gap in outcomes associated with some measures of social inequities in Calgary compared to Edmonton
  - OR of untreated decay without dental insurance
    - Calgary 2009/10: 1.79; 2013/14: 2.0; 2018/19: 3.34
    - Edmonton: 2013/14: 2.06; 2018/19: 2.31

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Juneau, AK

- City of Juneau voted to discontinue CWF in 2007. Fairbanks, AK similarly discontinued CWF in 2011. This reduced the total population with access to CWF from ~65% to ~50% between 2007 and 2014
- Meyer et al. examined the impact of CWF cessation in children and adolescents 0-18 living in families meeting Medicaid requirements.
- Retrospective comparative research design
  - Examined Medicaid dental claims in 2003 and 2012
  - Examined dental caries procedures and dental caries-related costs

Table 2 The Mean (SD) Number of Caries Procedures per Child in 2003 and 2012, and a Summary of the Bivariate and Binary Regression Analyses

Age Group (years)	*Mean (SD) 2003 Optimal CWF*	*Mean (SD) 2012 Suboptimal CWF*	*Mann-Whitney U p*	*Logistic Regression[a] Optimal CWF OR, [95% CI]*
0 to < 6	1.55 (3.89) *n* = 194	2.52 (4.35) *n* = 301	0.0001	0.488, [0.33, 0.73]
0 to < 7	2.01 (4.22) *n* = 303	2.68 (4.57) *n* = 461	0.004	0.699, [0.52, 0.95]
7 to < 13	1.61 (3.38) *n* = 352	1.64 (2.60) *n* = 400	NS	NS
13 to 18	2.75 (4.73) *n* = 198	3.04 (4.66) *n* = 191	NS	NS
0 to 18	2.02 (4.05) *n* = 853	2.35 (3.99) *n* = 1052	0.001	0.748, [0.62, 0.90]

NS Not Significant
[a]Adjusted for gender and race

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Juneau, AK

Table 3 Mean Caries-related Treatment Costs by Age in 2003 and 2012 and Adjusted for Inflation

Age Group (years)	*Mean ($) 2003 Optimal CWF*	*Mean ($) 2012 Suboptimal CWF*	*Mann-Whitney U p*	*Total Cost Inc/ % Inc*	*Adjusted[a] ~25% Inflation*	*Increase ($) Attributed to Suboptimal CWF*
0 to < 6	272.72	644.72	0.0001	372.00/136%	111%	302.71
0 to < 7	350.13	692.87	0.0001	342.74/98%	73%	255.60
7 to < 13	241.52	382.44	0.001	140.92/58%	33%	79.70
13 to 18	519.07	795.68	0.035	276.61/53%	28%	145.34
0 to 18	344.34	593.70	0.0001	249.36/72%	47%	161.84

[a]Service provider charges were used rather than Medicaid reimbursement amounts for comparisons by accurately adjusting for inflation

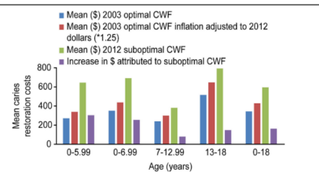

Fig. 1 Mean caries restoration costs according to age for children with optimal or suboptimal community water fluoridation (CWF). First, the mean cost in 2003 for children with optimal CWF was calculated; the mean cost in 2003 was then adjusted for inflation (*1.25) according to the 2012 dollar value; and lastly the increase cost attributed to suboptimal CWF was calculated

Slide 20

Conclusions

- Community water fluoridation has **REPEATEDLY** been demonstrated to be a highly effective public health intervention across many studies to prevent dental carries in both children and adults
  - Contemporary studies have again demonstrated this benefit
- Cochrane metanalysis has limited applicability due to its inclusion/exclusion criteria, but **NO STUDY IS PERFECT** (especially in public health)
- Detrimental effects are NOT the focus of this discussion, but a ***critical*** part of the overall discussion related to CWF
  - Causation vs. Association
  - Probable mechanism of action
  - Defining a gradient of potential benefit and potential harm at various CWF concentrations is essential

Absence of evidence ≠ Evidence of absence

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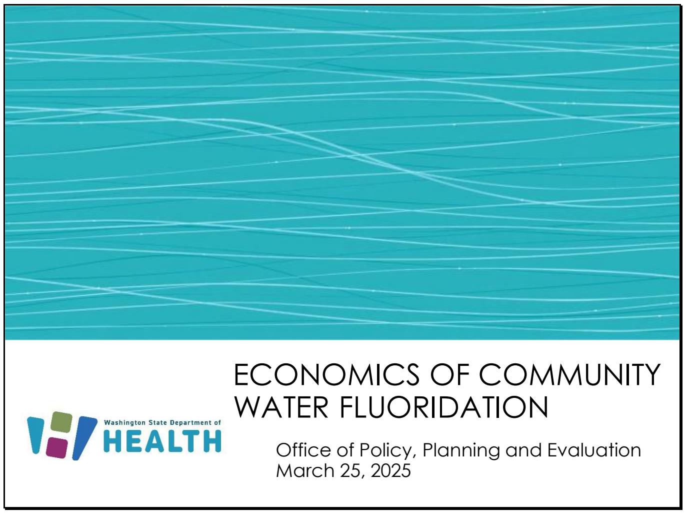
March 25; Anna Hidle; Economic Analysis

Slide 1



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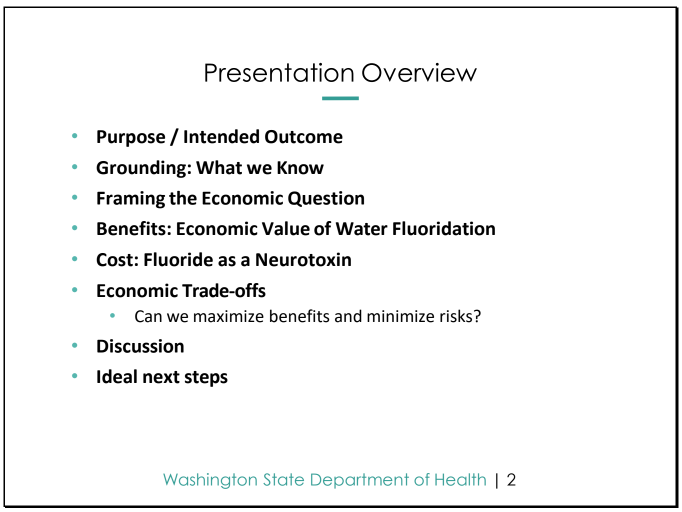

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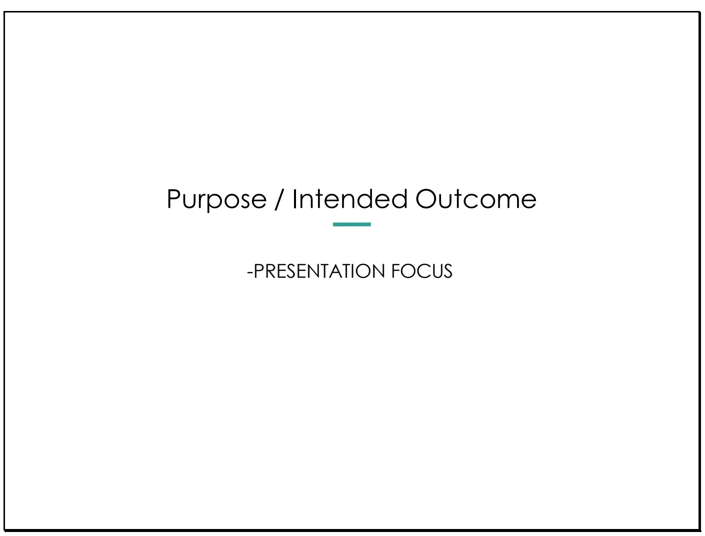

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Purpose / Intended Outcome

Meeting Purpose:

- Discussion of the economic costs and benefits of community water fluoridation.

Intended Outcome:

- Shared understanding of the economic costs and benefits of community water fluoridation.

Presentation Focus:

- Economics
- Community water fluoridation

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Grounding: What we know

Slide 6

Grounding: What we know

General:

- Fluoride = Good oral health, reduces poor oral outcomes
- Topical & Systemic
- Benefit realized when fluoride encounters teeth
- 73% of U.S. drinking water is fluoridated
- Recommended water fluoridation at 0.7 mg fluoride/L

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Slide 7

Grounding: What we know

Not including potential risks of fluoride (fluorosis, lost IQ points)

Economics of Fluoride:

- **Benefits of fluoridating water is documented in literature to have declined** since 1970, with the introduction of other methods of fluoride.
- Community fluoridation of water has **historically been presented in literature to be cost-effective and provide a return on investment.**
  - The **higher the incidence of tooth decay** before fluoridation and the **larger the population served**, the **greater the economic benefits**.

Slide 8

Grounding: What we know

Not including potential risks of fluoride (fluorosis, lost IQ points)

CDC reports the Economics of Fluoride:

- The savings associated with water fluoridation in communities (>1,000 people) yields an **average savings of $20 per dollar invested**. (1)
- A study of a community water fluoridation in Colorado compared program costs with treatment savings achieved through reduced tooth decay. Analysis of 172 public water systems (<1,000 people or more in each) found that **1 year of exposure to fluoridated water yielded an average savings of $60 per person** when the lifetime costs of maintaining a restoration were included. (2)
- Analyses of Medicaid claims data in 3 states (Louisiana, New York, and Texas), have also found that **children living in fluoridated communities have lower cavity related treatment costs as compared to similar children living in non-fluoridated communities; the difference in annual per child treatment costs ranged from $28 to $67**. (3,4,5)

Reference: CDC Scientific Statement on Community Water Fluoridation

(1) O'Connell et. al., Costs And Savings Associated With Community Water Fluoridation In The United States | Health Affairs. 2016
(2) O'Connell et. al., Costs and savings associated with community water fluoridation programs in Colorado. Prev Chronic Dis. 2005;2(Spec No): A06.
(3) Water Fluoridation and Costs of Medicaid Treatment for Dental Decay -- Louisiana, 1995-1996
(4) Kumar et. al., Geographic variation in Medicaid claims for dental procedures in New York State: role of fluoridation under contemporary conditions. Public Health Rep. 2010;125(5):647–654.
(5) Texas Department of State Health Services. Water fluoridation costs in Texas: Texas Health Steps (EPSDT-MEDICAID). Texas Department of State Health Services; 2000. Accessed January 31, 2024.

Slide 9

Grounding: What we know

Not including potential risks of fluoride (fluorosis, lost IQ points)

American Fluoridation Society reports the Economics of Fluoride:

- For most cities, **every $1 invested in water fluoridation saves $38** in dental treatment costs. (CDC)
- A Texas study confirmed that **the state saved $24 per child, per year in Medicaid expenditures** for children because of the cavities that were prevented by drinking fluoridated water. (Texas Dept of Oral Health)
- A 2010 study in New York State found that **Medicaid enrollees in less fluoridated counties needed 33 percent more fillings, root canals, and extractions than those in counties where fluoridated water** was much more prevalent. As a result, the **treatment costs per Medicaid recipient were $23.65 higher for those living in less fluoridated counties.** (Kumar et. al.)
- Researchers estimated that in 2003 **Colorado saved nearly $149 million in unnecessary treatment costs by** fluoridating public water supplies—**average savings of roughly $61 per person**. (Ntl Center for Biotech Info)
- A 1999 study compared Louisiana parishes (counties) that were fluoridated with those that were not. The study found that **low-income children in communities without fluoridated water were three times more likely** than those in communities with fluoridated water **to need dental treatment** in a hospital operating room. (CDC)
- By reducing the incidence of decay, fluoridation makes it less likely that toothaches or other serious dental problems will drive people to hospital emergency rooms (ERs)—where treatment costs are high. A 2010 survey of hospitals in Washington State found that **dental disorders were the leading reason why uninsured patients visited ERs.** (Washington State Hospital Association)
- Scientists who testified before Congress in 1995 **estimated that national savings from water fluoridation totaled $3.84 billion each year**. (Florida Journal of Environmental Health)

Reference: Cost-Effectiveness | American Fluoridation Society

Slide 10

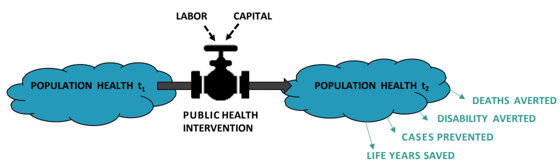
Framing the Economic Question

- LITERATURE REVIEW

Slide 11

Framing the Question: Cost Effectiveness Analysis

Compares the **net cost** of an intervention to the **changes in health outcomes**



Net cost =

Cost Effectiveness Ratio =

Slide 12

Framing the Economic Question

Intervention: Community Water Fluoridation

Includes cost of adverse effects of the intervention and other costs induced by the intervention

Costs of health outcome averted because of the intervention

Net cost =

Improvement in health produced by the intervention

Cost Effectiveness Ratio =

Slide 13

Framing the Economic Question

Intervention: Community Water Fluoridation

Intervention Cost

- Fixed costs
  - Fluoridation Facilities
- Annual costs
  - Maintenance
  - Operation (Staff cost)
  - Monitoring

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Reference: Ran et. al. 2016. Economic Evaluation of Community Water Fluoridation: A Community Guide Systematic Review - PMC

Slide 14

Framing the Economic Question

Not including potential risks of fluoride (fluorosis or lost IQ points)

Intervention: Community Water Fluoridation

Costs averted or Intervention Benefit*

- **Healthcare cost averted**
  - dental examination
  - **restoration**
  - extraction
  - **lifetime treatment**
- **Productivity cost averted**
  - worktime lost
  - missed school/learning
- **Other losses averted**
  - transport to dental visits

Risks

*Benefits listed in bold are common drivers of cost analysis

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Reference: Ran et. al. 2016. Economic Evaluation of Community Water Fluoridation: A Community Guide Systematic Review - PMC

Slide 15

Framing the Economic Question

Intervention: Community Water Fluoridation

Costs averted or Intervention Benefit*

- **Healthcare cost averted**
  - dental examination
  - **restoration**
  - extraction
  - **lifetime treatment**
- **Productivity cost averted**
  - worktime lost
  - missed school/learning
- **Other losses averted**
  - transport to dental visits

Risks

- Fluorosis
- Loss of IQ Points

Economic Question:

How do we…

maximize the benefits of fluoride

while

minimizing the risk of fluoride as a neurotoxin?

*Benefits listed in bold are common drivers of cost analysis

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Reference: Ran et. al. 2016. Economic Evaluation of Community Water Fluoridation: A Community Guide Systematic Review - PMC

Slide 16

Framing the Economic Question

Study Perspective: costs to whom

Health Care perspective

Typically includes all direct health care costs:

- Easier to value
  - Cost of intervention
  - Changes in Health Outcomes
    - Costs of morbidity and mortality

Societal perspective

Typically includes healthcare perspective plus may include:

- Easier to value
  - Out-of-pocket costs (healthcare, transportation, etc.)
  - Productivity losses (caregiver)
- More difficult to value
  - Productivity losses (non-wage earners)
  - Equity

References:
1) Resch S, Menzies N, Portnoy A, Clarke-Deelder E, O'Keeffe L, Suharlim C, Brenzel L. How to cost immunization programs: a practical guide on primary data collection and analysis. 2020. Cambridge, MA: immunizationeconomics.org/ Harvard T.H. Chan School of Public HealthtoCost_Digital_12.24.20.pdf (squarespace.com)
2) AJPH202032033_Bloom 1049..1054 (nih.gov)

Slide 17

Framing the Economic Question: Literature Review

Year	Author(s)	Title	Subject Matter	Learning(s)
2015	Ko & Thiessen	A critique of recent economic evaluations of community water fluoridation	Fluoride	Critique of previous econ evals, challenging published estimate, adds fluorosis
2022	Goodwin et. al.	Evaluation of water fluoridation scheme in Cumbria: the CATFISH prospective longitudinal cohort study	Fluoride	Clinical and cost-effectiveness of water fluoridation
2024	Moore et. al.	How effective and cost-effective is water fluoridation for adults and adolescents? The LOTUS 10-year retrospective cohort study	Fluoride	Clinical and cost-effectiveness of water fluoridation
2025	Osmunson & Cole.	Community Water Fluoridation a Cost-Benefit-Risk Consideration	Fluoride	Critique of previous econ evals, adds fluorosis and lost IQ points

Slide 18

Framing the Economic Question: Literature Review

Reviewed literature on the cost of elevated blood lead levels in children to better understand the potential costs of lost IQ points.

Year	Author(s)	Title	Subject Matter	Learning(s)
2002	Grosse et. al.	Economic gains resulting from the reduction in children's exposure to lead in the United States.	Lead	IQ points and lifetime earnings lost
2021	Boyle et. al.	Estimated IQ points and lifetime earnings lost to early childhood blood lead levels in the United States	Lead	IQ points and lifetime earnings lost

Slide 19

Benefits: Economic Value of Water Fluoridation

- NOTABLE AND RECENT COST EFFECTIVENESS LITERATURE

Slide 20

Perspective: Societal
US$: 2010

Journal Article Review

Cost Effectiveness of Community Water Fluoridation

December 2014 – Ko & Thiessen. A critique of recent economic evaluations of community water fluoridation

Focus: Examine cost-effectiveness studies of water fluoridation

Methods: Examine and propose alternative methods and underlying data from US economic evaluation on community water fluoridation.

Findings: Incorrect dental treatment costs, flawed effectiveness estimates, and overestimate of benefits. Costs to water treatment plants and communities not reflected.

Conclusion: Minimal correction reduced the savings to $3 per person per year (PPPY) for a best-case scenario, but this savings is eliminated by the estimated cost of treating dental fluorosis (minimum cost of $3.24 PPPY).

Note: Does not include cost of lost IQ points.

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Reference: Ko & Thiessen. 2014. Full article: A critique of recent economic evaluations of community water fluoridation

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Perspective: Payer
GBP: 2014

Journal Article Review

Cost-Effectiveness of Community Water Fluoridation

November 2022 – Goodwin et. al., Evaluation of water fluoridation scheme in Cumbria: the CATFISH prospective longitudinal cohort study

Question: Is the reduction of caries due to community water fluoridation and is it cost-effective?

Methods: 2 cohorts (birth cohort and children in school cohort), United Kingdom

Findings:
- Modest beneficial effect for birth cohort (4% less decay in dentine)
- **Likely cost-effective for both the birth cohort and the older school cohort** at a willingness-to-pay threshold of £20,000 per quality-adjusted life-year (sensitivity probability CE 77% & 64%)
- No significant difference in the performance of water fluoridation on caries experience across deprivation quintiles

Conclusion: Prevalence of caries and impact of water fluoridation smaller than previous studies. Effective in birth cohort. **Cost-effective.**

Note: **Suggest long-term follow-up to fully understand the balance of benefits and potential risks (e.g. fluorosis)** of water fluoridation in contemporary low-caries populations.

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Reference: Goodwin et. al. 2022 Evaluation of water fluoridation scheme in Cumbria: the CATFISH prospective longitudinal cohort study

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Perspective: Public Sector
US$: 2020

Journal Article Review

Effectiveness and Cost-Effectiveness of Community Water Fluoridation

August 2024 – Moore et. al. How effective and cost-effective is water fluoridation for adults and adolescents? The LOTUS 10-year retrospective cohort study

Focus: Assess clinical and cost-effectiveness of water fluoridation for adults and adolescents.

Methods: 10-year retrospective (2010-2020), 6.4 million matched pairs, 12 and older, England

Findings:
- Lifetime reduction in invasive dental procedures of 3%
- Lifetime reduction in cavities of 2%
- Missing teeth no difference
- Reduction of inequities no difference

Conclusion:
- Reduction in invasive dental procedures and cavities
- **Positive ROI but may not be meaningful**

Note: Does **not include the cost of dental fluorosis and lost IQ points**

Reference: Moore et. al. 2024. How effective and cost-effective is water fluoridation for adults and adolescents? The LOTUS 10-year retrospective cohort study.

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Summary - Benefits: Economic Value of Water Fluoridation

- Quality of inputs determine the quality of the outputs.
- Even with the decline of benefits from community water fluoridation, literature reports it as a cost-effective intervention.
- Recent cost-effectiveness literature does not include risks of fluoride as a neurotoxin (cost of fluorosis, cost of lost IQ points) from a societal perspective.

Slide 24

Cost: Fluoride as a Neurotoxin

-MAGNITUDE OF IMPACT BETWEEN FLUORIDE & OUTCOMES
-COST OF RISKS: FLUOROSIS
-COST OF RISKS: LOST IQ POINTS

Slide 25

Journal Article Review: Magnitude of Impact

Slide from previous presentation *NTP Monograph Fluoride Tox Review*:

Fluoride & IQ:

- For every 1 mg/L in increased maternal urinary fluoride (MUF) **=> 1.14 – 1.63 IQ points** (Taylor et. al. 2025)
- MUF third trimester Los Angeles CA cohort median 0.8 mg/L and 95 C.I. of 1.89 mg/L (Malin et. al. 2023)
- **~1 IQ point at median and 2-3 IQ points** at 95th C.I. (typical protection level)
- For context - estimated average impact of lead is 2.6 IQ points (McFarland 2022)
- Any contributing shift leftward from a population perspective is of note

Reference(s):

- Taylor et al. Fluoride Exposure and Children's IQ Scores: A Systematic Review and Meta-Analysis. JAMA. 2025 Fluoride Exposure and Children's IQ Scores: A Systematic Review and Meta-Analysis | Pediatrics | JAMA Pediatrics | JAMA Network
- Malin et. al. 2023. Maternal Urinary Fluoride and Child Neurobehavior at Age 36 Months | Public Health | JAMA Network Open | JAMA Network
- McFarland et. al. 2022. Half of US population exposed to adverse lead levels in early childhood - PMC

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Cost of Risks

FLUOROSIS

Slide 27

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Perspective: Societal
US$: 2010

Journal Article Review: Cost of Risks

Cost of Fluorosis

December 2014– Ko & Thiessen. A critique of recent economic evaluations of community water fluoridation

Cost of Fluorosis

- In previous studies, not included, and if mentioned, stated as negligible.
- Community water fluoridation, in the absence of other fluoride sources, expected to result in a prevalence of mild-to-very mild (cosmetic) dental fluorosis in about 10% of the population and almost no cases of moderate or severe dental fluorosis.
- In the 1999–2004 NHANES survey, 41% of U.S. children ages 12-15 years were found to have dental fluorosis, including 3.6% with moderate or severe fluorosis.
- National Research Council (NRC) concluded that ''severe dental fluorosis'' qualified as an adverse health effect due to increased risk of caries and loss of dental function.
- Societal costing perspective should include cost of fluorosis.

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Reference: Ko & Thiessen. 2014. Full article: A critique of recent economic evaluations of community water fluoridation

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Perspective: Societal
US$: 2010

Journal Article Review: Cost of Risks

Cost of Fluorosis

December 2014– Ko & Thiessen. A critique of recent economic evaluations of community water fluoridation

Estimated Cost

- Each moderate or severe fluorosis tooth receives a porcelain veneer treatment
- Child with fluorosis gets first treatment at age 13.5 years
- Replaced every 12 years
- Cost of veneer $1,000 (lower-end)
- Suggested lifetime cost, one-tooth $2,217, cost driven by Dean's Enamel Fluorosis Index, two-most affected teeth.
- Lifetime cost of veneers for a child with moderate or severe fluorosis $4,434 (low-end)

Estimated Impact

- 3.6% of children 12-15 had moderate or severe fluorosis* but did not provide fluoridation status of children
- Calculated using 5% of children in fluoridated areas have moderate or severe fluorosis
- 1.46% of children at age 13.5 years
- Minimum cost of treating dental fluorosis $4,434 x 5% x 1.46% = **$3.24 PPPY**

Reference: Ko & Thiessen. 2014. Full article: A critique of recent economic evaluations of community water fluoridation
*Beltran-Agular et. al. 2010. NCHS Data Brief, Number 53, November 2010

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Perspective: Societal
US$: 2021

Journal Article Review: Cost of Risks

Cost of Fluorosis & Lost IQ Points

November 2025 – Osmunson & Cole. Community Water Fluoridation a Cost-Benefit-Risk Consideration

Focus: Including costs of fluorosis and lost IQ points in community water fluoridation

Methods: Review of literature, propose the addition of and calculate for cost of fluorosis & lost IQ points.

Findings:

- **Benefit:** caries averted, less operational costs $8 to $ 41 PPPY
- **Cost:** fluorosis $126 PPPY
- **Cost:** lower earnings from harm of developmental neurotoxicity $438 PPPY
- **Suggested Net Loss:** $556 PPPY

Conclusion: Fluoridation is not cost-effective if the cost of harm is included

Reference: November 2024. Osmunson & Griffin. Community Water Fluoridation a Cost-Benefit-Risk Consideration
Community Water Fluoridation a Cost–Benefit–Risk Consideration - Osmunson - 2024 - Public Health Challenges - Wiley Online Library

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Perspective: Societal
US$: 2021

Journal Article Review: Cost of Risks

Cost of Fluorosis

November 2025 – Osmunson & Cole. Community Water Fluoridation a Cost-Benefit-Risk Consideration

Assumptions:
- 30% of those on fluoridation will have perceived fluorosis.
- Option A selected by 10%
- Option B selected by 20%

Option A

- Micro-abrasion grinding of the outer layer of enamel, sealants, or resin infiltration (fillings) can improve dental fluorosis appearance and minor functional damage.
- Repeated treatment or "touch up" bleaching and/or minor restorations and re-treatments are estimated every 5 years for a conservative $100 PPPY for 60 years.

Option B

- Highest quality of treatment.
- Comprehensive cosmetic and functional treatments are estimated based on experience and dental insurance fees at $1,200 per tooth.
- Classification of dental fluorosis is based on the two worst teeth, although 1–32 teeth can be damaged.
- An estimate is used here for an average of 10 teeth per person (high-end).
- Treatment is estimated to be replaced an average of four times during a person's life.

Reference: November 2024. Osmunson & Griffin. Community Water Fluoridation a Cost-Benefit-Risk Consideration. Community Water Fluoridation a Cost–Benefit–Risk Consideration - Osmunson - 2024 - Public Health Challenges - Wiley Online Library. 2021 USD

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Perspective: Societal
US$: 2021

Journal Article Review: Cost of Risks

Cost of Risks - Fluorosis

November 2025 – Osmunson & Cole. Community Water Fluoridation a Cost-Benefit-Risk Consideration

Option A

- Clinically based estimated cost of $100 a year per person × 60 years = $6,000.
- Inflation at 3.57% and dental inflation at 4.33% ($1,200) = $7,200
- 20% choose Option A = $1,440
- 1.46% of the population at each age = **$21 PPPY**

Option B

- $1,200 × 10 teeth = $12,000 × 5 treatments = $60,000
- Inflation at 3.57% and dental inflation at 4.33% ($12,000) = $72,000
- 10% choose Option B = $7,200
- 1.46% of the population at each age = **$105 PPPY**

Cost: "Combining Options A of $21 PPPY with Option B of $105 PPPY equals a conservative estimate of **$126 PPPY** for the treatment of dental fluorosis."

Reference: November 2024. Osmunson & Griffin. Community Water Fluoridation a Cost-Benefit-Risk Consideration. Community Water Fluoridation a Cost–Benefit–Risk Consideration - Osmunson - 2024 - Public Health Challenges - Wiley Online Library.

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Cost of Risks

LOST IQ POINTS

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Perspective: Societal
US$: 2021

Journal Article Review: Cost of Risks

Cost of Fluorosis & Lost IQ Points

November 2025– Osmunson & Cole. Community Water Fluoridation a Cost-Benefit-Risk Consideration

Focus: Including costs of fluorosis and lost IQ points in community water fluoridation studies.

Methods: Review of literature, propose the addition of and calculate cost of fluorosis & lost IQ points.

Findings:

- **Benefit:** caries averted, less operational costs $8 to $ 41 PPPY
- **Cost:** fluorosis $126 PPPY
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- **Suggested Net Loss:** $556 PPPY

Conclusion: Fluoridation is not cost-effective if the cost of harm is included

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Community Water Fluoridation a Cost–Benefit–Risk Consideration - Osmunson - 2024 - Public Health Challenges - Wiley Online Library

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Perspective: Societal
US$: 2021

Journal Article Review: Cost of Risks

Cost of Risks – Lost IQ Points

November 2025 – Osmunson & Cole. Community Water Fluoridation a Cost-Benefit-Risk Consideration

Estimated Cost

- 1 IQ point increase = $500 increased earnings per year
- Conservative estimate of $500 PPPY

Estimated Impact

- Conservative estimate of 3 IQ points lost
- 3 IQ points x $500/year = $1,500
- Assuming 40 work years x $1,500 = $60,000 lifetime lost wages
- 50% drink a significant amount of CWF = $30,000
- 1.46% of population at each age = $438 PPPY lost wages

Reference: November 2024. Osmunson & Griffin. Community Water Fluoridation a Cost-Benefit-Risk Consideration
Community Water Fluoridation a Cost–Benefit–Risk Consideration - Osmunson - 2024 - Public Health Challenges - Wiley Online Library

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Perspective: Societal
US$: 2024

Journal Article Review: Cost of Risks

2002. Grosse et. al. Economic Gains Resulting from the Reduction in Children's Exposure to Lead in the US.

Table. Converting Estimated cost per IQ point lost in lifetime earnings to 2021 & 2024 US$

Level	Estimated cost per IQ point lost in lifetime earnings	$ Year	Adjusted to 2021 US$	Adjusted to 2024 US$
Lower Bound	$12,700	2000	**$20,349**	$23,036
Base Case	$14,500	2000	**$23,234**	$26,300
Upper Bound	$17,200	2000	**$27,560**	$31,198

Reference: Grosse SD et. al. Economic gains resulting from the reduction in children's exposure to lead in the United States. Environ Health Perspect. 2002. Economic gains resulting from the reduction in children's exposure to lead in the United States – PMC
Adjusted using U.S. BLS CPI Inflation Calculator

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Perspective: Societal
US$: 1999-2010

Journal Article Review: Cost of Risks

Understanding the effects of fluoride as a neurotoxin

February 2021 – Boyle et. al. Estimated IQ points and lifetime earnings lost to early childhood blood lead levels in the United States

Focus: Examined undetermined racial/ethnic disparities in anticipated IQ points and associated lifetime earnings lost to early childhood blood lead.

Methods: Nationally-represented estimates produced using weighted simulation model. Age 2.

Findings:

- Black infants experienced approximately 46–55% greater average estimated loss of grade school IQ points from blood lead than Hispanic or White infants (−1.78 IQ points vs. −1.15 and−1.21 respectively).
- Similar disparities in costs to expected lifetime earnings (−$47,116 USD vs. −$30,393 and − $32,356 respectively).

Conclusion: Black infants experienced higher IQ point and earning loss due to blood lead. Low levels of blood lead explain the majority of estimated lifetime earning loss.

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Reference: Boyle et. al. 2021. Estimated IQ points and lifetime earnings lost to early childhood blood lead levels in the United States - ScienceDirect

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Summary - Cost: Fluoride as a Neurotoxin

- Literature estimates lost IQ points from fluoride between 1-3
- Societal perspective should include risks of fluoride
  - Literature demonstrates reduction in the historical return on investment when you add the risks
- Learnings from Lead
  - Calculations of lost IQ points should potentially consider:
    - Level of impact from neurotoxin
    - Racial disparities

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General Comments & Limitations

- As costs go up, holding everything else constant, less cost effective, lower return on investment.
- Inputs (costs and outcomes) for calculating the cost of risk of community water fluoridation were difficult to verify.
- No sensitivity analysis around estimates, therefore difficult to discern what inputs are driving them.
- Focus was on community water fluoridation; more work should be done investigating literature on costs and outcomes for other modes of fluoride.

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Ideal Next Steps

- **Better understand the Impact in Washington.**
  - Prevalence of Excess Fluoridation
- **Conduct cost-effectiveness including other modes of Fluoride.**
- **Conduct Economic Modeling.**
  - Include cost of fluorosis
  - Include cost of lost IQ points
- **Consider the cost of status quo or eliminating water fluoridation.**

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Economic Trade-offs

Can we…

- Maximize the benefits of fluoride

while

- Minimizing the risk of fluoride as a neurotoxin

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Questions / Discussion

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Washington State Department of HEALTH

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Slide 1

Fluoride and Neurodevelopment

Presentation prepared for the
Washington State Dept. of Health Fluoride Panel

Christine Till, PhD, C.Psych
Faculty of Health, York University, Canada

May 6, 2025

YORK UNIVERSITÉ UNIVERSITY

Slide 2

Brief Bio

- PhD (2004) from University of Toronto
  - Neuropsychology with specialization in toxicology and neurosciences
- Licensed Clinical Neuropsychologist
- Parent
- Professor in the Faculty of Health at York University, Toronto, Canada
- I have studied the impact of toxic chemicals (fluoride, solvents, lead, pesticides, and other chemicals) for >25 years
- Research funded by NIH and CIHR
- Research has been published in leading medical and scientific journals
- My fluoride research has been extensively relied upon by environmental and public health agencies and played a major role in the U.S. Federal trial on the safety of community water fluoridation.

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Slide 3

MIREC Maternal-Infant Research on Environmental Chemicals

The New Hampshire Birth Cohort Study

PROGRESS

ELEMENT

ODENSE CHILD COHORT

Canadian Health Measures Survey

nhanes

Cohorts that I have conducted research related to fluoride neurotoxicity

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Slide 4

Disclosure

I have no actual or potential conflict of interest in relation to this program/presentation.

Slide 5

Objectives

1. What does the scientific literature demonstrate on the issue of developmental fluoride neurotoxicity?
2. What do we know about potential mechanisms of neurotoxicity?
3. How is the overall evidence on fluoride neurotoxicity relevant to community water fluoridation?

Slide 6

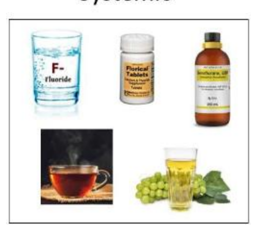
What is fluoride?

- Naturally occurring mineral
- Fluoride helps to prevent dental decay
- Added to dental hygiene products

- Systemic sources include fluoridated water and water-based beverages/foods
- Many other systemic sources of exposure

Topical

Systemic



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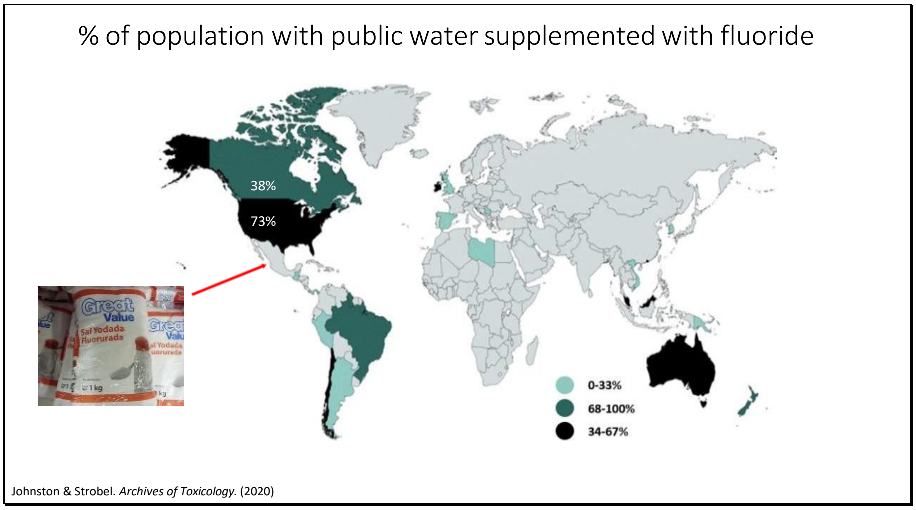

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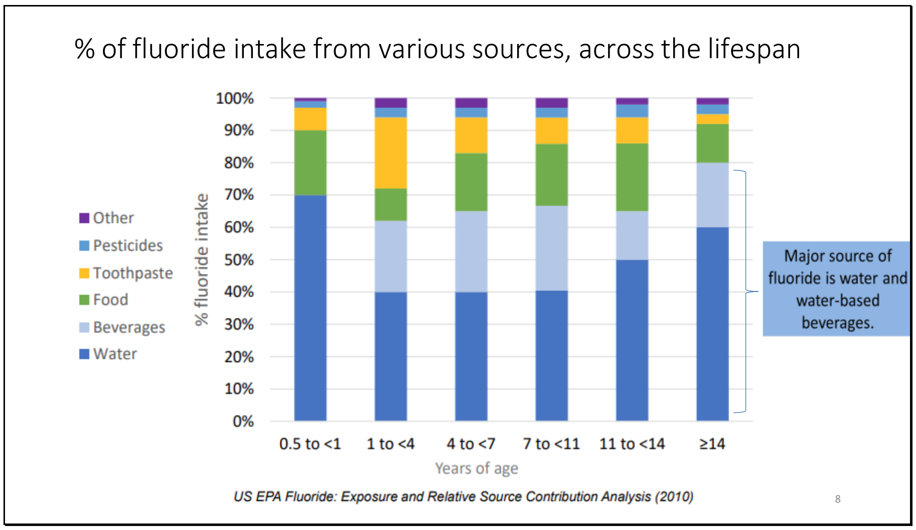
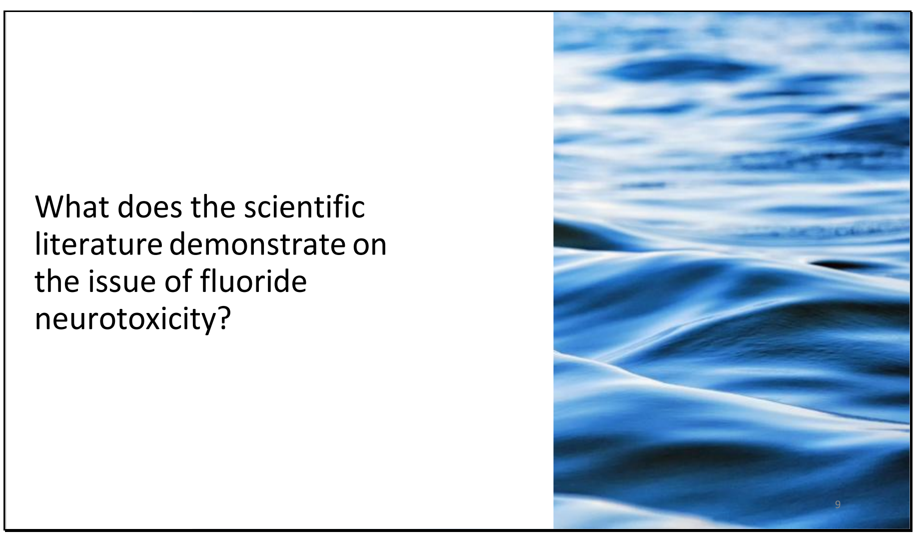


Slide 9



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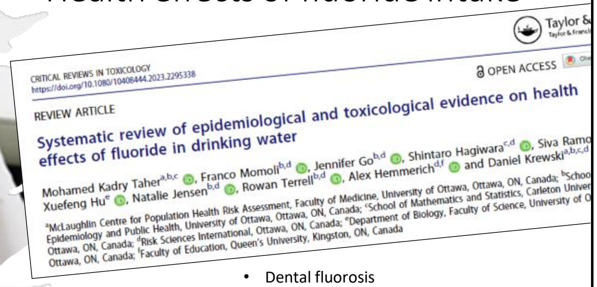
Health effects of fluoride intake



CRITICAL REVIEWS IN TOXICOLOGY
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REVIEW ARTICLE

Systematic review of epidemiological and toxicological evidence on health effects of fluoride in drinking water

Mohamed Kadry Taher[a,b,c], Franco Momoli[b,d], Jennifer Go[b,d], Shintaro Hagiwara[c,d], Siva Ramo… Xuefeng Hu[e], Natalie Jensen[b,d], Rowan Terrell[b,d], Alex Hemmerich[d,f] and Daniel Krewski[a,b,c,d]

[a]McLaughlin Centre for Population Health Risk Assessment, Faculty of Medicine, University of Ottawa, Ottawa, ON, Canada; [b]Schoo… Epidemiology and Public Health, University of Ottawa, Ottawa, ON, Canada; [c]School of Mathematics and Statistics, Carleton Univer… Ottawa, ON, Canada; [d]Risk Sciences International, Ottawa, ON, Canada; [e]Department of Biology, Faculty of Science, University of O… Ottawa, ON, Canada; [f]Faculty of Education, Queen's University, Kingston, ON, Canada

In addition to dental fluorosis, evidence was considered **strong for reduction in IQ scores** in children, **moderate for thyroid dysfunction**, weak for kidney dysfunction, and limited for sex hormone disruptions.

- Dental fluorosis
- Bone fractures and skeletal fluorosis
- Reproductive/developmental outcomes
- Renal/kidney outcomes
- **Behavioural and cognitive outcomes**
- Endocrine outcomes (**thyroid**, sex hormones)
- Immune system
- Sleep outcomes
- And more.

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Slide 11

Developmental Neurotoxicity of fluoride

- Developing nervous system is especially vulnerable to neurotoxicants
- Some pregnant women and children ingest more fluoride than needed (due to many sources). Must consider total intake.
  - Fluoride stored in bone remobilized into bloodstream during pregnancy
- Fetal exposure
  - Fluoride from maternal blood can readily cross the placenta
  - Penetrates blood-brain barrier
  - Accumulates in brain regions implicated in learning, memory, attention, and executive function

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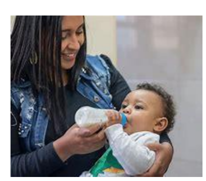
Slide 12

Developmental Neurotoxicity of fluoride – cont'd

- Formula-fed infants residing in fluoridated communities
  - **3-4x greater exposure** to fluoride than adults on a per body weight basis (NRC, 2006)
  - **70x higher fluoride intake** than exclusively breastfed infants (Zohoori, 2018)
  - Breastmilk contains extremely low levels of fluoride (0.005 mg/L)
- Infants and young children retain 80-90% of absorbed fluoride compared with 50% in adults (Ekstrand, 1994)



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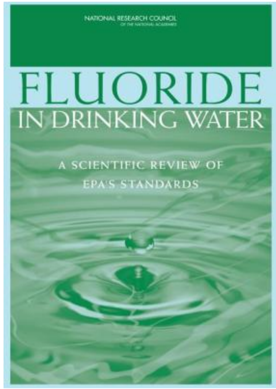
A prior review by the NRC (2006) on the adverse health effects of fluoride concluded:

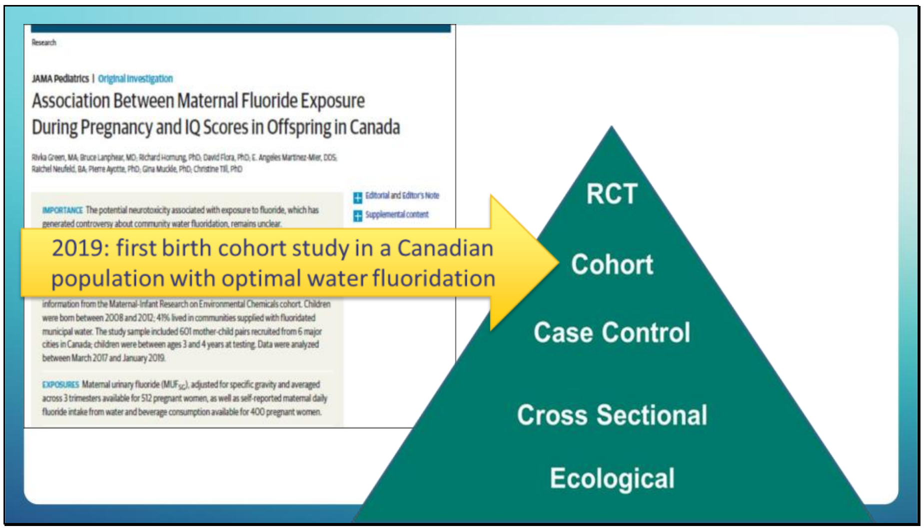


"Further study is necessary, especially for vulnerable populations."

The report "should be a wake-up call".

-Dr. Isaacson, NRC panel member

Slide 14



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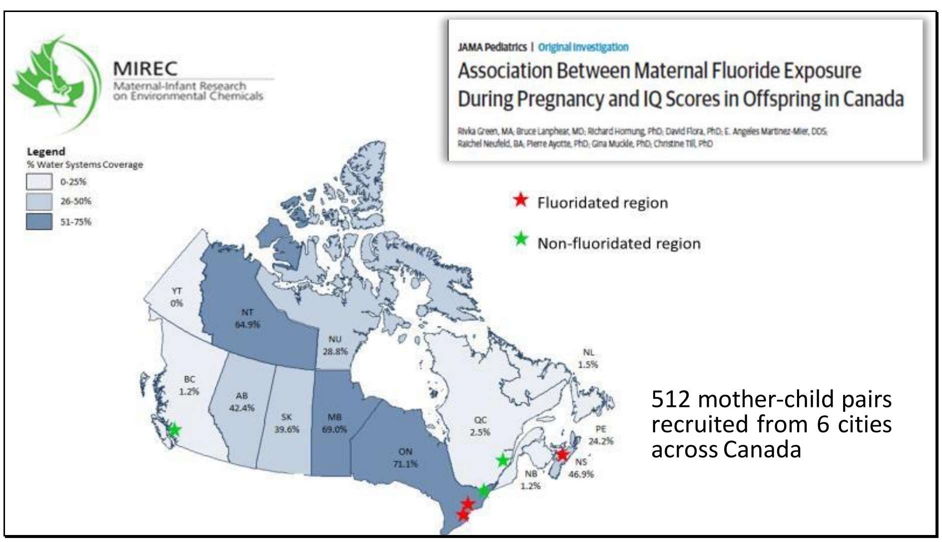
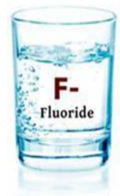


Slide 16

3 measures of fluoride exposure

Maternal urinary fluoride (MUF_{sg}) concentration (mg/L)
*averaged across 3 spot samples

Mean = 0.51 (± 0.36)
RANGE: 0.06-2.44
N = 512



Water fluoride concentration (mg/L)

Mean = 0.32 (± 0.23)
RANGE: 0.04-0.76
N = 420

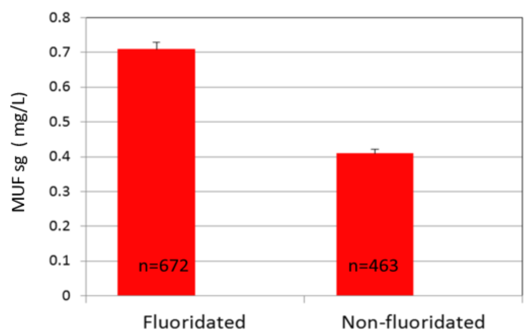
Fluoride intake (mg F/d)

Mean = 0.55 (± 0.46)
RANGE: 0.01-2.65
N = 400

Slide 17

Urinary fluoride levels are 2x higher among pregnant women living in fluoridated vs. non-fluoridated communities

MIREC Maternal-Infant Research on Environmental Chemicals



Till et al., *Environ Health Perspect*, 2018

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Urinary fluoride (mg/L) concentration among pregnant women living in fluoridated communities

Study	Cohort	Country/ State	N	Median Urinary F (mg/L)	Dilution adjustment
Till et al 2018	**MIREC**	**Canada**	**530** **672**	**0.74** **0.62**	**Creatinine** **SG**
Thomas et al 2016	ELEMENT	Mexico	515	0.91	creatinine
Ibarluzea et al 2022	INMA	Spain	316	0.91	creatinine
Malin et al 2023	MADRES	California	490	0.80	SG
Abduweil et al 2020	--	California	48	0.69	SG
Griebel-Thompson 2025	ADORE	Ohio, Kansas	965	1.0	SG

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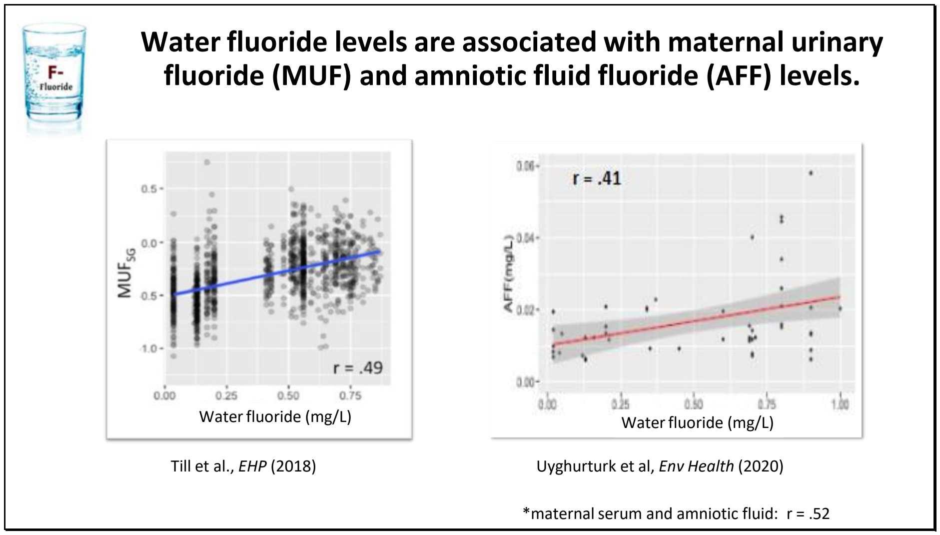

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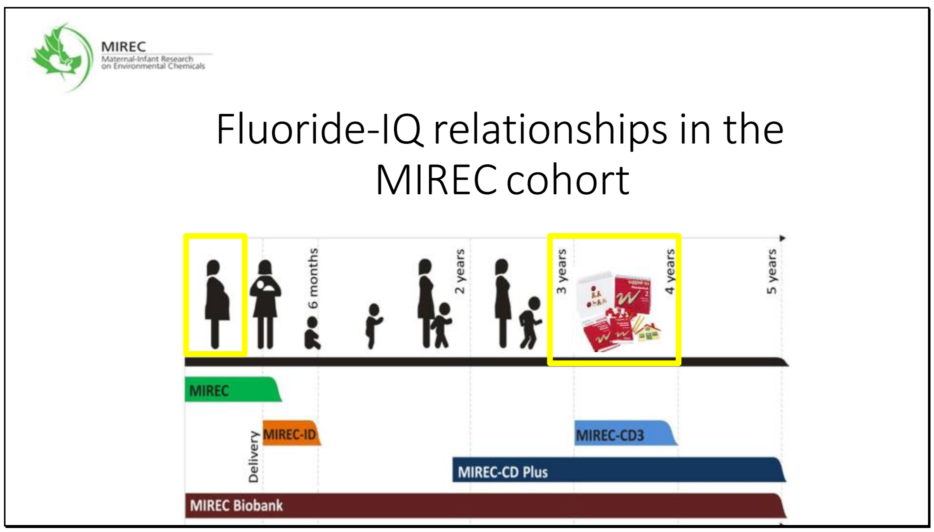

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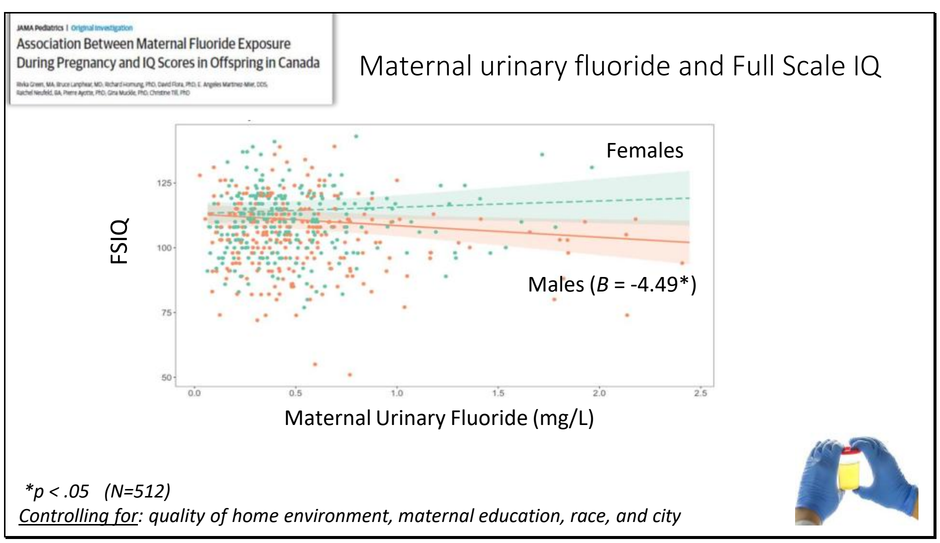

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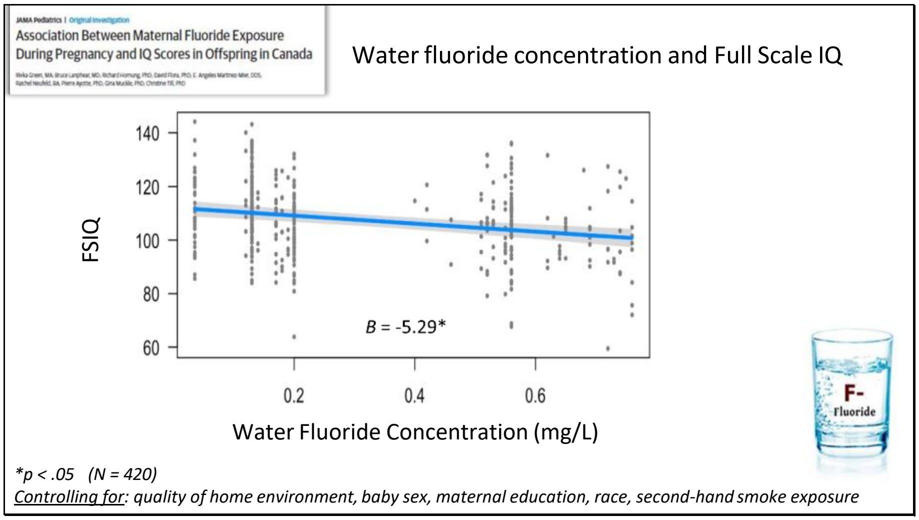

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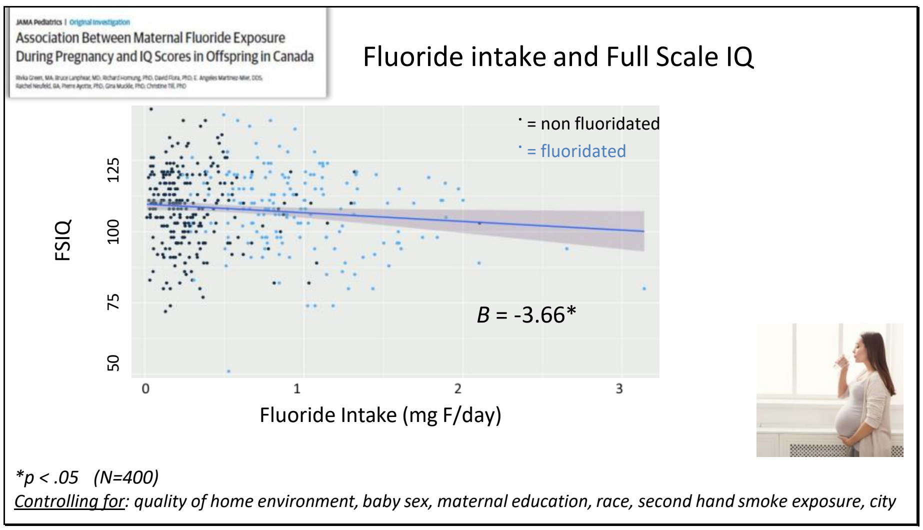

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MIREC
Maternal-Infant Research on Environmental Chemicals

Potential confounders considered and/or adjusted for

Child characteristics:
- Sex
- Gestational age
- Weight at birth
- Parity (being first child)
- Age at testing

Paternal characteristics:
- Age
- Education
- Employment status
- Smoking status
- Race/ethnicity

Excluded from study if:
- Known fetal abnormality
- Medical complications
- Illicit drug use during pregnancy

Maternal characteristics:
- City
- Race/ethnicity
- Education
- HOME score
- Exposure to second-hand smoke
- Smoked in trimester 1
- Marital status
- Age at delivery
- Net household income
- Employment status at time of pregnancy
- **Exposure to lead, arsenic, mercury, PFOA, manganese, alcohol**
- Pre-pregnancy body mass index (BMI)
- Chronic condition during pregnancy (e.g. diabetes, depression, high blood pressure)
- Birth country and English as first language
- Parental stress
- Breastfeeding status and duration
- Time of void / time since last void

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Sensitivity analyses for MUF-IQ model

MLR Models	*N*	*B (SE)* of MUF among males	*p*	*95% CI*
Model $_{A}$	512	-4.49 (1.98)	.02	-8.38, -0.60
Model $_{A+lead}$	504	-4.61 (1.98)	.02	-8.50, -0.71
Model $_{A+mercury}$	456	-5.13 (2.05)	.01	-9.16, -1.10
Model $_{A+arsenic}$	512	-4.44 (1.99)	.03	-8.35, 0.54
Model $_{A+second\ hand\ smoke\ exposure}$	512	-4.18 (1.98)	.03	-8.06, -0.30
Model $_{A+prenatal\ alcohol\ consumption}$	512	-4.48 (1.98)	.02	-8.38, -0.59
Model $_{B}$	510	-4.11 (1.92)	.03	-7.89, -0.33
Model $_{C}$	407	-4.96 (1.83)	.007	-8.56, -1.36

Model$_{A}$ – MUF$_{SG}$ controlling for city, HOME score, race and maternal level of education with baby sex as effect modifier

Model$_{B}$ – Model$_{A}$ without two FSIQ outliers (males with FSIQ <60)

Model$_{C}$ – MUF adjusted for creatinine with same covariates as Model$_{A}$

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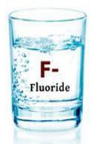
One unit increase in fluoride exposure associated with:



UNIT: 1 mg/L — ↓ 4.5 IQ pts (*males)

1 mg/L — ↓ 5.3 IQ pts

1 mg F — ↓ 3.7 IQ pts

Green et al., *JAMA Pediatrics*, 2019

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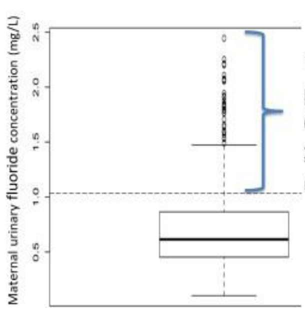
MIRECx
Maternal-Infant Research on Environmental Chemicals

In fluoridated regions, 1 mg/L MUF represents a woman at the 86th percentile. Therefore:



14% of pregnant Canadians have ≥ 1 mg/L urinary fluoride

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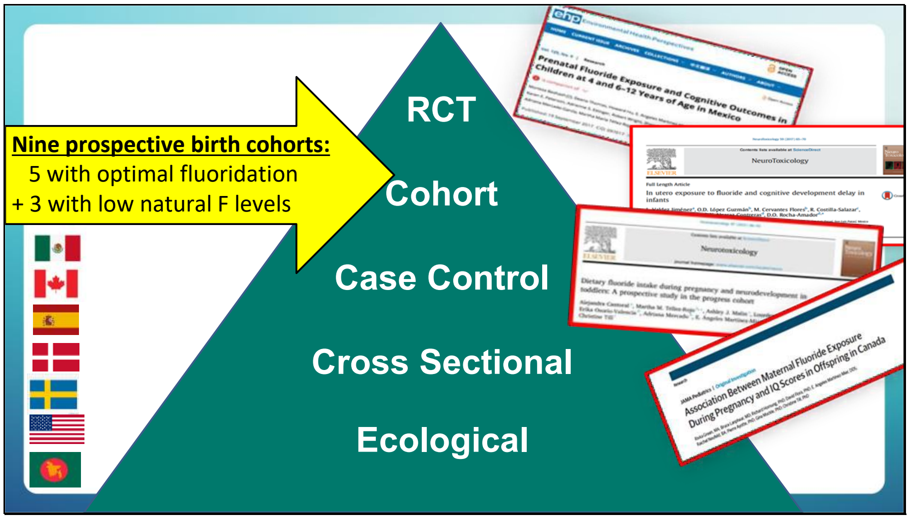

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Stability of prenatal F-IQ findings

Goodman et al., *Environ Res*, 2022

- F-IQ association **is stable** across ages 4, 5, and 6-12 yrs
- A 0.5 mg/L increase in MUF predicted an average 2.1 decrease in FSIQ/GCI
- Association stronger for Performance IQ than Verbal IQ

ELEMENT

Environ Res. 2022 August ; 211: 112993. doi:10.1016/j.envres.2022.112993.

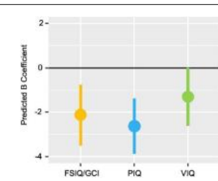
Domain-specific effects of prenatal fluoride exposure on child IQ at 4, 5, and 6–12 years in the ELEMENT cohort

Carly V. Goodman[a], Morteza Bashash[b], Rivka Green[a], Peter Song[c], Karen E. Peterson[c], Lourdes Schnaas[d], Adriana Mercado-Garcia[e], Sandra Martinez-Medina[d], Mauricio Hernández-Avila[f], Angeles Martinez-Mier[g], Martha M. Téllez-Rojo[e,*], Howard Hu[b], Christine Till[a]

Table 2.

MSCA and WASI scores (Mean ± SD) and Pearson correlations among the scores at each time point

			Pearson Correlations		
FSIQ/GCI	N	M ± SD	Age 4	Age 5	Age 6-12
Age 4	386	96.58 ± 13.96	-		
Age 5	308	96.62 ± 12.52	0.76**[a]	-	
Age 6-12	278	96.20 ± 11.12	0.58**[b]	0.64**[c]	-



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Karolinska Institutet

Stability of prenatal F-IQ findings

Singh et al., *EHP*, 2025

- 500 mother-child pairs from MINIMat cohort from Bangladesh
- Median MUF = 0.63 mg/L (almost identical to a Californian sample)
- Household water F concentrations ranged from 0.04 to 0.74 mg/L
- A 1 mg/L increase in MUF was associated with a FSIQ raw score decrease of 0.11 to 0.14 standard deviations at ages 5 and 10 years, respectively

Research

A Section 508–conformant HTML version of this article is available at https://doi.org/10.1289/EHP14534.

Prenatal and Childhood Exposure to Fluoride and Cognitive Development: Findings from the Longitudinal MINIMat Cohort in Rural Bangladesh

Taranbir Singh,[1] Klara Gustin,[1] Syed Moshfiqur Rahman,[2,3] Shamima Shiraji,[3] Fahmida Tofail,[3] Marie Vahter,[1] Mariza Kampouri,[1] and Maria Kippler[1]

[1]Institute of Environmental Medicine, Karolinska Institutet, Stockholm, Sweden
[2]Department of Women's and Children's Health, Uppsala University, Uppsala, Sweden
[3]Maternal and Child Health Division, International Centre for Diarrhoeal Disease Research, Bangladesh (ICDDR,B), Dhaka, Bangladesh

Linear regression of MUF concentration in early pregnancy with child IQ at 5 and 10 years in the MINIMat study

	All children	
Outcomes	*B* (95% CI)	*p*-Value
Cognition at 5 years (WPPSI-III)[b]	$n = 457$	—
Full-scale raw score		
Unadjusted model	−0.2 (−3.1, 2.7)	0.870
Adjusted model	−2.8 (−5.1, −0.6)	0.014
Cognition at 10 years (WISC-IV)[d]	$n = 500$	—
Full-scale raw score		
Unadjusted model	−2.8 (−6.7, 1.1)	0.160
Adjusted model	−4.9 (−8.0, −1.8)	0.002

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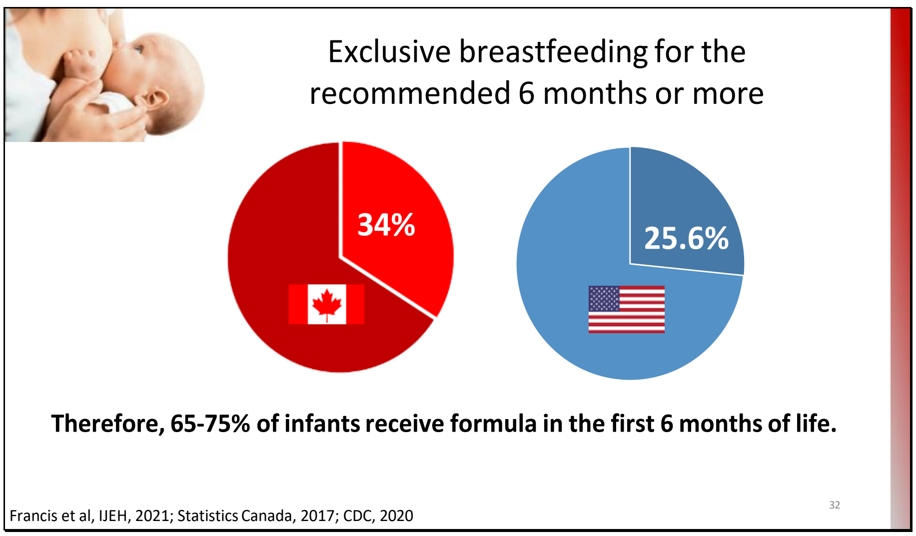

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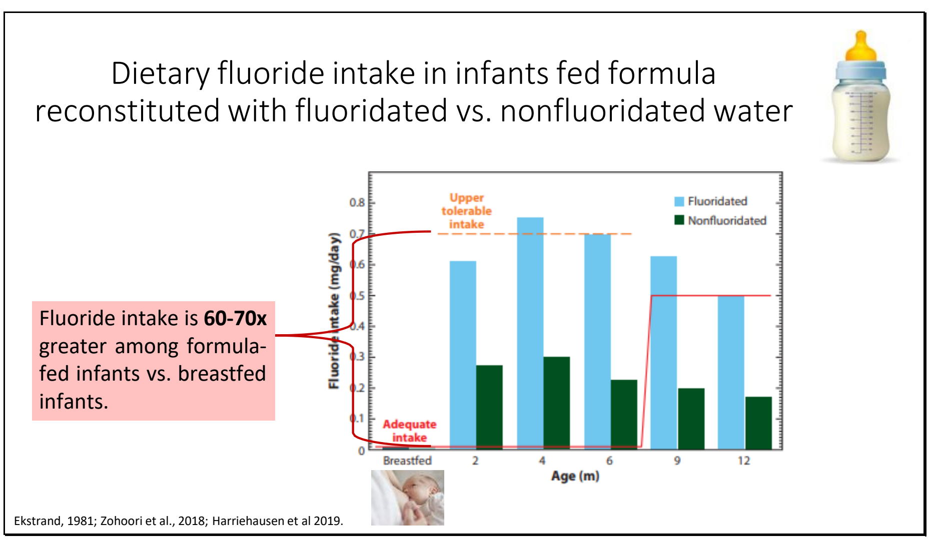

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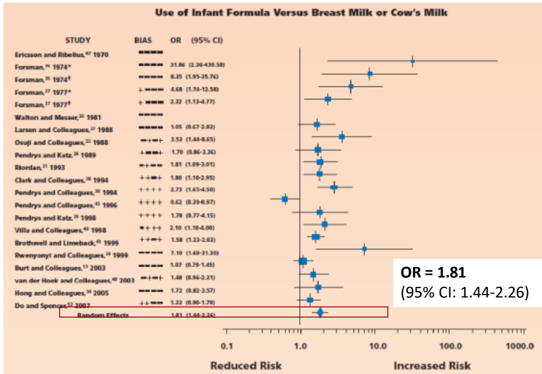
Risk of enamel fluorosis is higher among formula fed infants.

Hujoel et al., JADA, 2009



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MIREC

Are formula-fed infants at risk of lower IQ if formula is made with fluoridated water?

Infant feeding → Childhood IQ

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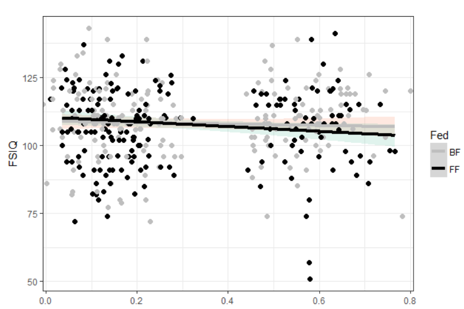
A 0.5 mg/L increase in water fluoride level was associated with a **4.4-point decrement in FSIQ** in the formula-fed (FF) group. No significant association in breastfed (BF) group.



Breastfed: B = -1.34 (-5.04, 2.38)

Formula: B = -4.40 (-8.34, -0.46)*

Till et al., Envir Intern, 2020

*Controlling for child sex, age, maternal educ, race, smoke in home, HOME

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Are there any benefits of using fluoridated tap water to mix infant formula?

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No.

Fluoride's predominant beneficial effect is <u>post-tooth eruption!</u>

(Berg et al, 2011; Limeback, 1999; Featherstone, 2001; NRC, 2006; Warren & Levy, 2003)

American Academy of Pediatrics recommends fluoride tablets only <u>after</u> primary teeth erupt

- Only if child is susceptible to high caries activity and not exposed to other fluoride-based interventions

Table. DIETARY FLUORIDE SUPPLEMENTATION SCHEDULE

Age	<0.3 ppm F	0.3 to 0.6 ppm F	>0.6 ppm F
Birth to 6 months	0	0	0
6 mo to 3 years	0.25 mg	0	0
3 to 6 years	0.50 mg	0.25 mg	0
6 to at least 16 years	1.00 mg	0.50 mg	0

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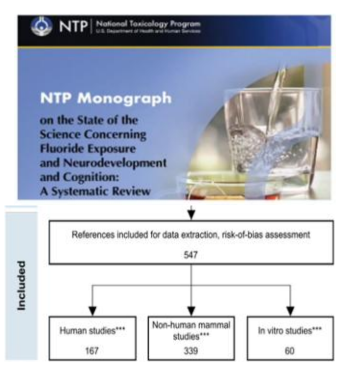
A more comprehensive evaluation of the developmental neurotoxicity of fluoride



Research

JAMA Pediatrics | Original Investigation

Fluoride Exposure and Children's IQ Scores

A Systematic Review and Meta-Analysis

Kyla W. Taylor, PhD; Sorina E. Eftim, PhD; Christopher A. Sibrizzi, MPH; Robyn B. Blain, PhD; Kristen Magnuson, MESM; Pamela A. Hartman, MEM; Andrew A. Rooney, PhD; John R. Bucher, PhD

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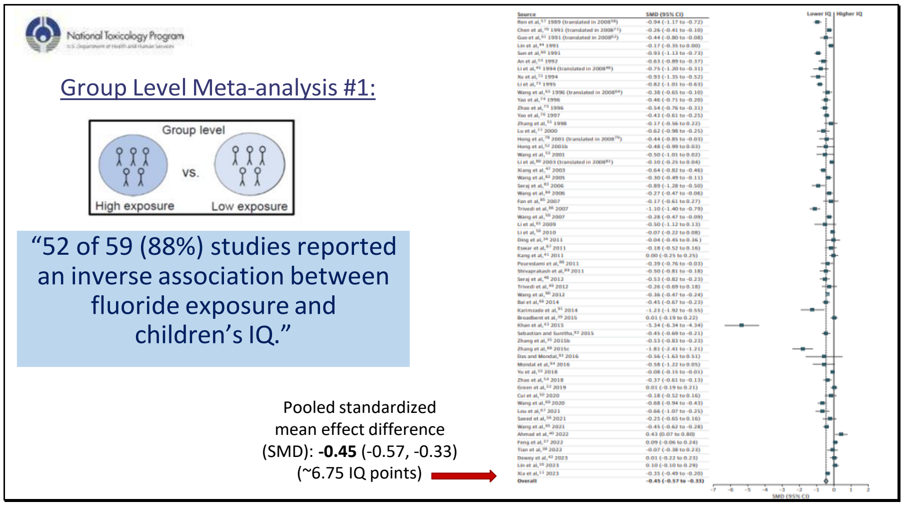

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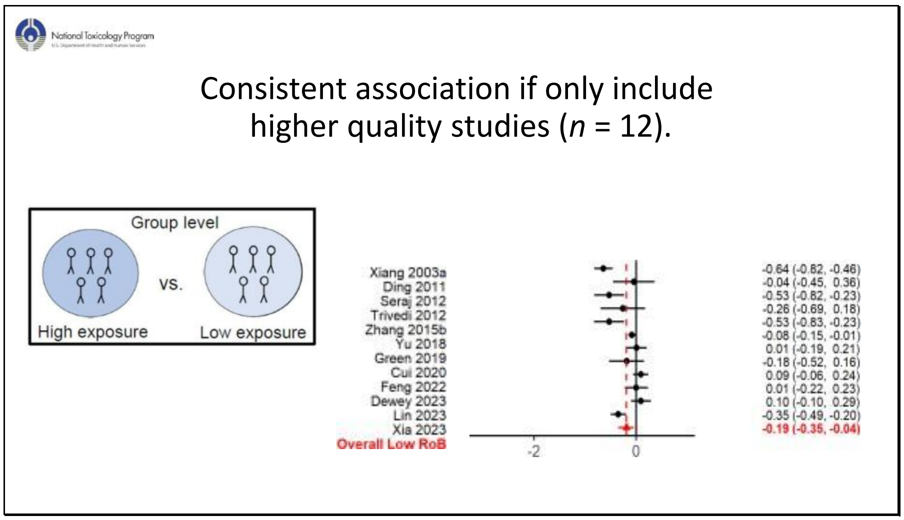

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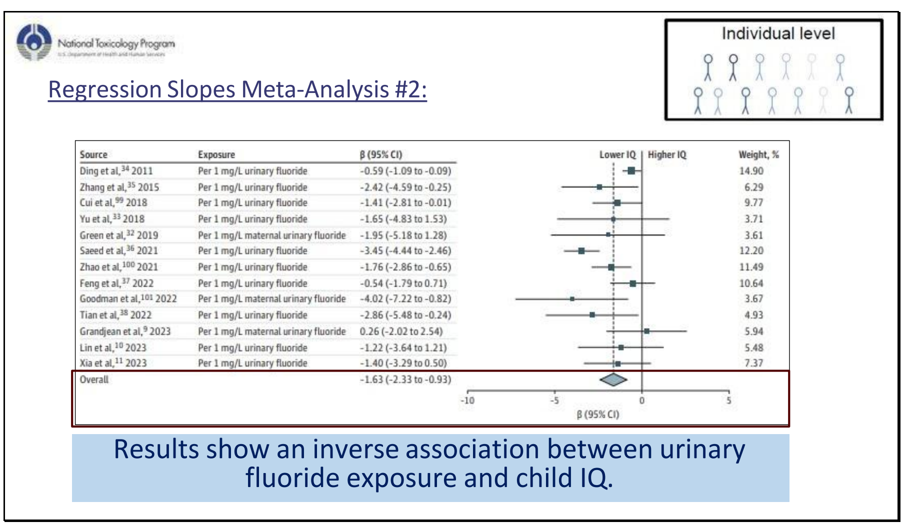

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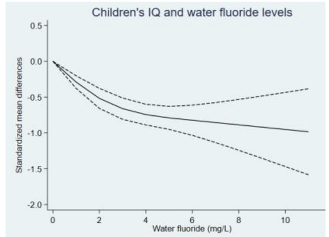
National Toxicology Program
U.S. Department of Health and Human Services

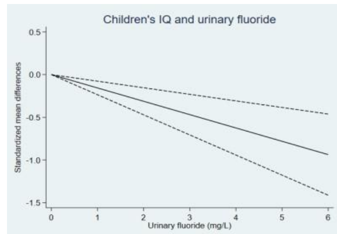
Dose-Response Mean Effects Meta-Analysis #3:

IQ drops with increasing levels of F in water and urine.

There is no obvious threshold.



N= 31 studies with water F exposure and at least two exposure levels.



N = 20 studies with urinary F exposure and at least two exposure levels.

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Dose-Response Mean Effects Meta-Analysis #3:

Table 2. Pooled Changes in Standardized Mean Differences (SMDs) From the Linear Model From the Dose-Response Mean-Effects Meta-Analyses Using Group-Level Measures of Fluoride Exposure

Fluoride exposure, mg/L	Studies, No.	Effect estimates, No.[a]	Children, No.	Parameter estimates[b] β (95% CI)	P value
Urinary fluoride, all studies					
All data	20	32	9756	−0.15 (−0.23 to −0.07)	<.001
<4	14	25	8019	−0.20 (−0.31 to −0.08)	.001
<2	6	10	4692	−0.08 (−0.15 to −0.005)	.04
<1.5	5	8	4219	−0.08 (−0.15 to −0.003)	.04
Urinary fluoride, low risk-of-bias studies					
All data	10	14	6847	−0.13 (−0.23 to −0.03)	.01
<4	10	14	6847	−0.13 (−0.23 to −0.03)	.01
<2	4	7	4179	−0.08 (−0.15 to −0.002)	.04
<1.5	4	7	4179	−0.08 (−0.15 to −0.002)	.04

Equivalent to an IQ decrement of 1.2 points

Taylor et al., 2025

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Dose-Response Mean Effects Meta-Analysis #3:

Water F levels <2 mg/L associated with an IQ decrement of ~5 points

Coefficient remains the same, but no longer significant at <1.5 mg/L

Table 2. Pooled Changes in Standardized Mean Differences (SMDs) From the Linear Model From the Dose-Response Mean-Effects Meta-Analyses Using Group-Level Measures of Fluoride Exposure

Fluoride exposure, mg/L	Studies, No.	Effect estimates, No.[a]	Children, No.	Parameter estimates[b] β (95% CI)	P value
Water fluoride, all studies					
All data	31	41	12 487	−0.15 (−0.20 to −0.11)	<.001
<4	23	29	9554	−0.22 (−0.27 to −0.17)	<.001
<2	8	10	3682	−0.18 (−0.40 to 0.03)	.10
<1.5	7	7	2832	0.05 (−0.36 to 0.45)	.82
Water fluoride, low risk-of-bias studies					
All data	7	12	5066	−0.21 (−0.33 to −0.09)	.001
<4	7	10	4962	−0.23 (−0.34 to −0.11)	<.001
<2	4	5	1632	−0.33 (−0.53 to −0.13)	.001
<1.5	3	3	879	−0.32 (−0.91 to 0.26)	.28
Urinary fluoride, all studies					
All data	20	32	9756	−0.15 (−0.23 to −0.07)	<.001
<4	14	25	8019	−0.20 (−0.31 to −0.08)	.001
<2	6	10	4692	−0.08 (−0.15 to −0.005)	.04
<1.5	5	8	4219	−0.08 (−0.15 to −0.003)	.04
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Taylor et al., 2025

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Opinion

EDITORIAL

Caution Needed in Interpreting the Evidence Base on Fluoride and IQ

Steven M. Levy, DDS, MPH

Opinion

EDITORIAL

Time to Reassess Systemic Fluoride Exposure, Again

Bruce P. Lanphear, MD, MPH; Pamela Den Besten, DDS, MS; Christine Till, PhD

Thus, despite the presentation of some evidence of a possible association between IQ and high fluoride levels in water, there is no evidence of an adverse effect at the lower water fluoride levels commonly used in CWF systems. Therefore, public policy concerning the addition of fluoride to community water systems and recommendations concerning the use of topical fluoride in its many forms should not be affected by the study findings, and the widespread use of fluoride for caries prevention should continue.

Research

JAMA Pediatrics | Original Investigation

Fluoride Exposure and Children's IQ Scores
A Systematic Review and Meta-Analysis

Kyla W. Taylor, PhD; Sorina E. Eftim, PhD; Christopher A. Sibrizzi, MPH; Robyn B. Blain, PhD; Kristen Magnuson, MESM; Pamela A. Hartman, MEM; Andrew A. Rooney, PhD; John R. Bucher, PhD

Editorial pages 1 and 1
Supplemental content

IMPORTANCE Previous meta-analyses suggest that fluoride exposure is adversely associated with children's IQ scores. An individual's total fluoride exposure comes primarily from fluoride in drinking water, food, and beverages.

OBJECTIVE To perform a systematic review and meta-analysis of epidemiological studies investigating children's IQ scores and prenatal or postnatal fluoride exposure.

DATA SOURCES BIOSIS, Embase, PsycInfo, PubMed, Scopus, Web of Science, CNKI, and Wanfang, searched through October 2023.

STUDY SELECTION Studies reporting children's IQ scores, fluoride exposure, and effect sizes.

DATA EXTRACTION AND SYNTHESIS Data were extracted into the Health Assessment Workplace Collaborative system. Study quality was evaluated using the OHAT risk-of-bias tool. Pooled standardized mean differences (SMDs) and regression coefficients were estimated with random-effects models.

MAIN OUTCOMES AND MEASURES Children's IQ scores.

The absence of a statistically significant association of water fluoride less than 1.5 mg/L and children's IQ scores in the dose-response meta-analysis does not exonerate fluoride as a potential risk for lower IQ scores at levels found in fluoridated communities. Water fluoride concentration does not capture the amount of water ingested or other sources of ingested fluoride.[11] In contrast, urinary fluoride is a biological measure of total fluoride exposure, including the dynamic interface between bone fluoride stores and blood fluoride.[11] The

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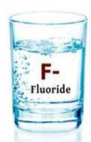
Exposure Considerations



- Provides useful estimate of long-term population exposure
- Underestimates total exposure because it does not capture amount of water ingested or other sources of fluoride.

- Urinary fluoride is a reliable biological measure that captures an individual's total fluoride exposure
- Represents a limited (recent) time-period
- Influenced by when sample was taken and differences in dilution
- Routinely used by regulatory agencies for risk assessment

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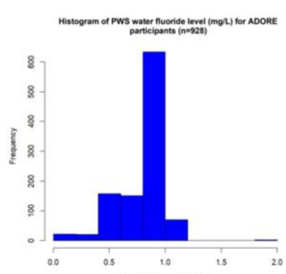
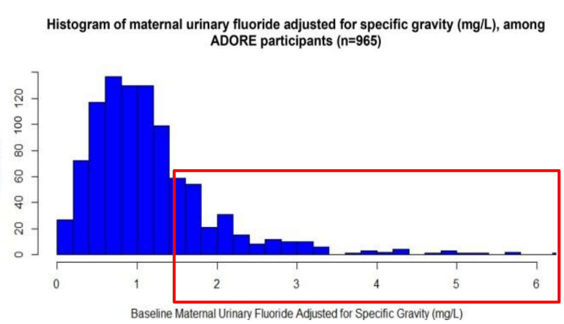
Evidence of fluoride neurotoxicity at urine F levels <1.5 mg/L is relevant to community water fluoridation.





Griebel-Thompson et al., EHP, 2025

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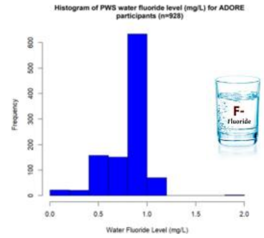

Pregnant women (and children) can exceed 1.5 mg/L depending on amount of fluoridated water ingested and exposure to other sources.

Table 2. Median (Q1, Q3) baseline and third trimester maternal urinary fluoride levels (adjusted for specific gravity) among ADORE participants and estimated fluoride intake by PWS water fluoridation level.

	p	All cohort ($n=965$)	Water fluoridation[a] <0.7 mg/L ($n=215$) [median (IQR)]	Water fluoridation[a] ≥0.7 mg/L ($n=713$) [median (IQR)]	p-Value[b]	Missing (n)
Baseline maternal urinary fluoride, adjusted (mg/L)[c]	965	1.0 (0.6, 1.5)	0.8 (0.5, 1.2)	1.0 (0.7, 1.5)	<0.01	—
Third trimester maternal urinary fluoride, adjusted (mg/L)[c]	307	1.1 (0.8, 1.6)	1.1 (0.8, 1.4)	1.1 (0.8, 1.6)	0.28	658
Fluoride intake (mg)[d]	728	0.4 (0.1, 1.4)	0.2 (0.1, 0.8)	0.4 (0.1, 1.9)	<0.01	237

Note: —, no data; ADORE, Assessment of DHA on Reducing Early Preterm Birth; IQR, interquartile range; PWS, public water systems.
[a]PWS water fluoridation level missing for $n=37$ participants.
[b]Mann-Whitney U tests were used to determine significance.
[c]Adjusted for specific gravity. Baseline specific gravity [median (Q1, Q3)], 1.0 (1.0, 1.0); third trimester specific gravity [median (Q1, Q3)], 1.0 (1.0, 1.0), missing 658.
[d]Fluoride intake was calculated by multiplying the participant's PWS water fluoridation level by self-reported amount of tap water consumed (daily average).

Griebel-Thompson et al., EHP, 2025

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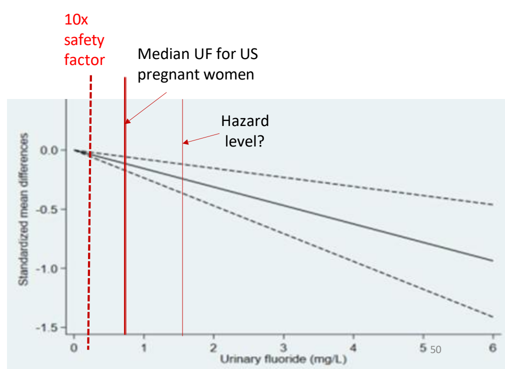
Based on the evidence of fluoride neurotoxicity at 1.5 mg/L, fluoridation at 0.7 mg/L offers a safety margin of 2x.

"Under even the most conservative estimates, there is not enough of a margin between the accepted hazard level (i.e., 1.5 mg/L) and the actual human exposure levels to find that fluoride is safe."

Judge Chen, October 2024



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Maternal-Infant Research on Environmental Chemicals

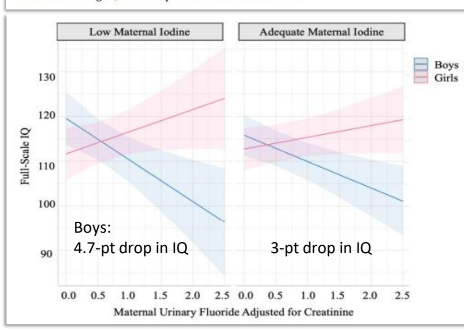
Iodine deficiency may increase risk of fluoride neurotoxicity.

nutrients

Article

Iodine Status Modifies the Association between Fluoride Exposure in Pregnancy and Preschool Boys' Intelligence

Carly V. Goodman [1], Meaghan Hall [1], Rivka Green [1], Jonathan Chevrier [2], Pierre Ayotte [3], Esperanza Angeles Martinez-Mier [4], Taylor McGuckin [1], John Krzeczkowski [1], David Flora [1], Richard Hornung [5,†], Bruce Lanphear [6] and Christine Till [1,*]



Goodman et al., *Nutrients*, 2022;

*3-way interaction significant for boys (p = .04), but not girls (p =.19)

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Genetic factors

Individuals with certain genetic variants in dopamine receptor D2 or the catechol-O-methyltransferase (*COMT*) gene may have heightened sensitivities to fluoride exposure (Cui et al., 2018; Zhang et al., 2015).

SOT Society of Toxicology
www.toxsci.oxfordjournals.org

TOXICOLOGICAL SCIENCES, 144(2), 2015, 238–245

Modifying Effect of COMT Gene Polymorphism and a Predictive Role for Proteomics Analysis in Children's Intelligence in Endemic Fluorosis Area in Tianjin, China

Shun Zhang, Xiaofei Zhang, Hongliang Liu, Weidong Qu, Zhizhong Guan, Qiang Zeng, Chunyang Jiang, Hui Gao, Cheng Zhang, Rongrong Lei, Tao Xia, Zhenglun Wang, Lu Yang, Yihu Chen, Xue Wu, Yushan Cui, Linyu Yu, and Aiguo Wang

Contents lists available at ScienceDirect

Ecotoxicology and Environmental Safety

journal homepage: www.elsevier.com/locate/ecoenv

Dopamine receptor D2 gene polymorphism, urine fluoride, and intelligence impairment of children in China: A school-based cross-sectional study

Yushan Cui, Bin Zhang, Jing Ma, Yang Wang, Liang Zhao, Changchun Hou, Jingwen Yu, Yang Zhao, Zushan Zhang, Junyan Nie, Tongning Gao, Guoli Zhou, Hongliang Liu

Genotype	*N*	IQ points lost per 1 mg/L urine F	*p*-value
combined	108	–2.42	0.030
val/val	28	–9.67	0.003

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Mechanisms of Fluoride Neurotoxicity

- Contribute to mitochondrial dysfunction
- Increase oxidative stress
- Alter cholinergic activity
  - α4 and α7 nAChRs subunits
- Alter glutamate metabolism
- Decreases in neural receptors and stunted neuronal development
- *Thyroid hormone disruption

Barbier et al. 2010. Molecular mechanisms of fluoride toxicity. Chem. Biol. Interact. 188(2):319–33
Johnston et al., 2020. Principles of fluoride toxicity and the cellular response: a review. Arch. Toxicol. 94(4):1051–69

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Contents lists available at ScienceDirect

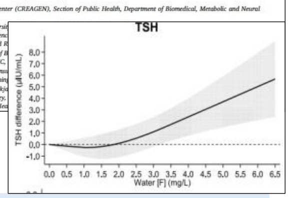
Environmental Research

journal homepage: www.elsevier.com/locate/envres

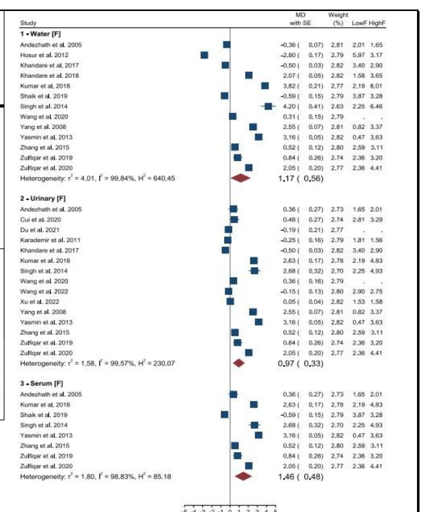
Review article

Does fluoride exposure affect thyroid function? A systematic review and dose-response meta-analysis

Inga Iamandii, Lisa De Pasquale, Maria Edvige Giannone, Federica Veneri, Luigi Generali, Ugo Consolo, Linda S. Birnbaum, Jacqueline Castenmiller, Thorhallur I. Halldorsson, Tommaso Filippini, Marco Vinceti



Higher water F, urine F, and serum F concentrations were associated with higher TSH in children, with little evidence of a threshold.



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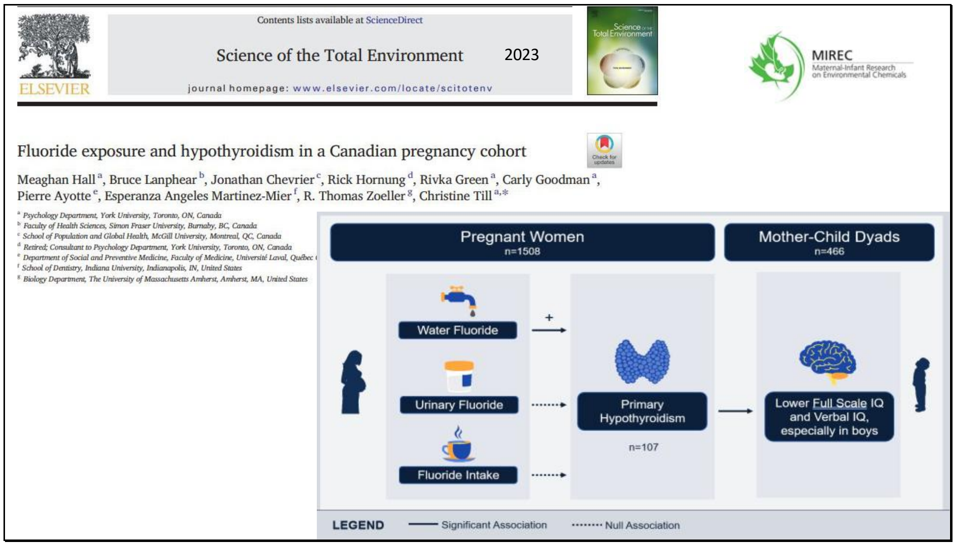

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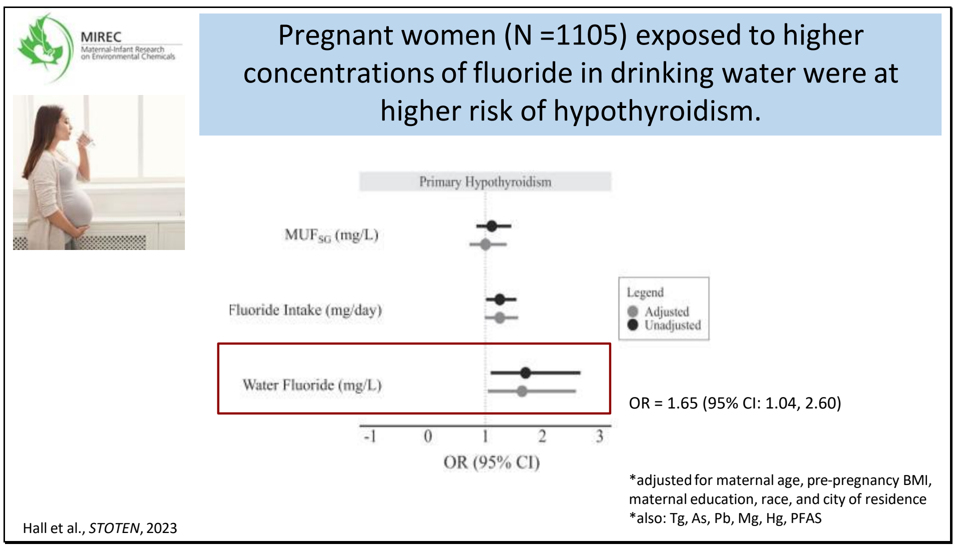

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Published in final edited form as:
Sci Total Environ. 2024 July 10; 933: 173121. doi:10.1016/j.scitotenv.2024.173121.

Letter to the editor regarding Hall et al. (2023): Fluoride exposure and hypothyroidism in a Canadian pregnancy cohort

Meaghan Hall[a], Bruce Lanphear[b], Jonathan Chevrier[c], Rick Hornung[d], Rivka Green[a], Carly Goodman[a], Pierre Ayotte[e], Esperanza Angeles Martinez-Mier[f], R. Thomas Zoeller[g], Christine Till[a]

Association between water fluoride concentration and risk of primary hypothyroidism.

	n	aOR*	95% CI	*p*
Total Sample	1105	1.65	1.04, 2.60	.03
+ Lived at residence for ≥ 1 year	889	1.80	1.07, 3.01	.03
+ Normal[a] TPO Ab Levels	1094	2.85	1.25, 6.60	.01

[a] TPO Ab < 5.61 IU/mL.
* adjusted OR reported for 0.5 mg/L increase in water fluoride concentration.

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Hall et al. (*2023*). *STOTEN.*

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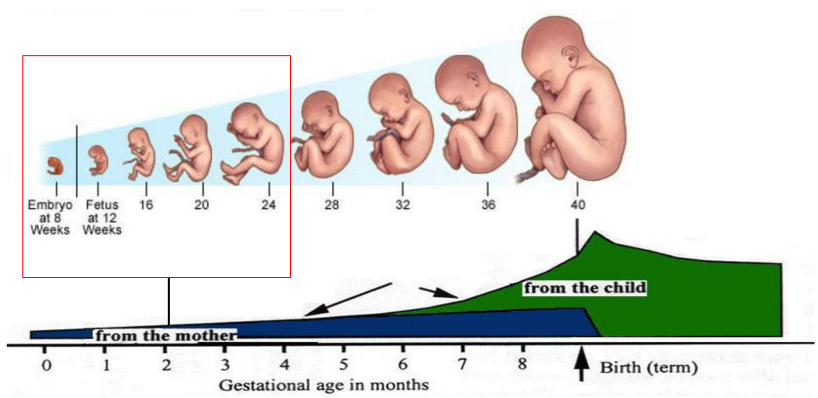
Thyroid hormone is critical in gestational development



Thorpe-Beeston & Nicholaides, 1995

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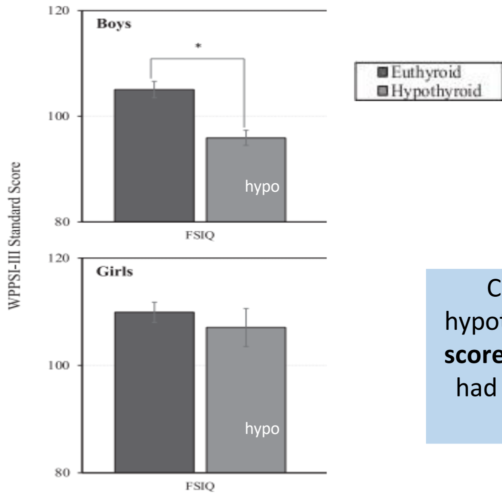

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Children whose mothers had hypothyroidism (n=28) had **lower IQ scores** than children whose mothers had normal thyroid levels (n=411), especially for boys.

Hall et al., *STOTEN*, 2023

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Research

JAMA Pediatrics | Original Investigation

Fluoride Exposure and Children's IQ Scores
A Systematic Review and Meta-Analysis

Kyla W. Taylor, PhD; Sorina E. Eftim, PhD; Christopher A. Sibrizzi, MPH; Robyn B. Blain, PhD; Kristen Magnuson, MESM; Pamela A. Hartman, MEM; Andrew A. Rooney, PhD; John R. Bucher, PhD

"Confidence in the associations at lower fluoride levels could be increased by additional prospective cohort studies with individual fluoride exposure measures."

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7 of 9 prospective birth cohort studies report adverse effects of gestational exposure to fluoride.

Prospective Birth Cohort	Significant adverse effects (lower IQ, behavior problems) reported	No adverse effects reported
Optimal fluoridation	**ELEMENT**: Bashash 2017/Goodman 2022 (Mexico) **MIREC**: Green 2019/Till 2020 (Canada) **PROGRESS**: Cantoral 2021 (Mexico) **MADRES***: Malin 2024 (USA)	**INMA**: Ibarluzea 2022 (Spain)
Low natural F	**NICE***: Kampouri 2025 (Sweden) **MINIMat**: Singh 2025 (Bangladesh)	**OCC**: Grandjean 2023 (Denmark)
High natural F	Valdez-Jiminez 2017 (Mexico)	

*MUF associated with increased risk of behavioral problems

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8 of 10 prospective birth cohort studies report adverse effects of gestational exposure to fluoride.

Prospective Birth Cohort	Significant adverse effects (lower IQ, behavior problems) reported	No adverse effects reported
Optimal fluoridation	**ELEMENT**: Bashash 2017/Goodman 2022 (Mexico) **MIREC**: Green 2019/Till 2020 (Canada) **PROGRESS**: Cantoral 2021 (Mexico) **MADRES***: Malin 2024 (USA)	**INMA**: Ibarluzea 2022 (Spain)
Low natural F	**NICE***: Kampouri 2025 (Sweden) **MINIMat**: Singh 2025 (Bangladesh) + ***NHBCS****: *in progress (USA)*	**OCC**: Grandjean 2023 (Denmark)
High natural F	Valdez-Jiminez 2017 (Mexico)	

*MUF associated with increased risk of behavioral problems

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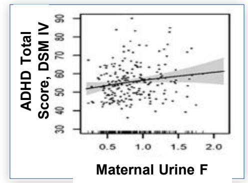
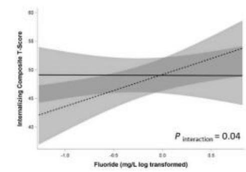
Fluoride and Neurobehavioural Outcomes

Ecologic Studies:
- USA: Higher rates of ADHD found in states with most CWF compared to those with least (Malin & Till, *Envir Health*, 2015)
- Canada: Higher tap water F associated with poorer inhibitory control (Dewey et al., 2023)

Prenatal F Studies:
- Mexico: Higher maternal urinary F associated with more ADHD-like symptoms in children (Bashash et al., *EHP*, 2017)
- USA: Higher maternal urinary F associated with increased risk of internalizing problems and somatic complaints (Malin et al, JAMA Network, 2024)
- Sweden: Higher maternal urinary F associated with ADHD problems in children (Kampouri et al., *Env Res*, 2024)

Cross sectional studies:
- Canada: Higher tap water F concentration associated with higher prevalence of ADHD (Riddell et al., *Environ Int'l*, 2019)
- USA: Higher child urine F associated with increased somatization and internalizing symptoms in males (Adkins et al., 2021)





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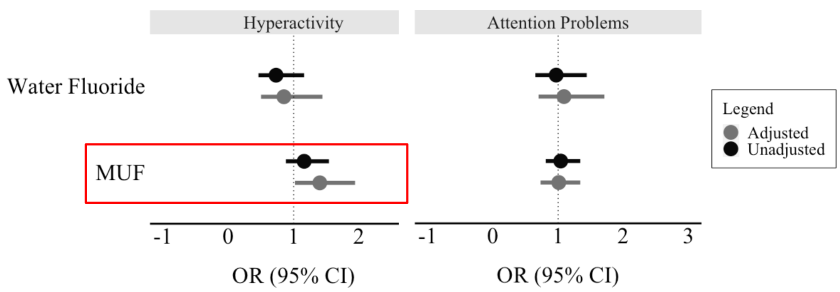
MIREC Maternal-Infant Research on Environmental Chemicals

Higher maternal urinary F level in pregnancy associated with elevated symptoms of hyperactivity. (OR=1.42; 95%CI (1.03-1.95)



Radmilovic et al., in preparation

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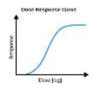
Criteria for Causality (Bradford Hill, 1965)



- Strength of the association
- Consistency
- Temporality
- Biological plausibility
- Dose-response relationship
- Coherence
- Experimental evidence

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Why should we care about a few IQ points?

Shift of 3 IQ points*

*3 IQ points selected based on Grandjean et al's (2022) benchmark dose model showing that a urinary F level of 0.28 mg/L is associated with a loss of 1 IQ point. 3 IQ points is a rough estimate if we factor in both prenatal and postnatal exposure and consider total fluoride intake.

Little Things Matter, Lanphear

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ANNUAL REVIEWS

Annual Review of Public Health

Health Risks and Benefits of Fluoride Exposure During Pregnancy and Infancy

Christine Till,[1] Philippe Grandjean,[2,3] E. Angeles Martinez-Mier,[4] Howard Hu,[5] and Bruce Lanphear[6]

[1]Faculty of Health, York University, Toronto, Ontario, Canada; email: ctill@yorku.ca
[2]Department of Biomedical and Pharmaceutical Sciences, University of Rhode Island, Kingston, Rhode Island, USA
[3]Department of Public Health, University of Southern Denmark, Odense, Denmark
[4]Department of Dental Public Health and Dental Informatics, School of Dentistry, Indiana University, Indianapolis, Indiana, USA
[5]Keck School of Medicine, University of Southern California, Los Angeles, California, USA
[6]Faculty of Health Sciences, Simon Fraser University, Vancouver, British Columbia, Canada

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Given that fluoride offers little benefit to the fetus and young infant, community-wide administration of systemic fluoride may pose an unfavorable risk–benefit ratio for the pregnant woman, fetus, and infant.

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Acknowledgements

Co-Investigators
- Dr. Bruce Lanphear
- Dr. David Flora
- Dr. Rick Hornung
- Dr. Gina Muckle
- Dr. Pierre Ayotte

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- Carly Goodman
- Linda Farmus
- Ana Radmilovic
- Raichel Neufeld
- Dr. John Krzeczkowski
- Dr. John Grundy

YORK UNIVERSITÉ UNIVERSITY

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MIREC Maternal-Infant Research on Environmental Chemicals

- Participants!!
- Dr. William Fraser
- Dr. Tye Arbuckle
- Nicole Lupien
- Romy McMaster

INSPQ Staff

Institut national de santé publique Québec Centre de toxicologie

- Alain LeBlanc and staff

Indiana University
- Dr. Angeles Martinez-Mier
- Dr. Frank Lippert
- Sharon Gwinn

SCHOOL OF DENTISTRY INDIANA UNIVERSITY IUPUI

Funding

NIH National Institutes of Health

CIHR IRSC Canadian Institutes of Health Research

WEPGN Water Economics, Policy and Governance Network

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Thank you

ctill@yorku.ca

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IQ scores are valid in MIREC study

1. FSIQ is an aggregate of different cognitive skills (e.g. verbal/nonverbal reasoning). Considered the **most valid and reliable** measure of overall cognitive ability. Proven validity for use with diverse samples and across the lifespan.
2. Psychometrists underwent **rigorous training** to ensure competency in test administration.
   - Completed a 3-day training session that was led by a PhD-level psychologist
   - Integrity of test administration ensured by conducting **regular site visits** to observe testers.
3. Test protocols **double scored** by a PhD level supervisor to ensure accuracy of scores and consistency in how responses are interpreted across sites.
4. Regression models **controlled for study site**, which would control for variability in test administration between cities.
   - Results remained consistent (and significant)
5. Removed data from 9 children (1.5% of sample who underwent IQ testing) for whom the IQ data were not deemed valid or did not complete the test in its entirety.

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Why developmental neurotoxicology studies measure IQ in preschool-aged children:

- Environmental factors (e.g. neurotoxic exposures) are responsible for a larger proportion of the variance than genetics among younger-aged children.
- The longer the time following toxic exposure, the more opportunities there are for other environmental factors (e.g. education, home envir) to impact IQ

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Stability of IQ scores

Intelligence 69 (2018) 8–15

Contents lists available at ScienceDirect

Intelligence

journal homepage: www.elsevier.com/locate/intell

Stability of intelligence from infancy through adolescence: An autoregressive latent variable model

Huihui Yu[a,*], D. Betsy McCoach[b], Allen W. Gottfried[c], Adele Eskeles Gottfried[d]

[a] Yale University, United States
[b] University of Connecticut, United States
[c] Fullerton Longitudinal Study, California State University, Fullerton, United States
[d] California State University, Northridge, United States

Table 2
Correlation matrix of IQ scores.

	Measures	Age (in years)	1	2	3	4	5	6	7	8	9	10	11	12
1.	*BSID* MDI	1.0	–											
2.		1.5	0.41**	–										
3.		2.0	0.43**	0.62**	–									
4.	*MSCA* GCI	2.5	0.33**	0.63**	0.64**	–								
5.		3.0	0.37**	0.65**	0.67**	0.79**	–							
6.		3.5	0.37**	0.54**	0.68**	0.74**	0.76**	–						
7.	*WISC-R*	6.0	0.26**	0.45**	0.60**	0.57**	0.59**	0.67**	–					
8.		7.0	0.22*	0.41**	0.55**	0.56**	0.59**	0.63**	0.79**	–				
9.		8.0	0.20*	0.42**	0.54**	0.55**	0.59**	0.62**	0.79**	0.83**	–			
10.		12.0	*0.17*	0.39**	0.51**	0.42**	0.47**	0.47**	0.72**	0.78**	0.80**	–		
11.	*WISC-III*	15.0	*0.15*	0.35**	0.48**	0.40**	0.45**	0.45**	0.64**	0.70**	0.77**	0.80**	–	
12.	WAIS-R	17.0	*0.16*	0.39**	0.43**	0.44**	0.49**	0.44**	0.67**	0.70**	0.77**	0.82**	0.85**	–

Note. BSID MDI = Bayley Scales of Infant Development Mental Development Index; MSCA GCI = McCarthy Scales of Children's Abilities General Cognitive Index; WISC-R = Wechsler Intelligence Scales for Children-Revised; WISC-III = Wechsler Intelligence Scale for Children Third Edition; WAIS-R = Wechsler Adult Intelligence Scale-Revised. Statistically non-significant correlations are in italics and underlining.

* $p < .05$.

** $p < .01$.

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Benchmark concentration value
(i.e. urine F concentration that corresponds to a 1-point IQ loss)

Derived using 3 cohort studies:
MIREC, ELEMENT, OCC (n=1599)

European Journal of Public Health, 1–7
Published by Oxford University Press on behalf of the European Public Health Association 2023.
This work is written by (a) US Government employee(s) and is in the public domain in the US.
https://doi.org/10.1093/eurpub/ckad170

Dose dependence of prenatal fluoride exposure associations with cognitive performance at school age in three prospective studies

Philippe Grandjean [1,2], Alessandra Meddis [3], Flemming Nielsen [1], Iben H. Beck [1], Niels Bilenberg[4], Carly V. Goodman[5], Howard Hu[6], Christine Till[5], Esben Budtz-Jørgensen[3]

Table S3. BMC values for creatinine-adjusted maternal U-F (mg/L) for three models and for both sexes of the three studies and the combined data, where the outcome in the ELEMENT study is the McCarthy GCI score. The fit of the regression models was compared by the AIC (where lower values indicate a better fit).

		OCC (n= 837)		MIREC (n=407)		ELEMENT GCI (n=355)		All three studies (n=1,599)		
	Sex	BMC	BMCL	BMC	BMCL	BMC	BMCL	BMC	BMCL	AIC
Linear	All	0.920	0.303	0.497	0.228	0.245	0.142	0.474	0.284	12552
	Girls	0.487	0.189	∞	0.609	0.182	0.106	0.633	0.280	12550
	Boys	3.609	0.309	0.201	0.125	0.426	0.149	0.393	0.225	12550

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Contents lists available at ScienceDirect
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journal homepage: www.elsevier.com/locate/envres

Critical windows of fluoride neurotoxicity in Canadian children

Linda Farmus [a], Christine Till [a,*], Rivka Green [a], Richard Hornung [b], E. Angeles Martinez Mier [c], Pierre Ayotte [d,e], Gina Muckle [d,f], Bruce P. Lanphear [g,h], David B. Flora [a]

Prenatal	Infancy	Childhood
T1 T2 T3 		
Maternal urinary fluoride concentration (mg/L)	Infant fluoride intake (mg F)	Child urinary fluoride concentration (mg/L)
Mean = 0.51 (SD = 0.36) RANGE: 0.06-2.38	Mean = 0.14 (SD = 0.13) RANGE: 0-0.61	Mean = 0.66 (SD = 0.70) RANGE: 0-6.44
(MUF)	(IFI)	(CUF)

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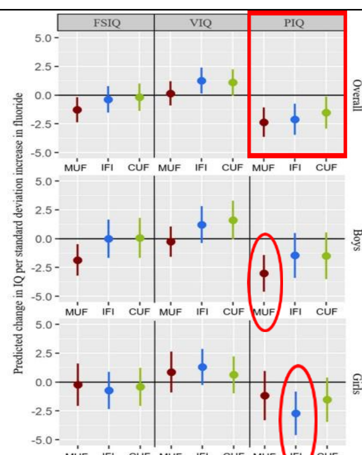

Fig. 2. Standardized associations between fluoride exposure windows and IQ outcomes using GEE. *Note.* Dots represent point estimates and tails represent 95% confidence intervals.

For overall sample, both the prenatal and infancy periods were critical.

For boys, prenatal period was critical.

For girls, infancy period was critical.

Farmus et al., 2021

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Animal studies on fluoride and sex effects

- Mullenix et al. (1995):
  - male rats most sensitive to fluoride in the late prenatal period, female rats most sensitive in the postnatal period
- Findings are consistent with some (e.g. Baran-Poesine et al., 2013; Bera et al., 2007; Flace et al., 2010), but not all (e.g. Bartos et al., 2015; Jiang et al., 2014) rat studies examining sex-specific effects of prenatal exposure to fluoride
- Further research should examine sex-specific effects of fluoride neurotoxicity as many of the animal studies conducted to date have been identified as having a high risk of bias (NTP, 2016)

Reviewed in Green et al., 2020

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What does the current scientific literature indicate about the benefits of community water fluoridation?

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October 2024

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[Intervention Review]

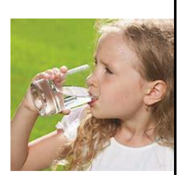
Water fluoridation for the prevention of dental caries

Zipporah Iheozor-Ejiofor[1], Tanya Walsh[2], Sharon R Lewis[2], Philip Riley[2], Dwayne Boyers[3], Janet E Clarkson[2,4], Helen V Worthington[2], Anne-Marie Glenny[2], Lucy O'Malley[2]

[1]School of Medicine, University of Central Lancashire, Preston, UK. [2]Cochrane Oral Health, Division of Dentistry, School of Medical Sciences, Faculty of Biology, Medicine and Health, The University of Manchester, Manchester, UK. [3]University of Aberdeen, Aberdeen, UK. [4]Division of Oral Health Sciences, School of Dentistry, University of Dundee, Dundee, UK

Older evidence may not be applicable to contemporary societies where fluoride toothpastes and other preventative measures are widely used.

Reviewed studies conducted post-1975:
1. To evaluate the effects of CWF for the prevention of dental caries (dmft/DMFT; n=21);
2. To evaluate the association of CWF with dental fluorosis (n=90)



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[Intervention Review]

Water fluoridation for the prevention of dental caries

Zipporah Iheozor-Ejiofor[1], Tanya Walsh[2], Sharon R Lewis[2], Philip Riley[2], Dwayne Boyers[3], Janet E Clarkson[2,4], Helen V Worthington[2], Anne-Marie Glenny[2], Lucy O'Malley[2]

[1]School of Medicine, University of Central Lancashire, Preston, UK. [2]Cochrane Oral Health, Division of Dentistry, School of Medical Sciences, Faculty of Biology, Medicine and Health, The University of Manchester, Manchester, UK. [3]University of Aberdeen, Aberdeen, UK. [4]Division of Oral Health Sciences, School of Dentistry, University of Dundee, Dundee, UK

Main conclusions:

- There is a **much smaller benefit of CWF** compared with pre-1975 studies.
- CWF led to a reduction in number of decayed, missing, and filled primary teeth (dmft) of **not more than 4% or possibly no benefit** given uncertainty of the estimate.
- **Fluorosis at 0.7 mg/L**: 12% of aesthetic concern; 40% had fluorosis of any level.
- **Inconsistent evidence** to show that CWF reduces oral health inequalities
- **Insufficient evidence** to determine the effect of cessation of CWF on caries.

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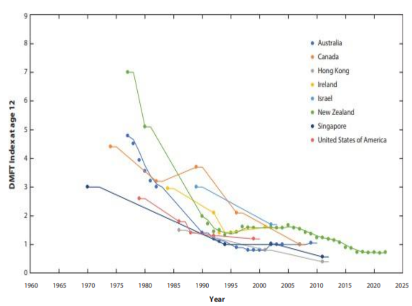
Dental caries trends over last 50 years

Fluoridated countries



Figures based on Country/Area Profile Program data accessed from the WHO Collaborating Centre for Education, Training, and Research in Oral Health, Malmö University, Sweden.

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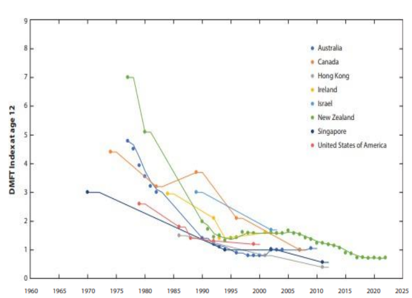
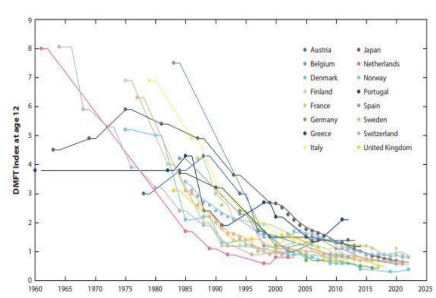
Dental caries trends over last 50 years

Fluoridated countries



Non-fluoridated countries



Figures based on Country/Area Profile Program data accessed from the WHO Collaborating Centre for Education, Training, and Research in Oral Health, Malmö University, Sweden.

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PERSPECTIVE

Water fluoridation for the prevention of dental caries

Cochrane Oral Health

Lucy O'Malley, Jan Clarkson, Sharon Lewis, Tanya Walsh and Anne-Marie Glenny are oral health researchers based at the Universities of Manchester and Dundee. They are all authors on the 'Cochrane review of water fluoridation' and members/Coordinating Editors/Editors for *Cochrane Oral Health*.

Key points

- Early studies of community water fluoridation showed an important effect on prevention of tooth decay in children. Recent studies show smaller effects.
- Any potential oral health benefits should be comprehensively considered alongside potential harms and costs (taking contemporary effect estimates into account).
- There is inconsistent evidence with regards to the impact of water fluoridation on oral health inequalities.
- Where community water fluoridation is implemented, monitoring of water fluoride concentrations is critical to ensure schemes consistently provide optimal potential benefits in terms of caries prevention.

no conclusive evidence for an association between optimal CWF and most conditions evaluated.[5,7]

Given that observed benefits have reduced over time, before introducing new CWF schemes, careful thought needs to be given to costs and ability to properly implement

'We must be open to changes in the evidence, even when they challenge strongly held beliefs.'

O'Malley et al (2025). British Dental Journa, 238 (4): 241-42.

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Research Reports: Clinical

Water Fluoridation and Dental Caries in U.S. Children and Adolescents

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G.D. Slade[1], W.B. Grider[2], W.R. Maas[3], and A.E. Sanders[1]

Table 4. Unadjusted Mean Caries Experience According to Fluoridation Status among U.S. 2- to 17-y-olds: National Health and Nutrition Examination Survey 1999 to 2004 and 2011 to 2014.

	2- to 8-y-old dfs		6- to 17-y-old DMFS	
% of County Fluoridated[a]	*n*	Mean (95% CL)	*n*	Mean (95% CL)
<75% of county population (a)	2,914	4.6 (3.9, 5.4)	5,107	2.2 (2.0, 2.4)
≥75% of county population (b)	4,086	3.3 (2.8, 3.7)	7,497	1.9 (1.8, 2.1)
Absolute difference: (a) minus (b)		1.3 (0.6, 2.2)		0.3 (0.0, 0.5)
Prevented fraction: [(a) minus (b)]/(a) × 100 (%)		30 (11, 48)		12 (1, 23)

CL, confidence limit; dfs, number of decayed or filled primary tooth surfaces per person; DMFS, number of decayed, missing, or filled permanent tooth surfaces per person; *n*, unweighted number of participants in descriptive sample.
[a]Percentage of county population served by public water systems with ≥0.7 ppm fluoride.

Conclusion:
Findings show a significant caries-preventive benefit of CWF for U.S. children. The benefit is most pronounced in primary teeth.

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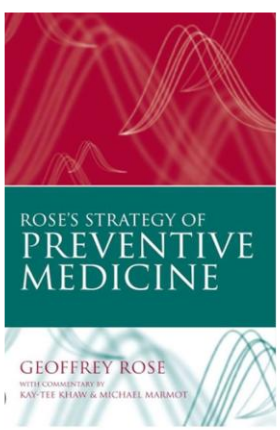

"People can buy toothpaste with or without added fluoride, but if fluoride is added to the drinking water, they can hardly avoid imbibing it.
We should expect a higher level of scientific evidence and popular acceptability for measures such as water fluoridation which are imposed and not chosen by the recipients."

Geoffrey Rose, pp. 148