The Academy *of* Medical Sciences

Evidence synthesis report on the optimal concentration of water fluoridation in the UK

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Executive summary

The Chief Medical Officer (CMO) in England requested that the Academy of Medical Sciences synthesise the evidence to support government policy on an optimal concentration of water fluoridation in the UK. This report aims to summarise the most relevant contemporary evidence on water fluoridation in the UK and internationally.

Oral health in the UK has improved over recent decades due to:

- **increased fluoride exposure**
- **better dental hygiene**

24%
of 5-year-olds still experience tooth decay

Oral health in the UK has improved significantly over recent decades, with significant reductions in tooth decay among children and in tooth loss among adults, due to increased fluoride exposure and better dental hygiene.[1] However, caries are still prevalent, with 31% of adults and 23.7% of 5-year-olds experiencing tooth decay.[2,3] Inequalities also remain, with more deprived communities experiencing poorer oral health outcomes.[4] This report focuses specifically on the benefits, harms, and uncertainties of water fluoridation in relation to oral health outcomes and does not assess other influential factors, such as the introduction of fluoridated toothpaste and changes in dental behaviours. When deciding the target concentration of water fluoridation, there will be a trade-off between maximising the oral health benefits and minimising the increased risk of potential side effects. Cost-effectiveness and public perception must also be considered.

Key findings:

- In both children and adults, evidence indicates that water fluoridation at optimal concentration (between 0.7 and 1.2 mg/L) has a beneficial effect on reducing dental caries, as measured by the number of decayed, missing, or filled teeth (dmft for primary teeth and DMFT for permanent teeth).[5]
- In children, evidence indicates that water fluoridation at optimal concentration has a beneficial effect on reducing the incidence of admissions for decay-related dental extractions.[6]
- In adults, evidence indicates that water fluoridation at optimal concentration has a beneficial effect on reducing the number of invasive dental treatments (fillings and extractions).[7]
- In children, the evidence is unclear on whether water fluoridation narrows dental inequalities. In 3-year-olds, evidence shows no consistent effect across deprivation quintiles. In 5-year-olds, evidence indicates that increased fluoride concentration lowers the prevalence of dental caries across all deprivation quintiles.[8]
- In adults, the evidence on whether water fluoridation narrows dental inequalities is also unclear. Across all deprivation deciles, optimal water fluoridation reduces the predicted number of invasive dental treatments when compared to suboptimal fluoride concentrations, with the

greatest reduction appearing in the most deprived decile. For DMFT, differences between optimal and suboptimal water fluoride concentrations were inconsistent across deprivation deciles.[9]

- Evidence indicates that higher water fluoride exposure is associated with a higher prevalence of dental fluorosis.[10] At the concentrations discussed in this report, this is normally a cosmetic problem and is often reported as an 'unwanted effect' rather than 'harm' or 'adverse effect'. Development of fluorosis can only occur when fluoride is present during tooth development.
- At suboptimal and optimal water fluoride concentrations (<1.2 mg/L) there is no evidence of an effect on neurodevelopment or cognition, as measured by intelligence quotient (IQ).[11,12,13,14,15] Some available evidence suggests that fluoride concentrations of >1.5 mg/L may have a detrimental effect on IQ, and that this relationship is dose-dependent.[16,17,18,19,20] Much of the evidence base for this outcome is contested and still under debate.
- Other potential harms that have been linked to water fluoridation include increased risks of being born with Down's syndrome, having kidney stones, hip fractures, and bladder or bone cancer (osteosarcoma). At concentrations up to 1 mg/L, there is no evidence of an association between exposure to fluoridated water and these potential harms.[21] Many of these harms are age-associated and have not explicitly been investigated in children, therefore, most of the evidence comes from adults, or age-brackets spanning both children and adults.
- The Cochrane Oral Health group is undertaking a review of harms related to water fluoridation, with preliminary findings consistent with the findings of this evidence synthesis. The review is expected to be published in early 2026.
- There have been several analyses of cost-effectiveness, with the overall message that water fluoridation schemes are cost-effective or net beneficial compared to not fluoridating. The extent to which schemes are cost-effective depends on the magnitude of treatment effect size used in the underlying economic models. Older studies with larger effect sizes lead to definitive conclusions of cost-effectiveness. Using more contemporary evidence, water fluoridation is still cost-effective but should be considered within the context that the scheme is being implemented, for example, the population size and oral health status of the population. The cost of setting up schemes should also be considered. There is limited evidence comparing water fluoridation to other public health measures.
- Public support for water fluoridation based on preventing tooth decay has been consistently high across regions in the UK over the last 15 years. In several public surveys approximately two-thirds of respondents favoured adding fluoride to water.
- The body of evidence used in this evidence synthesis varies in quality; it is observational and subject to biases. Where possible, we have cited peer-reviewed literature. Most evidence relates to children and there are limited studies investigating the effects on adults. The evidence base for water fluoridation can broadly be divided into two key periods: before and after the widespread adoption of fluoridated toothpaste in the 1970s. To ensure this synthesis reflects current public health contexts, we have prioritised contemporary evidence from the post-fluoride toothpaste era.

Context

Background to this report

International and national agencies and dental associations across the world support the safety and effectiveness of water fluoridation in preventing dental decay. However, some experts have raised concerns about the strength of the scientific evidence supporting water fluoridation as a clinically effective and cost-effective public health measure. The Chief Medical Officer (CMO) in England requested that the Academy of Medical Sciences synthesise the evidence to support government policy on an optimal concentration of water fluoridation in the UK.

This report aims to summarise the most relevant evidence on water fluoridation in the UK and internationally, outlining the key areas relevant to UK policy. The report contains evidence related to outcomes including the benefits, harms and uncertainties of water fluoridation, with a focus on the effects on oral health. This report did not assess the evidence on other factors improving oral health, such as the introduction of fluoridated toothpaste, since these were out of scope. However, these factors should be acknowledged alongside the evidence presented in the report – Box 1 articulates these factors and how they may contribute to the dialogue surrounding water fluoridation.

The report has been developed with oversight from a steering group of experts from across the Academy's Fellowship and beyond. The group was chaired by Professor Caroline Sabin FMedSci, Professor of Medical Statistics & Epidemiology, Director NIHR HPRU in Blood Borne and Sexually Transmitted Infections at UCL, and other members included experts in oral health, dentistry, public health, toxicology and economics.

The Academy is pleased to have collaborated closely with Cochrane Oral Health during the development of this report and is grateful for their support in providing evidence.

Water fluoridation in the UK

The UK Government has acknowledged oral health as a key area for action in the 2025 10 Year Health Plan for England.[22] In 2022, measures in the Health and Care Act 2022 gave the Secretary of State for Health and Social Care the power to introduce, vary or terminate water fluoridation schemes in England. Previously, this was the responsibility of local authorities. It should be noted that there are currently no water fluoridation schemes in Scotland, Wales or Northern Ireland.

In England, the target concentration of water fluoridation is one milligram per litre of water (1 mg/L) with a maximum legal concentration of 1.5 mg/L.[23] This is in line with the World Health Organization's recommended maximum concentration of 1.5 mg/L,[24] but above that of some other nations such as Ireland (0.6–0.8 mg/L),[25] the USA (0.7 mg/L),[26] and Canada (0.7 mg/L with a maximum acceptable concentration of 1.5 mg/L).[27] England's target concentration is generally in line with the range for Australia (0.6–1.1 mg/L).[28]

Just over 6.1 million people in the UK receive fluoridated water, whether naturally occurring or added. The number of people whose water supplies contain naturally occurring fluoride (typically 0.5–0.9 mg/L) is estimated to be around 330,000.[29] Around 5.8 million people in England are supplied with artificially fluoridated water, because the naturally occurring fluoride is below target concentrations.

Parts of the country with fluoridation schemes include parts of Cumbria, Cheshire, Tyneside, Northumbria, Durham, Humberside, Lincolnshire, Nottinghamshire, Derbyshire, the West Midlands and Bedfordshire.[30] The water fluoridation programme is expanding to the North East of England from 2028 and is expected to reach an additional 1.6 million people by 2030 – bringing the total count of people receiving community fluoridated water to almost 8 million – approximately 12% of the total population of the UK.[31]

Fluoridation of water in some areas of England is technically challenging due to complex water supply networks, leading to variability in fluoride concentrations, and, at times, suboptimal fluoridation. The evidence in this report should be taken within the context of this variation in concentration across geographic areas and time frames.[32] It should also be acknowledged that such variability may influence decision-making by individuals and dental professionals regarding oral health behaviours and interventions.

Box 1: Wider behavioural and environmental factors improving oral health

Oral health in the UK has significantly improved in the past few decades, with the proportion of 5-year olds with obvious tooth decay decreasing from 47% in 1983 to 23% in 2020.[33] For adults, the proportion who were edentate fell from 37% in 1968 to 6% in 2009.[34] There are several reasons for the improvement in oral health, including the increased use of fluoride. Despite these improvements, inequalities in dental health remain, with those in more deprived areas experiencing worse oral health outcomes.[35]

This report focuses on the fluoridation of water, but it is important to acknowledge the wider changes to policy and behaviours that impact the concentrations of fluoride ingested by people in England. Fluoride toothpaste was widely adopted in the UK in the 1970s and along with other factors, such as dietary changes and improved toothbrushing habits, contributed to significant improvements to oral health. Other interventions such as supervised toothbrushing programmes, dentistry innovations (for example, fluoride varnish) and regular dental visits have resulted in a less pronounced positive effect of water fluoridation in improving oral health.[36]

Evidence on water fluoridation outcomes

When deciding the target concentration for water fluoridation, there will be a trade-off between maximising the oral health benefits and minimising the increased risk of potential side effects. The outcomes of water fluoridation at different concentrations for children and adults are **summarised in Tables 1 and 2**, respectively. These tables provide a snapshot of the evidence and are not intended to represent a dose–response relationship between water fluoride concentration and outcomes. A table of evidence providing further detail on the evidence can be found in Annexe 1.

The body of evidence used in this evidence synthesis varies in quality; it is mostly observational and subject to biases. Where possible, we have cited peer-reviewed literature. The Cochrane Oral Health reviews have been conducted to a high standard, but it must be noted that the underlying evidence base is of low to moderate quality and subject to biases, and it includes some studies with naturally high water fluoridation concentrations, which exceed the WHO limit of 1.5 mg/L. Although the health monitoring reports are not peer-reviewed, they are used widely by policy-makers and contain large population data for England, and have been included. For some concentrations of water fluoride there are limited published data on specific outcomes and these gaps in the literature have been highlighted.

Beneficial outcomes

Dental caries

In children

Snapshot

Evidence indicates that water fluoridation has a beneficial effect on reducing dental caries, as measured by the number of decayed, missing, or filled teeth (dmft for primary teeth and DMFT for permanent teeth).[37] Children exposed to optimal fluoride concentrations in drinking water (0.7 to <1.2 mg/L) show greater reductions in mean dmft (0.24 fewer) and DMFT (0.27 fewer) over time compared with children exposed to non- or low-fluoride concentrations (<0.1 to <0.4 mg/L).[38] No consistent dose–response relationship is observed for mean dmft or DMFT across fluoride concentrations at a single time point, giving unclear effects for suboptimal fluoride concentrations (0.4 to <0.7 mg/L). The lowest mean values for caries severity scores are reported at optimal fluoride concentrations.[39]

Further detail

The Cochrane review provides a systematic review of mostly repeated cross-sectional studies looking at the association of community water fluoridation initiation or cessation with the prevention of dental caries.[40] Before the widespread use of fluoridated toothpaste in 1975, studies showed that water fluoridation led to a substantial reduction in dmft (mean difference of 2.10 teeth) compared to no fluoridation. Studies conducted after 1975 suggest a smaller, yet still positive effect, with a mean difference of 0.24 (around a quarter of a tooth) although confidence intervals (CIs) span values showing both potential benefit and no benefit.[41] Pre-1975 data showed a greater reduction in DMFT with water fluoridation (mean difference of 1.00). Post-1975 studies also suggest a modest reduction in DMFT (mean difference of 0.27), though the evidence is less certain, with CIs consistent with both benefit and no benefit, and one study favouring the non-fluoridated group.[42] The review also showed a positive change in the proportion of study participants who were caries-free, both with primary (a 4% increase in the proportion) and permanent dentition (an increase of 3%). These indicate small but important effects at the population level, although the CIs span values consistent with both potential benefit and no benefit.[43]

One study in the review conducted in Canada looked at the effects of cessation of water fluoridation schemes.[44] This study reported on the number of decayed missing or filled surfaces in permanent teeth (DMFS). Overall, there was no difference in the number of new dental caries between the group that stopped community water fluoridation and the group that continued. However, there were baseline imbalances in DMFS between the groups, so the results should be interpreted with caution. The study was conducted in an affluent area, with low prevalence of dental caries, so the results are not widely applicable. The 2024 Cochrane review concluded that there was insufficient evidence to determine the effect of cessation of water fluoridation schemes on dental caries.

The 2022 health monitoring report for England measured mean dmft at a single timepoint. There was no consistent dose–response relationship across the fluoride concentrations, making the effect unclear at no/low fluoride (<0.1 to 0.4 mg/L) and suboptimal (0.4–0.7 mg/L) fluoride concentrations. However, the lowest mean severity score was seen at optimal fluoride concentrations of 0.7–1.2 mg/L. The report showed that prevalence of dmft in 3-year-olds was 12.36% in areas where water fluoride concentration was less than 0.1 mg/L, compared to 8.03% in areas where water fluoride concentration was greater than 0.7 mg/L.[45] For 5-year-olds, the picture was similar, with the prevalence of caries being 25.16% in areas with the lowest fluoride concentration and 20.49% in the areas with the highest fluoride concentration.

Further evidence obtained from an initiation study in Queensland, Australia is being analysed by the Cochrane Oral Health group. The preliminary findings of this analysis suggest that while contributing valuable contemporary evidence, the overall interpretation of the Cochrane 2024 review will not substantially change.

In adults

Snapshot

Evidence indicates that water fluoridation has a beneficial effect on reducing dental caries, as measured by the number of decayed, missing, or filled teeth (DMFT). Adults exposed to optimal fluoride concentrations in drinking water (0.7 to <1.2 mg/L) show a 2% lower mean DMFT compared to adults exposed to suboptimal fluoride concentrations (0.1 to <0.7 mg/L).[46]

Further detail

The LOTUS study is the only contemporary study providing dental data on adults. Its limitations should be noted as it is a retrospective cohort study using routine data from NHS dental claims forms from 2010 to 2020.[47] It took the initial data from individuals with a minimum age of 12 years who were followed up over a 10-year period. Results showed that the mean DMFT count was 2% lower in the group with water fluoride concentrations of >0.7 mg/L. No upper limit to water fluoride concentration was given in the study.

Invasive dental treatment

In children

Snapshot

Evidence indicates that water fluoridation has a beneficial effect on reducing the incidence of admissions for decay-related dental extractions. Children exposed to optimal and above-optimal fluoride concentrations of drinking water show a 60% reduction in the incidence of admissions for dental extractions compared to children exposed to non-fluoride concentrations (<0.1 mg/L). Children exposed to low- and suboptimal fluoride concentrations in drinking water also showed a reduction in the incidence of admissions for dental extractions of 38%–44%; however, dose–response relationships were inconsistent across fluoride concentrations.[48]

Further detail

The 2022 health monitoring report for England showed the crude incidence rate ratio of hospital admissions for dental extraction in children and young people (0–19-year-olds) was 0.4, making it 60% lower in areas with water fluoride concentrations ranging from 0.7 to 1.5 mg/L than in areas where concentrations were less than 0.1 mg/L. Even at suboptimal water fluoride concentrations (vs no/low fluoride), the rate of admissions was 40% lower.[49]

In areas that had a community water fluoridation scheme, incidence of extraction-related hospital admissions was 47% lower than in areas with no scheme and low fluoride. This was the case across all deprivation levels and when adjusted for age and sex. Residents of areas in the most deprived quintile exposed to a community water fluoridation scheme had a 56% lower admission rate than those not exposed to a scheme.[50]

Limitations of the health monitoring reports should be noted as the report is not peer-reviewed, and it is assumed that water fluoride concentrations remained stable since 2015, which does not factor in variations or the potential for misclassification of geographical areas. Another potentially biasing factor is that in some areas, tooth extractions are offered by specialised community dentists rather than in hospitals and so may not be captured in the 2022 health monitoring report for England.

In adults

Evidence from the LOTUS study indicates a beneficial effect of optimal water fluoridation in reducing invasive dental treatments, including restorations (fillings) and tooth extractions. At optimal fluoride concentrations (≥0.7 mg/L), the average number of invasive treatments per person was 5.443 compared to 5.616 in the suboptimal group (<0.7 mg/L), representing a 3% reduction. The greatest benefit was observed in the most deprived decile.[51]

Dental inequalities

In children

Snapshot

The evidence is unclear on whether water fluoridation narrows dental inequalities in children. In 3-year-olds, evidence shows no consistent effect across quintiles. However, children in the least deprived quintile have 86% reduced odds of experiencing dental caries if they are exposed to optimal fluoride concentrations (0.7–1.2 mg/L) compared to matched children exposed to no/low fluoride concentrations (<0.1 mg/L). In the most deprived quintile, the same comparison demonstrated a reduction in the odds of experiencing dental caries by only 36%. Across other deprivation quintiles, optimal water fluoridation had no significant effect. In contrast, in 5-year-olds, evidence indicates that increased fluoride concentration lowers the prevalence of dental caries across all deprivation quintiles but does not necessarily reduce inequalities.[52]

Further detail

The 2024 Cochrane review concluded that there was insufficient evidence to determine whether water fluoridation results in a change in disparities in caries according to socioeconomic status.[53]

As highlighted in the section on dental caries, the 2022 health monitoring report for England showed that 3-year-olds were more likely to have tooth decay in areas with very low fluoride concentrations (<0.1 mg/L) compared to areas with higher concentrations (>0.7 mg/L). When stratified by Indices of Multiple Deprivation (IMD) quintiles, exposure to water fluoride concentration levels of 0.7 mg/L and above was associated with lower odds of dmft across deprivation levels. For water fluoridation concentrations lower than 0.7 mg/L (specifically 0.1 to <0.2 mg/L, 0.2 to <0.4 mg/L, and 0.4 to <0.7 mg/L) the associations were less certain, with wider CIs that crossed the null value (odds ratio, OR = 1), indicating that these findings were not statistically significant. For mean dental caries severity score, areas with the lowest fluoride concentration had a score of 0.34, while the highest concentration areas had a lower score of 0.21. The crude odds of 3-year-olds being in a higher severity category were generally lower in areas with higher concentrations of fluoride than in those with the lowest (P =0.01). For example, 3-year-olds in an area with >0.7mg/L may have 33% reduced odds compared to 3-year-olds in an area with a fluoride concentration of <0.1 mg/L. However, the CI was wide and crossed the null value (0.39–1.14).

For 5-year-olds, the prevalence of caries in areas with the lowest fluoride concentration was higher than in the areas with the highest fluoride concentration. In the most deprived quintile, children had lower odds of dmft at all water fluoride concentrations when compared to areas with <0.1 mg/L fluoride. Across all levels of deprivation, the biggest reduction in dmft was seen where fluoride concentration was at least 0.7 mg/L. The average dmft score decreased as fluoride concentration increased. However, this trend was less consistent in areas with fluoride concentrations between 0.4 and 0.7 mg/L. The link between fluoride and decay severity also varied by deprivation level, with children in more deprived areas generally benefiting more. Across all deprivation groups, higher fluoride concentrations were associated with lower odds of having the most severe decay.

The results from the health monitoring reports are supported by findings from a systematic review commissioned by the New Zealand Ministry of Health.[54] The review narratively synthesised evidence from eight studies from Australia, Canada, Israel, New Zealand, the USA and the UK. Seven found that the presence of a community water fluoridation scheme resulted in improved oral health outcomes for children from ethnic minorities or low-income, uninsured households, compared to their counterparts in non-fluoridated areas. However, these seven studies were mostly cross-sectional, not capturing change over time or retrospective data. The one study in this review that showed insufficient evidence that exposure to fluoridated water reduced inequalities in children was a prospective study from England (the CATFISH study).[55]

In adults

Snapshot

Evidence indicates that water fluoridation has an unclear effect on narrowing dental inequalities in adults. Across all deprivation deciles, optimal water fluoridation (>0.7 mg/L) reduces the predicted number of invasive dental treatments when compared to suboptimal fluoride concentrations (0.1 to <0.7 mg/L), with the greatest reduction appearing in the most deprived decile (0.34 fewer invasive treatments). For DMFT, differences between optimal and suboptimal water fluoride concentrations were inconsistent across deprivation deciles.[56]

Further detail

As outlined in the sections above, the LOTUS study found the greatest reduction in invasive dental treatments in the most deprived decile when comparing fluoride levels above and below 0.7 mg/L. When looking at the average DMFT scores, only the two most deprived groups had lower values in areas with water fluoride concentrations of more than 0.7 mg/L.

Local level evidence has been provided by the Consultant in Dental Public Health North East of England on Mean Dental Decay, comparing Teesside (where water was not fluoridated) and Hartlepool (where water is naturally fluoridated). The data were collected in the National Dental Epidemiology Programme oral health survey 2017,[57] and showed that across areas with similar IMD deprivation rankings, mean dental decay was around 55% lower in Hartlepool than in Teesside for the most deprived areas and around 23% lower for the least deprived areas.

Potential harms

Dental fluorosis of aesthetic concern

Dental fluorosis in adult teeth

During tooth formation, enamel crystals form within a protein scaffold. Once embryonic crystals have formed, the scaffold is removed, replaced by water, and the crystals grow into this water-filled space until they touch each other. This produces an extremely hard tissue suitable for cutting and grinding food. Fluoride inhibits this crystal growth, resulting in dental fluorosis – visible white spots or patches on the tooth surface. This is normally a cosmetic problem and is often reported as an 'unwanted effect' rather than a 'harm' or an 'adverse effect'. Development of fluorosis can only occur when fluoride is present during tooth development. Fluorosis cannot occur on erupted teeth due to the presence of topical dietary fluoride. Therefore, only outcomes for children are reported.

In children

Snapshot

Evidence indicates a detrimental outcome as higher prevalence of dental fluorosis is associated with increased fluoride exposure. At suboptimal water fluoride concentrations (0.4–0.7 mg/L), the percentage of participants with fluorosis is 10%–12% compared to ≥ 18% at water fluoride concentrations above optimal (1.2–1.5 mg/L).[58]

Further detail

The 2015 Cochrane review provides a systematic review of observational studies.[59] The search was not updated in the 2024 Cochrane review but was published. The analysis shows a positive linear relationship. For every 1 mg/L increase in water fluoride concentration, the odds of dental fluorosis of aesthetic concerns may increase by a factor of 2.9. For water fluoride concentrations of 0.4 mg/L, approximately 10% of people (95% CI: 6%–15%) may have fluorosis that causes them to be concerned about the appearance of their teeth. At 0.7 mg/L, this increases to approximately 12% of people (95% CI: 8%–17%). At concentrations of 1.0 mg/L, this increases to 15% of people, and at concentrations of 2.0 mg/L, this continues to increase to around 31% of people.

The 2018 health monitoring report for England includes a study by Pretty *et al*. looking at fluorosis in 11–14-year-olds.[60] Dental fluorosis was measured using the Thylstrup and Fejerskov (TF) index, and images of participants' teeth were scored by a dental examiner who did not know where they lived. For fluorosis of aesthetic concern (TF score above 3), prevalence was 10.3% in fluoridated areas (Birmingham and Newcastle, where the target concentration is 1 mg/L) and 2.2% in non-fluoridated areas (Liverpool and Manchester). However, there was no difference between fluoridated and non-fluoridated areas in the proportion of children who self-reported concerns about the appearance of their teeth. Like the studies included in the 2015 Cochrane review, this was a single time point observational study that did not follow the children up over time.

Neurodevelopment and IQ

The developing brain in foetuses and young children is more vulnerable to the effects of chemical toxins than the mature brain, making the quality of water consumed during pregnancy and early childhood particularly important. The most critical window of susceptibility spans from foetal development through infancy and into early childhood. Therefore, outcomes related to neurodevelopment, cognition and IQ are reported only for children and adolescents.[61] It should be noted that not all studies use IQ as the outcome of interest. Other tests of cognitive ability such as the *Wechsler Intelligence Scale* and *British Ability Scales* are also used to determine cognitive abilities and are not always comparable with each other.

In children

Snapshot

At suboptimal and optimal water fluoride concentrations (<1.2 mg/L) there is no evidence of an effect on neurodevelopment or cognition, as measured by IQ.[62,63,64,65,66] Some available evidence suggests that fluoride concentrations of >1.5 mg/L may have a detrimental effect on IQ, and that this relationship is dose-dependent.[67,68,69,70,71] Much of the evidence base is contested and still under debate.

The Cochrane Oral Health group is undertaking a review of harms related to water fluoridation, with preliminary findings consistent with the findings of this evidence synthesis. The review is expected to be published in early 2026 and review considered evidence from several sources, including Taylor *et al*., 2025; Braithwaite *et al*., 2024; Veneri *et al*., 2023; Kumar *et al*., 2023; Lambe *et al*., 2021; Duan *et al*., 2018 and the Australian National Health and Medical Research Council (NHMRC) statement from 2017. Some of these studies are outlined below in further detail.

Further detail

A publication by the US National Toxicology Programme (NTP) and the associated meta-analysis by Taylor *et al*., used a systematic review of 74 studies of varying weak to moderate quality, looking at the association between fluoride exposure and children's IQ scores.[72] Overall, the analysis showed an inverse association between fluoride exposure and children's IQ scores. Every 1 mg/L increase in urinary fluoride was associated with a statistically significant decrease of 1.63 IQ points. When the analysis was restricted to studies evaluating fluoride concentrations of less than 1.5 mg/L, there was no evidence of an association between water fluoride concentration and IQ. There was a dose–response association in studies with less than 4 mg/L and less than 2 mg/L. However, there are numerous limitations to this review. Most studies included are from countries with naturally high fluoride concentrations that are more than double the legal limits of artificial community water fluoridation programmes. Also, the review included many studies that did not account for socioeconomic factors known to influence childhood development and educational attainment. An OSF preprint by Jane *et al*. (2025) has further critiqued the methodological and statistical flaws in this review.[73] The preprint also found problems with the review sources, which included non-MEDLINE-indexed publications with anti-fluoridation editorial stances.

Another systematic review by Veneri *et al*. (2023) also looked at the association between water fluoride and cognitive neurodevelopment, by examining the dose–response relationship across 30 studies.[74] The linear regression analysis indicated that for every 1 mg/L increase in water fluoride, IQ scores decreased by 3.05 points. However, the dose–response curve showed that for up to 1 mg/L there is no evidence of an association between concentration level and IQ. It is only at concentrations above 1 mg/L that increases in water fluoride concentration were associated with a lower IQ. The downward curve becomes considerably steeper at fluoride concentrations over 2 mg/L, although the wide CIs indicate a high degree of imprecision in these estimates. Similar to the NTP review, many of the studies included in this review did not report on their management of relevant confounding variables that would also influence children's IQ. This review mostly includes studies from countries with naturally high water fluoride concentrations such as China, India and Iran. Therefore, the results of both the Veneri *et al*. review and the NTP review have limited applicability to community water fluoridation programmes and should be interpreted with caution.

There is a small selection of moderate- to high-quality prospective birth cohort studies in countries with community water fluoridation programmes such as Canada (0.59 mg/L), Spain (0.8 mg/L), Australia (0.7–1.1 mg/L) and New Zealand (0.7–1.0 mg/L). There is also a prospective study in Denmark that does not have a community water fluoridation programme (0.3 mg/L). Sample size in these cohorts ranged from 65 to 922 participants. The majority have been narratively summarised in a review from the European Food Safety Authority (EFSA).[75] Apart from the Canadian study, no other study reported an association between consumption of fluoridated water during pregnancy and negative neurodevelopment in their children. The results from the Canadian cohort analysis indicated that each 1 mg/day increase in maternal fluoride intake from drinking tap water during pregnancy was associated with a 3.7-point lower IQ in children aged 3–4 years. While this study was rated as being at low risk of bias by the EFSA review authors in all areas apart from attrition, it has received methodological critiques from authors stating that the study's IQ measurements are invalid and cannot support the claim that water fluoridation is associated with IQ decline in children.[76]

In the UK, a study by Lee *et al*. (2025) investigated exposure during pregnancy to fluoride in drinking water and child cognitive ability outcomes in the Millenium Cohort Study (the British Ability Scales). The relationship between fluoride exposure via drinking water (between 0.01 and 1 mg/L), and six cognitive ability outcomes at age 5 years and age 7 years were examined, adjusting for child and maternal characteristics, and other socioeconomic factors. They did not find evidence of an association between drinking-water fluoride concentration and any of the cognitive ability scales.The study is expected to be published in early 2026.

Other non-dental harms

In children and adults

Snapshot

Other potential harms that have been linked to water fluoridation include increased risks of being born with Down's syndrome, having kidney stones, hip fractures, and bladder or bone cancer (osteosarcoma). Up to concentrations of 1 mg/L, evidence suggests that there is no association between exposure to fluoridated water and these potential harms.[77] Many of these harms are age-associated and have not explicitly been investigated in children, therefore, most of the evidence comes from adults, or age-brackets spanning both children and adults.

Further detail

The Cochrane Oral Health group is undertaking a review of harms related to water fluoridation, with preliminary findings consistent with the findings of this evidence synthesis. The review is expected to be published in early 2026. It identified 21 reviews, with seven providing evidence relevant to community water fluoridation programmes (Hajduga *et al*., 2025; Iamandi *et al*., 2024; Wasick *et al*., 2024; Lambe *et al*., 2021; Whiting *et al*., 2001; Jones *et al*., 1999; NHMRC, 2017). Of the reviews providing evidence for fluoride concentrations close to optimal, there is no consistent evidence of an association between optimal water fluoridation and non-dental adverse health outcomes. These harms include: attention-deficit hyperactivity disorder (ADHD); cognitive decline (including Alzheimer's); thyroid function and thyroid-stimulating hormone (TSH) concentrations; bone cancer, Ewing's sarcoma, total cancer incidence; fracture risk and bone health; Down's syndrome, trisomies, neural tube defects and clefts; stillbirths, sudden infant death syndrome (SIDS); kidney stones and kidney disease; musculoskeletal pain; gastric discomfort and headache. There is some evidence of an increase in certain harms above 1.5 mg/L. It should be noted that the evidence included in all the systematic reviews is of variable quality.

The 2018 and 2022 health monitoring reports for England looked at harms including risks of being born with Down's syndrome, having kidney stones, hip fractures, and bladder or bone cancer (osteosarcoma) by analysing hospital admission records, rare disease registries and cancer registries.[78] Prevalence of these conditions fluctuated inconsistently across water fluoride concentrations, indicating that there is no trend. Results from the 2018 health monitoring report for England indicate that when factors such as age, gender and deprivation level are accounted for, prevalence of these conditions does not increase as water fluoride concentrations increase. While there was some evidence in the 2022 health monitoring report's age-stratified analysis to suggest that higher fluoride may have a protective effect in the youngest age group (0–49 years), there was no consistent trend between water fluoride concentration and hip fracture admissions in the other age categories.

Table 1: Summary of evidence on the outcomes for children at different water fluoride concentrations after 1975

Outcome		Suboptimal 0.4 to <0.7 mg/L	Optimal 0.7 to <1.2 mg/L	Above optimal 1.2–1.5 mg/L
Dental caries (dmft)	Summary of effect	Effect unclear*	Beneficial	Effect unclear*
	Outcome measured	Mean dmft at single timepoint	Mean difference in reduction in dmft over time between optimal and no/low fluoride	Mean dmft at single timepoint
	Effect size	0.35	0.24**	0.21 (covers optimal and above-optimal ranges)
	Reference	Health Monitoring Report, 2022	Cochrane review, 2024	Health monitoring report, 2022
Hospital-related tooth extraction	Summary of effect	Effect unclear	Beneficial	
	Outcome measured	Incidence rate ratio of admissions to hospital compared to no/low fluoride	Incidence rate ratio of admissions to hospital compared to no/low fluoride	
	Effect size	0.56	0.4	
	Reference	Health Monitoring Report, 2022	Health Monitoring Report, 2022	
Dental inequalities	Summary of effect	Effect unclear	Beneficial	
	Outcome	Odds of experiencing dmft compared to no/low fluoride	Odds of experiencing dmft compared to no/low fluoride	
	Effect size	Most deprived: 0.85 (3-year-olds) 0.8 (5-year-olds) Least deprived: 1.26 (3-year-olds) 0.87 (5-year-olds)	Most deprived: 0.64 (3-year-olds) 0.61 (5-year-olds) Least deprived: 0.14 (3-year-olds) 0.74 (5-year-olds)	
	Reference	Health Monitoring Report, 2022	Health Monitoring Report, 2022	
Dental fluorosis of aesthetic concern	Summary of effect	Detrimental	Detrimental	Detrimental
	Outcome	Percentage of participants	Percentage of participants	Percentage of participants
	Effect size	10%–12%	12%–15%	18%
	Reference	Cochrane Review, 2024	Cochrane Review, 2024	Cochrane Review, 2024
Neurodevelopment and IQ	Summary of effect	No effect		
	Reference	Cochrane Harms Review, 2025 (unpublished)		
Other non-dental harms***	Summary of effect	No effect		
	Reference	Health Monitoring Report, 2018; Cochrane Harms Review, 2025 (unpublished)		

Note that this table is a snapshot of the evidence and is **not** intended to represent a dose–response relationship between fluoride concentration and outcomes. The table presents evidence only for fluoridated water at a minimum of concentration of 0.4 mg/L to a maximum of 1.5 mg/L. However, some studies have taken into consideration non-fluoridated water, which may contain concentrations of fluoride outside these ranges.

* Despite no consistent dose–response relationship, the health monitoring report from 2022 does show the lowest mean severity score at optimal water fluoride concentration.

** The evidence reviewed for this report indicates that optimal concentrations of water fluoridation had a greater beneficial effect prior to 1975, with an estimated preservation of two additional healthy teeth per person compared to areas without fluoridation. After 1975, the beneficial effect was of approximately one-quarter of a tooth per person in a healthy state due to optimal fluoridation.

*** Potential non-dental harms investigated in relation to water fluoridation include congenital and developmental conditions (for example, Down's syndrome, neural tube defects, clefts), pregnancy and infant outcomes (stillbirths, SIDS), certain cancers (osteosarcoma, Ewing's sarcoma, bladder cancer), bone health and fracture risk, kidney disease and stones, neurological and cognitive effects (ADHD, Alzheimer's), thyroid function, and other reported symptoms such as musculoskeletal pain, gastric discomfort, and headaches.

Table 2: Summary of evidence on the outcomes for adults at different water fluoride concentrations after 1975

Outcome		Suboptimal <0.1 to <0.7 mg/L	Optimal >0.7 mg/L
Dental caries (dmft)	Summary of effect		Beneficial
	Outcome measured	Mean DMFT	Mean DMFT
	Effect size	13.361	13.149
	Reference	LOTUS, 2024	LOTUS, 2024
Invasive dental treatments (fillings and extractions)	Summary of effect		Beneficial
	Outcome measured	Mean number of invasive dental treatments	Mean number of invasive dental treatments
	Effect size	5.616	5.443
	Reference	LOTUS, 2024	LOTUS, 2024
Dental inequalities	Summary of effect		Effect unclear
	Outcome	Predicted number of invasive dental treatments	Predicted number of invasive dental treatments
	Effect size	Most deprived: 6.324 Least deprived: 4.985	Most deprived: 5.988 Least deprived: 4.867
	Reference	LOTUS, 2024	LOTUS, 2024
Other non-dental harms***	Summary of effect	No effect	
	Reference	Health Monitoring Report, 2018; Cochrane Harms Review, 2025 (unpublished)	

Note that this table is a snapshot of the evidence and is **not** intended to represent a dose–response relationship between fluoride concentration and outcomes. Evidence on adult outcomes at different water fluoride concentrations after 1975 is limited to one study on dental effects. The dental study is non-longitudinal and compared only two concentrations: ‘suboptimal’ (<0.1 to <0.7 mg/L) and ‘optimal’ (>0.7 to <1.3 mg/L). Differences in fluoride ranges between adult and child studies reflect study design, not biological variation.

***Potential non-dental harms investigated in relation to water fluoridation include congenital and developmental conditions (for example, Down’s syndrome, neural tube defects, clefts), pregnancy and infant outcomes (stillbirths, SIDS), certain cancers (osteosarcoma, Ewing’s sarcoma, bladder cancer), bone health and fracture risk, kidney disease and stones, neurological and cognitive effects (ADHD, Alzheimer’s), thyroid function, and other reported symptoms such as musculoskeletal pain, gastric discomfort, and headaches.

Other considerations

Cost-effectiveness

Snapshot

The cost-effectiveness of community water fluoridation should be considered when deciding whether to implement further schemes in the UK. There have been several analyses of cost-effectiveness, with the overall message that water fluoridation schemes are cost-effective or net beneficial compared to not fluoridating. The extent to which schemes are cost-effective depends on the magnitude of treatment effect size used in the underlying economic models. Older studies with larger effect sizes lead to definitive conclusions of cost-effectiveness. Using more contemporary evidence, water fluoridation is also cost-effective but should be considered within the context in which the scheme is being implemented, for example, the population size and oral health status of the population. There is limited evidence comparing water fluoridation to other public health measures.

Further detail

The 2025 FLuOridated WAter: Public Values & Evaluation of Cost-Benefit (FLO-WAVE) study is being finalised and at the time of writing this report has not yet been published. Publication is expected in early 2026. The study aims to conduct a cost–benefit analysis of community water fluoridation that includes relevant long-term costs to the NHS, patients and society. It will look at outcomes and valuations of the impact of water fluoridation on dental decay, modelled over a lifetime horizon, looking at both children and adults. The model is based on the UK population and the key considerations and pieces of evidence used to inform the model include:

- The oral health of all individuals (from Child and Adult Oral Health Surveys).
- The direct cost of implementing water fluoridation schemes.
- The costs of monitoring and maintaining water fluoridation schemes.
- The probability and direct cost of dentist and hospital treatments for dental decay, incorporating both the NHS and patient incurred (co-charge) costs for dental care.
- The indirect costs such as productivity losses, such as missing work due to needing dental treatment (from ONS data).
- General population valuations (willingness to pay) to avoid dental decay.

The preliminary results from the model, based on data reported in the 2015 Cochrane review, show positive incremental net benefit, with average benefits of fluoridation outweighing the costs by £258 per person over a lifetime horizon, leading to a probability of almost 100% that community water fluoridation is net beneficial compared to no fluoridation. Specific analyses, conducted for the North East of England, showed similar results. Using more contemporary evidence within the FLO-WAVE model, based on adaptation of the reported effect sizes from the CATFISH study to fit the FLO-WAVE model structure, community water fluoridation continued to generate positive incremental net benefit, but the magnitude of that benefit was lower when compared with models based on larger effect sizes from earlier studies. Using more contemporary evidence, the certainty of the conclusion of cost-effectiveness depended on the context (for example, the size of the fluoridated population and the underlying oral health of the population). The model has been developed into a tool that allows inputs to be changed to account for different population sizes, oral health status and choices of data sources (either the 2022 CATFISH study or 2015 Cochrane review). Further updates are planned to include the data from the 2024 Cochrane review.[79]

The group also conducted an online and telephone survey to determine how much the public would be willing to pay to avoid dental treatment and if they were in favour of or against community water fluoridation (sample number =811). Preliminary findings of the survey showed that most responders (570) supported community water fluoridation, with only 92 respondents opposing it.

The 2024 Cochrane review had a brief economic commentary alongside its publication, which covered economic evaluations conducted in the USA, the UK, Australia and New Zealand, among others.[80] The commentary states that community water fluoridation schemes appear to be a cost-effective intervention as they are relatively cheap to implement on a per-person level, particularly when delivered at scale to large populations, and have the potential to reduce dental caries and reduce costs due to future cases of dental treatment avoided. However, the cost-effectiveness of community water fluoridation depends on context, such as how many cases of tooth decay it prevents, the underlying risk of decay in the population (with lower cost-effectiveness in low-risk groups), and the size of the population being served (smaller populations tend to be less cost-effective).

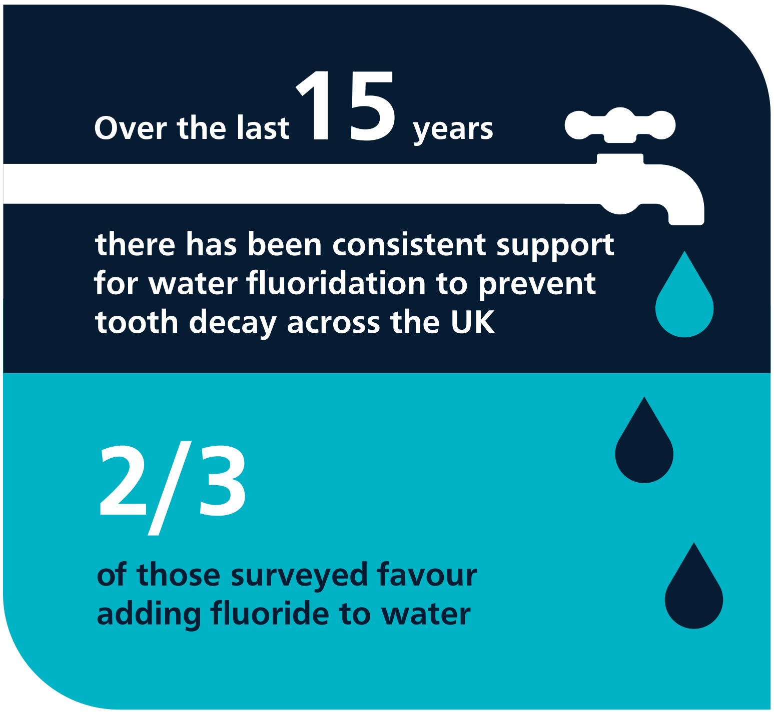
The 2024 LOTUS study estimated a public sector return on investment of £16,884,595 for water fluoridation schemes in England.[81] This was based on a total cost of £46,791,388 between 2010 and 2020, and assuming 62.9% of the fluoridated population visits an NHS dentist at least twice over 10 years, with the cost to prevent one invasive dental treatment at £94.55. It should be noted that the LOTUS study does not include initial set-up costs.

The 2022 CATFISH study cost-effectiveness analysis looked at the reintroduction of community water fluoridation in certain parts of Cumbria.[82] The main findings of the study indicate that average dental treatment costs were lower for children in water-fluoridated areas than for those not in water-fluoridated areas. There were two cohorts studied. The birth cohort (followed from 0 to 5 years old) represented a £21.60 saving overall, and the older cohort (followed from 5 to 11 years old) showed a saving of £64 when considering the cost of water fluoridation at £14.14 per person per year. There was also some indication of higher quality-adjusted life year (QALY) scores in the community water fluoridation group compared to the group without water fluoridation. Given that water fluoridation showed lower costs and QALY scores, it is said to be a dominant intervention over no water fluoridation and represents a strong case for cost-effectiveness. However, the estimated QALY gain is uncertain due to wide CIs. The probability of community water fluoridation being cost-effective in the birth cohort is therefore 77%, and in both cohorts is 62%.

The 2016 York Health Economic Consortium (YHEC) rapid review looked at different interventions for oral health for 0–5-year-olds, including supervised toothbrushing, provision of toothpaste and a brush, home visits from a healthcare worker, fluoride varnish and water fluoridation.[83] The studies with data on water fluoridation both showed cost savings. One study on children up to 5 years old in Alaska showed a cost saving of £3,081 per child per year. This study was deemed to be of moderate quality. The second study on the cost of implementing water fluoridation schemes in New York City estimated net savings of $10,979,753 over 10 years. This study was deemed to be of weak quality due to the lack of information on the study design used to calculate the effect estimate and lack of justifications for the parameters included in the economic model. The evidence from the YHEC review has informed a return-on-investment modelling tool that can be used by local authorities in the UK to determine the cost-effectiveness of different oral health interventions. We are aware that work will shortly commence to update the tool to allow a direct comparison of oral health interventions, scheduled to report in the first half of 2026.

Public opinion

In addition to scientific and cost considerations, public attitudes may influence policymakers' decisions to start, expand or terminate water fluoridation schemes in the UK. Support for water fluoridation based on preventing tooth decay has been consistent across regions in the UK over the least 15 years. In several public surveys, approximately two-thirds of respondents have favoured adding fluoride to water.



Between 2009 and 2010, Ipsos MORI surveyed 3,516 people aged 16 and over in the West Midlands.[84] Only half the sample (51%) thought adding fluoride to the water supply helped reduce tooth decay. However, 67% thought fluoride should be added to tap water if it did reduce tooth decay, while 22% thought it should not be added. For respondents who strongly opposed water fluoridation (6% of the total sample), commonly cited reasons were wanting water to be natural without additives (20% of this subset), wanting a choice (18%), concerns about possible side effects (13%) and taste (9%). Those who were undecided wanted more scientific evidence and more information on the risks and benefits.

In 2019, 761 adults from the North East of England (where an expansion is currently underway) were surveyed.[85] Overall, 16% of respondents opposed water fluoridation, whereas 60% thought fluoride should be added to the water supply if it prevents tooth decay. A third of respondents (37%) had heard about water fluoridation in the last year, mostly from the local news or their dental practice.

Although Scotland does not have a community water fluoridation scheme in place, 410 adults from Glasgow, Edinburgh and Aberdeen were surveyed in 2021.[86] Only 17% correctly knew that their water supply was not artificially fluoridated. The rest of the sample incorrectly thought it was or did not know. Two-thirds (63%) thought that fluoride should be added to the water supply if it prevents tooth decay (28% did not know and 9% opposed).

How other nations approach water fluoridation

England's target fluoride concentration of 1.0 mg/L is below the World Health Organization's recommended maximum concentration of 1.5 mg/L but above that of some other nations such as Ireland (0.6–0.8 mg/L), the USA (0.7 mg/L) and Canada (0.7 mg/L), with a maximum acceptable concentration of 1.5 mg/L. England's target concentration is generally in line with the range for Australia (0.6–1.1 mg/L).

Other nations continue to monitor their water fluoridation concentrations and policies, and in recent years have published reviews. As outlined in the section on the potential harms, EFSA published an updated consumer risk assessment of the fluoride in food and drinking water, including the contribution from other sources of oral exposure.[87] The review concluded that the current limit of 1.5 mg/L may not be sufficiently protective, citing adverse effects on the developing brain. However, it also stated that evidence of such associations below 1.5 mg/L was not sufficiently consistent to draw conclusions for risk assessment.

In 2024, the New Zealand Ministry of Health conducted a review of evidence published since 2021.[88] The review concluded that there are ongoing benefits from community water fluoridation, even when fluoridated toothpaste has become available. The review states that community water fluoridation supports oral health equity by reducing tooth decay more effectively in deprived areas than in less deprived ones. No high-quality evidence published since 2014 has shown that fluoride concentrations used in water fluoridation schemes cause significant harm to health.

In 2023, Health Canada convened an expert panel to review the evidence on water fluoridation for fluorosis and neurodevelopment to provide recommendations.[89] For moderate fluorosis, the panel agreed with the use of a 1% lower-limit benchmark dose of 1.56 mg/L in drinking water as the point of departure for deriving the health-based value. For neurodevelopment, the panel agreed there is not a sufficient basis to recommend a specific point of departure and health-based value for neurocognitive effects.

In 2016, the Australian NHMRC reviewed the scientific research on water fluoridation.[90] The review confirmed that community water fluoridation helps to reduce tooth decay, and that there is no reliable evidence that water fluoridation at current concentrations in Australia causes health problems. The NHMRC published a Public Statement in 2017 outlining recommendations for community water fluoridation, which was guided by the Fluoride Reference Group (a committee of health, dental and other experts).[91]

Conclusions

The evidence base on the outcomes of water fluoridation is of varied quality; it is mostly observational and subject to biases. Most evidence relates to children and there are limited studies investigating the effects on adults.

The findings of this evidence synthesis indicate that the effects of water fluoridation in England are, overall, beneficial to dental health in children and adults at the current target concentration of 1 mg/L. The benefits include reducing dental caries in children and adults and reducing the incidence of admissions for dental extractions in children. However, since the widespread availability of fluoride toothpaste, the beneficial effects on dental health are less. The evidence is unclear on whether water fluoridation narrows dental inequalities. Evidence on the detrimental effects of water fluoridation does not show any effect on neurodevelopment or other non-dental harms.

Overall, water fluoridation schemes are cost-effective but should be considered within the context in which the scheme is being implemented, for example, the population size, and oral health status of the population. There is limited evidence comparing water fluoridation to other public health measures in improving dental health.

Annexe 1: Evidence table

	Non/low fluoridated			Suboptimal	Optimal	Above optimal	Comments
	<0.1 mg/L	**0.1 to <0.2mg/L**	**0.2 to <0.4mg/L**	**0.4 to <0.7 mg/L**	**0.7 to <1.2 mg/L**	**1.2 – 1.5 mg/L**	
CARIES SEVERITY (dmft)							
Cochrane review: Change in mean dmft from baseline to follow-up (time between repeated cross-sectional surveys ranged from 3 to 12 years)	Caries reduced over time in the non/low-fluoridated groups. Mean reduction in dmft ranged from 0.44 to 0.88.			—	Reduction in caries of approximately a quarter of a tooth over and above reductions seen in the non/low-fluoridated group. Mean difference in reduction in dmft: 0.24 (95% CI –0.03 to 0.52)	—	**Favours optimal fluoridation** (note: CI includes both benefit and no benefit)
Health Monitoring Report: Mean dmft at single timepoint (95% CI)	0.34 (0.31 to 0.36)	0.31 (0.29 to 0.34)	0.25 (0.22 to 0.27)	0.35 (0.27 to 0.43)	0.21 (0.17 to 0.25)		**No consistent dose–response relationship across reported fluoride concentrations** but lowest mean severity score seen with optimal fluoride
CARIES SEVERITY (DMFT)							
Cochrane review: Change in mean DMFT from baseline to follow-up (time between repeated cross-sectional surveys ranged from 3 to 12 years)	Caries reduced over time in the non/low-fluoridated groups. Mean reduction in DMFT ranged from 0.27 to 2.83.				Reduction in caries of approximately a quarter of a tooth over and above reductions seen in the non/low-fluoridated group. Mean difference in reduction in DMFT: 0.27 (95% CI –0.11 to 0.66)		**Favours optimal fluoridation** (note: CI includes both benefit and no benefit)

Health Monitoring Report: Mean DMFT at single timepoint (95%CI)	0.88 (0.87 to 0.89)	0.79 (0.78 to 0.80)	0.71 (0.69 to 0.72)	0.77 (0.75 to 0.80)	0.60 (0.59 to 0.62)		**No consistent dose–response relationship across reported fluoride concentrations** but lowest mean severity score seen with optimal fluoride
EXPERIENCE OF CARIES							
Cochrane review: Proportion of caries-free children with primary dentition	The proportion of caries-free children in the non/low-fluoridated groups reduced over time, ranging from a reduction of 11% to 19%.			-	There was a reduction of four percentage points in the proportion of caries-free children with primary dentition over and above reductions seen in the non/low-fluoridated group. Mean difference –0.04 (95% CI –0.09 to 0.01)		**Favours optimal fluoridation** (note: CI includes both benefit and no benefit)
Cochrane review: Proportion of caries-free children with permanent dentition	The proportion of caries-free children in the non/low-fluoridated groups reduced over time, ranging from a reduction of 5% to 78%.				There was a reduction of three percentage points in the proportion of caries-free children with permanent dentition over and above reductions seen in the non/low-fluoridated group. Mean difference –0.03 (–0.07 to 0.01)		**Favours optimal fluoridation** (note: CI includes both benefit and no benefit)
Health Monitoring Report: Crude OR of experiencing carious teeth in 3-year-olds	Reference group	18% lower odds of experiencing dmft in 3-year-olds compared to less than 0.1 mg/L	38% lower odds of experiencing dmft in 3-year-olds compared to less than 0.1 mg/L	26% lower odds of experiencing dmft in 3-year-olds compared to less than 0.1 mg/L Note: CI includes both benefit and no benefit	38% lower odds of experiencing dmft in 3-year-olds compared to less than 0.1 mg/L Note: CI includes both benefit and no benefit		**No consistent effect across reported fluoride concentrations**

Crude OR of experiencing carious teeth in 5-year-olds	Reference group	12% lower odds of experiencing dmft in 5-year-olds compared to less than 0.1 mg/L	19% lower odds of experiencing dmft in 5-year-olds compared to less than 0.1 mg/L	6% lower odds of experiencing dmft in 5-year-olds compared to less than 0.1 mg/L	23% lower odds of experiencing dmft in 5-year-olds compared to less than 0.1 mg/L	
INVASIVE DENTAL TREATMENTS/GAs						
Health Monitoring Report: Crude incidence rate ratio (IRR) of admissions for dental extractions for 0–19-year-olds IRR (95% CI)	Reference group	0.62 (0.51 to 0.76) Note: CI includes both benefit and no benefit	0.41 (0.31 to 0.53)	0.56 (0.40 to 0.77) Note: CI includes both benefit and no benefit	0.40 (0.23 to 0.69)	**No consistent effect across reported fluoride concentrations**
DENTAL INEQUALITIES						
Health Monitoring Report: OR for experiencing dental caries in 3-year-olds	Reference IMD 5 (least deprived)	0.91 (0.62 to 1.32)	0.75 (0.46 to 1.23)	1.26 (0.47 to 3.35)	0.14 (0.02 to 0.79)	**No consistent effect across reported fluoride concentrations/IMD quintiles** (note: CIs for optimal fluoridation include both benefit and no benefit for IMD 2–4)
	IMD 4	0.88 (0.66 to 1.16)	0.50 (0.36 to 0.71)	0.59 (0.25 to 1.35)	0.63 (0.37 to 1.05)	
	IMD 3	1.07 (0.79 to 1.45)	0.57 (0.35 to 0.93)	0.65 (0.34 to 1.24)	0.99 (0.37 to 2.62)	
	IMD 2	0.87 (0.67 to 1.13)	0.77 (0.58 to 1.02)	0.52 (0.26 to 1.03)	0.61 (0.34 to 1.10)	
	IMD 1 (most deprived)	0.90 (0.70 to 1.16)	0.74 (0.51 to 1.09)	0.85 (0.36 to 2.01)	0.64 (0.46 to 0.88)	
Health Monitoring Report: OR for experiencing dental caries in 5-year-olds	Reference IMD 5 (least deprived)	1.01 (0.89 to 1.15)	0.97 (0.84 to 1.12)	0.87 (0.65 to 1.15)	0.74 (0.63 to 0.88)	Favours fluoridation A lower caries prevalence is associated with increased fluoride exposure. Greatest reduction seen in most deprived quintile.
	IMD 4	0.99 (0.88 to 1.12)	0.93 (0.82 to 1.05)	0.90 (0.72 to 1.12)	0.73 (0.60 to 0.88)	
	IMD 3	1.12 (0.98 to 1.28)	1.00 (0.84 to 1.17)	0.95 (0.76 to 1.19)	0.80 (0.70 to 0.91)	
	IMD 2	1.04 (0.92 to 1.17)	0.92 (0.77 to 1.10)	0.92 (0.77 to 1.11)	0.77 (0.68 to 0.88)	
	IMD 1 (most deprived)	0.75 (unknown)	0.73 (0.63 to 0.84)	0.80 (0.67 to 0.96)	0.61 (0.54 to 0.70)	

<table>
<tr><th colspan="8">DENTAL FLUOROSIS OF AESTHETIC CONCERN</th></tr>
<tr><td>Cochrane review:

Participants with fluorosis of aesthetic concern</td><td></td><td>8% to 9%</td><td>9% to 10%</td><td>10% to 12%</td><td>12% to 15%</td><td>>18%</td><td>Favours non/low-fluoridation

A higher prevalence of dental fluorosis is associated with increased fluoride exposure</td></tr>
<tr><th colspan="8">IQ</th></tr>
<tr><td>Taylor, 2025</td><td colspan="6">Dose–response analyses for studies with water F as exposure:

• <4 mg/L: change in Standard Mean Difference (SMD) (β [95% CI]): –0.22 (95% CI –0.27 to –0.17); 23 studies; 9554 children
• <2 mg/L: –0.18 (95% CI –0.40 to –0.17); 8 studies; 3682 children
• <1.5 mg/L: 0.05 (95% CI –0.36 to 0.45); 7 studies; 2832 children

Restricting this analysis to low-risk-of-bias studies only:

• <4 mg/L: –0.23 (95% CI –0.34 to –0.11); 7 studies; 4962 children
• <2 mg/L: –0.33 (95% CI –0.53 to –0.13); 4 studies; 1632 children
• <1.5 mg/L: –0.32 (95% CI –0.91 to 0.26); 3 studies; 879 children

Additional evidence from meta-analysis comparing higher vs lower F concentrations that higher F levels are associated with a moderate reduction in IQ level in children, but this includes levels of F that are above optimal:

Children exposed to higher F levels vs children exposed to lower F levels (all exposure types): SMD –0.45 (95% CI –0.57 to –0.33); 59 studies; 20,932 children; I2 = 94%

Restricting this analysis to low-risk-of-bias studies only: SMD –0.19 (95% CI –0.35 to –0.04); 12 studies; I2 = 87%</td><td>When the analysis was restricted to studies evaluating F concentrations of less than 1.5 mg/L, there was no evidence of an association between F exposure and IQ.

There was a dose–response association in studies with less than 4 and less than 2 mg/L.

The same results were found when looking at a subset of the best available evidence.</td></tr>
<tr><td>Braithwaite, 2024</td><td colspan="6">Children exposed to higher F levels (ranging from 0.6 to 8.3 mg/L) vs children exposed to lower F levels (ranging from 0.1 to 2 mg/L): SMD –0.43 (95% CI –0.63 to –0.24); 23 studies; 9539 children; I2 = 94%. This comparison includes F levels that are greater than optimal.

Subgroups:

• Moderate F levels (< 1.5 ppm): SMD 0.04 (95% CI –0.08 to 0.15); 4 studies; I2 = 0%
• High F levels (1.5 to 3 ppm): SMD –0.52 (95% CI –0.92 to –0.12); 11 studies; I2 = 96%
• Extremely high F levels (> 3 ppm): SMD –0.60 (95% CI –0.87 to –0.33); 6 studies; I2 = 85%</td><td>There was no evidence of an association between F and IQ when moderate F levels (< 1.5 ppm) were compared with lower F levels (concentration unclear). When F levels were 1.5 ppm or higher, there was an association.</td></tr>
</table>

Lambe, 2021	**Narrative synthesis** 'The three studies investigating the influence of fluoride on IQ have mixed findings; that is, two found generally no association, and one found a negative association'.	Contradictory evidence
NHMRC, 2017	**Narrative synthesis** 'One … prospective cohort study of sufficient quality was identified that found no association between the IQ of children and adults and water fluoridation at current Australian levels.'	Limited evidence
Veneri, 2023	Children exposed to higher F levels vs children exposed to lower F levels (water F as exposure): IQ mean difference (MD) −5.6 (95% CI −7.76 to −3.44); 21 studies; I2 = 91.7% Dose−response analyses (linear regression analysis): the IQ score decreased by 3.05 (95% CI −4.06 to −2.04) for every 1 mg/L increase in F level	Higher F level was associated with an IQ of 5.6 points lower. There is very high heterogeneity, which may be because studies have highly variable levels of F exposure (0.13 to 5.55 mg/L). Dose−response relationship observed.
Kumar, 2023	At the recommended F level (0.9 mg/L) vs lower F level (0.3 mg/L), there is no association with lower IQ scores in children: SMD 0.07 (95% CI −0.02 to 0.17); 8 studies; 2551 participants; $I^2 = 0\%$ Children exposed to higher F levels (mean 3.7 mg/L) vs children exposed to lower F levels (mean 0.7 mg/L): SMD −0.46 (95% CI −0.58 to −0.35); 23 studies; 8410 participants; $I^2 = 81\%$ Dose−response analyses: 'The summarised estimates of linear and non-linear terms from the restricted cubic spline are 0.0959 (P = 0.59; 95% CI −0.2498 to 0.4416) and 0.1960 (P = 0.77; 95% CI −1.1338 to 1.5257)' 'the change in pooled IQ score of 0.16 points (95% CI: −0.40 to 0.73) for every 0.5 mg/L increase in children's urinary F was not statistically significant (P = 0.57)'	F levels above those recommended are associated with a moderate reduction in IQ level in children when compared to recommended F levels. No dose−response relationship shown
Duan, 2018	Dose–response analyses (0.25 to 11 mg/L): • Dose–response non-linear and linear association between the relative dosage of fluoride and the children's intelligence levels, and absolute concentration of fluoride and the children's intelligence levels: P < 0.001 • No dose-response linear association between the absolute dosage of fluoride and the children's intelligence levels: P = 0.976 Note: additional evidence from meta-analysis comparing higher vs lower F concentrations that higher F levels are associated with a moderate reduction in IQ level in children, but this includes levels of F that are above optimal	Equivocal dose–response analysis results observed according to measure of exposure

Summary: Seven systematic reviews evaluated the association of water F levels close to optimal concentration (Taylor *et al.*, 2025; Braithwaite *et al.*, 2024; Kumar *et al.*, 2023; Lambe *et al.*, 2021; Veneri *et al.*, 2023; Duan *et al.*, 2018, NHMRC, 2017). They varied in terms of risk of bias (according to ROBIS assessment) and methodological and analytical approach. There is also a high degree of overlap in terms of included primary studies. Analysis of studies evaluating F concentrations of less than 1.5 mg/L compared to lower/no F exposure: there is no evidence of an association between F exposure and IQ (Taylor et al, 2025; Braithwaite et al, 2024; Kumar et al 2023). There is evidence of an association between F and a reduction in IQ for F levels of 1.5 mg/L or greater (Taylor *et al.*, 2025; Braithwaite *et al.*, 2024; Kumar *et al.* 2023; Veneri *et al.*, 2023, Duan *et al.,* 2018). Four systematic reviews presented a dose–response analysis; findings were inconsistent (this may be due to the differences in ranges of fluoride concentration included in the analyses).
OTHER NON-DENTAL HARMS
Summary: A total of 21 reviews have been identified. Seven provided evidence relevant to community water fluoridation programmes (Hajduga *et al*., 2025; Iamandi *et al.*, 2024; Wasick *et al.*, 2024; Lambe *et al.*, 2021; Whiting *et al.*, 2001; Jones *et al.*, 1999; NHMRC 2017; others reviewed high F levels (up to 20 mg/L). Of the reviews providing evidence for F levels close to optimal, there is no consistent evidence of an association between optimal water fluoridation and non-dental adverse health outcomes. These harms include: • ADHD • cognitive decline (including Alzheimer's) • thyroid function and TSH concentrations • bone cancer, Ewing's sarcoma, total cancer incidence • fracture risk, bone health • Down's syndrome, trisomies, neural tube defects, clefts • stillbirths, SIDS • kidney stones, kidney disease • musculoskeletal pain • gastric discomfort • headache There is some evidence of an increase in certain harms above 1.5 ppm. It should be noted that the evidence included in all the systematic reviews is of variable quality.

Annexe 2: Report preparation

This evidence synthesis was prepared with the support of a steering group. The Academy is most grateful to the members of the Steering Group for undertaking this study. Contributions by the Steering Group were made purely in an advisory capacity. The members of the Steering Group participated in an individual capacity and not as representatives of their organisations. Steering Group members are detailed below.

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