OROVILLE EXECUTIVE COMMITTEE
Oroville City Hall – Fireside Room
1735 Montgomery Street
Oroville, CA. 95965

April 28, 2023
SPECIAL MEETING
OPEN SESSION 10:30 AM
AGENDA

REQUESTS TO ADDRESS COMMITTEE

Council has established time limitations of two (2) minutes per speaker on all items. **(California Government Code §54954.3(b))**. Pursuant to Government Code Section 54954.2, the Committee is prohibited from taking action except for a brief response to statements or questions relating to a non-agenda item.

CALL TO ORDER / ROLL CALL

Committee Members: David Pittman, Eric Smith and Janet Goodson

OPEN SESSION

1. Pledge of Allegiance

REGULAR BUSINESS

1. The Committee may approve the minutes of December 15, 2021 and April 7, 2023.
2. The Executive Committee may discuss and provide direction staff regarding the Hmong Museum.
3. The Committee may discuss and provide staff direction related to a Downer Street parcel conversion to a parking lot and a request for a pedestrian easement along the western edge of the parcel.
4. The Committee may discuss and provide direction to staff related to CalWater Fluoride treatment within the City.

ADJOURN THE MEETING

The meeting will be adjourned.

Accommodating Those Individuals with Special Needs – In compliance with the Americans with Disabilities Act, the City of Oroville encourages those with disabilities to participate fully in the public meeting process. If you have a special need in order to allow you to attend or participate in our public meetings, please contact the City Clerk at (530) 538-2535, well in advance of the regular meeting you wish to attend, so that we may make every reasonable effort to accommodate you. Documents distributed for public session items, less than 72 hours prior to meeting, are available for public inspection at City Hall, 1735 Montgomery Street, Oroville, California.

OROVILLE EXECUTIVE COMMITTEE
Oroville City Hall – Fireside Room
1735 Montgomery Street
Oroville, CA. 95965

December 15, 2021
MINUTES

This agenda was posted on December 3, 2021.

CALL TO ORDER / ROLL CALL

Mayor Reynolds called the meeting to order at 8:30am.

PRESENT: Committee Members: David Pittman, Eric Smith and Chuck Reynolds

STAFF: City Administrator Bill LaGrone, Assistant City Clerk Jackie Glover,

OPEN SESSION

1. Pledge of Allegiance – Led by Mayor Reynolds

PUBLIC COMMUNICATION – HEARING OF NON-AGENDA ITEMS

There were 0 public comments at this meeting.

REGULAR BUSINESS

1. **Motion by Committee Member Smith and second by Committee Member Pittman to approve the minutes of the November 8, 2021 meeting. Motion approved unanimously.**

2. **The Executive Committee reviewed applications and gave direction to staff regarding a recommendation to council to fill vacancies on various committees, commissions, and boards.**

ADJOURN THE MEETING

Meeting adjourned at 8:52am.

Committee Member David Pittman

Assistant City Clerk Jackie Glover

OROVILLE EXECUTIVE COMMITTEE
Oroville City Hall – Fireside Room
1735 Montgomery Street
Oroville, CA. 95965

April 07, 2023
MINUTES

This agenda was posted at 1:45 p.m. on April 6, 2023.

CALL TO ORDER / ROLL CALL

Mayor Pittman Called the meeting to order at 2 p.m.

PRESENT: Committee Members: David Pittman, Eric Smith and Janet Goodson

STAFF: City Administrator Brian Ring, City Attorney's Scott Huber and David Ritchie, Assistant City Clerk Jackie Glover

OPEN SESSION

1. Pledge of Allegiance – Led by Mayor Pittman

PUBLIC COMMUNICATION – HEARING OF NON-AGENDA ITEMS

There were 0 public comments.

REGULAR BUSINESS

1. **The Committee discussed and provided staff direction related to a request by Oroville Hospital for 2023 tax exempt bond funding.**

2. **The Committee discussed and provided direction related to a request for funding by the County to maintain existing level of service of 4 days per week for the Oroville Branch Library in Fiscal Year 2023/24.**

3. **The Committee discussed and provided direction to staff related to an Aquatic Center**

4. **The Committee discussed and provided staff direction related to a Downer Street parcel conversion to a parking lot and a request for a pedestrian easement along the western edge of the parcel.**

ADJOURN THE MEETING

The meeting was adjourned at approximately 4:24pm.

APPROVED: ATTESTED:

____
Mayor David Pittman

____
Assistant City Clerk Jackie Glover

04.28.2023

HANDOUTS

Environmental Research 221 (2023) 115239

Contents lists available at ScienceDirect

Environmental Research

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

Review article

Fluoride exposure and cognitive neurodevelopment: Systematic review and dose-response meta-analysis

Federica Veneri [a,b], Marco Vinceti [c,d,*], Luigi Generali [a], Maria Edvige Giannone [c], Elena Mazzoleni [c], Linda S. Birnbaum [e], Ugo Consolo [a], Tommaso Filippini [c,f]

[a] Department of Surgery, Medicine, Dentistry and Morphological Sciences with Transplant Surgery, Oncology and Regenerative Medicine Relevance (CHIMOMO), Unit of Dentistry & Oral-Maxillo-Facial Surgery - University of Modena and Reggio Emilia, Modena, Italy

[b] PhD Program in Clinical and Experimental Medicine, Department of Biomedical, Metabolic and Neural Sciences - University of Modena and Reggio Emilia, Modena, Italy

[c] Environmental, Genetic and Nutritional Epidemiology Research Center (CREAGEN), Department of Biomedical, Metabolic and Neural Sciences, Medical School - University of Modena and Reggio Emilia, Modena, Italy

[d] Department of Epidemiology, Boston University School of Public Health, Boston, MA, USA

[e] Nicholas School of the Environment, Duke University, Durham, NC, USA

[f] School of Public Health, University of California Berkeley, Berkeley, CA, USA

ARTICLE INFO

Keywords:
Caries prevention
Cognitive neurodevelopment
Fluoride
Intelligence
Urinary fluoride
Water fluoridation

ABSTRACT

Many uncertainties still surround the possible harmful effect of fluoride exposure on cognitive neurodevelopment in children. The aim of this systematic review and meta-analysis was to characterize this relation through a dose-response approach, by comparing the intelligence quotient (IQ) scores in the highest versus the lowest fluoride exposure category with a random-effects model, within a one-stage dose-response meta-analysis based on a cubic spline random-effects model.

Out of 1996 potentially relevant literature records, 33 studies were eligible for this review, 30 of which were also suitable for meta-analysis. The summary mean difference of IQ score, comparing highest versus lowest fluoride categories and considering all types of exposure, was −4.68 (95% confidence interval-CI −6.45; −2.92), with a value of −5.60 (95% CI −7.76; −3.44) for drinking water fluoride and −3.84 (95% CI −7.93; 0.24) for urinary fluoride. Dose-response analysis showed a substantially linear IQ decrease for increasing water fluoride above 1 mg/L, with −3.05 (95% CI −4.06; −2.04) IQ points per 1 mg/L up to 2 mg/L, becoming steeper above such level. A weaker and substantially linear decrease of −2.15 (95% CI −4.48; 0.18) IQ points with increasing urinary fluoride emerged above 0.28 mg/L (approximately reflecting a water fluoride content of 0.7 mg/L). The inverse association between fluoride exposure and IQ was particularly strong in the studies at high risk of bias, while no adverse effect emerged in the only study judged at low risk of bias. Overall, most studies suggested an adverse effect of fluoride exposure on children's IQ, starting at low levels of exposure. However, a major role of residual confounding could not be ruled out, thus indicating the need of additional prospective studies at low risk of bias to conclusively assess the relation between fluoride exposure and cognitive neurodevelopment.

1. Introduction

The trace element fluoride (F) has been used since 1930 for the prevention and management of dental caries, which is considered a global health issue, especially in pediatric populations (ten Cate and Buzalaf, 2019; World Health Organisation, 2021). In nature, this mineral can be found in different amounts in water, plants, and food. Fluoride compounds are also used in aluminum, petroleum, chemical, and plastics industries, therefore workers in such industries may be exposed to higher levels of fluoride than the standard population (Choubisa and Choubisa, 2016). As a dental caries preventive approach, fluoride can be delivered through topical self- or professional applications (e.g. toothpastes, mouth rinses, gels, and varnishes), which are considered safe and cost-effective at the recommended amount, thus

* Corresponding author. Section of Public Health, Department of Biomedical, Metabolic and Neural Sciences, Medical School - University of Modena and Reggio Emilia, Modena, Italy.

E-mail address: marco.vinceti@unimore.it (M. Vinceti).

https://doi.org/10.1016/j.envres.2023.115239
Received 30 November 2022; Received in revised form 4 January 2023; Accepted 5 January 2023
Available online 10 January 2023
0013-9351/

many scientific health authorities have endorsed their use (Iheozor-Ejiofor et al., 2015; NHS - National Health System, 2021; NIH - National Institute of Health, 2021; World Health Organization, 2017). Community-based strategies (e.g. water, salt, and milk fluoridation), as well as individually prescribed drops or tablet supplementation, however, raise concerns on their efficacy and safety both for dental and general health (European Commission, 2011; U.S. Department of Health and Human Services Federal Panel on Community Water Fluoridation, 2015). Also, since a considerable amount of fluoridated water is not actually used for direct oral uptake and rather ends up in the environment, contamination from fluoride is addressed as a possible source of biohazard for plants and animals (Aguirre-Sierra et al., 2013; Banerjee et al., 2021; Ranjan et al., 2008). Most fluoride consumption comes from fluoridated water and from foods and beverages prepared with fluoridated water, although a small part also comes from the accidental ingestion of fluoride-containing dental products (CDC - Center for Disease Control and Prevention, 2021). One of the public health policies that has been adopted to supplement children and adults with fluoride has been community water fluoridation (CWF), consisting of the controlled addition of fluoride to the public water supply, typically at concentrations ranging from 0.7 mg/L to 1.2 mg/L. However, in 2015 the Centers for Disease Control and Prevention (CDC) updated its water fluoridation guidelines setting such level at 0.7 mg/L in the U.S. (U.S. Department of Health and Human Services Federal Panel on Community Water Fluoridation, 2015). CWF policy was first introduced in the United States in 1945 and is currently applied in many regions worldwide, covering approximately 400 million people in over 25 countries (British Fluoridation Society, 2013; CDC - Center for Disease Control and Prevention, 2021). In addition to the beneficial effects of fluoride on dental caries, some adverse health effects deriving from the chronic overexposure to this element have long been documented (Dhar and Bhatnagar, 2009; European Commission, 2011; Vieira, 2022). Among these, dental and skeletal fluorosis are well known and supported by a strong body of evidence (Abanto Alvarez et al., 2009; Saldarriaga et al., 2021; Srivastava and Flora, 2020). In addition, a possible neurotoxic effect of excess fluoride exposure in children has been reported by the U. S. Environmental Protection Agency (EPA) and U.S. National Research Council (NRC) and has continued to be investigated (Bashash et al., 2017; Broadbent et al., 2015; Lu et al., 2000; National Research Council, 2006; Neurath, 2020). These effects could be due to the capacity of fluoride to accumulate in brain regions responsible for memory and learning, affecting them through oxidative stress. In fact, while the blood-brain barrier, to some extent, can protect the adult brain from various toxic agents, it is less efficient in the fetus, newborn, and young child (Grandjean, 2019; Srivastava and Flora, 2020). In addition, fluoride exposure has been linked to hypothyroidism, which negatively affects early neurodevelopment both in fetuses and newborn children (Peckham et al., 2015; Prezioso et al., 2018). Two previous published systematic reviews have investigated the relation between fluoride exposure and neurocognitive development in humans, yielding somewhat inconsistent results, and only one of them performed a dose-response meta-analysis, focusing their assessment on fluoride exposure through drinking water (Duan et al., 2018), while the other only conducted a high-versus-low fluoride analysis (Duan et al., 2018; Miranda et al., 2021). Also, a draft systematic review by the National Toxicology Program (NTP) analyzed such a relationship, but did not perform a meta-analysis (NTP - National Toxicology Program, 2020).

Therefore, the aim of this study was to investigate the relation between exposure to inorganic fluoride, in all forms, and neurodevelopmental toxicity in children, through a comprehensive, updated systematic review and meta-analysis with a dose-response approach.

2. Methods

2.1. Protocol and registration

This systematic review and meta-analysis was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) 2020 guidelines (Page et al., 2021). The protocol was registered in the PROSPERO database (registration no. CRD42022321899).

2.2. Search strategy and study selection

The research framework was defined by the following question: "What is the effect of early or prenatal fluoride exposure on the risk of abnormal neurodevelopment according to a dose-response relation?" According to the PECOS statement (Population, Exposure, Comparator, Outcomes, and Study design), we considered (S) observational studies and clinical trials investigating the relation between (E) early or prenatal fluoride exposure from any source (e.g. water, dietary, and supplemental intake, topical dental products) or evaluating a biomarker of exposure (e.g. urinary, bone, hair fluoride) and (O) neurodevelopmental function in (P) children less than or equal to 18 years of age, compared to (C) exposure to any lower dose of fluoride. We included only studies reporting (i) type and dose/concentration of known fluoride exposure (dose, mean/median levels or category boundaries); (ii) outcome assessment through validated measures of neurodevelopment or cognitive development such as intelligence quotient (IQ), school performance, Standardized Scale for the Intelligence of Children; (iii) outcome in relation to fluoride exposure; (iv) outcome difference for each different fluoride exposure category, such as mean difference, or standardized mean difference, along with the 95% confidence interval (CI) or data allowing their calculation. We considered only original research articles, while conference proceedings, abstracts, letters to the editor, commentaries, case reports, reviews, and meta-analysis were eliminated from consideration. We disregarded papers concerning exposure to fluoride from coal-burning or volcanic eruptions, since they are limited to very specific geographical and socio-cultural situations. Studies based on specific populations, such as children born preterm and institutionalized children, were also excluded, along with studies addressing specific health conditions including autism, Down's syndrome, attention-deficit/hyperactivity disorder (ADHD) or other behavioral issues, anxiety, and depression. When multiple studies addressed an overlapping population, only the most complete (generally the most recent) report was considered for this review and meta-analysis.

The online literature search was conducted on PubMed/MEDLINE, Web of Science, and Embase databases from inception up to December 30, 2022. No language or date restrictions were applied.

The search was performed using a combination of terms related to "fluoride" and "fluorosis" as exposure and to "neurodevelopmental disorders" or "neurocognitive disorders" as outcomes, by using related MeSH terms, topic terms, and exploded terms on the three databases respectively. The details of the search strategy are reported in Supplementary Table S1.

Backward and forward citation chasing methods were conducted including manually checking the reference lists of all included studies to identify possible additional eligible articles. The screening of titles, abstracts, and full texts for inclusion was performed independently by three authors (FV, MEG, and EM). Another author (TF) was involved in resolving possible disagreements.

2.3. Data extraction

From each of the included studies, whenever available we extracted data regarding location and year, study design, total population, population age and sex, type and dose of exposure, assessment method of exposure, type of neurodevelopment assessment and assessment criteria, the methodology for quantification of the outcome and mean difference between each exposure category, along with its standard deviation (SD), standard error (SE), or 95% confidence interval (CI). We also extracted details regarding confounding factors or adjustments, when available.

2.4. Risk of bias assessment

We assessed the risk of bias (RoB) of the included studies using the Risk of Bias in Non-Randomized Studies of Exposure (ROBINS-E) tool (Morgan et al., 2019). Two authors (MEG and EM) conducted the evaluation. Any discrepancies were resolved through consensus-based discussion with a third author (TF). Criteria used for this assessment are shown in Supplementary Table S2. In the final tiering of the studies, we considered an overall "low RoB" if all domains of the study were rated at low risk; we considered an overall "moderate" or "high" RoB if one or more domains was at moderate or high RoB, respectively.

2.5. Data analysis

We performed a meta-analysis through forest plots comparing the highest versus lowest fluoride exposure using a random-effects model, computing the weighted mean difference (MD) of IQ and the 95% CI. The analyses were stratified according to type of exposure monitored (e.g. water, urinary fluoride, serum fluoride), type of outcome (e.g. intelligence level, IQ score), overall RoB, study design, sex, and age categories, whenever the data were available.

We also assessed the relation between fluoride exposure and IQ using one-stage dose-response meta-analysis with a cubic spline random-effects model, as previously implemented in other fields (Filippini et al., 2022; Hogervorst et al., 2022; Vinceti et al., 2021), and using the knot placement method recommended by Harrell (2001). In particular, we selected the optimal number of knots according to Akaike's information criterion (AIC), thus we used three knots at fixed percentiles (10th, 50th, and 90th) for both drinking water fluoride and urinary fluoride (Orsini, 2021; Orsini, N. and Spiegelman, D., 2020). For the graphical representation of such relations, the respective median values of the considered doses were used as references (i.e. 1.2 mg/L for water fluoride; 1.4 mg/L for urinary fluoride). We also performed sensitivity analysis using alternative values as reference dose, namely the current U.S. safety threshold for water fluoride in drinking water (0.7 mg/L) and the previous upper boundary, also equivalent to the median value (1.2 mg/L).

According to Villa et al. (2010), the relation between daily urinary fluoride excretion (UF) and total daily fluoride intake (TDFI) in children is approximately $UF = 0.03 + 0.35 * TDFI$, where 0.03 is the intercept and 0.35 is the slope of such linear relationship. Therefore, assuming that most of fluoride intake comes from water fluoride, 1 mg/L of fluoride in drinking water translates in a concentration of fluoride in urine of approximately 0.38 mg/L. Using such formula, we estimated the values for urinary fluoride in children corresponding to the above-mentioned references for water fluoride, resulting respectively in 0.28 mg/L and 0.45 mg/L, and we performed the additional sensitivity analysis accordingly.

For all studies, we fitted a linear regression analysis model and reported its slope per 1 mg/L of fluoride increase alongside with the spline analysis.

Heterogeneity of included studies was assessed using the I^2 statistics (Higgins et al., 2003). We used the Stata software v17.0 (Stata Corp., College Station, TX, 2021) to perform data analyses.

3. Results

3.1. Study selection

The literature search retrieved 1996 potentially relevant records. After the removal of duplicate records (n = 162) and the screening of titles and abstracts of the remaining 1834 records, 1773 records were discarded. After a full text evaluation of the remaining 61 records, additional 32 records were excluded since 3 of them addressed a wrong outcome, 3 were not eligible as publication types, 2 did not have their full texts available, 8 addressed overlapping cohorts of subjects, 10 did not report a correlation between dose and IQ, 5 investigated the correlation between dental fluorosis and IQ, and one addressed only co-exposure to fluoride and arsenic. We eventually further excluded 3 studies that did not allow the analysis of the correlation between dose and IQ. Four papers were instead added to the database after having been retrieved though citation chasing, based on the reference lists of the included studies and the recent meta-analyses.

Overall, 33 publications eventually met the inclusion criteria for the qualitative analysis, 30 of which were included in the meta-analysis. The detailed overall process of study selection is shown as a PRISMA flow-chart (Fig. 1).

3.2. Study characteristics

The main characteristics of included studies, divided by type of exposure, are summarized in Table 1. The publication year of the included studies ranges from 1991 to 2022. Among the 33 included studies, 29 were designed as cross-sectional studies and 4 as cohort studies. Overall, a total population of 12,263 children was enrolled in 7 countries (China, India, Canada, Iran, Mexico, Pakistan, New Zealand). The age of the participants ranged from 3 to 14 years. Most of the studies (n = 25) investigated exposure to fluoride from drinking water and the estimation of exposure was drawn by measuring water fluoride concentration; 14 studies estimated fluoride exposure by measuring urinary fluoride; 2 studies measured serum fluoride and 2 studies addressed total daily fluoride intake. Hair and nail fluoride were analyzed by 1 study, respectively. Only 1 included study addressed exposure from fluoride tablet supplementation.

In our analysis, fluoride concentration in drinking water ranged from 0.13 to 5.55 mg/L. Urinary fluoride ranged from 0.16 to 7 mg/L. For the one study addressing hair and nail fluoride, the considered doses were 6.9 and 27.8 μg/g, and 8.3 and 57 μg/g respectively, while serum fluoride ranged from 0.04 to 0.18 mg/L in the two related studies.

With regards to neurodevelopment evaluation, all the included studies assessed intelligence based on IQ measurement. Most of them (n = 32) used IQ scores, whereas one of them used an IQ derived scale of intelligence. The most common tests applied to perform IQ evaluation were the Combined Raven's Tests for Rural China (CRT-RC; n = 14), Raven's Standard Progressive Matrices test (RSPM; n = 4 – RPM; n = 2), the Raven's Color Progressive Matrices test (RCPM; n = 2), followed by other less frequent IQ tests, such as the Wechsler Preschool and Primary Scale of Intelligence (WPPSI), Wechsler Abbreviated Scale of Intelligence (WASI), the Wechsler Adult Intelligence Scale-Revised (WISC-R), Stanford-Binet Intelligence Scale (SBIS), Rui-Wen's test, and the Raymond B Cattell's test.

All the studies excluded from meta-analysis for not specifying children's doses of exposure reported lower IQ scores in those exposed to higher levels of fluoride (Farmus et al., 2021; Goodman et al., 2022; Rocha-Amador et al., 2007).

3.3. Risk of bias analysis

Details of RoB assessment are displayed in Table 2. Among the included studies, the overall RoB was "high" in 11 studies, "moderate" in 19 studies, and "low" in 3 studies. The main source of high RoB was related to the lack of adjustments for potential confounders (n = 11). Participant selection was another critical aspect, as the enrollment was based on different fluoride exposure in most studies (e.g. areas with different fluoride concentration in drinking water), resulting in a moderate RoB in such domain (n = 25).

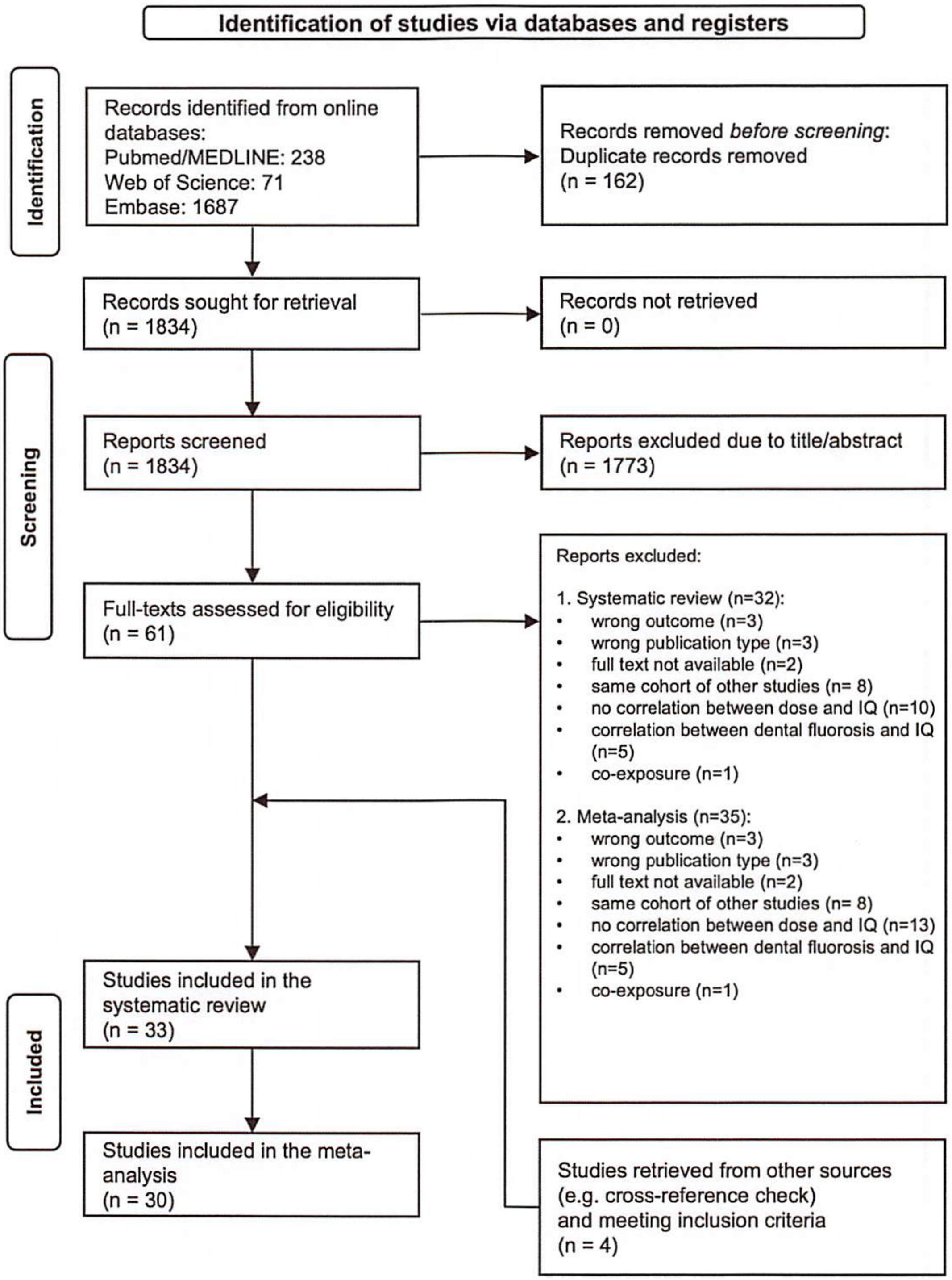


Fig. 1. PRISMA flow-chart of study selection process.

3.4. *Quantitative analysis*

The summary MD of IQ score, comparing the highest versus lowest fluoride categories considering all types of exposure was −4.68 (95% CI −6.45; −2.92). For less represented types of exposure, the summary IQ score MDs were −0.25 (95% CI −3.18; 2.68) for fluoride tablet supplementation (1 study), 1.92 (95% CI 1.56; 2.28) for hair fluoride (1 study), 0.61 (95% CI 0.30; 0.92) for nail fluoride (1 study), and −7.69 (95% CI −9.99; −5.38) for serum fluoride (2 studies). The individual and summary mean differences of IQ score, comparing the highest versus lowest fluoride categories considering all types of exposure are available in Supplementary Fig. S1.

When performing a subgroup analysis by RoB levels, a MD of 1.11 (95% CI −0.67; 2.89) emerged for the only low RoB study, −4.27 (95% CI −6.44; −2.11) for moderate RoB studies, and −6.31 (95% CI −9.56; −3.06) for high RoB studies (Fig. 2). The pooled analysis considering only cohort-designed studies eligible for meta-analysis (n = 3) yielded a MD of −0.74 (95% CI −2.90; 1.42), while a cumulative MD of −5.21 (95% CI −7.02; −3.39) was found for the cross-sectional studies. With regards to exposure to fluoride in drinking water, ranging from 0.13 to 5.55 mg/L, the overall IQ score mean difference was −5.60 (95% CI −7.76; −3.44), showing slight differences in subgroup analysis by sex,

Table 1
Characteristics of included studies for by type of exposure: water fluoride, urinary fluoride and other exposures.

Reference	Study design	Country	Age (mean)	Participants	Geographical area	Exposure	Exposure assessment	Unit	Dose	Outcome	Outcome assessment	Main findings	Management of confounders
WATER FLUORIDE													
Ahmad et al., 2022	Cross-sectional	Pakistan	9 to 11	120 (M/F = 86/34)	Karachi and Umerkot, Sindh Province; Pakistan	Water fluoride	Records based on another study	mg/L	1.07; 2.04	IQ score	CRT-RC	No significant differences in the distribution of the IQ scores between the urban (Low F) and rural (High F) areas	Age, sex
Aravind et al., 2016	Cross-sectional	India	10 to 12	288	Karnataka stat; India	Water fluoride	Fluoride ion selective electrode, Orion 9609BN	mg/L	0.96; 1.6; 2.4	IQ score	RSPM	Lower IQ in children from high F areas	Age, sex
Broadbent et al., 2015	Cohort study (DMHDS)	New Zealand	7 to 13	992	Dunedin; New Zealand	Water fluoride	Records based on residential data	mg/L	0.15; 0.85	IQ score	WISC-R	No clear differences in IQ because of fluoride exposure	Age, sex, socioeconomic status based on parental occupation and the educational level and income associated with that occupation, low birth weight, breastfeeding
Chen et al., 2008	Cross-sectional	China	7 to 14	640	Biji and Jiaobei villages; China	Water fluoride	Records based on residential data	mg/L	0.89; 4.55	IQ score	CRT-RC	Significant difference in IQ between endemic and non endemic areas	Sex
Eswar et al., 2011	Cross-sectional	India	12 to 14	133	Ajjihalli and Holesirigere village, District of Karnataka; India	Water fluoride	Records based on residential data	mg/L	0.29; 2.45	IQ score	RSPM	No significant differences between the endemic and non endemic areas, but a trend towards lower IQ in a great number of children from high F village	Age
Hong et al., 2008	Cross-sectional	China	8 to 14	117	Wukang, Boxing, Zouping, Shangdong Province; China	Water fluoride	Conventional chemical assay methods	mg/L	0.75; 2.9	IQ score	CRT-RC	No significant differences between the high F and control areas, but a trend towards lower IQ in a number of children from high F area	NR
Karimzade et al., 2014	Cross-sectional	Iran	9 to 12	39	Poldashi and Piranshahr village, Azerbaijan; India	Water fluoride	SPADNS colorimetric method	mg/L	0.25; 3.94	IQ score	RB Cattell	Lower IQ in children from high F areas	Age (education, economic factors, sociocultural environment, general demographic characteristics)
Li et al., 2008	Cross-sectional	China	6 to 13	956	Inner Mongolia; China	Water fluoride	Records based on residential data		High; Low	IQ score	CRT-RC2	Lower IQ in children from high F areas	NR
Lu et al., 2000	Cross-sectional	China	10 to 12	118	Xiqing District, Tianjin; China	Water fluoride	Fluoride ion selective electrode	mg/L	0.37; 3.15	IQ score	CRT-RC	Lower IQ in children from high F areas	Age (sex, past history of illness, residential history,

(*continued on next page*)

Table 1 (*continued*)

Reference	Study design	Country	Age (mean)	Participants	Geographical area	Exposure	Exposure assessment	Unit	Dose	Outcome	Outcome assessment	Main findings	Management of confounders
													parents' past history of illness, parents' socioeconomic status, parents' level of education, family income, parents' smoking and drinking habits)
Poureslami et al., 2011	Cross-sectional	Iran	7 to 9	119 (M/F = 57/62)	Koohbanan and Baft city, Kerman Province; Iran	Water fluoride	Records based on residential data	mg/L	0.41; 2.38	IQ score	RPM	Lower IQ in children from high F areas	Age, sex
Rocha-Amador et al., 2007	Cross-sectional	Mexico	7 to 8	132	Moctezuma, Salitral, 5 de Febrero; Mexico	Water fluoride	TISAB buffer and specific ion electrode method	log	/	IQ score; Performance IQ and Verbal IQ	WISC-RM	Lower IQ in children with high F exposure	Age, Pb blood, socioeconomic status, mother's education, height-for-age z-score, and transferrin saturation
Saxena et al., 2012	Cross-sectional	India	12	170	Madhya Pradesh state; India	Water fluoride	Fluoride ion selective electrode, Orion 9609BN	ppm	1.2; 2.25; 3.8; 5.4	Intelligence grade	RSPM	Lower IQ in children from high F areas	Age, sex, height, weight, residential history, medical history (including illness affecting the nervous system and head trauma), educational level of the head of the family (in years), socioeconomical status
Sebastian and Sunitha, 2015	Cross-sectional	India	10 to 12	405	Mysore District; India	Water fluoride	Records from Rajiv Gandhi National Rural Drinking Water Program (RGNRDWP)	mg/L	0.4; 1.2; 2	IQ score	RCPM	Lower IQ in children from high F areas	Age, sex, parental education, family income
Seraj et al., 2007	Cross-sectional	Iran	7 to 11	126	Dehistan; Iran	Water fluoride	Records based on residential data	mg/L	0.4; 2.5	IQ score	RSPM	Lower IQ in children from high F areas	NR
Seraj et al., 2012	Cross-sectional	Iran	6 to 11	293 (M/F = 142/151)	Makoo; Iran	Water fluoride	SPADNS method utilizing 400 UV–Vis spectrophotometer	mg/L	0.75; 3.1; 5.2	IQ score	RCPM	Lower IQ in children from high F areas	NR
Shivaprakash et al., 2011	Cross-sectional	India	7 to 11	160	Bakalkot, Hungund; India	Water fluoride	Records based on residential data	mg/L	0.4; 3.0	IQ score	RPM	Lower IQ in children from high F areas	Age, sex
Till et al., 2020	Cohort study (MIREC)	Canada	3 to 4 (age of IQ test)	198	Vancouver, Toronto, Hamilton, Halifax, Kingston, Montreal; Canada	Water fluoride	Records based on residential data	mg/L	0.13; 0.59	IQ score; Performance IQ and Verbal IQ	CRT-RC	Lower IQ in children with high F exposure	Sex and age at testing, maternal education, maternal race, second-hand smoke in the home, quality of the

(*continued on next page*)

Table 1 (*continued*)

Reference	Study design	Country	Age (mean)	Participants	Geographical area	Exposure	Exposure assessment	Unit	Dose	Outcome	Outcome assessment	Main findings	Management of confounders
													child's home environment
Trivedi et al., 2007	Cross-sectional	India	12 to 13	190 (M/F = 118/62)	Chandlodia (Ahmedabad) and Sachana (Sanand District of Gujarat); India	Water fluoride	Fluoride ion selective electrode, Orion 9609BN	mg/L	2.01; 5.55	IQ score	SBIS	Lower IQ in children with high F exposure	Age, sex
Wang et al., 2007	Cross-sectional	China	8 to 12	449	Rural areas in Shanxi; China	Water fluoride	Fluoride ion selective electrode with an LOD of 50 μg/L ± 2%.	mg/L	0.5; 0.8	IQ score	CRT-RC	Lower IQ in children with high F exposure	Age, income, parental education
Wang et al., 2008	Cross-sectional	China	4 to 7	230	Rural area of Shehezi in Xinjiang Province; China	Water fluoride	Fluoride ion selective electrode method	mg/L	0.8; 1.2	IQ score; Performance IQ and Verbal IQ	WPPSI	Lower IQ in children with high F exposure	Age
Wang et al., 2021	Cross-sectional	China	9.86 ± 1.16	709 (M/F = 381/328)	Rural areas of Tianjin City; China	Water fluoride	Fluoride ion selective electrode (INESA, Shanghai, China)	mg/L	0.24; 0.65; 1.3; 1.92	IQ score	CRT-RC	Lower IQ in children with high F exposure	Age, sex, BMI, low birth weight, paternal education, maternal education, family incomes
Xiang et al., 2003	Cross-sectional	China	8 to 13	512	Wamiao and Xinhuai villages; China	Water fluoride	Fluoride ion selective electrode method	mg/L	0.36; 0.75; 1.53; 2.46; 3.28; 4.16	IQ score	CRT-RC	Lower IQ in children with high F exposure	NR
Yu et al., 2021	Cross-sectional	China	9.8 ± 1.1	952	rural areas of Baodi District , Tianjin; China	Water fluoride	Fluoride ion selective electrode method	mg/L	1.8; 3.65	IQ score	CRT-RC	Lower IQ in children with high F exposure	Age, sex, maternal education, paternal education
Zhang et al., 2015	Cross-sectional	China	10 to 12	180 (M/F = 74/106)	Jinnan District, Tianjin; China	Water fluoride	Ion analyzer EA940 with a fluoride ion selective electrode	mg/L	1.4; 0.63	IQ score	CRT-RC	Lower IQ in children with high F exposure	Age, sex, educational levels of parents
Zhao et al., 1996	Cross-sectional	China	7 to 14	320 (M/F = 160/160)	Sima (Xiaoy city) and Xingua village (Fenyang city); China	Water fluoride	NR	mg/L	0.91; 4.12	IQ score	NR	Lower IQ in children with high F exposure	Age, sex
URINARY FLUORIDE													
Ahmad et al., 2022	Cross-sectional	Pakistan	9 to 11	120 (M/F = 86/34)	Karachi and Umerkot, Sindh Province; Pakistan	Urinary fluoride	NR	mg/L	3.53; 5.99	IQ score	CRT-RC	No significant differences in distribution of IQ scores between rural and urban areas	Age, sex
Bashash et al., 2017	Cohort study (ELEMENT)	Mexico	6 to 12	189 (M/F = 95/116)	Mexico city; Mexico	Urinary fluoride	Ion-selective electrode	mg/L	0.64; 0.96	IQ score	WASI	Higher prenatal fluoride exposure was associated with lower scores on tests of cognitive function in the offspring at age 4 and 6–12 years	Urinary creatinine

(*continued on next page*)

Table 1 (*continued*)

Reference	Study design	Country	Age (mean)	Participants	Geographical area	Exposure	Exposure assessment	Unit	Dose	Outcome	Outcome assessment	Main findings	Management of confounders
Das and Mondal, 2016	Cross-sectional	India		149 (M/F = 66/83)	Laxmisagar Village, Simlapal Block of Bankura District. W.B.; India	Urinary fluoride	Ion-selective electrode and TISAB	mg/L	2.5; 2.58; 2.91; 2.95; 3.81; 4.82	IQ score	CRT-RC	Exposure dose has a positive correlation with Dental fluorosis and urinary fluoride has a negative correlation with IQ	NR
Ding et al., 2011	Cross-sectional	China	7 to 14	331	Manzhouli City in Hulunbuir, Inner Mongolia; China	Urinary fluoride	Ion-selective electrode and TISAB	mg/L	0.8; 1.11; 1.13; 1.31; 1.46	IQ score	CRT-RC	Low levels of F exposure in drinking water had negative effects on children's intelligence and dental health and confirmed the dose-response relationship between urinary fluoride and IQ scores as well as dental fluorosis	NR
Farmus et al., 2021	Cohort study (MIREC)	Canada	3 to 4	596 (M/F = 291/305)	Vancouver, Toronto, Hamilton, Halifax, Kingston, Montreal; Canada	Urinary fluoride	Records based on residential address data	mg/L	/	IQ score; Performance IQ; Verbal IQ	WPPSI	F was not significantly associated with verbal IQ accross any exposure window; associations between fluoride exposure and IQ differed based on timing of exposure	Maternal education, maternal race, total HOME score, age at urine sampling, and prenatal second-hand smoke
Feng et al., 2022	Cross-sectional	China	8 to 12	683 (M/F = 324/359)	Tongxu County, Henan Province; China	Urinary fluoride	Ion-selective electrode	mg/L	0.83; 0.98; 1.56; 2.15	IQ score	CRT-RC	Excessive F exposure may have adverse effects on children's intelligence	Age, sex, BMI, age at which pregnancy occurred, gestational weeks, birth weight, birth modes, paternal and maternal education level
Goodman et al., 2022	Cross-sectional	Mexico	8 to 12	348	Birobouli and Talise sub-villages; Mexico	Maternal urinary fluoride	Ion-selective electrode	mg/mL	/	IQ score; Performance IQ; Verbal IQ	MSCA	The decrease in non-verbal intelligence was assessed to determine the negative association between prenatal fluoride exposure and IQ. This may mean that visual-spatial and perceptual reasoning skills, as opposed to verbal skills, may be affected more by prenatal fluoride exposure	NR
Li et al., 1995	Cross-sectional	China	8 to 13	907 (M/F = 570/337)	Anshu and Zhijin counties of Guizhou	Urinary fluoride	NR	mg/L	1.02; 1.81; 2.01; 2.69	IQ score	Rui-Wen test	High F intake is associated with a lower intelligence	Sex

(*continued on next page*)

Table 1 (*continued*)

Reference	Study design	Country	Age (mean)	Participants	Geographical area	Exposure	Exposure assessment	Unit	Dose	Outcome	Outcome assessment	Main findings	Management of confounders
					Province; China								
Lu et al., 2000	Cross-sectional	China	10 to 12	118	Tianjin Xiqing District; China	Urinary fluoride	Ion-selective electrode	mg/L	1.43; 4.99	IQ score	CRT-RC	The IQ of the children in the high-F area was significantly lower than that of the children in the low-F area; an inverse relationship was also present between IQ and the urinary fluoride level. Exposure of children to high levels of fluoride may carry the risk of impaired development and intelligence	Age (sex, past history of illness, residential history, parents' past history of illness, parents' socioeconomic status, parents' level of education, family income, parents' smoking and drinking habits)
Rocha-Amador et al., 2007	Cross-sectional	Mexico	7 to 8	132	Moctezuma, Salitral, 5 de Febrero; Mexico	Urinary fluoride	Ion-selective electrode and TISAB	log	NR	IQ score	WISC-RM	Children exposed to either F or As have increased risk of reduced IQ scores	Age, Pb blood, socioeconomic status, mother's education, height-for-age z-score, and transferrin saturation
Saxena et al., 2012	Cross-sectional	India	12	170 (M/F = 87/83)	Madhya Pradesh state; India	Urinary fluoride	Ion-selective electrode	ppm	2.25; 3.28; 4.85; 7.00	Intelligence grade	RSPM	Children in endemic areas of fluorosis are at risk for impaired development of intelligence; urinary fluoride level was a significant predictor of intelligence	Age, sex, height, weight, residential history, medical history (including illness affecting the nervous system and head trauma), educational level of the head of the family (in years), socioeconomical status
Trivedi et al., 2007	Cross-sectional	India	12 to 13	190 (M/F = 118/72)	Chandlodia (Ahmedabad) and Sachana (Sanand District of Gujarat); India	Urinary fluoride	Ion-selective electrode	mg/L	2.3; 6.13	IQ score	SBIS	Exposure to elevated F can cause lower IQ and the excessive intake of F can produce harmful effects on the developing brain	Age
Wang et al., 2021	Cross-sectional	China	9.86 ± 1.16	709 (M/F = 381/328)	Rural areas of Tianjin City; China	Urinary fluoride	Ion-selective electrode (INESA, Shangai, China)	mg/L	0.16; 0.34; 0.69; 1.08	IQ score	CRT-RC	Low to moderate F exposure is associated with dysfunction of cholinergic system for children. AchE may partly mediate the prevalence of DF and lower probability of having superiorintelligence	Age, sex, body mass index, maternal education, paternal education, household income and low birth weight

(*continued on next page*)

Table 1 (*continued*)

Reference	Study design	Country	Age (mean)	Participants	Geographical area	Exposure	Exposure assessment	Unit	Dose	Outcome	Outcome assessment	Main findings	Management of confounders
Yu et al., 2021	Cross-sectional	China	9.8 ± 1.1	952 (M/F = 471/481)	Rural areas of Baodi District, Tianjin; China	Urinary fluoride	Ion-selective electrode and TISAB	mg/L	0.81; 2.05; 4.02	IQ score	CRT-RC	F is inversely associated with intelligence; the interactions of F with mitochondrial function-related SNP-set, genes and pathways may also be involved in high intelligence loss	Age, sex, maternal education, paternal education
Zhang et al., 2015	Cross-sectional	China	10 to 12	180 (M/F = 74/106)	Jinnan District, Tianjin; China	Urinary fluoride	Ion-selective electrode	mg/L	1.1; 2.4	IQ score	CRT-RC	Significant high levels of F along with poor IQ score were observed in the high F area	Age, sex, educational levels of parents
OTHER EXPOSURES													
Broadbent et al., 2015	Cohort study (DMHDS)	New Zealand	7 to 13	992	Dunedin; New Zealand	Fluoride Tablets	Parental interviews	mg (ever/never used)	0.5	IQ score	WISC-R	Fluoride exposure does not affect neurologic development or IQ	Age, sex, socioeconomic status, low birth weight, breastfeeding
Das and Mondal, 2016	Cross-sectional	India	7 to 18	149	Laxmisagar Village, Simlapal Block of Bankura District. W.B.; India	Intake fluoride	Fluoride ion-selective electrode (model: Thermo Scientific Orion4-Star) and adjustment with buffer (TISAB III)	mg/kg/day	0.069; 0.064; 0.060; 0.099; 0.093	IQ score	CRT-RC	Lower IQ in children from high F areas	NR
Farmus et al., 2021	Cohort study (MIREC)	Canada	3 to 4 (age at intelligence test)	596	Vancouver, Toronto, Hamilton, Halifax, Kingston, Montreal; Canada	Intake fluoride	Records based on residential data	mg/day	Linear increase of the dose	IQ score; Performance IQ; Verbal IQ	WPPSI	Lower IQ in children exposed to high fluoride concentration; stronger association in fetal exposure than postnatal exposure	Maternal education, maternal race, total HOME score, age at urine sampling, and prenatal second-hand smoke
Xiang et al., 2011	Cross-sectional	China	8 to 13	512 (M/F = 282/230)	Wamiao and Xinhuai villages; China	Serum fluoride	Fluoride ion-selective electrode	mg/L	0.04; 0.065; 0.088	IQ score	CRT-RC	Mean IQ significantly higher and fewer children with an IQ less than 80 in the two quartiles with a serum fluoride level of less than 0.05 mg F/L	Age, sex
Yu et al., 2021	Cross-sectional	China	9.8 ± 1.1	952	Rural areas of Baodi District , Tianjin; China	Hair fluoride; Nail Fluoride	Fluoride ion-selective electrode and adjustment with buffer (TISAB)	μg/g	Hair (6.865; 27.77); Nail (8.29; 57)	IQ score	CRT-RC	The probability of high intelligence was inversely correlated with fluoride contents in water, urine, hair and nail	Age, sex, maternal education, paternal education
Zhang et al., 2015	Cross-sectional	China	10 to 12	180	Jinnan District, Tianjin; China	Serum fluoride	Ion analyzer EA940 with a fluoride ion selective electrode	mg/L	0.06; 0.18	IQ score	CRT-RC	Fluoride exposure negatively associated with children's intelligence	Age, sex, educational levels of parents

NR: not reported; CRT-RC: Combined Raven's Tests for Rural China; RCPM: Raven's Colored Progressive Matrices; RSPM: Raven's Standard Progressive Matrices; WISC-R: Wechsler Adult Intelligence Scale-Revised; WPPSI: Wechsler Preschool and Primary Scale of Intelligence.

Parentheses in the column "Management of confounders" indicate that such confounders have been considered, according to the plain text, but data are not shown.

with a MD of −8.02 (95% CI −13.48; −2.56) for males, and of −5.96 (95% CI −8.78; −3.14) for females (Fig. 3). The stratification by age categories showed some noticeable differences, with an IQ MD of −3.21 (95% CI −8.00; 1.58) for preschool children and −5.85 (95% CI −8.20; −3.50) for children over 6 years (Supplementary Fig. S2). The individual and summary IQ MD for urinary fluoride as the exposure biomarker, which ranged from 0.16 to 7 mg/L, are shown in Fig. 4 and resulted in −3.84 (95% CI −7.93; 0.24), with mild fluctuations for males −5.83 (95% CI -14.71; 3.04) and females −6.97 (95% CI −12.49; −1.46). The stratification by age categories (Supplementary Fig. S3), was only computable for school aged children over 6 years (MD −3.84, 95% CI −7.93; 0.24). The overall mean difference of IQ scores in studies assessing specific Performance IQ and Verbal IQ (2 studies each), were −6.62 (95% CI −9.73; −3.50) and 0.39 (95% CI −6.22; 6.99), respectively (Supplementary Fig. S4).

Concerning potential publication bias, the Egger's test suggested a low risk of such bias both for water and urinary fluoride analyses (Supplementary Figs. S5–S6).

In the dose-response meta-analysis based on both non-linear spline regression model and linear regression analysis, we only considered water fluoride and urinary fluoride, as the other types of exposure data were not sufficient to perform such analysis. For the same reason, we limited our dose-response analysis to studies reporting the IQ score as the cognitive outcome. The dose-response curve for water fluoride exposure clearly showed a decrease in IQ score starting at a drinking water fluoride concentration of 1 mg/L, this negative relation becoming considerably steeper over 2 mg/L, though being statistically imprecise (Fig. 5A). In linear regression analysis, the IQ score decrease was 3.05 (95% CI −4.06; −2.04) per mg/L. Compared with the analysis based on water fluoride concentrations, the dose-response analysis based on urinary fluoride showed a weaker but substantially linear decrease in IQ scores with increasing urinary fluoride and already starting at very low levels of exposure, with −2.15 (95% CI −4.48; 0.18) IQ points per each 1 mg/L in urinary fluoride, again with statistically imprecise estimates at high levels of exposure (Fig. 5B). Additional dose-response splines obtained by the sensitivity analysis using alternative reference values are shown in Supplementary Figs. S7 and S8.

4. Discussion

What is new in this work, as compared to the other systematic reviews and meta-analyses on this topic, is that we applied a recent and novel statistical approach that allows the full modeling of the dose-response relation between fluoride and cognitive endpoints, yielding its shape across the entire range of exposure, considering both exposure from fluoride in drinking water and urinary fluoride as biomarkers of exposure, conducting such analysis separately and allowing a comparison between the two. Also, we added a stratified analysis by RoB, which contributes to the characterization of the overall findings.

This review aimed to investigate all type of fluoride exposure assessments available in the peer-reviewed literature; however, no eligible records or sufficient data were available regarding fluoride exposure from drops or tablets supplementation, and topical dental products. Drinking water and water-based beverages are the main sources of exposure to fluoride in the general population, and fluoride intake from water positively correlates to urinary fluoride concentration (Abduweli Uyghurturk et al., 2020; Till et al., 2018). Naturally occurring and intentionally added water fluoride accounts for up to 90–95% of the total intake in fluoridated areas (Erdal and Buchanan, 2005). However, in young children toothpaste can be another important source of fluoride, reaching up to 25% of the total intake (European Commission, 2011). According to the European Food Safety Authority (EFSA) water intake report, although it is considered underestimated due to scarcity of specific data, children younger than 14 years old have a mean daily water intake of approximately 0.6 L, whereas other estimates report a higher daily water intake of 0.8–1.3 L, since the amount of water intake

Table 2
Risk of bias assessment of included studies.

Studies	Type of exposure assessment	Bias due to confounding	Bias in selecting participants	Bias in exposure classification	Bias in departure from intended exposure	Bias due to missing data	Bias in outcome measurement	Bias in selection of reported results	Overall Risk of Bias
Ahmad et al., 2022	W, U	Moderate	Moderate	Moderate Low	Low	Low	Low	Low	**Moderate**
Aravind et al., 2016	W	Moderate	Moderate	Moderate	Low	Low	Low	Low	**Moderate**
Bashash et al., 2017	U	High	Low	Low	Low	Low	Low	Low	**High**
Broadbent et al., 2015	W, I	Low	Low	Moderate Moderate	Low	Low	Low	Low	**Moderate**
Chen et al., 2008	W	High	Moderate	Moderate	Low	Low	Low	Moderate	**High**
Das and Mondal, 2016	I, U	High	Low	Low Low	Low	Low	Low	Moderate	**High**
Ding et al., 2011	U	High	Low	Low	Low	Low	Low	Low	**High**
Eswar et al., 2011	W	Moderate	Moderate	Moderate	Low	Low	Low	Low	**Moderate**
Farmus et al., 2021	I, U	Low	Low	Low Low	Low	Low	Low	Low	**Low**
Feng et al., 2022	U	Low	Low	Low	Low	Low	Low	Low	**Low**
Goodman et al., 2022	MUF	Low	Low	Low	Low	Low	Low	Low	**Low**
Hong et al., 2008	W	High	Moderate	Moderate	Low	Low	Low	Moderate	**High**
Karimzade et al., 2014	W	Moderate	Moderate	Moderate	Low	Low	Low	Moderate	**Moderate**
Li et al., 1995	U	High	Moderate	Low	Low	Low	Low	Moderate	**High**
Li et al., 2008	W	High	Moderate	Moderate	Low	Low	Low	Moderate	**High**
Lu et al., 2000	W, U	Moderate	Moderate	Moderate Low	Low	Low	Low	Moderate	**Moderate**
Poureslami et al., 2011	W	Moderate	Moderate	Moderate	Low	Low	Low	Moderate	**Moderate**
Rocha-Amador et al., 2007	W, U	Low	Moderate	Moderate Low	Low	Low	Low	Moderate	**Moderate**
Saxena et al., 2012	W, U	Low	Moderate	Moderate Low	Low	Low	Low	Low	**Moderate**
Sebastian and Sunitha, 2015	W	Low	Moderate	Moderate	Low	Low	Low	Moderate	**Moderate**
Seraj et al., 2012	W	High	Moderate	Moderate	Low	Low	Low	Moderate	**High**
Seraj et al., 2007	W	High	Moderate	Moderate	Low	Low	Low	Moderate	**High**
Shivaprakash et al., 2011	W	Moderate	Moderate	Moderate	Low	Low	Low	Moderate	**Moderate**
Till et al., 2020	W	Low	Low	Moderate	Low	Low	Low	Low	**Moderate**
Trivedi et al., 2007	W, U	Moderate	Moderate	Moderate Low	Low	Low	Low	Moderate	**Moderate**
Wang et al., 2008	W	Moderate	Moderate	Moderate	Low	Low	Low	Moderate	**Moderate**
Wang et al., 2021	W, U	Low	Moderate	Moderate Low	Low	Low	Low	Low	**Moderate**
Wang et al., 2007	W	Low	Moderate	Moderate	Low	Low	Low	Low	**Moderate**
Xiang et al., 2003	W	High	Moderate	Moderate	Low	Low	Low	Low	**High**
Xiang et al., 2011	B	Moderate	Moderate	Low	Low	Low	Low	Low	**Moderate**
Yu et al., 2021	W, U, H, N	Low	Moderate	Moderate Low Low Low	Low	Low	Low	Low	**Moderate**
Zhang et al., 2015	W, S, U	Low	Moderate	Moderate Low Low	Low	Low	Low	Low	**Moderate**
Zhao et al., 1996	W	High	Moderate	Moderate	Low	Low	High	Moderate	**High**

W: water; U: urinary; I: intake; N: nail; H: hair; B: blood; S: serum; MUF: maternal urinary fluoride.

can vary along with different environmental and seasonal temperatures. Based on EFSA report, the European Commission for Health and Food Safety estimated a systemic fluoride intake from water and water-based beverages of approximately 0.4–0.5 mg/day for a water fluoride concentration of 0.8 mg/L and of 0.7–0.9 mg/day for a water fluoride concentration of 1.5 mg/L (European Commission, 2011). For instance in 5 years old child with 20 kg weight, the cumulative exposure, considering all additional sources, can easily be above the adequate daily intake (ADI) of 1 mg/day (i.e. 0.05 mg/kg, as established by EFSA for both adults and children) (EFSA - European Food Safety Authority, 2013). Although the ADI generally aims to provide a balanced effect in preventing dental caries without increasing the risk of dental fluorosis, the results of the present meta-analysis seem to indicate that such an ADI may not be deemed safe from a cognitive development perspective.

Interestingly and unfortunately, neither among the 33 included studies and the studies excluded during full-texts evaluation, none were conducted in the U.S. or Europe, where community water fluoridation programs are applied extensively. Only some of the included cohort studies were conducted in countries with artificially fluoridated water (Canada and New Zealand). Most of the studies were performed in countries with drinking water naturally rich in fluoride; however concentrations of 1 mg/L and lower were considered, thus making such data comparable to the CWF programs.

Despite some heterogeneity in the effect size and occasionally its direction, we found a consistent indication of a negative association between fluoride exposure and children's intelligence, occurring from

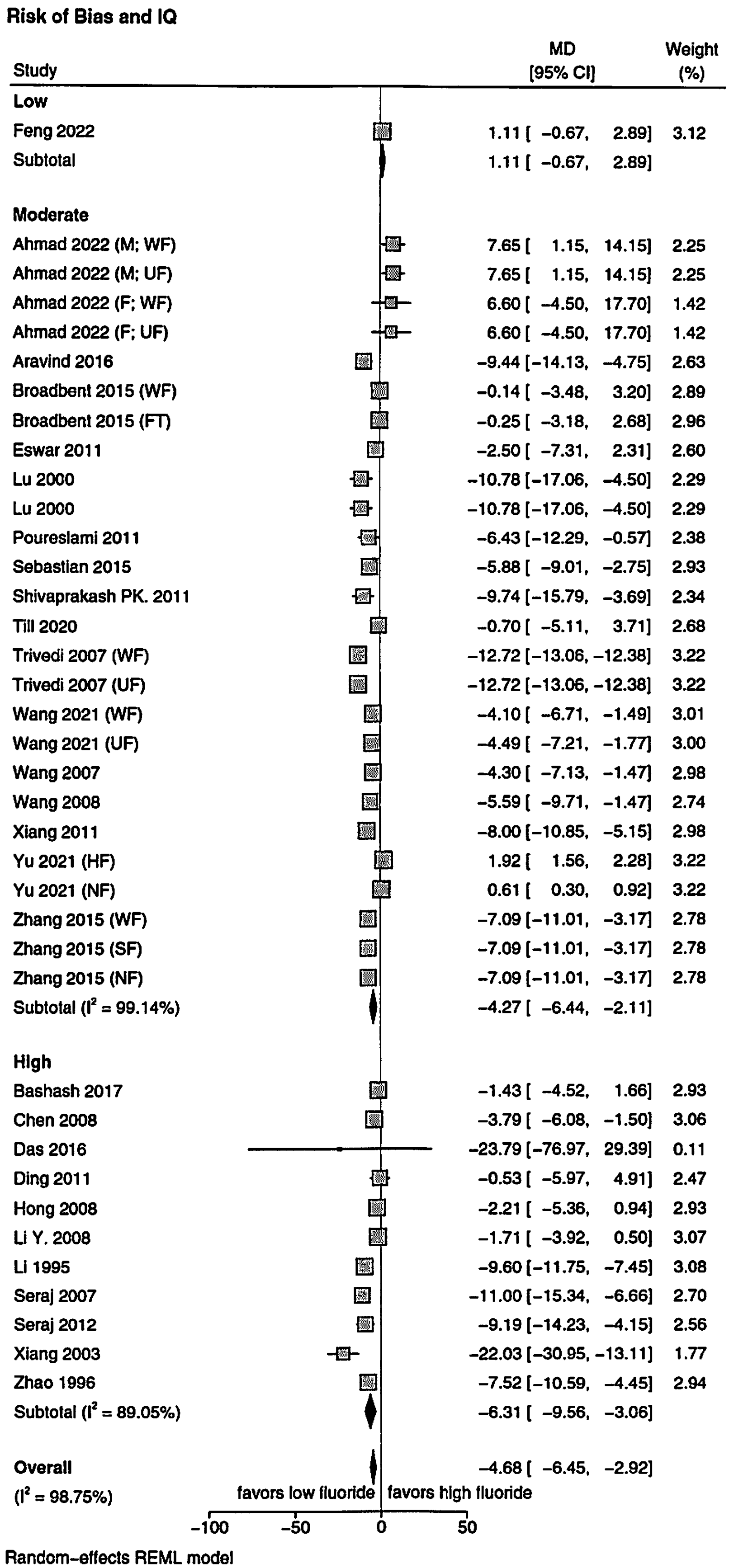


Fig. 2. Forest plot of the included studies stratified by Risk of Bias (RoB). Individual and summary mean differences (MD) of IQ for exposure to fluoride in relation to RoB levels. F: females; M: males; FT: fluoride tablets; HF: hair fluoride; NF: nail fluoride; SF: serum fluoride; UF: urinary fluoride; WF: water fluoride.

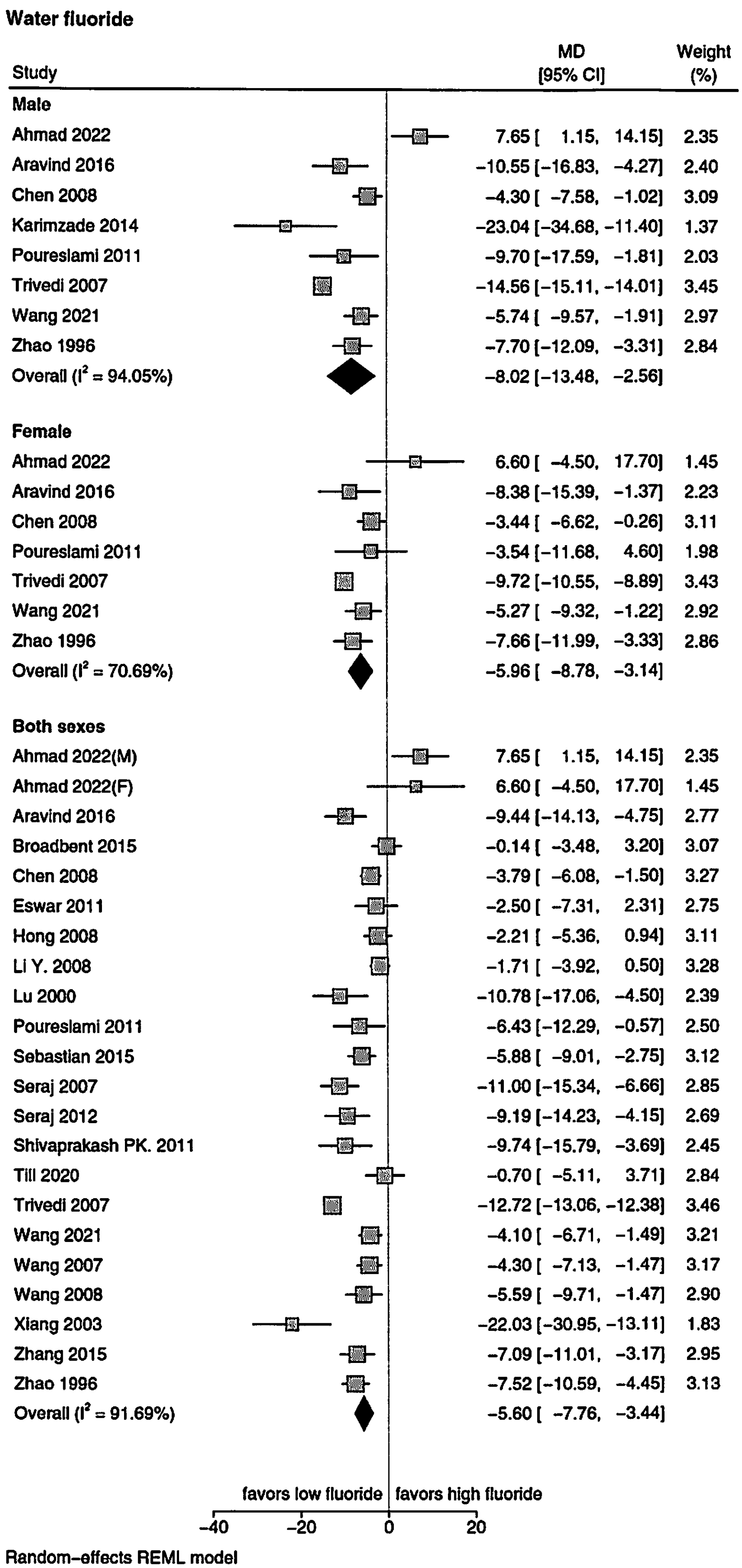


Fig. 3. Forest plot of the included drinking water studies. Mean difference (MD) in IQ with 95% confidence interval (CI) in relation to exposure to fluoride, stratified by sex. The squares represent risk estimate and horizontal lines represent their 95% CI. The area of each square is proportional to the weight of the study in the meta-analysis. The diamonds represent the combined risk for both sexes, and the solid line represents null value. The inverse-variance estimation method was used for study weighting. M: males; F: females.

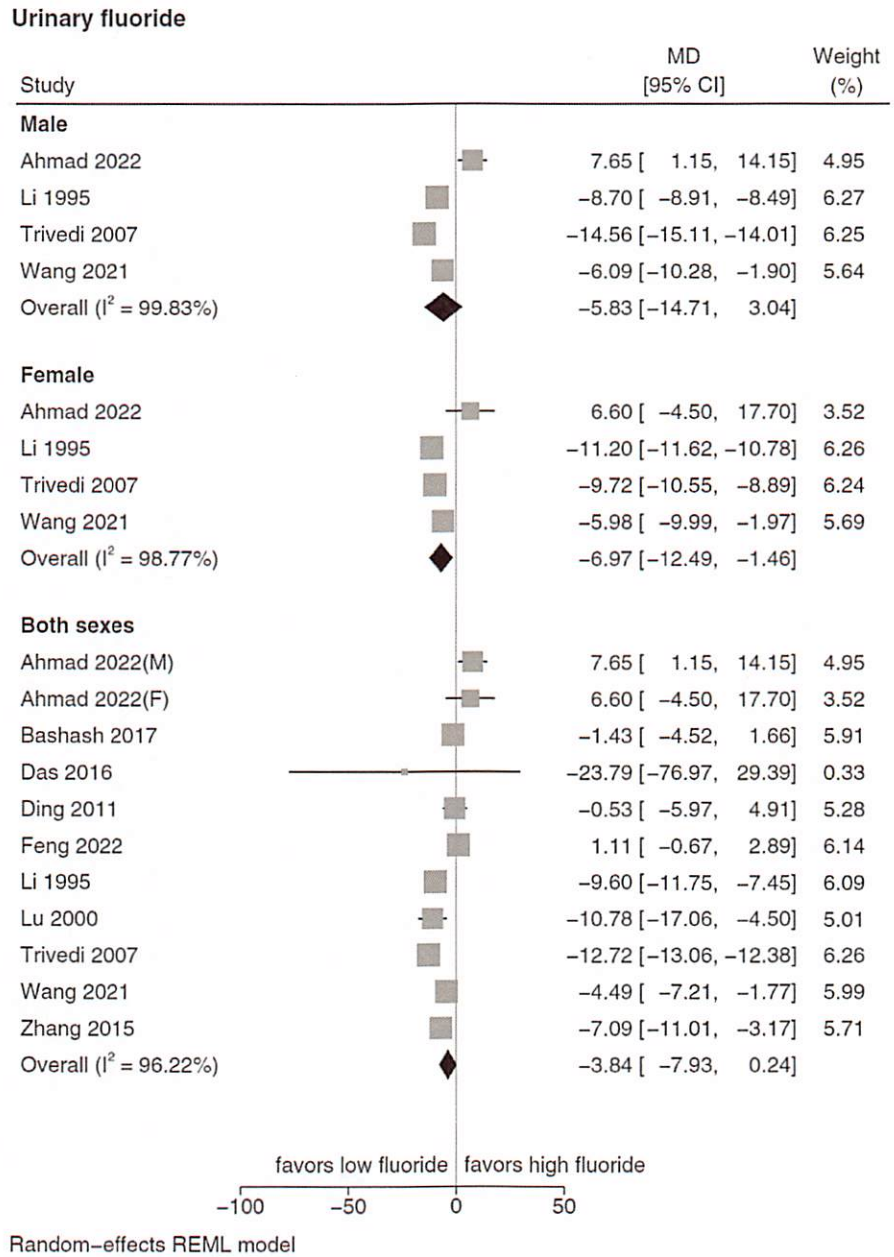


Fig. 4. Forest plots of the included urinary fluoride studies. Mean difference (MD) in IQ with 95% confidence interval (CI), stratified by sex. The squares represent risk estimate and horizontal lines represent their 95% CI. The area of each square is proportional to the weight of the study in the meta-analysis. The diamonds represent the combined risk for both sexes, and the solid line represents null value. The inverse-variance estimation method was used for study weighting. M: males; F: females.

low fluoride concentrations when exposure was assessed through a biomarker (urinary fluoride), while some evidence of a threshold around 1 mg/L emerged from the pooled analysis based on drinking water fluoride. We also found some slight differences in subgroup analysis by sex, with an indication of greater adverse effect on males than on females in some studies (Boyle et al., 2011; Cantoral et al., 2021; Till et al., 2020). This is supported by evidence that there may be a sex-specific presentation of such disorders, as already found for other contaminants (Desrochers-Couture et al., 2018). This difference in prevalence could be due at least in part to referral errors and misdiagnosis in females. Behavioral or intellectual disorders can be modulated by hormonal changes, often resulting in a more complex and blended clinical presentation as compared to males, associated with the development of different coping strategies, thus delaying or hindering the diagnosis (Young et al., 2020).

Additionally, subgroup analysis by outcome showed a greater adverse association between fluoride exposure and performance IQ, as compared with verbal IQ. This finding may be explained, by the fact that verbal abilities are especially susceptible to home environment and parenting factors, that play a pivotal role on the cognitive development of young children and a positive stimulating environment can somehow act as a buffer for this domain and compensate for the toxicants harmful effect (Goodman et al., 2022). Moreover, thyroid hormones and hippocampal synaptic structures, that are specifically involved in the development of non-verbal, visual-spatial skills, are particularly affected by fluoride (Lee et al., 2012; Levie et al., 2018). Concerning the critical thresholds of exposure involved, the dose-response spline regression analysis for water fluoride suggests a roughly linear adverse effect on IQ

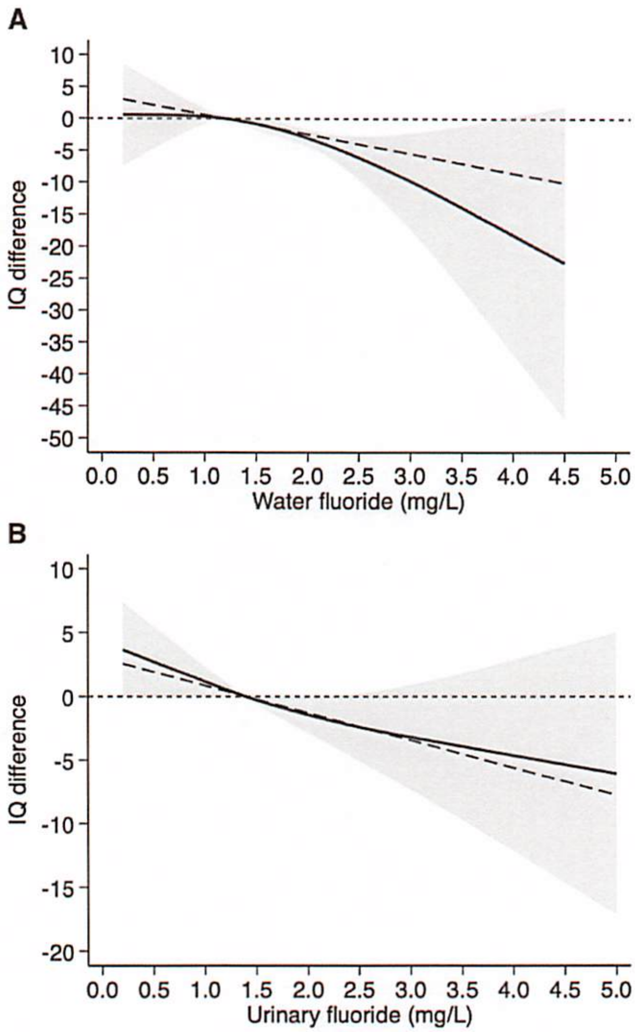


Fig. 5. Dose-response splines of intelligence (IQ score) and exposure to fluoride from drinking water (A) and urinary fluoride (B). Spline curve (black solid line) with 95% confidence limits (grey area), linear relation (black dotted line). Median values used as reference: 1.2 mg/L for drinking water fluoride and 1.4 mg/L for urinary fluoride, respectively.

above an approximate threshold of 1 mg/L, which becomes steeper over 2 mg/L.

The dose-response curve based on urinary fluoride shows a considerably more linear trend of the inverse association with the IQ score, with an early dose-dependent decrease in the endpoint, already detectable at the level corresponding to the current U.S. safety threshold of 0.7 mg/L of fluoride in drinking water. The inconsistency between the indication of a threshold and a more marked IQ decrease at high exposure levels for fluoride in drinking water, and a milder but continuous trend for urinary fluoride, is difficult to explain. It may be interesting to investigate the hypothesis that additional naturally occurring contaminants are also found in drinking water with high levels of naturally occurring fluoride and may either exert a deleterious effect on children's IQ or interact with fluoride by increasing its harmful effects. On the other hand, as a marker of cumulative exposure, urinary fluoride should provide a more reliable assessment and therefore allow a more valid dose-response relation.

Our results differ slightly from those of a recent meta-analysis, based on a linear meta-regression model, that indicated an early and linear decrease of IQ, with −2.94 IQ points per 1 mg/L fluoride increase (Neurath, 2020). However, among other possible common sources of heterogeneity, the fact that they considered water fluoride levels and urinary fluoride as equivalent for the purpose of pooled analyses, according to the National Toxicology Program guidance, may have affected their estimates, in addition to the choice of a linear regression model. Using instead a non-linear dose-response model, Duan et al. (2018) found an association between increasing water fluoride exposure and IQ decrease, also starting from concentrations as low as 1 mg/L, however they limited their analysis to fluoride exposure from drinking water. Despite the methodological differences and possible limitations, the effect direction resulting from these reviews, in line with our results, suggest a harmful effect from fluoride in drinking water within a concentration range previously considered as safe, such as 0.7–1.2 mg/L (CDC - Center for Disease Control and Prevention, 2021). In 2015, however, the safety threshold for community water fluoridation was set to 0.7 mg/L in the U.S. primarily to lower the risk of dental fluorosis (U. S. Department of Health and Human Services Federal Panel on Community Water Fluoridation, 2015).

In addition to a general indication of an inverse association between fluoride exposure and IQ levels, a key finding of this meta-analysis was provided in the subgroup analysis by risk of bias, which showed noticeable differences of the estimates across categories of overall study quality, with a general trend towards weaker or null associations in the most carefully conducted studies. The fact that the only low RoB study (Feng et al., 2022) reported a non-adverse effect of fluoride on children's IQ, and that studies at intermediate RoB found a weaker association compared with studies affected by more severe biases, raises indeed some doubts on such association, despite the caution that must be given to single studies. Such a pattern may suggest that the serious adverse effect found in lower quality studies according to RoB, could be at least in part due to the methodological limitations of those studies, thus increasing the uncertainty about the actual association between fluoride exposure and children's cognitive neurodevelopment and reaffirming the strong need for properly designed and higher quality research on this topic. In our meta-analysis, the primary reason for downgrading the studies with reference to the risk of bias was the lack of adequate consideration of major confounders, such as age and socioeconomic status. The domain concerning participant selection was also a common reason for downgrading study quality, since in most the eligible studies the enrollment was primarily based on the participants' different fluoride exposures. In this regard, it should be highlighted that among the 4 cohort-designed studies that did not have such limitation, 3 of them that also adjusted for major confounding (Broadbent et al., 2015; Farmus et al., 2021; Till et al., 2020) found only a mild effect on children's IQ. Likewise, this considerably milder association with IQ score decrease found in these high-quality longitudinal studies (MD −0.74) compared with the cross-sectional studies (MD −5.21) raises additional concerns about the potential influence of biases in the latter estimates, and the key role of methodological issues in the epidemiologic literature.

Age at outcome evaluation, as a possible source of confounding, varied widely over the included studies, possibly affecting both the cumulative exposure and the adequacy of the intelligence tests that were administered, whose results cannot be easily compared, also explaining to some extent the heterogeneous results of the studies and of the subgroup analysis by age groups. We tried to overcome some of such limitations by performing a subgroup analysis stratified by age categories, and we found interestingly a slightly higher IQ loss in children over 6 years of age, compared to preschool children. This could be explained by a higher exposure to fluoride coming from an increased intake of water and water-based beverages of older children compared to younger ones, as supported by a recent report from the Food Safety Authority of Ireland (FSAI - Food Safety Authority of Ireland, 2018). However, current evidence from cohort studies seems to indicate that *in utero* exposure to fluoride has a stronger association to neurodevelopmental issues as compared to post-natal exposure (Bashash et al., 2017; Cantoral et al., 2021; Farmus et al., 2021; Goodman et al., 2022). Another possible limitation of the evidence generated by this review lies in the fact that many studies included in this review assessed water fluoride concentration and could not give a reliable insight on the total daily intake of fluoride. On the other hand, a considerable number of studies assessed urinary fluoride as the exposure marker, which reflects the cumulative exposure from all sources. Villa et al. (2010) estimated that in children 0–7 years old a daily fluoride intake of 0.07 mg leads to a neutral fluoride balance, being the fluoride retained equals zero. Differently, whatever the total daily fluoride intake might be and regardless of the sources, over approximately 0.5 mg/day a constant 55% of it will be retained, reaching teeth, bones, and brain regions, accounting for an increased 35% excretion through urine for each mg/day. Urinary fluoride excretion is therefore considered a valid biomarker of contemporary fluoride intake for population groups, although for individuals and different age groups it varies with renal function and acid-base balance (EFSA - European Food Safety Authority, 2013; Villa et al., 2010). In this regard, it should be noted that only a few studies reported the urinary fluoride adjusted for creatinine (Bashash et al., 2017; Feng et al., 2022; Wang et al., 2021). The differences, when reported, were however negligible, as renal function is generally efficient and comparable in the age groups considered by this review (Wang et al., 2018), thus only mildly affecting the estimates on the relation between intelligence and urinary fluoride.

Overall, we note that the observational design of all the included studies, mostly having in addition a cross-sectional design, may be a relevant source of bias, primarily due to unmeasured or residual confounding. However, eligible randomized clinical trials on this subject were not available, let alone investigating long-term exposure, understandably because of ethical issues. Therefore, and also in light of the differences found in the related subgroup analysis, well-designed cohort studies with complete data for both exposure and confounding and proper blinding of the study personnel are urgently needed, to adequately assess the relation between fluoride exposure and neurocognitive development, and to clarify the current sources of uncertainty, that also limit the adoption of public health measures.

Lastly, we acknowledge that the statistical estimates generated by our meta-analysis at high levels of fluoride exposure were statistically imprecise, thus suggesting additional caution.

In conclusion, we found an overall indication of dose-dependent adverse effects of fluoride on children's cognitive neurodevelopment, starting at rather low exposure. However, the limitations of most studies included in this meta-analysis, with particular reference to the risk of residual confounding, raise uncertainties about both the causal nature of such relation and the exact thresholds of exposure involved. Such key issues can only be confirmed by additional, high-quality longitudinal studies.

Credit author statement

Federica Veneri: conceptualization of the research protocol, methodology, data collection, data analysis, writing-original draft preparation; Marco Vinceti: conceptualization of the research protocol, methodology, data analysis, writing-reviewing and editing; Luigi Generali: supervision, writing-reviewing and editing; Maria Edvige Giannone: methodology, data collection and data synthesis; Elena Mazzoleni: methodology, data collection and data synthesis; Linda Birnbaum: writing-reviewing and editing; Ugo Consolo: writing-reviewing; Tommaso Filippini: conceptualization of the research protocol, methodology, modeling, data analysis, writing-reviewing and editing, supervision.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

All data generated or analysed during this study are included in this published article and its supplementary information files

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.envres.2023.115239.

References

Abanto Alvarez, J., Rezende, K.M.P.C., Marocho, S.M.S., Alves, F.B.T., Celiberti, P., Ciamponi, A.L., 2009. Dental fluorosis: exposure, prevention and management. Med. Oral Patol. Oral Cir. Bucal 14, E103–E107.

Abduweli Uyghurturk, D., Goin, D.E., Martinez-Mier, E.A., Woodruff, T.J., DenBesten, P. K., 2020. Maternal and fetal exposures to fluoride during mid-gestation among pregnant women in northern California. Environ. Health 19, 38. https://doi.org/10.1186/s12940-020-00581-2.

Aguirre-Sierra, A., Alonso, Á., Camargo, J.A., 2013. Fluoride bioaccumulation and toxic effects on the survival and behavior of the endangered white-clawed crayfish austropotamobius pallipes (lereboullet). Arch. Environ. Contam. Toxicol. 65, 244–250. https://doi.org/10.1007/s00244-013-9892-6.

Ahmad, M.S., Sarker, M.N.I., Ahmad, M.N., Ali, M., Sadiq, ., Abbas, M., 2022. Does high fluoride intake cause low IQ? A case of Islamic religious schools (Madrassas) in rural and urban areas of Sindh, Pakistan. Fluoride 55, 49–62.

Aravind, A., Dhanya, R.S., Narayan, A., Sam, G., Adarsh, V.J., Kiran, M., 2016. Effect of fluoridated water on intelligence in 10-12-year-old school children. J. Int. Soc. Prev. Community Dent. 6, S237–S242. https://doi.org/10.4103/2231-0762.197204.

Banerjee, A., Singh, A., Roychoudhury, A., 2021. Fluoride toxicity variably affects overall physiology and grain development in three contrasting rice genotypes, representing a potential biohazard. Environ. Sci. Pollut. Res. 28, 40220–40232. https://doi.org/10.1007/s11356-020-10604-7.

Bashash, M., Thomas, D., Hu, H., Martinez-Mier, E.A., Sanchez, B.N., Basu, N., Peterson, K.E., Ettinger, A.S., Wright, R., Zhang, Z., Liu, Y., Schnaas, L., Mercado-García, A., Téllez-Rojo, M.M., Hernández-Avila, M., 2017. Prenatal fluoride exposure and cognitive outcomes in children at 4 and 6-12 Years of age in Mexico. Environ. Health Perspect. 125, 097017 https://doi.org/10.1289/EHP655.

British Fluoridation Society, 2013. One in a Million - the Facts about Water Fluoridation. https://bfsweb.org/one-in-a-million/. (Accessed 4 January 2023).

Boyle, C.A., Boulet, S., Schieve, L.A., Cohen, R.A., Blumberg, S.J., Yeargin-Allsopp, M., Visser, S., Kogan, M.D., 2011. Trends in the prevalence of developmental disabilities in US children, 1997–2008. Pediatrics 127, 1034–1042. https://doi.org/10.1542/peds.2010-2989.

Broadbent, J.M., Thomson, W.M., Ramrakha, S., Moffitt, T.E., Zeng, J., Foster Page, L.A., Poulton, R., 2015. Community water fluoridation and intelligence: prospective study in New Zealand. Am. J. Publ. Health 105, 72–76. https://doi.org/10.2105/AJPH.2013.301857.

Cantoral, A., Téllez-Rojo, M.M., Malin, A.J., Schnaas, L., Osorio-Valencia, E., Mercado, A., Martínez-Mier, E.Á., Wright, R.O., Till, C., 2021. Dietary fluoride intake during pregnancy and neurodevelopment in toddlers: a prospective study in the progress cohort. Neurotoxicology 87, 86–93. https://doi.org/10.1016/j.neuro.2021.08.015.

CDC - Center for Disease Control and Prevention, 2021. Community Water Fluoridation. https://www.cdc.gov/fluoridation/index.html?CDC_AA_refVal=https%3A%2F%2Fwww.cdc.gov%2Ffluoridation%2Findex.htm. Accessed January 4, 2023.

Chen, Y., Han, F., Zhou, Z., Zhang, H., Jiao, X., Zhang, S., Huang, M., Chang, T., Dong, Y., 2008. Research on the intellectual development of children in high fluoride areas. Fluoride 41, 120–124.

Choubisa, S.L., Choubisa, D., 2016. Status of industrial fluoride pollution and its diverse adverse health effects in man and domestic animals in India. Environ. Sci. Pollut. Res. 23, 7244–7254. https://doi.org/10.1007/s11356-016-6319-8.

Das, K., Mondal, N.K., 2016. Dental fluorosis and urinary fluoride concentration as a reflection of fluoride exposure and its impact on IQ level and BMI of children of Laxmisagar, Simlapal Block of Bankura District, W.B., India. Environ. Monit. Assess. 188, 218. https://doi.org/10.1007/s10661-016-5219-1.

Desrochers-Couture, M., Oulhote, Y., Arbuckle, T.E., Fraser, W.D., Séguin, J.R., Ouellet, E., Forget-Dubois, N., Ayotte, P., Boivin, M., Lanphear, B.P., Muckle, G., 2018. Prenatal, concurrent, and sex-specific associations between blood lead concentrations and IQ in preschool Canadian children. Environ. Int. 121, 1235–1242. https://doi.org/10.1016/j.envint.2018.10.043.

Dhar, V., Bhatnagar, M., 2009. Physiology and toxicity of fluoride. Indian J. Dent. Res. 20, 350. https://doi.org/10.4103/0970-9290.57379.

Ding, Y., Gao, Y., Sun, H., Han, H., Wang, W., Ji, X., Liu, X., Sun, D., 2011. The relationships between low levels of urine fluoride on children's intelligence, dental

fluorosis in endemic fluorosis areas in Hulunbuir, Inner Mongolia, China. J. Hazard Mater. 186, 1942–1946. https://doi.org/10.1016/j.jhazmat.2010.12.097.
Duan, Q., Jiao, J., Chen, X., Wang, X., 2018. Association between water fluoride and the level of children's intelligence: a dose–response meta-analysis. Publ. Health 154, 87–97. https://doi.org/10.1016/j.puhe.2017.08.013.
EFSA - European Food Safety Authority, 2013. Scientific opinion on dietary reference values for fluoride. EFSA J. 11, 3332. https://doi.org/10.2903/j.efsa.2013.3332.
Erdal, S., Buchanan, S.N., 2005. A quantitative look at fluorosis, fluoride exposure, and intake in children using a health risk assessment approach. Environ. Health Perspect. 113, 111–117. https://doi.org/10.1289/ehp.7077.
Eswar, P., Nagesh, L., Devaraj, C.G., 2011. Intelligence quotients of 12-14 year old school children in a high and a low fluoride village in India. Fluoride 44, 168–172.
European Commission, 2011. Critical Review of Any New Evidence on the Hazard Profile, Health Effects, and Human Exposure to Fluoride and the Fluoridating Agents of Drinking Water. https://data.europa.eu/doi/10.2772/38897.
Farmus, L., Till, C., Green, R., Hornung, R., Martinez Mier, E.A., Ayotte, P., Muckle, G., Lanphear, B.P., Flora, D.B., 2021. Critical windows of fluoride neurotoxicity in Canadian children. Environ. Res. 200, 111315 https://doi.org/10.1016/j.envres.2021.111315.
Feng, Z., An, N., Yu, F., Ma, J., Li, N., Du, Y., Guo, M., Xu, K., Hou, X., Li, Z., Zhou, G., Ba, Y., 2022. Do methylenetetrahydrofolate dehydrogenase, cyclohydrolase, and formyltetrahydrofolate synthetase 1 polymorphisms modify changes in intelligence of school-age children in areas of endemic fluorosis? Chin. Med. J. 135, 1846–1854. https://doi.org/10.1097/CM9.0000000000002062.
Filippini, T., Wise, L.A., Vinceti, M., 2022. Cadmium exposure and risk of diabetes and prediabetes: a systematic review and dose-response meta-analysis. Environ. Int. 158, 106920 https://doi.org/10.1016/j.envint.2021.106920.
FSAI - Food Safety Authority of Ireland, 2018. Total Diet Study 2014–2016: Assessment of Dietary Exposure to Fluoride in Adults and Children in Ireland. Report of the Scientific Committee of the Food Safety Authority of Ireland. https://www.fsai.ie/news_centre/tds_fluoride_30042018.html. Accessed January 4, 2023.
Goodman, C.V., Bashash, M., Green, R., Song, P., Peterson, K.E., Schnaas, L., Mercado-García, A., Martínez-Medina, S., Hernández-Avila, M., Martinez-Mier, A., Téllez-Rojo, M.M., Hu, H., Till, C., 2022. Domain-specific effects of prenatal fluoride exposure on child IQ at 4, 5, and 6-12 years in the ELEMENT cohort. Environ. Res. 211, 112993 https://doi.org/10.1016/j.envres.2022.112993.
Grandjean, P., 2019. Developmental fluoride neurotoxicity: an updated review. Environ. Health 18, 110. https://doi.org/10.1186/s12940-019-0551-x.
Harrell, F.E., 2001. Regression Modeling Strategies: with Applications to Linear Models, Logistic Regression, and Survival Analysis. Springer Series in Statistics. Springer, New York, New York, NY. https://doi.org/10.1007/978-1-4757-3462-1.
Higgins, J.P.T., Thompson, S.G., Deeks, J.J., Altman, D.G., 2003. Measuring inconsistency in meta-analyses. BMJ 327, 557–560. https://doi.org/10.1136/bmj.327.7414.557.
Hogervorst, J., Virgolino, A., Halldorsson, T.I., Vinceti, M., Akesson, A., Leander, K., Nawrot, T., Filippini, T., Laguzzi, F., 2022. Maternal acrylamide exposure during pregnancy and fetal growth: a systematic review and dose-response meta-analysis of epidemiological studies. Environ. Res. 213, 113705 https://doi.org/10.1016/j.envres.2022.113705.
Hong, F., Cao, Y., Yang, D., Wang, H., 2008. Research on the effects of fluoride on child intellectual development under different environmental conditions. Fluoride 41, 156–160.
Iheozor-Ejiofor, Z., Worthington, H.V., Walsh, T., O'Malley, L., Clarkson, J.E., Macey, R., Alam, R., Tugwell, P., Welch, V., Glenny, A.-M., 2015. Water fluoridation for the prevention of dental caries. Cochrane Database Syst. Rev. https://doi.org/10.1002/14651858.CD010856.pub2, 2015, CD010856.
Karimzade, S., Aghaei, M., Mahvi, A.H., 2014. Investigation of intelligence quotient in 9-12-year-old children exposed to high- and low-drinking water fluoride in West Azerbaijan province. Iran. Fluoride 47, 9–14.
Lee, A.C.H., Yeung, L.-K., Barense, M.D., 2012. The hippocampus and visual perception. Front. Hum. Neurosci. 6, 91. https://doi.org/10.3389/fnhum.2012.00091.
Levie, D., Korevaar, T.I.M., Bath, S.C., Dalmau-Bueno, A., Murcia, M., Espada, M., Dineva, M., Ibarluzea, J.M., Sunyer, J., Tiemeier, H., Rebagliato, M., Rayman, M.P., Peeters, R.P., Guxens, M., 2018. Thyroid function in early pregnancy, child IQ, and autistic traits: a meta-analysis of individual participant data. J. Clin. Endocrinol. Metab. 103, 2967–2979. https://doi.org/10.1210/jc.2018-00224.
Li, Y., Jing, X., Chen, D., Lin, L., Wang, Z., 2008. Effects of endemic fluoride poisoning on the intellectual development of children in Baotou. Fluoride 41, 161–164.
Li, X.S., Zhi, J.L., Gao, R.O., 1995. Effect of fluoride exposure on intelligence in children. Fluoride 28, 189–192.
Lu, Y., Sun, Z.R., Wu, L.N., Wang, X., Lu, W., Liu, S.S., 2000. Effect of high-fluoride water on intelligence in children. Fluoride 33, 74–78.
Miranda, G.H.N., Alvarenga, M.O.P., Ferreira, M.K.M., Puty, B., Bittencourt, L.O., Fagundes, N.C.F., Pessan, J.P., Buzalaf, M.A.R., Lima, R.R., 2021. A systematic review and meta-analysis of the association between fluoride exposure and neurological disorders. Sci. Rep. 11, 22659 https://doi.org/10.1038/s41598-021-99688-w.
Morgan, R.L., Thayer, K.A., Santesso, N., Holloway, A.C., Blain, R., Eftim, S.E., Goldstone, A.E., Ross, P., Ansari, M., Akl, E.A., Filippini, T., Hansell, A., Meerpohl, J.J., Mustafa, R.A., Verbeek, J., Vinceti, M., Whaley, P., Schünemann, H.J., 2019. A risk of bias instrument for non-randomized studies of exposures: a users' guide to its application in the context of GRADE. Environ. Int. 122, 168–184. https://doi.org/10.1016/j.envint.2018.11.004.
National Research Council, 2006. Fluoride in Drinking Water: A Scientific Review of EPA's Standards. National Academies Press, Washington, D.C. https://doi.org/10.17226/11571.
Neurath, C., 2020. Dose-Response Assessment of Fluoride Neurotoxicity Studies - Submission to the NAS and NTP. fluoridealert.org, Fluoride Action Network, pp. 1–30. https://fluoridealert.org/wp-content/uploads/neurath-2020.fan-dose-response-assessment-of-ntp-studies-with-corrections.pdf. Accessed January 4, 2023.
NHS - National Health System, 2021. Fluoride. https://www.nhs.uk/conditions/fluoride/. Accessed January 4, 2023.
NIH - National Institute of Health, 2021. Fluoride - Fact Sheet. https://ods.od.nih.gov/factsheets/Fluoride-HealthProfessional/. Accessed January 4, 2023.
NTP - National Toxicology Program, 2020. Draft NTP Monograph on the Systematic Review of Fluoride Exposure and Neurodevelopmental and Cognitive Health Effects. https://fluoridealert.org/wp-content/uploads/ntp.revised-monograph.9-16-2020.pdf. Accessed January 4, 2023.
Orsini, N., 2021. Weighted mixed-effects dose–response models for tables of correlated contrasts. Stata J. 21, 320–347. https://doi.org/10.1177/1536867X211025798.
Orsini, N., Spiegelman, D., 2020. Meta-analysis of dose-response relationships. In: Schmid, C.H., Stijnen, T. (Eds.), Handbook of Meta-Analysis. Chapman and Hall/CRC, White I., New York.
Page, M.J., McKenzie, J.E., Bossuyt, P.M., Boutron, I., Hoffmann, T.C., Mulrow, C.D., Shamseer, L., Tetzlaff, J.M., Akl, E.A., Brennan, S.E., Chou, R., Glanville, J., Grimshaw, J.M., Hróbjartsson, A., Lalu, M.M., Li, T., Loder, E.W., Mayo-Wilson, E., McDonald, S., McGuinness, L.A., Stewart, L.A., Thomas, J., Tricco, A.C., Welch, V.A., Whiting, P., Moher, D., 2021. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 372, n71. https://doi.org/10.1136/bmj.n71.
Peckham, S., Lowery, D., Spencer, S., 2015. Are fluoride levels in drinking water associated with hypothyroidism prevalence in England? A large observational study of GP practice data and fluoride levels in drinking water. J. Epidemiol. Community Health 69, 619–624. https://doi.org/10.1136/jech-2014-204971.
Poureslami, H.R., Horri, A., Garrusi, B., 2011. A comparative study of the IQ of children age 7–9 in a high and a low fluoride water city in Iran. Fluoride 44, 163–167.
Prezioso, G., Giannini, C., Chiarelli, F., 2018. Effect of thyroid hormones on neurons and neurodevelopment. Horm. Res. Paediatr. 90, 73–81. https://doi.org/10.1159/000492129.
Ranjan, R., Swarup, D., Bhardwaj, B., Patra, R.C., 2008. Level of certain micro and macro minerals in blood of cattle from fluoride polluted localities of udaipur, India. Bull. Environ. Contam. Toxicol. 81, 503–507. https://doi.org/10.1007/s00128-008-9492-8.
Rocha-Amador, D., Navarro, M.E., Carrizales, L., Morales, R., Calderón, J., 2007. Decreased intelligence in children and exposure to fluoride and arsenic in drinking water. Cad. Saúde Pública 23, S579–S587. https://doi.org/10.1590/S0102-311X2007001600018.
Saldarriaga, A., Rojas-Gualdrón, D., Restrepo, M., Santos-Pinto, L., Jeremias, F., 2021. Dental fluorosis severity in children 8-12 years old and associated factors. Acta Odontol. Latinoam. 34, 156–165. https://doi.org/10.54589/aol.34/2/156.
Saxena, S., Sahay, A., Goel, P., 2012. Effect of fluoride exposure on the intelligence of school children in Madhya Pradesh, India. J. Neurosci. Rural Pract. 3, 144–149. https://doi.org/10.4103/0976-3147.98213.
Sebastian, S.T., Sunitha, S., 2015. A cross-sectional study to assess the intelligence quotient (IQ) of school going children aged 10-12 years in villages of Mysore district, India with different fluoride levels. J. Indian Soc. Pedod. Prev. Dent. 33, 307–311. https://doi.org/10.4103/0970-4388.165682.
Seraj, B., Shahrabi, M., Shadfar, M., Ahmadi, R., Fallahzadeh, M., Eslamlu, H.F., Kharazifard, M.J., 2012. Effect of high water fluoride concentration on the intellectual development of children in Makoo/Iran. J. Dent. (Tehran) 9, 221–229.
Seraj, B., Sharabi, M., Falahzade, M., 2007. Effect of high fluoride concentration in drinking water on children's intelligence. J. Dent. Med. 19, 80–86.
Shivaprakash, P.K., Ohri, K., Noorani, H., 2011. Relation between dental fluorosis and intelligence quotient in school children of Bagalkot district. J. Indian Soc. Pedod. Prev. Dent. 29, 117–120. https://doi.org/10.4103/0970-4388.84683.
Srivastava, S., Flora, S.J.S., 2020. Fluoride in drinking water and skeletal fluorosis: a review of the global impact. Curr. Environ. Health Rep. 7, 140–146. https://doi.org/10.1007/s40572-020-00270-9.
ten Cate, J.M., Buzalaf, M.A.R., 2019. Fluoride mode of action: once there was an observant dentist. J. Dent. Res. 98, 725–730. https://doi.org/10.1177/0022034519831604.
Till, C., Green, R., Grundy, J.G., Hornung, R., Neufeld, R., Martinez-Mier, E.A., Ayotte, P., Muckle, G., Lanphear, B., 2018. Community water fluoridation and urinary fluoride concentrations in a national sample of pregnant women in Canada. Environ. Health Perspect. 126, 107001 https://doi.org/10.1289/EHP3546.
Till, C., Green, R., Flora, D., Hornung, R., Martinez-Mier, E.A., Blazer, M., Farmus, L., Ayotte, P., Muckle, G., Lanphear, B., 2020. Fluoride exposure from infant formula and child IQ in a Canadian birth cohort. Environ. Int. 134, 105315 https://doi.org/10.1016/j.envint.2019.105315.
Trivedi, M.H., Verma, R.J., Chinoy, N.J., Patel, R.S., Sathawara, N.G., 2007. Effect of high fluoride water on intelligence of school children in India. Fluoride 40, 178–183.
U.S. Department of Health and Human Services Federal Panel on Community Water Fluoridation, 2015. U.S. Public health service recommendation for fluoride concentration in drinking water for the prevention of dental caries. Publ. Health Rep. 130, 318–331. https://doi.org/10.1177/003335491513000408.
Vieira, A.R., 2022. Fluoride toxicity. In: Monographs in Oral Science. S. Karger AG, pp. 140–148. https://doi.org/10.1159/000520789.
Villa, A., Anabalon, M., Zohouri, V., Maguire, A., Franco, A.M., Rugg-Gunn, A., 2010. Relationships between fluoride intake, urinary fluoride excretion and fluoride retention in children and adults: an analysis of available data. Caries Res. 44, 60–68. https://doi.org/10.1159/000279325.
Vinceti, M., Filippini, T., Wise, L.A., Rothman, K.J., 2021. A systematic review and dose-response meta-analysis of exposure to environmental selenium and the risk of type 2

diabetes in nonexperimental studies. Environ. Res. 197, 111210 https://doi.org/10.1016/j.envres.2021.111210.

Wang, W., Du, C., Lin, L., Chen, W., Tan, L., Shen, J., Pearce, E.N., Zhang, Y., Gao, M., Bian, J., Wang, X., Zhang, W., 2018. Anthropometry-based 24-h urinary creatinine excretion reference for Chinese children. PLoS One 13, e0197672. https://doi.org/10.1371/journal.pone.0197672.

Wang, S.X., Wang, Z.H., Cheng, X.T., Li, J., Sang, Z.P., Zhang, X.D., Han, L.L., Qiao, X.Y., Wu, Z.M., 2007. Arsenic and fluoride exposure in drinking water: children's IQ and growth in Shanyin county, Shanxi province, China. Environ. Health Perspect. 115, 643–647. https://doi.org/10.1289/ehp.9270.

Wang, G., Yang, D., Jia, F., Wang, H., 2008. A study of the IQ levels of four- to seven-year-old children in high fluoride areas. Fluoride 41, 340–343.

Wang, S., Zhao, Q., Li, G., Wang, M., Liu, H., Yu, X., Chen, J., Li, P., Dong, L., Zhou, G., Cui, Y., Liu, L., Wang, A., 2021. The cholinergic system, intelligence, and dental fluorosis in school-aged children with low-to-moderate fluoride exposure. Ecotoxicol. Environ. Saf. 228, 112959 https://doi.org/10.1016/j.ecoenv.2021.112959.

World Health Organisation, 2021. Oral Health - Overview, Impact, Prevention and Response. https://www.who.int/health-topics/oral-health#tab=tab_2. Accessed January 4, 2023.

World Health Organization, 2017. Guidelines for Drinking-Water Quality: Fourth Edition Incorporating the First Addendum. https://www.who.int/publications/i/item/9789241549950. Accessed January 4, 2023.

Xiang, Q., Liang, Y., Chen, B., Chen, L., 2011. Analysis of children's serum fluoride levels in relation to intelligence scores in a high and low fluoride water village in China. Fluoride 44, 191–194.

Xiang, Q., Liang, Y., Chen, L., Wang, C., Chen, B., Chen, X., Zhou, M., 2003. Effect of fluoride in drinking water on children's intelligence. Fluoride 36, 84–94.

Young, S., Adamo, N., Ásgeirsdóttir, B.B., Branney, P., Beckett, M., Colley, W., Cubbin, S., Deeley, Q., Farrag, E., Gudjonsson, G., Hill, P., Hollingdale, J., Kilic, O., Lloyd, T., Mason, P., Paliokosta, E., Perecherla, S., Sedgwick, J., Skirrow, C., Tierney, K., van Rensburg, K., Woodhouse, E., 2020. Females with ADHD: an expert consensus statement taking a lifespan approach providing guidance for the identification and treatment of attention-deficit/hyperactivity disorder in girls and women. BMC Psychiatr. 20, 404. https://doi.org/10.1186/s12888-020-02707-9.

Yu, X., Xia, L., Zhang, S., Zhou, G., Li, Y., Liu, H., Hou, C., Zhao, Q., Dong, L., Cui, Y., Zeng, Q., Wang, A., Liu, L., 2021. Fluoride exposure and children's intelligence: Gene-environment interaction based on SNP-set, gene and pathway analysis, using a case-control design based on a cross-sectional study. Environ. Int. 155, 106681. https://doi.org/10.1016/j.envint.2021.106681.

Zhang, S., Zhang, X., Liu, H., Qu, W., Guan, Z., Zeng, Q., Jiang, C., Gao, H., Zhang, C., Lei, R., Xia, T., Wang, Z., Yang, L., Chen, Y., Wu, X., Cui, Y., Yu, L., Wang, A., 2015. Modifying effect of COMT gene polymorphism and a predictive role for proteomics analysis in children's intelligence in endemic fluorosis area in Tianjin, China. Toxicol. Sci. 144, 238–245. https://doi.org/10.1093/toxsci/kfu311.

Zhao, L.B., Liang, G.H., Zhang, D.N., Wu, X.R., 1996. Effect of a high fluoride water supply on children's intelligence. Fluoride 29, 190–192.

CALIFORNIA WATER SERVICE
1720 North First Street
San Jose, CA 95112-4598 *Tel:* (408) 367-8200

April 26, 2023

Dear Executive Committee,

In 1957, the Oroville City Council gained the approval of the California Public Utilities Commission to mandate that California Water Service's (Cal Water) Oroville District add fluoride to the drinking water of its customers. It was a decision made on the best available data at the time and with the health of citizens in mind.

Fluoride is an odorless, colorless chemical that is not an essential nutrient but has been found, on average, to play a role in dental health by helping to prevent dental caries. At too low concentrations, without other sources of fluoride, children and adults may experience dental caries. Therefore, it is recommended by California's Division of Drinking Water (DDW) that it be added at a pharmaceutical dosage within specific limits in community water systems where it is monetarily feasible to do so. At too high concentrations, fluoride can cause dental and bone fluorosis (making bones and teeth hard but brittle), and in extreme cases even death. Our treatment plant operators are highly trained and skilled at handling this otherwise dangerous chemical. We take every precaution necessary to ensure that the fluoride we add is dosed according to the safety guidelines set by the health experts at DDW, which sets drinking water standards for health and safety.

Now, 66 years later, fluoride has become more readily available in other sources. According to the American Dental Association (ADA), fluoride application has been found to be most effective via topical application (i.e., brushing, rinsing, etc.) and at higher concentrations than are safe for ingestion. Currently, it is less expensive to buy toothpaste with ADA-approved amounts of fluoride in it than it is to buy toothpaste without fluoride. Every year, we field questions from a handful of Oroville customers asking whether their water is fluoridated, and what can be done to remove the fluoride from the water on the customer's end. Unfortunately, the cost of fluoride removal once it is in the water is high – it requires reverse osmosis or an equivalent treatment. We even receive occasional inquiries from city officials who are unfamiliar with the city's decision 66 years ago to require the water to be fluoridated.

We are asking the Oroville City Council to re-evaluate the mandate for fluoride to be added to the drinking water of Cal Water customers. We do not keep records of fluoride-related inquiries, nor are we presenting such inquiries as an inconvenience. However, the decision to fluoridate Oroville's water supply was made nearly seven decades ago by people who are (likely) no longer drinking the water – today's customers may have different priorities.

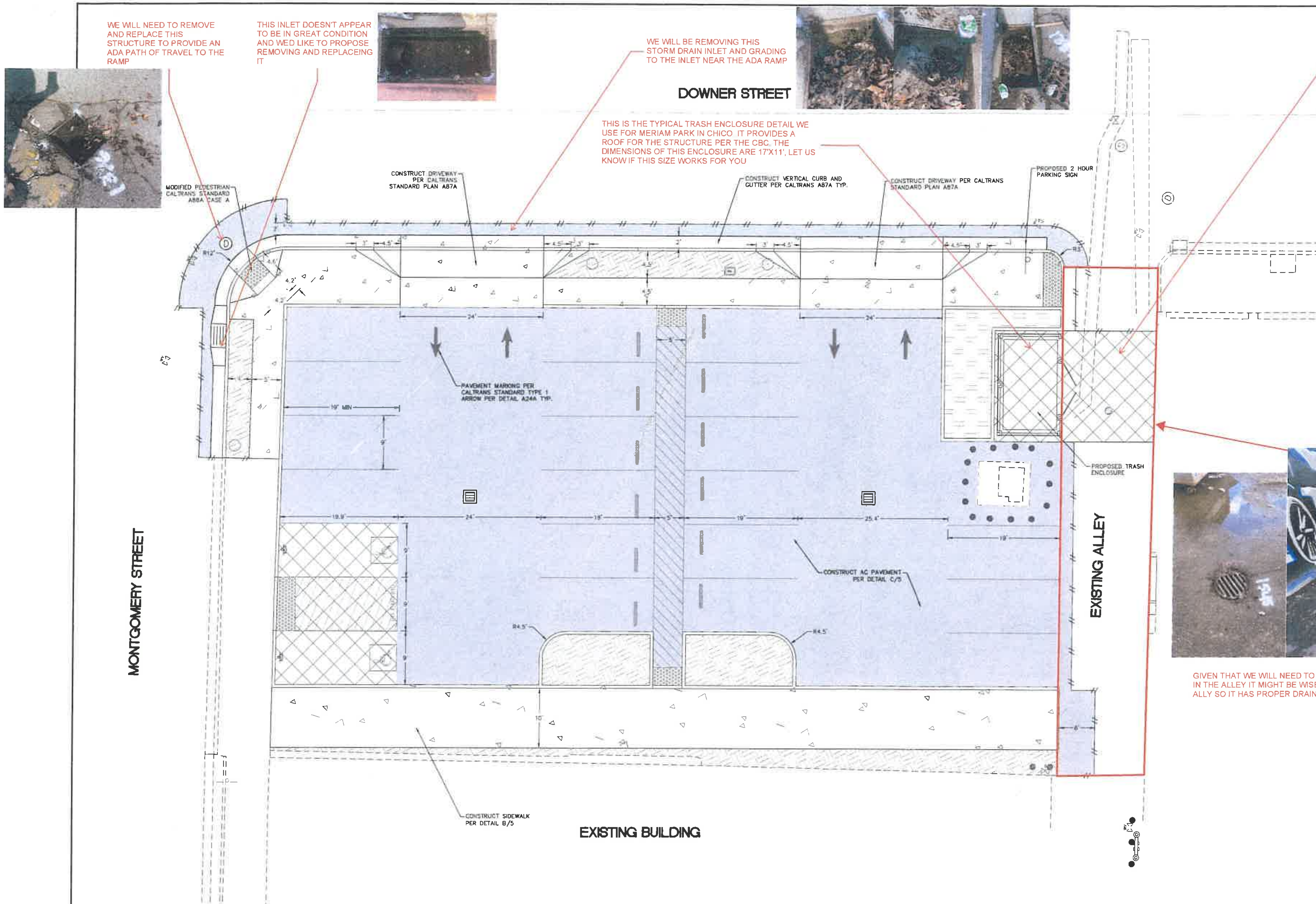
Cal Water is, necessarily, neutral on any health questions related to this topic. We are not health experts and defer such questions to DDW, which recommends, but does not require, the addition of fluoride in a system of our size. As this is a chemical that does not treat the water itself but is intended as a benefit to people who consume the water, we also defer to the City Council and our customers whether or not to continue to mandate the addition of this chemical.

Thank you for your time and consideration. Please let me know if I can answer any questions for you at (530) 720-8125 or at llind@calwater.com.

Sincerely,

Loni Lind

Loni Lind
Local Manager, Oroville
California Water Service



GENERAL NOTES

1. ALL WORK IN THE PUBLIC RIGHT OF WAY SHALL BE DONE IN ACCORDANCE WITH THE CITY OF OROVILLE IMPROVEMENT STANDARDS AND SPECIFICATIONS, AND APPLICABLE PORTIONS OF THE STATE OF CALIFORNIA DEPARTMENT OF TRANSPORTATION STANDARD PLANS AND SPECIFICATIONS DATED 2018. (APPROVAL OF CITY DIRECTOR OF PUBLIC WORKS OR THEIR AUTHORIZED REPRESENTATIVES IS REQUIRED.) CONTRACTOR SHALL HAVE SIGNED PLANS IN HIS POSSESSION PRIOR TO COMMENCEMENT OF WORK.
2. PRIOR TO THE START OF CONSTRUCTION THE CONTRACTOR SHALL BE RESPONSIBLE FOR CONTACTING ALL UTILITY COMPANIES AND/OR UTILITY DISTRICTS AS TO THE LOCATION OF ALL UNDERGROUND FACILITIES. THE CONTRACTOR SHALL BE RESPONSIBLE FOR THE LOCATION OF ALL UNDERGROUND FACILITIES OR OTHER BURIED OBJECTS WHICH MAY BE ENCOUNTERED BUT WHICH ARE NOT SHOWN ON THESE PLANS. THE CONTRACTOR SHALL CALL UNDERGROUND SERVICE ALERT (USA) AT 811 AT LEAST 3 DAYS PRIOR TO CONSTRUCTION.
3. LOCATIONS AND DEPTHS OF EXISTING UTILITIES SHOWN ON THESE PLANS ARE APPROXIMATE. THE CONTRACTOR SHALL VERIFY THE EXISTENCE, LOCATION AND DEPTH OF ALL UTILITIES PRIOR TO ORDERING MATERIALS OR BEGINNING SITE CONSTRUCTION.
4. THE CONTRACTOR SHALL REQUEST CONSTRUCTION STAKES FOR ANY PARTICULAR PHASE OF WORK AT LEAST 72 HOURS PRIOR TO COMMENCEMENT OF CONSTRUCTION. CONTRACTOR SHALL REQUEST A FORM OR GRADE STAKE PRIOR TO PLACING OF IMPROVEMENTS.
5. NORTHSTAR ASSUMES NO RESPONSIBILITY FOR ANY WORK CONSTRUCTED IF STAKED BY OTHERS.
6. PRIOR TO ANY CORRECTIVE ACTION BY THE CONTRACTOR WHICH IS NECESSARY DUE TO STAKING ERRORS, THE CONTRACTOR SHALL NOTIFY THE ENGINEER FOR RE-STAKING AND VERIFICATION OF PREVIOUS STAKING. THE ENGINEER ASSUMES NO LIABILITY FOR THE COST INCURRED FOR THIS WORK.
7. CONTRACTOR TO BE RESPONSIBLE FOR THE PROTECTION OF ALL EXISTING MONUMENTS AND OTHER SURVEY MARKERS DURING CONSTRUCTION. ALL SUCH MONUMENTS OR MARKERS DESTROYED DURING CONSTRUCTION SHALL BE REPLACED AT CONTRACTOR'S EXPENSE.
8. ALL PERMITS NECESSARY FOR THIS JOB ARE TO BE ACQUIRED BY THE CONTRACTOR.
9. THE CONTRACTOR SHALL BE RESPONSIBLE FOR VERIFICATION OF ALL ESTIMATES AND QUANTITIES.
10. SHOULD CONSTRUCTION ACTIVITIES EXPOSE BURIED ARTIFACTS OR OTHER EVIDENCE OF EARLY HISTORIC OCCUPATION. A QUALIFIED ARCHEOLOGIST SHALL BE CONTACTED IMMEDIATELY. ALL CONSTRUCTION ACTIVITIES SHALL BE HALTED UNTIL HIS RECOMMENDATIONS ARE IMPLEMENTED.
11. EXISTING FACILITIES IN CONFLICT WITH IMPROVEMENTS ARE TO BE RELOCATED OR ADJUSTED TO GRADE AT THE DEVELOPER'S EXPENSE.
12. THE CONTRACTOR SHALL OBTAIN ALL NECESSARY PERMITS FROM THE CITY OF OROVILLE AND CALTRANS PRIOR TO BEGINNING ANY CONSTRUCTION WITHIN THE RIGHT OF WAY.

GIVEN THAT WE WILL NEED TO PLACE TRAFFIC RATED CONCRETE IN THE ALLEY IT MIGHT BE WISE TO REPAVE THIS STRETCH OF THE ALLY SO IT HAS PROPER DRAINAGE

8 0 8 16

PRELIMINARY

Designed: FPM	Revision	Date	By
Drawn By: CLM			
Approved:			
Date:			

NORTHSTAR
111 MISSION RANCH BLVD. SUITE 100, CHICO, CA 95926
PHONE: (530) 893-1600 www.northstareng.com

CITY OF OROVILLE
DOWNER ST
OROVILLE, CALIFORNIA

SITE PLAN
DOWNER STREET

APN Number	Job Number	Scale	Sheet
-	21-103	1"= 8' Horz. N/A Vert.	Sheet 3 Of 7

Proposal/Agreement to Provide Services

March 14, 2023

To:	From:
Warren Roll	David Popa
SBCGlobal	President
Historic Building	PPCS Corp.
1675 Broderick	100 Linda Lane
Oroville, CA 95965	Pleasant Hill, CA 94523
w.roll@sbcglobal.net	dmpopa@ppc-restore.com
Cell: 1(530) 518-2482	Cell: 1(510)-376-4919

Proposal No: BR 23-356
Subject: Brick Restoration / Tuckpointing
Property: 1675 Broderick, Oroville, CA 95965

Forward:
PPCS Corp is a multi-faceted national restoration contracting company with completed or ongoing projects in multiple states. Based in San Francisco, California the PPCS Corp. of today descends from a small single man operation founded by Paul M. Popa in 1983. Always an innovator, PPCS Corp. consistently remains at the forefront in developing new and effective restoration materials, means, methods and technologies. This coupled with our exemplary safety record and an available work force of over 20 highly trained and dedicated men and women has transformed PPCS Corp. into one of the largest, fastest growing, and most respected Building Restoration Companies in the United States. Rooted in the deep belief that if we consistently provide our customers with a superior product, excellent service, and absolute reliability we will succeed. Because of these deep commitments PPCS Corp. currently enjoys ongoing relationships with nearly all its past clients.

Historic buildings are a crucial element in our perception of culture and identity through time and are therefore important for our future. These valuable resources require restoration and protection from future damage; at PPC Corp. restoring and protecting historical buildings is a passion with us, not just a business. Historic renovation projects are incredibly special opportunities to revive aging, often fragile buildings of major historical significance. Treating these buildings is our priority and one we take very seriously. It is one reason some of the most notable buildings anywhere have been trusted to our care.

PPCS

Scope of the Project and Proposal

PPCS Corp. is pleased to present our proposal to provide services on the above referenced project. The general scope of this project is:

Remove old motor, Tuckpoint, Fill, Clean and Restore approximately 6,000 sqft. of brick on the interior and exterior of 1675 Broderick in Oroville CA 95965.

COST	**$165,000.00**	**Labor to remove old motor, power wash, walnut blast, tuckpoint to completely restore approx. 6000 sqft. of brick Interior and exterior**
COST	**$12,750.00**	**Materials and Supplies**

COST	**$7,200.00**	**Equipment – scissor lift rentals**
COST	**$15,200.00**	**Lodging and Per Diem**

Exclusions and Clarifications:

1 Because of the logistics PPC Corp. will perform the work using boom/scissor lifts. PPCS Corp. with coordinate use of lift with the owner to minimize traffic impact as much as reasonable possible.
2 PPCS Corp. will provide and onsite working Forman during all working hours.
3 The owner/owner's representative will assign a specific person to make regularly scheduled inspections with a PPCS Corp. representative to approve and "sign off" the completed work. These sign offs will be evidence of final approval and acceptance of the work.
4 This Proposal/Agreement provides for two million dollars ($2,000,000) of general liability and workers' compensation insurance. If additional insurance is required additional cost will occur.
5 In the event the owner will be issuing a contract, this proposal is subject to reaching a mutually acceptable contract.
6 Payment or performance bonds are not included.
7 Unless agreed upon in writing no retention will be withheld from any payment that becomes due and owing to PPC&S.

Terms and Conditions:
A mobilization fee equaling 20% of the total contact amount will be due within 10 days from the effective date of this contract and prior to the start of the work. PPCS Corp. will submit monthly application for payments. Payment will be due not later than 15-days from the date of the invoice.

We appreciate the opportunity to provide this Proposal/Contract and look forward to serving you now and in the future. If you would like to discuss or clarify any items in this Proposal/Contact, please feel free to contact via phone (510) 376-4919 or email at dmpopa@ppc-restore.com .

Presented by:		Accepted by:	
Signature:	______________________	Signature:	______________________
Print Name:	David Popa	Print Name:	
Title:	President	Title:	
Date:		Date:	

PPCS, Corp.
100 Linda Lane
Pleasant Hill, CA 94523
(510) 376-4919

April 29, 2022

Butte County Building Division
7 County Center Drive
Oroville, CA 95965
Attention: Dawn Nevers

Re: Structural Review of Existing Building
Project: City of Oroville – Annex Building
Location: 1675 Broderick Street, Oroville, CA
Streamline Job No.: 4735

To Whom It May Concern:

On April 20, 2022 our office made an on-site observation of an existing brick and cast-in-place concrete building located at 1675 Broderick Street in Oroville. The purpose of our site visit was to observe the structural integrity of the building and to identify any structural elements that might be deficient or require a more in depth evaluation.

The building we observed at 1675 Broderick Street is a single-story structure constructed as noted below:

Roof System: The roofing material that we observed from the ground level consists of corrugated metal panels located over the pitched roof portion located on the northeastern portion of the building. It was not in our scope of work to perform any observations from the roof level. It appears from overhead photos provided by others that there may be another type of roofing material used over the flatter pitched sections of the roof. The primary roof structure is composed of field-built wood trusses spaced at about 10 feet on center with 2 x 4 purlins at 16 inches on center ladder framed between the trusses.

Parapet Walls: There are parapet walls located on the north, south and west side of the building. These walls are constructed of the same material as the exterior walls below them and appear to be an extension of the walls below them and built at the same time as one wall. These walls obstructed the flat area of the roof from our view. See photos 1 through 3.

Interior and exterior walls: The exterior walls that we observed consist of unreinforced bricks and cast-in-place concrete from the ground level to the roof framing. There are some wood framed interior partitions. It was not in our scope of work to determine if there was any reinforcement placed inside the concrete walls.

Floor: The floor consists of a concrete slab-on-grade. It was not in our scope to determine if there is any reinforcement in the slab or any base rock or vapor barrier below the slab.

2571 California Park Drive, Ste. 210 • Chico, CA 95928 • (530) 892-1100

OBSERVATIONS:

1. Upon arrival to the site we noticed a previous crack at the front of the building's façade that appeared to have been patched. See photo 4
2. Along the east side of the building we noticed the exterior wall had some bricks missing. Areas of brick, along the east side wall, appeared to have been removed and replaced. Most of the mortar bed between the rows of brick was deteriorating. The mortar was brittle and easy to remove by hand with little force. See photos 5 and 6.
3. Our office also noticed the wood trim at the top of the east wall was weathered and pulling away from the wall. See photo 7.
4. We noted hairline cracks at the rear and west walls at the top of most windows. See photos 8 through 10.
5. Accessing the interior we noted the roof framing at the gathering area to be timber trusses at ten feet on center. The trusses were built with double 2x8 members for the top and bottom chords. Above the trusses we found 2x4 purlins spaced at 16 inches on center with diagonal sheathing above. See photo 11.
6. The trusses are supported on one end by a brick bearing wall separating the gathering area and storage area, and 8 inch x 12 inch concrete pilasters. It appeared that the trusses did not have proper anchorage at the bearing ends. See photo 12.
7. The built-up beam supporting the roof trusses in the gathering area consisted of three ply's of 2x10 members. Our office noticed the splices in the beam members did not occur over a post. Our office also noticed a large crack in the beam at the location of the truss bearing point. See photos 13 and 14.
8. We noted an HVAC unit was supported by the bottom chord of a truss at the south end of the gathering area. See photo 15.
9. Accessing the utility room area we noticed the built up beam was cantilevered past the wall separating the gathering area and utility room and supported a roof truss. No bearing element was found below the cantilevered beam. See photo 16
10. We noted water staining and dry rot in the utility room wall and roof, along with a large crack in the utility room brick wall above the door. See photos 17 through 21
11. In the storage area we noted the loft to have a head height of about 6 feet. One of the posts supporting the loft appeared to be damaged from termites. The loft's stairs had no guardrail or handrail at the time of our site visit. Ascending the stairs to the loft we observed termite damage to the floor of the loft and we noticed a large crack in the brick wall. This crack appeared to be the same one as seen while in the utility room. See photos 22 through 27
12. While in the storage area we noted the 2x12 ceiling joist installed at 24 inches on center supported by a ledger anchored to the brick wall. It appeared that timber trusses at 48 inches on center were installed above the ceiling joists. See photo 28
13. Observing the interior brick wall, it appeared that the mortar was failing and we found bricks to be missing with daylight present on the inside. See photo 29
14. It appeared that the lintel header above the door separating the storage area and gathering area was deflecting. See photo 30

2571 California Park Drive, Ste. 210 • Chico, CA 95928 • (530) 892-1100

CONCLUSIONS:

Based on our site observations we have the following recommendations:

1. Based on the condition of the failing mortar bed between courses of brick, and areas of bricks that have been removed or are missing, we recommend a licensed masonry contractor evaluate the interior and exterior brick walls and provide a report of their findings.
2. Due to the extensive water staining throughout the building and areas appearing to have dry rot, our office recommends a dry rot inspection to be performed to find the extent of damage and provide advice on repairs as needed.
3. Based on the deflection found in the gathering room beam as well as the improper splice our office recommends a licensed engineer to evaluate the condition of the timber framing members and make repair recommendations.
4. Based on the termite damage found at the loft area of the storage room our office recommends a licensed pest inspector to investigate the damage and provide a report of their findings.

Note that we are assuming the construction of this building was installed per the building code at the time of construction and the original plans prepared by others. It was not within our scope of work to review the original plans and calculations or to insure that construction was per the original construction documents.

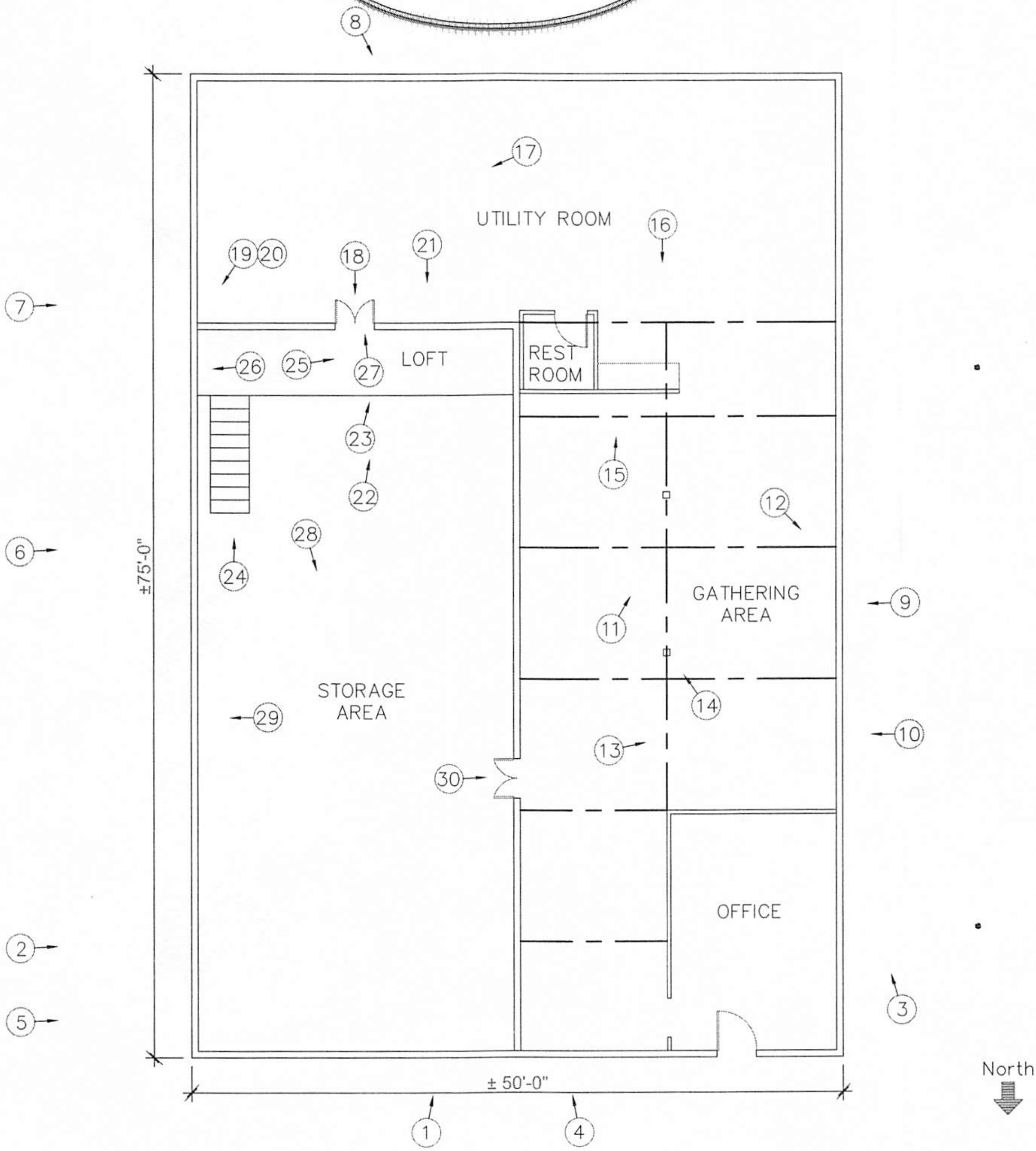
These findings are based on my professional opinion and are not intended as a warranty of any kind. Please contact me if you have any questions at 530-892-1100.

Sincerely,

Jeff Richelieu, PE
President
Streamline Engineering, Inc.

REGISTERED PROFESSIONAL ENGINEER
JEFFREY M. RICHELIEU
C53590
EXP. 6/30/23
CIVIL
STATE OF CALIFORNIA

04/29/2022



STRUCTURAL ASSESSMENT	JOB NO.: 4735
ANNEX BUILDING	DATE: 4/28/2022
1675 BRODERICK STREET	CHECKED BY: JMR
OROVILLE, CA	PAGE: OF

2571 California Park Drive, Ste. 210 Chico, CA 95928 Ph: (530) 892-1100