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Fluoride in drinking groundwater and prevalence of fluorosis in children and adolescents: A systematic review

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ABSTRACT

Fluorosis is a worldwide public health problem. One of the factors related to it is the type of water consumed, such as groundwater. High fluoride concentration in groundwater may be explained by contamination from local industries. Since fluoride and arsenic are the main pollutants of groundwater, some studies correlate groundwater consumption with high prevalence of fluorosis. ***Aim:*** *The aim of this study was to conduct a systematic review to determine whether children's risk of fluorosis is related to drinking groundwater.* ***Materials and Method:*** *The protocol for this systematic review was registered at the National Institute of Health Research Database (CRD42021227298). A comprehensive search was conducted to identify potentially relevant studies by exploring a range of electronic databases (Medline via PubMed, Scopus, Cochrane Library, Science Direct, Web of Science Core Collection, Medline via Ovid, Lilacs, Embase, and grey literature).* ***Results:*** *A total 2189 articles were found. After reading titles and abstracts, 63 were selected for screening, and the final data was extracted from 15 articles.* ***Conclusion:*** *A relationship was identified between drinking fluoridated water from wells and the prevalence of fluorosis in individuals up to 18 years old. This is the first study to assess the issue systematically worldwide.*

Keywords: *fluoride - groundwater - fluorosis - children*

Fluoruro en el agua subterránea potable y prevalencia de fluorosis en niños y adolescentes: Una revisión sistemática

RESUMO

La fluorosis es un problema de salud pública a nivel mundial y el tipo de agua consumida es uno de los factores relacionados con ella, como el consumo de aguas subterráneas. La alta concentración de fluoruro en estas aguas puede justificarse por la contaminación por industrias locales y las características del suelo, donde algunos estudios correlacionan el consumo de aguas subterráneas con una alta prevalencia de fluorosis, ya que el fluoruro, junto con el arsénico, se consideran los principales contaminantes de estas aguas. ***Objetivo:*** *El objetivo es realizar una revisión sistemática que relacione el riesgo de fluorosis en niños expuestos al consumo de agua procedente de pozos.* ***Materiales y Método:*** *El protocolo de esta revisión sistemática fue registrado en el National Institute of Health Research Database (CRD42021227298). Se realizó una búsqueda bibliográfica de estudios primarios explorando diversas bases de datos electrónicas (Medline vía PubMed, Scopus, Cochrane Library, Science Direct, Web of Science Core Collection, Medline vía Ovid, Lilacs, Embase y literatura gris).* ***Resultados:*** *Se encontraron 2189 artículos, tras la lectura de títulos y resúmenes se seleccionaron 63 referencias para examinar y, finalmente, se extrajeron los datos de 15 artículos.* ***Conclusiones:*** *Se identificó una relación entre el consumo de agua fluorada de pozo y la prevalencia de fluorosis en individuos de hasta 18 años, siendo este estudio el primero en evaluarlo sistemáticamente a nivel mundial.*

Palabras clave: *fluoruro - aguas subterráneas - fluorosis – niños - adolescentes.*

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INTRODUCTION

The use of fluoride in dental caries management is one of the great milestones in dentistry, and has been recognized as the main factor responsible for the significant decline in caries prevalence around the world[1,2]. Epidemiological data from communities with access to a fluoridated public water supply provided the initial evidence that fluoride promotes oral health[3,4].

Caries prevention mechanisms through the action of fluorides are post-eruptive, occurring through their topical cumulative effect, and acting on the dynamics of demineralization/remineralization[5]. However, excessive fluoride intake during the tooth development period can cause dental fluorosis, which is the only proven relevant side effect of fluoride use[2].

Fluorosis is a worldwide public health problem and, like caries, has also been related to socioeconomic factors. The type of water consumed is one of these factors, and the consumption of well water is one of the consequences of people's socioeconomic condition[6]. Many communities still drink groundwater, often with fluoride concentration greater than the 1.5 ppm recommended by the World Health Organization. This increases the risk of fluorosis, thereby constituting a serious public health problem[7].

The high fluoride concentration in well water may be caused by lithology or by contamination from local industries or agrobusiness operations that increase the risk of heavy metals, pesticides, nitrates, radon and fluoride in the water[8,9]. Other factors are the amount and duration of precipitation, infiltration rate, level of groundwater exploitation in the area, etc.[10]. The increasing uptake of groundwater resources can also affect the distribution and concentration of fluoride[11].

Some studies correlate the consumption of groundwater with high prevalence of fluorosis because fluoride and arsenic are the main pollutants in groundwater. Fluoride concentration in the water increases with depth, with wells deeper than 30 m containing the highest amounts. The risk of fluorosis is proportional to the amount of fluoridated water the child is exposed to.

Fluorosis is classified as mild, moderate or severe[6-8,12]. Plasma and urine fluoride concentration is proportional to the fluoride concentration in the water consumed[10,11].

In view of the growing concern about this issue, the aim of this study was to conduct a systematic review to determine whether children's risk of fluorosis is related to drinking fluoridated groundwater.

MATERIALS AND METHOD

This systematic review was conducted in accordance with the guidelines of the Cochrane handbook for systematic review of Interventions, following the four-phase diagram of the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA). The study protocol was registered at the National Institute of Health Research Database (CRD42021227298).

The research question was adapted from the PECO framework for the systematic review of clinical studies:

– Population (P): Patients up to 18 years
– Exposure (E): Groundwater
– Comparison (C): Exposure to water from supply network or commercial mineral water
– Outcome (O): Fluorosis

In terms of research questions, based on the PECO model, the review aimed to assess the current knowledge and literature for the effect of patient exposure to groundwater on the outcome of fluorosis. The criteria followed in this study are described in Table 1.

Table 1. Eligibility criteria.

Inclusion Criteria	Exclusion Criteria
• Studies including patients up to 18 years old • Peer-reviewed studies • Quantitative randomized controlled trials • Retrospective, prospective, or concurrent cohort studies • Cross-sectional studies • Studies published in any language • Studies published on any date	• Qualitative opinions • Editorials • Literature reviews • Expert opinions • Newsletters/opinion letters • Case reports

2.1 Literature search strategy

A comprehensive search was conducted to identify potentially relevant studies by exploring a range of electronic databases (Medline via PubMed, Scopus, Cochrane Library, Science Direct, Web of Science Core Collection, Medline via Ovid, Lilacs, and Embase). Additionally, a Google scholar and

reference search on grey literature was undertaken to identify any other relevant published work. The search was conducted without applying any date limits or language restrictions.
The search strategy included the terms: “Children”, “child” and “Fluoride”, “Fluorine”, “Water Well*”, and “Water Ground*”; and “Fluoridated water”, “water fluoridation” and “Enamel defect*”, “Fluorosis”.
Trade names of various classes of sealers were also used as a part of the search strategy. Boolean operators (“OR” and “AND”) were used to join search terms related to the search question (Table 2).
Table 3 shows the literature searches and results found in Pubmed, Scopus, Cochrane, Web of Science Core Collection, Medline via Ovid, BVS, and Embase.

Table 2. Search terms.

Search 1	“Children”, “child”
Search 2	“Fluoride”, “Fluorine”, “Water Well*”, “Water Ground*”
Search 3	“Fluoridated water”, “water fluoridation”, “drinking water”
Search 4	“Enamel defect*”, “Fluorosis”

2.2 Study Selection

Literature search results were de-duplicated by using Mendeley software (Thomson Reuters, New York, NY). Articles were initially screened based on the title and abstract according to the scope (i.e., articles that do not report fluorosis and exposure to groundwater) and publication type (i.e., reviews, comments, letters, or abstracts).

2.3 Data Extraction and Quality Assessment

Based on the selection criteria, two examiners (LV, FC) examined the titles and abstracts independently, and any disagreements were resolved according to a predefined strategy, using consensus and arbitration as appropriate. If the disagreement could not be resolved, then a third investigator (AS) agreed to help reach a consensus. Furthermore, a manual search of the reference lists of relevant studies was performed.
The seven domains of ROB-2 instrument were scored to quantify the risk of bias: confounding bias, measurement of exposure bias, selection bias, post-exposure interventions bias, missing data bias, measurement of the outcome bias and selection of the reported result. Subsequently, an overall judgement was made to mark each study as low risk of bias, high risk of bias or some concerns.

Table 3. Literature searches and number of articles found.

	Searches related to the descriptors				
	“Children” OR “child” **#1**	“Fluoride” OR “Fluorine” OR “Water Well*” OR “Water Ground*” **#2**	“Fluoridated water” OR “water fluoridation” OR “drinking water” **#3**	“Children” OR “child” **#4**	#1 AND #2 AND #3 AND #4
Pubmed	1,313,471	60,645	51,561	4,240	388
Scopus	3,169,927	246,326	1,185	4,935	-- 55
Cochrane	144,754	10,081	3,828	539	15
Web of Science	2,263,174	691,017	114,744	7,714	-- 665
Medline via Ovid	2,239,364	61,373	48,523	1,946	1
Virtual Health Library (BVS/VHL)	2,510,968	351,664	83,293	8,888	564
Embase	1,679,224	67,398	67,435	4,438	501
Total					2,189

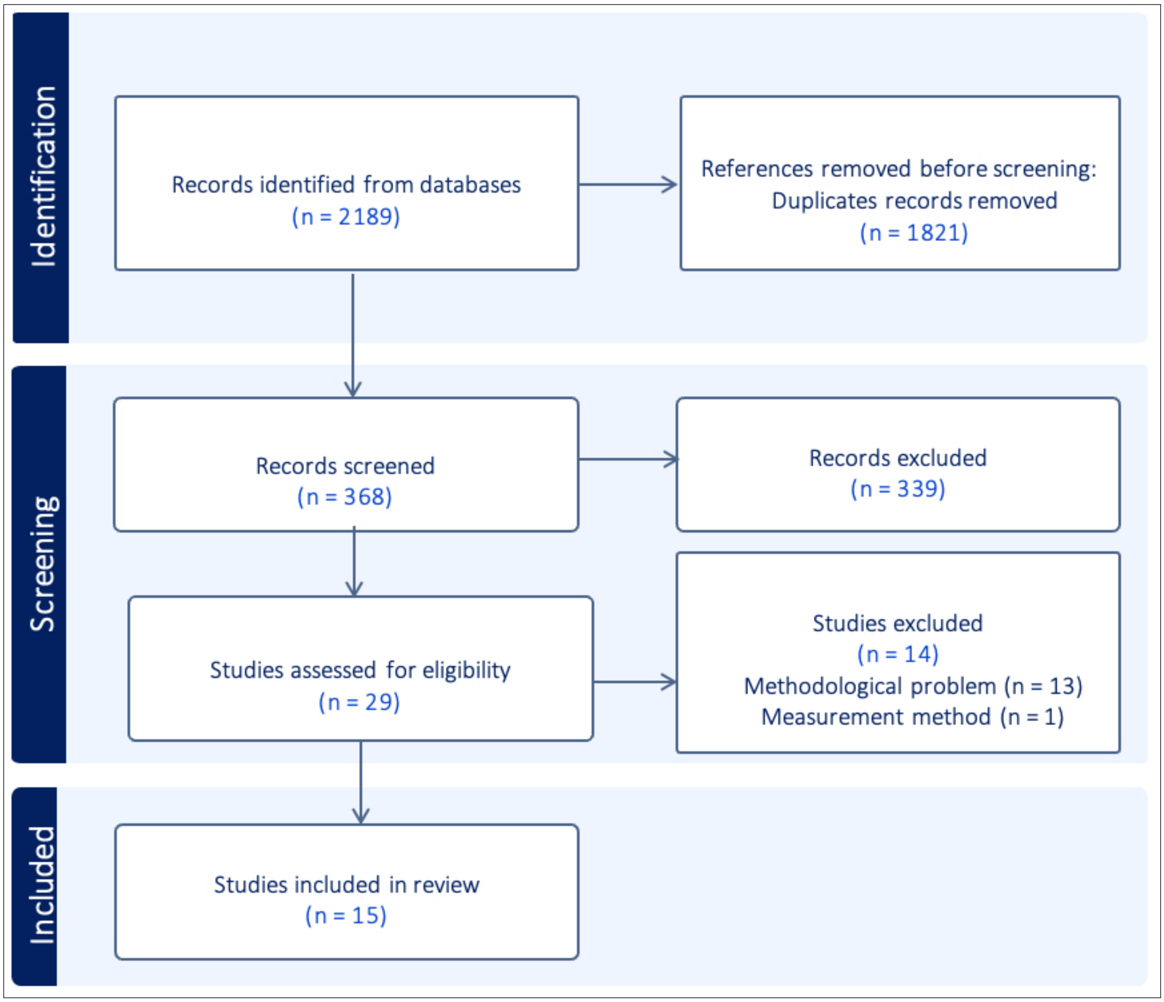

Fig. 1: Literature searches and results.

RESULTS

The literature search after the identification period found 2189 articles (Table 3), of which 368 were screened according to the selection criteria, and 15 were selected, as shown in Figure 1.

The main data extracted from the selected studies are shown in Table 4. Data came from 4 continents, including Asia with 53.3% of studies, Africa with 20%, and Europe and America with 13.3% each. Participant ages were 14 to 16 years. Regarding the index used for diagnosing dental fluorosis, Dean's index was the most frequent, being adopted in 60% of the studies, followed by the Thylstrup-Fejerskov Index (TFI) in 20%. Other indices used were WHO, Pendry's and Horowitz's, with 6.7%.

Table 5 shows the main data on fluoride concentration in the water (0.1 to 18mg/L), and prevalence of fluorosis (4.25 to 100%), which were both highly heterogenous.

Figure 2 shows the quality assessment of the studies considered. In general, the domains presented a low risk of bias.

DISCUSSION

This study performed a systematic review of the literature to assess the risk of fluorosis in children exposed to drinking groundwater. The studies evaluated reported high fluoride concentration in the water consumed.

Fluoride intake has beneficial effects, as a complement to prevent and control dental caries, as well as adverse effects, mainly tooth enamel and skeletal fluorosis following prolonged exposure to high concentrations[1-2]. Excessive fluoride intake usually occurs through the consumption of groundwater that is naturally rich in fluoride. The assessment of the distribution of high groundwater

Table 4. Summary of the studies selected for this systematic review.

Study ID	**Country**	**Subjects' age in years**	**Total number of children**	**Index used for diagnosing dental fluorosis**
Akpata et al.[13]	Saudi Arabia	12-15	2355	Modified Thylstrup-Fejerskov Index (TFI)
Alarcon-Herrera et al.[14]	Mexico	6-12	333	Dean's index
Arif et al.[15]	India	5-13	1136	Dean's index
Gautam et al.[16]	India	4–16	90	Dean's index
Ibrahim et al.[17]	Sudan	7-16	113	Dean's index
Indermitte et al.[18]	Estonia	7-15	2,627	Dean's index
Ismail et al.[19]	Canada	0-7	48	Pendrys' Fluorosis Risk Index (Modified Fluorosis Risk Index)
Mandinic et al.[20]	Serbia	12	164	Dean's index
Narwaria et al.[21]	India	5-12	750	Dean's index
Rango et al.[22]	Main Ethiopian Rift Valley	10-15	491	Thylstrup and Fejerskov index (TFI)
Ray et al.[23]	India	1-5 and 11-15	2,159	WHO
Shanthi et al.[24]	India	9-12	1,500	Dean's index
Shomar et al.[25]	Gaza Strip	5–16	353	Dean's index
Tobayiwa et al.[26]	Zimbabwe I	8-15	200	Thylstrup and Fejerskov index (TFI)
Zhu et al.[27]	China	8–12	9,030	Horowitz's Tooth Surface Index of Fluorosis (modification of Dean's index)

Table 5. Results of the studies selected for this systematic review.

Study ID	F- concentration informed by the authors, in ground water analyzed	Daily Water Consumption	Prevalence (total) of fluorosis	Prevalence of dental fluorosis (mild)	Prevalence of fluorosis (moderate)	Prevalence of fluorosis (severe)
Akpata et al[13]	0.543 to 2.848 ppm	-	90.7%	14.73%	31.25%	44.67%
Alarcon-Herrera et al[14]	< 1.5 to 16 mg/L	-	86.4%	67.88%	10.8%	7.8%
Arif et al[15]	0.5 to 8.5 mg/L.	>4 mg/day	69.3%	31.9%	58.6%	9.4%
Gautam et al[16]	0.64 to 14.62 mg/L	-	90.8%	-	-	-
Ibrahim et al[17]	0.25 to 2.56 ppm	-	95.5%	63.7%	27.4%	4.4%
Indermitte et al[18]	0.01 to 7.20 mg/L	-	17.5%	-	-	-
Ismail et al[19]	< 3.8 ppm	-	66.7 %	-	-	-
Mandinic et al[20]	0.10 to 11 ppm	-	4.2%	3.65	0	0.6
Narwaria et al[21]	1.5 to 3 ppm	-	45.4%	20.8 %	19.47 %	5.2 %
Rango et al[22]	1.1–18 mg/L (8.5 ± 4.1 mg/L)	1.2 ± 0.4 L/d	100%	17%	29%	45%
Ray et al[23]	0.2 to 2.1 ppm	-	24.9%	8.33%	2.17%	-
Shanthi et al[24]	< 0.7 to 3.5 ppm	-	48.3%	35%	9.2%	4.1%
Shomar et al[25]	0.7 to 2.6 ppm	-	60%	-	-	-
Tobayiwa et al[26]	5-10 ppm	-	64%	-	-	-
Zhu et al[27]	1.0 to 2.0 mg/L	-	38.6%	25.6%	10.0%	3.0%

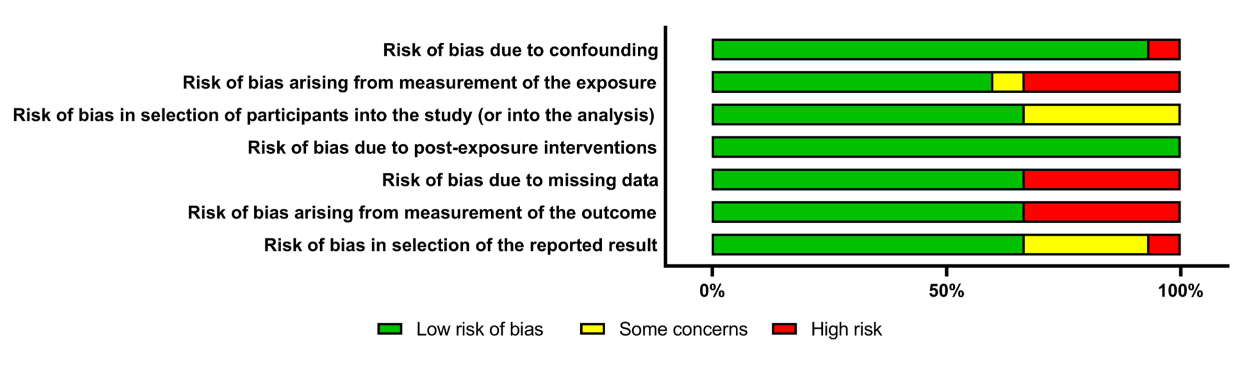

Fig. 2: Quality assessment of the studies evaluated.

fluoride is therefore of great practical significance for drinking water safety[28]. The WHO recommends a fluoride concentration in drinking water in the range of 0.5 to 1.5 mg/L[29]. The current review only included research papers reporting consumption of groundwater with fluoride concentration above 1.5 mg/L.

Fluorides are naturally ubiquitous in the environment (water, soil, air, etc.). The amount of fluoride in water can be georeferenced, and high levels have been reported in certain places, especially in Asia and Africa[20].

Several studies conducted around the world provide strong evidence of association between fluoride concentration in drinking water and prevalence of fluorosis [13,14,16,18,21,22]. To facilitate data collection, the current study evaluated the risk in children because most primary studies consider school-age children, who are easily screened.

Increasing fluoride intake with fluoridated water can increase the risk of dental fluorosis in a situation of high exposure in children under 8 years of age. Nevertheless, in adults, such exposure is not a problem, but provides protection against dental caries[30].

The only way to prevent dental fluorosis in children is to ensure that the fluoride concentration in the water they consume is within safe limits[18]. It should be noted that water is used in food preparation as well as for drinking. The current review found that in places all over the world where people drink groundwater with high fluoride concentration, there is higher prevalence of dental fluorosis. Even though public health officers are aware of the negative impact of dental fluorosis, a condition affecting much of the population in developing countries, governments do not address the issue[28]. The inability to find alternative water sources is a challenge to the reduction of exposure to high fluoride levels.

Some studies assess the risk and/or prevalence of fluorosis in populations exposed to groundwater, most of which consider water from wells or natural sources. The concentration of fluoride in spring water is lower than in groundwater. Only two systematic reviews addressed this issue, both of which were based on local data[7,31]. A study with data at global level was therefore considered necessary.

The selected studies indicate that the prevalence of dental fluorosis increases with the concentration of fluoride in groundwater. To prevent dental fluorosis, it is suggested that groundwater wells should be routinely analyzed for fluoride concentration, and if necessary, treated appropriately with fluoridation or defluoridation, to ensure an anti-caries effect with minimum risk of fluorosis.

CONCLUSIONS

A relationship was identified between the consumption of fluoridated groundwater and the prevalence of fluorosis in individuals up to 18 years of age, this study being the first to systematically assess the situation in different continents.

CONFLICT OF INTEREST

The authors declare no potential conflicts of interest regarding the research, authorship, and/or publication of this article.

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