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The 100 Most-Cited Articles About Fluoridation of Public Water Supplies

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ABSTRACT

Purpose: This study aimed to identify and analyse qualitatively and quantitatively the 100 most-cited articles related to the fluoridation of public water supplies.

Methods: The Web of Science Core Collection was searched. The position in the list, total number and density of citations, title, year of publication, study design, country and authors were extracted. Bibliometric networks were generated and analysed by using the VOSviewer software. Descriptive analysis and Poisson regression were performed ($p < 0.05$ was considered to indicate a significant difference).

Results: A total of 8,812 articles were retrieved. The average number of citations per article was 183.44 (range 91–932). A peak in publications occurred in the 2000s (n = 53). India, the United States and China presented the most publications in the top 100 (n = 61). S Ayoob and AK Gupta were the most-cited authors (1,190 citations each). Review and laboratory studies were predominant, and the subtopic involved adverse effects and the origin of high fluoride concentrations and defluoridation.

Conclusions: Review studies, published by authors from Asia and about adverse effects and the origin of high fluoride concentrations in water and defluoridation techniques presented a higher citation ratio in the Web of Science Core Collection. Longitudinal studies in humans are needed to increase the quality of scientific evidence to better evaluate the adverse effects of water fluoridation.

Key-words: Fluoridation; Fluorides; Bibliometrics.

INTRODUCTION

Water fluoridation is the most cost-effective cavity-prevention measure for public health when used at the ideal concentration for each region[1–3]. It is considered one of the 10 most important public health achievements of the 20th century[4]. The control of fluoride levels in water must be individualised and monitored frequently to ensure safe intake levels[5]. The World Health Organization (WHO) recommends a fluoride concentration of 1.5 ppm as the limit value for water for human consumption[6]. As it is an element commonly found in nature, contact with multiple sources of fluorides can occur, resulting in high levels of exposure[1,7,8]. Fluoride ingested from water and absorbed in the gastrointestinal tract enters the bloodstream and is distributed throughout the body,

which can cause systemic, acute or chronic effects[2]. Chronic toxicity is defined as the ingestion of small amounts of fluorides daily for long periods of time[2], resulting in adverse health effects[8]. The main oral manifestation of chronic exposure to fluorides is dental fluorosis, an enamel maturation disorder: enamel has more proteins and less minerals[1].

Interest in evidence on a given subject can be presented through bibliometric analyses, which use qualitative and quantitative methods to analyse academic literature, helping researchers to identify research focuses, the authors who contribute the most, the impact of publications, the countries that contribute the most publications and the journals that publish the most research on the topic[9–11]. Based on a prior study, in PubMed, there is a trend for studies to focus on water fluoridation related to tooth decay[12]. However, the information in that article was collected by an automatic web crawler and examined using linguistic and information technology analyses, and thus presented limitations in scope due to the database used and the methodology applied. The present bibliometric analysis aimed to identify and analyse the main characteristics of the 100 most-cited articles related to fluoridation of public water supplies. This endeavour should help researchers to identify trends for future research in this field.

MATERIAL AND METHODS

A comprehensive search – without filters, restrictions on language and the year of publication – was carried out in the Web of Science Core Collection (WoS-CC) (Clarivate Analytics®) using the following search string: TS=("oral health" OR "dental health surveys" OR "decayed tooth" OR "white spot* lesion*" OR "tooth decay" OR "dental caries" OR "caries, dental" OR fluorosis OR "fluorosis, dental" OR "fluoroses, dental" OR "dental fluoroses" OR "dental fluorosis") AND TS=(fluoridation OR "water fluoridation" OR "fluoridation, water" OR "drinking water" OR "water, drinking" OR "potable water" OR "water, potable" OR groundwater OR groundwaters OR ground-water OR ground-waters OR "underground water" OR "underground waters" OR "water, underground" OR "waters, underground" OR "ground water" OR "ground waters" OR "water table" OR "table, water" OR "tables, water" OR "water tables" OR "underground streams" OR "stream, underground" OR "streams, underground" OR "underground, stream" OR aquifers OR aquifer OR "underground lakes" OR "lake, underground" OR "lakes, underground" OR "underground lake" OR "subterranean lakes" OR "lake, subterranean" OR "lakes subterranean" OR "subterranean lake" OR fluoride OR fluorides OR fluorine OR "sodium fluoride" OR "hexafluorosilicic acid" OR "fluorosilicic acid" OR "hydrofluorosilicic acid").

Literature reviews, systematic reviews and meta-analyses, laboratory studies, cross-sectional studies and longitudinal studies were included. Editorials, conference articles and book chapters were excluded. The articles were organised by the number of citations in descending order, and two researchers selected the articles independently by title and summary, considering the eligibility criteria. In cases where two or more articles had the same number of citations, the citation density (the number of citations per year) was considered, followed by the number of citations in Scopus. The number of citations for each article in Web of Science All Databases (WoS-AD), Scopus and Google Scholar were collected for comparison.

The following data were extracted from the articles: position in the list of citations, authors, year of publication, title, language, study design, keywords, abstract, institutions, countries, continents, journal name, the total number of citations, citation density, and subtopics. The study designs were classified into literature review, laboratory studies, case report, case series, cross-sectional study, case-control study, cohort study, clinical trial, systematic review with and without meta-analysis.

Bibliometric networks were generated by using the Visualization of Similarities (VOSviewer) software (Centre for Science and Technology Studies, Leiden University, Leiden, The Netherlands)[13] to analyse authorship. A collaborative density map was constructed: this expressive schematic drawing includes the most relevant authors, with interconnected terms positioned closer together. The MapChart website (https://www.mapchart.net/) was used to illustrate the distribution of publications and citations among countries and continents.

SPSS Statistics for Windows version 24.0 (IBM Corp, Armonk, NY, USA) was used for data analysis. Poisson regression was performed to determine associations between the total number of citations in WoS-CC and bibliometric data (study design, country, main theme and period of publication). All tests used a significance level of 5% ($p < 0.05$). The study design was analysed in three categories: review studies (literature and systematic reviews), laboratory studies and others (longitudinal, cross-sectional and case-control studies, and clinical trials). The topics of interest were: origin of a high fluoride concentration and defluoridation, adverse effects and others. In the final model, all variables that presented $p < 0.20$ were included. The results are expressed as the rate ratio (RR) with a 95%

confidence interval (CI) at a significance level of 5% ($p < 0.05$).

The most-cited article in WoS-CC is a review, "Fluoride in drinking water: A review on the status and stress effects"[14], published in the journal *Critical Reviews in Environmental Science and Technology* in 2006; it was the most cited in Scopus (1,027 citations) and the third most cited in Google Scholar (1,401 citations). The article with the highest citation density (72.3) is the review "Fluoride removal from water by adsorption - A review"[15], published in *Chemical Engineering Journal* in 2011; it was the second most cited article in WoS-CC.

Table 1. The most cited articles on the fluoridation of public water supplies

Position	Articles	Number of citations (Citation density)		
		WoS-CC	Scopus	Google Scholar
1	Ayoob, S; Gupta, AK. **Fluoride in drinking water: A review on the status and stress effects**. Critical Reviews in Environmental Science and Technology. 2006.[14]	932 (58.2)	1027 (64.1)	1401 (87.5)
2	Bhatnagar, A; Kumar, E; Sillanpaa, M. **Fluoride removal from water by adsorption-A review**. Chemical Engineering Journal. 2011.[15]	796 (72.3)	862 (78.3)	1160 (105.4)
3	Meenakshi; Maheshwari, RC. **Fluoride in drinking water and its removal**. Journal of Hazardous Materials. 2006.[16]	635 (39.6)	743 (46.4)	1025 (64)
4	Mohapatra, M *et al*. **Review of fluoride removal from drinking water**. Journal of Environmental Management. 2009.[17]	609 (46.8)	687 (52.8)	979 (75.3)
5	Featherstone, JDB. **Prevention and reversal of dental caries: role of low level fluoride**. Community Dentistry and Oral Epidemiology. 1999.[18]	543 (23.6)	643 (27.9)	1448 (62.9)

The oldest article was published in 1988, entitled "Dental-caries, fluorosis and fluoride exposure in Michigan schoolchildren"[19], authored by Szpunar and Burt. The most-recent article was published in 2020, entitled "Fluoride in drinking water and skeletal fluorosis: A review of the global impact"[8], authored by Srivastava and Flora. A peak in publications occurred in the 2000s (n = 53), and 62% of the citations correspond to works published in the same period (11,416).

A total of 25 countries contributed to the 100 most-cited articles. Considering the number of publications by country, the top five are: (1) India with 30 publications and 5,735 citations; (2) the United States with 16 publications and 3,516 citations; (3) China with 15 publications and 1,819 citations; (4) the United Kingdom with 5 publications and 991 citations; and (5) Iran with 5 publications and 707 citations. The map of countries and continents with publications in the top 100 and respective citations is represented in Figure 1.

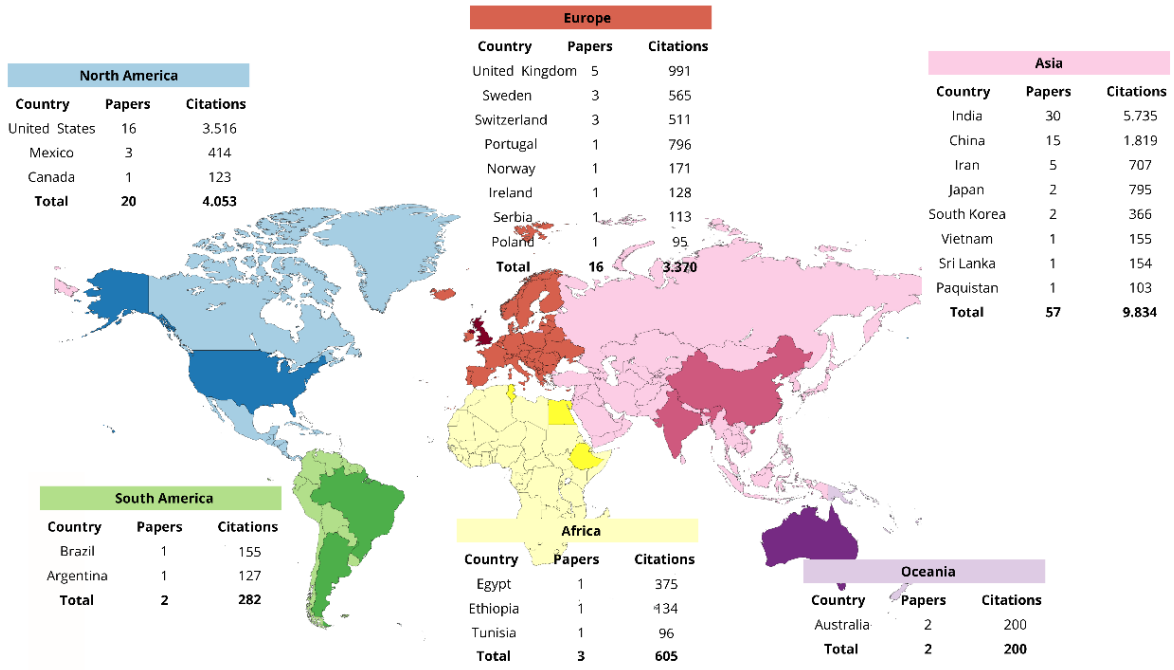

Figure 1. Map of countries and continents present among the 100 most cited articles. Source: MapChart

A total of 88 institutions contributed to the 100 most-cited articles. The Indian Institute of Technology topped the ranking with four articles, totalling 1962 citations. The journals with the most articles in the top 100 are described in Table 2, with the respective numbers of citations and impact factors.

A total of 426 authors contributed to the 100 most-cited articles. The frequency with which they appear is represented in Figure 2. The most frequent authors are presented in the areas of greatest heat, corresponding to the yellow colour. On the other hand, the names associated with the green/blue areas correspond to authors with fewer occurrences.

Table 2. Journals with the most articles in the list of the 100 most cited

Title of the journal	Number of articles	Number of citations	Impact factor
Journal of Hazardous Materials	6	1511	14.224
Environmental Geology	6	853	1.127
Fluoride	6	682	0.725
Science of the Total Environment	5	811	10.754
Environmental Geochemistry and Health	4	498	4.898
Journal of Public Health Dentistry	4	438	2.258
Chemical Engineering Journal	3	1068	16.744
Environmental Science & Technology	3	511	11.357
Journal of Dental Research	3	379	8.924
Environmental Monitoring and Assessment	3	333	3.307
Critical Reviews in Environmental Science and Technology	2	1190	11.75
Journal of Environmental Management	2	758	8.91
Ecotoxicology and Environmental Safety	2	390	7.129
Journal of Geochemical Exploration	2	352	4.166
Environmental Chemistry Letters	2	337	13.615
Environmental Research	2	287	8.431
Environment International	2	245	13.352
Environmental Pollution	2	256	9.988
Archives of Toxicology	2	216	6.168

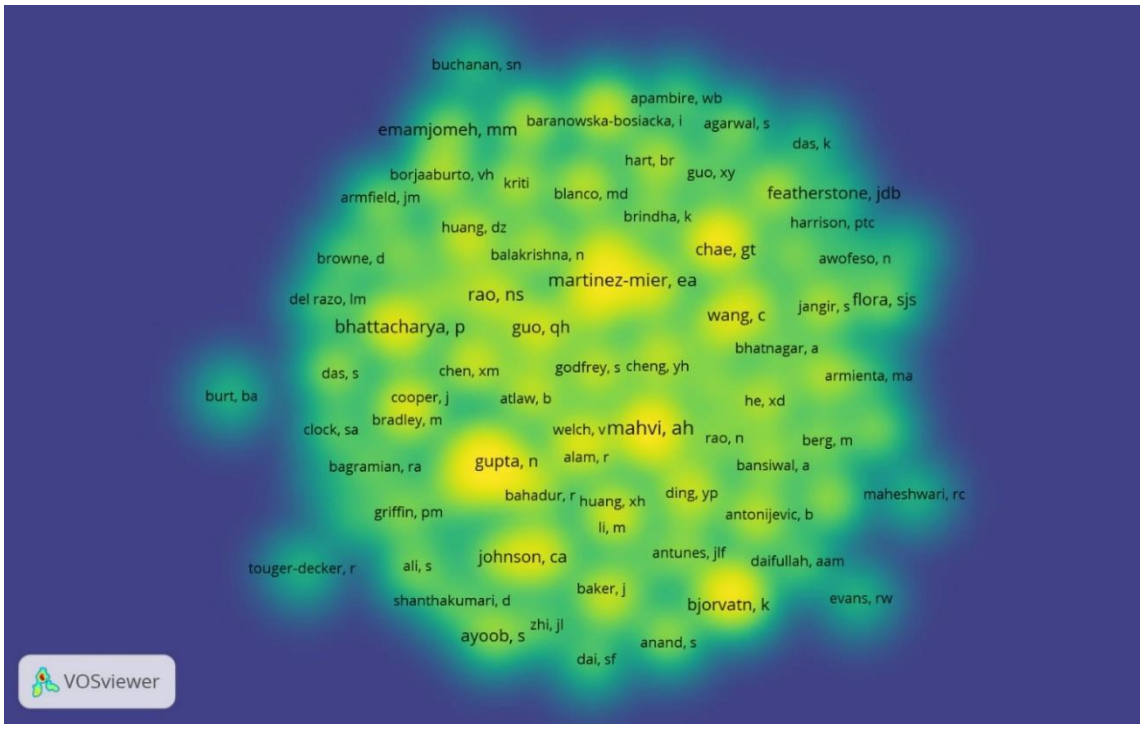

Figure 2. Author density map. Source: VOSviewer

Most articles in the top 100 were literature reviews (44 articles, 10,807 citations), followed by laboratory studies (40 articles, 5,591 citations), cross-sectional studies (14 articles, 1,697 citations) and longitudinal studies (2 articles, 249 citations).

Most of the articles presented as a subtopic the adverse effects arising from the consumption of fluorides present in the public water supply (43 articles, 6,270 citations), followed by articles that addressed the origin of high fluoride concentrations in water and defluoridation techniques (41 articles, 8,307 citations), the prevention of tooth decay (13 articles, 3,078 citations) and the benefits and safety of the presence of fluorides in the water supply (3 articles, 689 citations).

The final Poisson regression model demonstrated that literature reviews (RR 1.88, 95% CI 1.29–2.74) published between 2000 and 2009 (RR 1.72, 95% CI 1.24–2.40) have a higher citation rate in WoS-CC (Table 3).

Table 3. Regression between the total number of WoS-CC citations and independent variables

Variables	n (%)	Total number of citations			
		Unadjusted RR (95% CI)	p	Adjusted RR (95% CI)	p
Study design					
Review studies	10807 (59%)	2.02 (1.55 – 2.62)	<0.001	**1.88 (1.29 – 2.74)**	**0.001**
Laboratory studies	5591 (30%)	1.15 (0.93 – 1.42)	0.195	0.94 (0.68 – 1.29)	0.710
Others	1946 (11%)	1		1	
Continents					
Asia	9834 (54%)	0.89 (0.60 – 1.33)	0.569		
North America	4053 (22%)	1.05 (0.66 – 1.65)	0.847		
Others	4457 (24%)	1			
Main theme					
Origin of high F concentration and defluoridation	8307 (45%)	0.86 (0.58 – 1.28)	0.463	1.19 (0.83 – 1.73)	0.342
Adverse effects	6270 (34%)	0.62 (0.41 – 0.93)	0.022	0.93 (0.60 – 1.44)	0.738
Others	3767 (21%)	1		1	1
Publication Period					
1980-1999	1595 (9%)	1.26 (0.70 – 2.27)	0.434	1.48 (0.90 – 2.43)	0.122
2000-2009	11416 (62%)	1.53 (1.10 – 2.13)	0.011	1.72 (1.24 – 2.40)	0.001
2010-2020	5333 (29%)	1		1	

DISCUSSION

The present study is the first bibliometric analysis on water fluoridation carried out in WoS-CC, one of the main recommended databases for this type of study[20]. The 100 most-cited articles on public water fluoridation were mainly from India, the United States and China. Scientific progress on this topic is supported mainly by literature reviews and laboratory studies, which have analysed the origins of high fluoride concentrations in public water supplies in some regions of the world, the adverse effects of consuming these waters and defluoridation techniques for water with high fluoride concentrations. Although this bibliometric analysis addresses a topic that is currently widely discussed, the compilation of the 100 most-cited articles brings together research carried out more than 30 years ago and which, due to the large number of citations, has become important for the topic.

Articles that have received more than 100 citations in a specific area are considered classics[21]. This analysis highlights that 82 of the most-cited articles surpass this metric, demonstrating their importance and contribution to scientific development in this area. Although the practice of self-citation is not well interpreted and can be misused to increase bibliometric indicators, it can also occur due to the great contribution of authors in a specific area of knowledge[11,22,23]. Self-citations do not have a significant influence on bibliometric studies, and they do not correlate or affect the impact factor[11,23,24].

The most-cited article in the top 100 is a literature review on the status and effects of fluorides in drinking water. The incidence of disabling dental, skeletal and skeletal fluorosis has been reported in India with mean fluoride concentrations as low as 0.5, 0.7 and 2.8 mg/L, respectively[14]. However, dental fluorosis resulting in tooth discolouration is the only known adverse effect of water fluoridation at optimal levels; it does not affect tooth function or quality of life related to oral health[25]. The risk of developing fluorosis occurs during tooth formation, until approximately around 8 years of age. Severe cases of dental fluorosis are rare in communities with public water supply fluoridation at optimal levels[25]. The WHO recommends a concentration of 0.5–1.5 mg/L of fluoride for caries control, depending on the climate, local environment and other sources of the ions[25]. The authors of the most-cited literature review, S Ayoob and AK Gupta, appeared again in the top 20 (17th position), also as the first and second authors, respectively, for another literature review on sustainable technologies for water defluoridation.

In this bibliometric analysis, studies that addressed the adverse effects of consuming fluoridated water were predominant. The spread of fake news has increased, with a peak during the coronavirus disease 2019 (COVID-19) pandemic[26]. Public opinion about water fluoridation published on Twitter (now known as X) indicated that most users of the social network expressed negative aspects about this preventive method[27]. These data demonstrate that evaluation of information available online about water

fluoridation by professionals is necessary so that the public has easier access to reliable sources of information. Exposure to fluoridated water during the first 5 years of life was not associated with changes in children's emotional and behavioural development[25].

India led our top 100 ranking as the country with the highest number of publications on the topic. Groundwater with high fluoride content is reported in hard rock areas and the arid region of northwestern India[28]. Evapotranspiration appears to lead to the precipitation of calcite, reduction of calcium activity, and an increase in the sodium-to-calcium ratio, thereby elevating fluoride levels[28]. Thus, it is a geographic characteristic of the region to have high fluoride concentrations in water, which explains the prominence of laboratory studies exploring technologies for the removal of these ions. Defluoridation technologies can be classified into two main categories: membrane techniques (reverse osmosis, nanofiltration, dialysis, and electrodialysis) and adsorption, a conventional method employing adsorbents such as alumina/aluminum-based materials, carbon, and others[17]. It is essential to emphasize the importance of tailoring the research question for each study, as specific issues may arise depending on the chosen object of study.

AH Mahvi has the most publications in the top 100 – a total of four. The studies he carried out mainly addressed the health risks of the population in northwestern Iran exposed to high fluoride concentrations present in groundwater. However, the most-cited authors in the top 100 are S Ayoob and AK Gupta AK, who each have a total of 1,190 citations from two literature reviews, followed by JD Featherstone with 1,072 citations from two literature reviews, the fifth and sixth most-cited articles. In both works, JD Featherstone reviewed the role of low levels of fluorides in preventing and reversing tooth decay. Fluorides in drinking water and oral care products reduce tooth decay through topical mechanisms that include (1) inhibition of demineralisation at crystalline surfaces within the tooth, (2) enhancement of remineralisation at crystalline surfaces and (3) inhibition of bacterial enzymes[18].

The most cited articles on water fluoridation were literature reviews and laboratory studies. In bibliometric studies, rankings are based on numerical evaluations that emphasize the quantity of publications and citations, rather than the quality of evidence[11, 21, 22, 23]. The prominence of these study designs highlights a preference among researchers in this field. Although neither type of study represents the highest level of scientific evidence, they hold significant relevance in research. Literature reviews are vital for scientific writing as they compile studies with similarities and enable researchers to produce texts from a historical perspective on a given topic[29]. Laboratory studies, despite the limitation that not all results can be extrapolated to living organisms[17, 28], are indispensable in the context of water fluoridation. This is because many questions related to the topic are directly tied to the physicochemical alterations in water. It is noteworthy that the 10th position among the most cited articles in this bibliometric analysis is occupied by a systematic review. This review included various types of studies beyond clinical trials and provided an evaluation of the safety and efficacy of drinking water fluoridation[32].

The quality of the included studies was low to moderate, and the authors concluded that water fluoridation was associated with an increase in the proportion of children without cavities and a reduction in the number of teeth affected by the disease. There was also an increase in the prevalence of dental fluorosis in the beneficiary population, but there was no clear evidence of other potential adverse effects[32]. Therefore, more longitudinal studies in humans are needed, which would allow for a better assessment of the adverse effects of fluorides. These studies follow participants for long periods of time, which allows evaluating the cause–effect relationship between exposure and the development of the condition[33].

CONCLUSIONS

The 100 most-cited articles related to public water fluoridation were published mainly in Asia, with literature reviews and laboratory-based studies addressing adverse effects, the origin of high fluoride concentrations and technologies for defluoridation being the most prevalent. This bibliometric review described the main characteristics of the most-cited articles that studied the topic over the years and recognised the authors and institutions that have contributed to scientific development in this area of knowledge. Longitudinal studies in humans are needed to increase the quality of scientific evidence to better evaluate the adverse effects of water fluoridation.

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CONFLICT OF INTERESTS

No conflicts of interest.

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