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*Published in:*  
Stomatology Edu Journal

*Publication date:*  
2016

*Document version*  
Publisher's PDF, also known as Version of record

*Document license:*  
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*Citation for published version (APA):*  
Petersen, P. E. (2016). Prevention of dental caries through the effective use of fluoride: the public health approach. *Stomatology Edu Journal*, 3(2), 130-140.

## PREVENTION OF DENTAL CARIES THROUGH THE EFFECTIVE USE OF FLUORIDE - THE PUBLIC HEALTH APPROACH

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Received: July 08, 2016  
Accepted: July 11, 2016  
Available online: August 17, 2016

### Cite this article:

Petersen PE. Prevention of dental caries through the effective use of fluoride - the public health approach. *Stoma Edu J.* 2016;3(2):130-140.

### ABSTRACT

**Background:** The World Health Organization (WHO) emphasizes that dental caries is a severe public health problem across the world. The current global and regional patterns of dental caries reflect distinct risk profiles of countries which relate to the structure of the society, living conditions, lifestyles, and the existence of preventive oral health programmes. Research conducted in high income countries documents that systematic use of fluoride reduces the burden of dental caries; such research is scarce in low and middle income countries.

**Objectives:** This article reviews the evidence on effective use of fluoride, highlights the public health approach to fluoridation, and clarifies how automatic fluoridation contributes to breaking social inequities in dental caries.

**Data collection:** Scientific publications on fluoride administration stored in PubMed/Medline and caries data from the WHO databank.

**Outcome:** Dental caries identified from national surveys or country relevant data; extraction of scientific reports is based on their public health relevance.

**Conclusions:** The article outlines the history of fluoridation programmes and describes the sound evidence on automatic fluoridation through water, salt and milk, or from the use of high quality fluoridated toothpastes (1000-1500 ppm F). The experiences from the implementation of programmes in various countries are discussed and the potential for breaking the social inequalities in the burden of dental caries is clarified. Finally, the role of WHO in the development and implementation of fluoridation schemes is explained; WHO technical assistance in the outcome evaluation and assessment of fluoride exposure is enlightened.

**Keywords:** burden of dental caries, social inequalities, population-based disease prevention, automatic fluoridation, WHO.

### 1. Introduction

Dental caries continues to pose an important public health problem across the world.

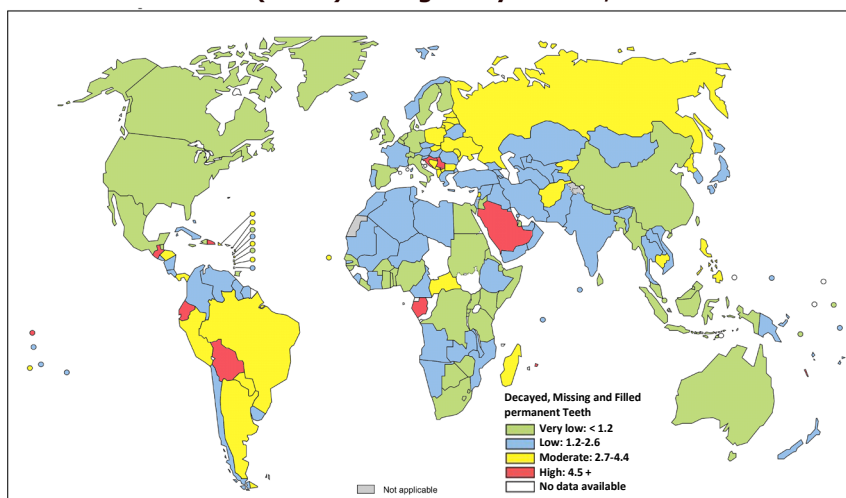
The World Health Organization (WHO) emphasizes that the disease affects about 60-90% of schoolchildren and the vast majority of adults; moreover, dental caries contributes to an extensive loss of natural teeth in older people globally.<sup>1,2</sup> Meanwhile, in most westernized high income countries, dental health has improved over the past three decades in parallel to the introduction of prevention-oriented oral health systems. A decline in the prevalence and the severity of dental caries is particularly observed in children and younger adults in countries having established public health programmes using fluoride for dental caries prevention, coupled with changing living conditions, healthier lifestyles, and

improved self-care practices. In Eastern Europe and Central Asia dental caries levels are high and with health systems in transition the exposure of the population to fluoride for disease prevention has diminished dramatically. In low and middle income countries of Asia, Latin America, and certain areas of Africa, the prevalence of dental caries is growing considerably. The lack of preventive programmes is further complicated by the fact that these countries have a shortage of oral health personnel and the capacity of oral health systems is mostly limited to treatment of symptoms or emergency care. In children and adults suffering from severe tooth decay, teeth are often left untreated or they are extracted to relieve oral pain or discomfort. In the future, tooth loss and impaired quality of life are therefore expected to increase as a public health problem in many developing

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**Dental caries levels (DMFT) among 12 - years old, December 2014**



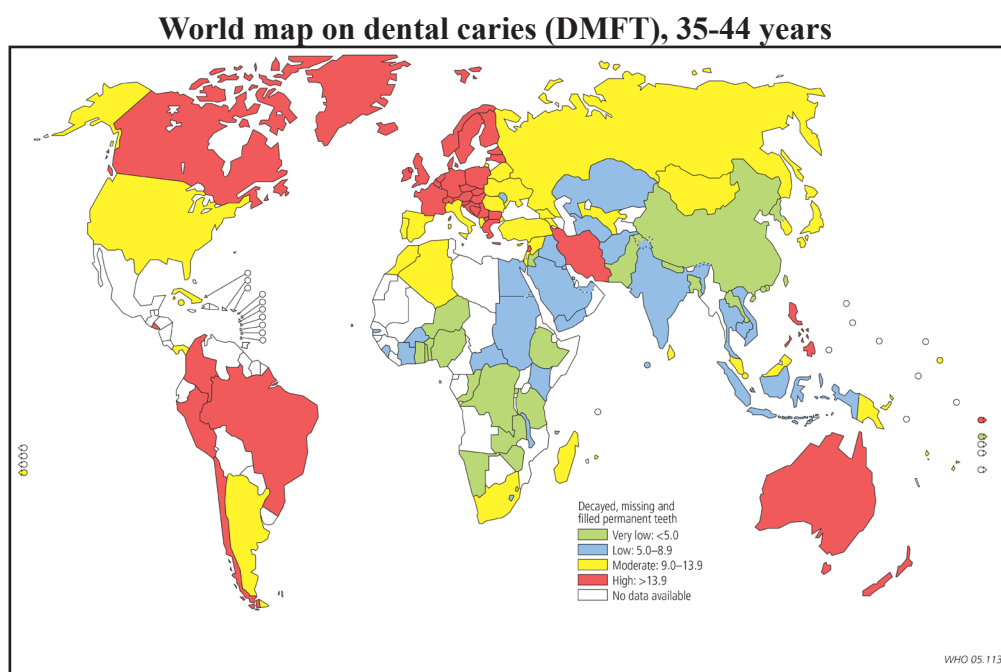
**Figure 1.** Levels of dental caries experience among 12-year-old across the world as measured by the DMFT index according to the WHO Global Oral Health Data Bank<sup>3</sup>

countries unless prevention is introduced. Figures 1-2 summarize the epidemiological information depicting the burden of dental caries across the world. The figures show the country scores of Decayed, Missing due to caries, and Filled index at ages 12 and 35-44-years.<sup>1,3</sup> Figure 3 demonstrates the high DMFT index among older people within the six WHO regions. The number of teeth missing due to caries is remarkably prominent. The current global and regional patterns of dental caries largely reflect distinct risk profiles of countries which relate to structure of society, living conditions, lifestyles, and the existence of preventive oral health systems.<sup>4</sup> The socio-behavioural risk factors in dental caries are found universally and they play significant roles in children, adults as well as older people. The disease level is relatively high among the underprivileged population groups, i.e. people with a low education background, poor living conditions, people with poor dietary habits and high consumption of sugars, and people with limited tradition of dental care.<sup>5</sup> Unless serious efforts are made to tackle the social inequity by modifying risk factors and by establishing effective caries prevention programmes, the level of dental caries in disadvantaged populations and countries will unduly increase.<sup>4</sup> Evidently, substantial population groups in low and middle income countries have not yet obtained the health benefit from fluoride in community prevention programmes. The reasons for not having been able to implement such prevention programmes varies in nature ranging from lack of national policy and systems for oral health to low awareness of the importance of oral health.

The purpose of this article is to review the evidence for using fluoride for prevention of dental caries and to summarize the public health benefit from usage of automatic fluoridation as recommended by WHO. In addition, the intention is to discuss one of the major public health advantages of automatic fluoridation in that the approach may break the prevailing oral health diversities between population groups.

## 2. Existing fluoridation programmes

Few low and middle income countries have large-scale fluoridation programmes in operation. Some countries in Latin America have introduced water and salt fluoridation, and remarkable caries reduction has been observed in the populations of those countries. However, effective exposure to fluoride is still fairly limited in other regions. In the African region, for example, salt fluoridation has been implemented in Madagascar with the support of UNICEF and WHO. In Asia, Thailand introduced high-quality fluoride-containing toothpaste and milk fluoridation in school programmes;<sup>6-8</sup> in parallel, WHO facilitated the implementation of salt fluoridation in Laos and Viet Nam. While the use of fluoride-containing toothpaste is becoming more common in low and middle income countries, its use is not the norm even among those who brush their teeth twice a day, and it is more likely to be used in urban rather than in rural communities.<sup>9,10</sup> Locally produced fluoride-containing toothpastes often have insufficient levels of fluoride. Two important events have analyzed the use of fluoride in Asia. In 2006, a WHO symposium reviewed the Chinese



**Figure 2.** Levels of dental caries in 35-44-year-olds in countries as measured by the DMFT index, WHO Global Oral Health Data Bank<sup>3</sup>

experiences from fluoridation programmes<sup>11</sup> and a workshop on the effective use of fluoride in Asia was held in Thailand in March 2011, which analyzed the opportunities and barriers in establishing sustainable fluoride programmes.<sup>7,8</sup>

Most industrialized countries have demonstrated a substantial decline of dental caries among children and growing proportions of adults tend to preserve their natural teeth. Several years ago high income countries in Europe, USA, New Zealand, and Australia<sup>12</sup> introduced several years ago comprehensive fluoride administration programmes based on water fluoridation, salt fluoridation, or milk fluoridation. The Scandinavian countries and Japan introduced systematic use of effective fluoridated toothpaste and this appears to be significant population-directed prevention as tooth brushing with fluoridated toothpastes is highly frequent.

### 2.1. Effective use of fluoride

Fluoride is a key agent in reducing the prevalence of dental caries, which it achieves in at least three ways<sup>12, 13</sup>:

- by encouraging repair (re-mineralization) of early damage to enamel caused by acid produced by the breakdown of sugars by plaque bacteria;
- by improving the chemical structure of the enamel, making it more resistant to acid attack; and
- by reducing the ability of the plaque bacteria to produce acid.

WHO<sup>1</sup> emphasizes that the prevalence and incidence of dental caries can be controlled by the joint action of communities, professionals and individuals. In many low and middle income countries, however, access to oral health services is

limited, while in high income countries significant numbers of the underprivileged population groups are underserved. For these reasons, professionally applied fluorides such as fluoride varnish or fluoride gel are considered less relevant to public health programmes. Thus, according to WHO<sup>14</sup> the public health approaches to effective use of fluoride include:

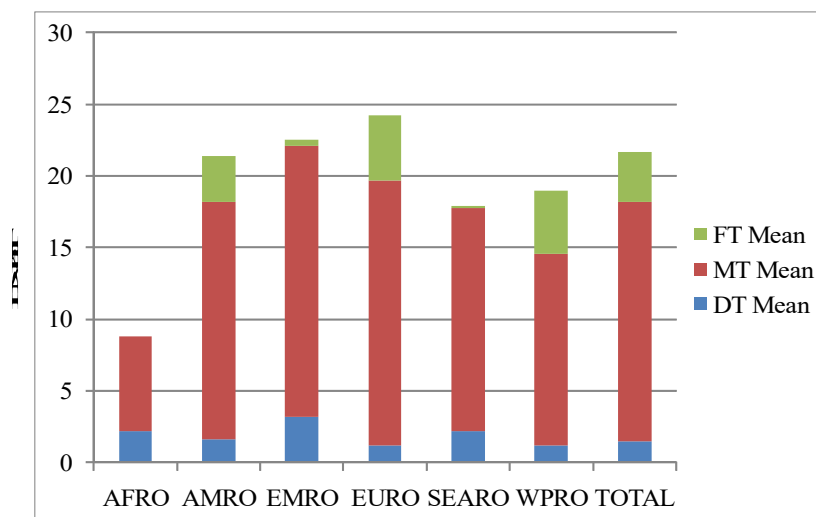
- water fluoridation
- salt fluoridation
- milk fluoridation; and
- development of affordable fluoride-containing toothpastes.

Government agencies and the private industry sector in charge of operation of water facilities, salt processing plants, dairies and toothpaste manufacturers have a very important role to collaborate on the development and implementation of community dental caries prevention programmes in which water, salt or milk alone or in combination with toothpaste are considered as vehicles for making fluoride available to the population.

### 3. Research on population-based prevention through fluoride

Research on the effects of fluoride on oral health started slightly over 100 years ago.<sup>15</sup> During the first third of the century research focused on studying causes of mottled enamel. The next twelve to fifteen years researchers studied the relationship between fluoride, dental caries and enamel fluorosis. In the second half of the 20th century research aimed at adding fluoride to community water supplies and later to salt for human consumption; it gradually shifted to the development and evaluation of fluoride-containing toothpastes and mouth rinses

### Mean DMFT of older people 65 years or more by WHO Region



**Figure 3.** Dental caries experience (DMFT) among older people (65+ years) across WHO regions of the world, as measured by the DMFT index, WHO Global Oral Health Data Bank<sup>3</sup> (AFRO= Africa, AMRO= Americas, EMRO= Eastern-Mediterranean, EURO= Europe, SEARO= South East Asia, WPRO= Western Pacific)

and, to studying the use of milk as a vehicle for fluoride as a possible public health alternative to water or salt fluoridation. More recently, efforts have been made to summarize these extensive data sets through systematic reviews, such as those conducted on water fluoridation by the University of York National Health Service Centre for Reviews and Dissemination<sup>16,17</sup>, on fluoride ingestion and bone fractures<sup>18</sup> and on fluoride toothpaste<sup>19</sup> and mouth rinses<sup>20</sup> by the Cochrane Collaboration Oral Health Group.

#### 3.1. Water fluoridation

The history of water fluoridation can be divided into three periods.<sup>21</sup> The first period from 1901 to 1933 focused on investigating causes of mottled enamel (Colorado brown stain, first reported by Frederick McKay). The second period between 1933 and 1945 attempted to study the relationship that might exist between fluoride concentrations, fluorosis and dental caries, and established that moderate levels of fluoride prevent dental caries. The third period, from 1945 to the present focused on adding fluoride to community water supplies. In 1945, the first controlled experiment of water fluoridation was initiated by H. Trendley Dean in the city of Grand Rapids, Michigan United States of America.<sup>22</sup> Five years later, Dean reported that there were significant reductions in dental caries. These results were complemented by Arnold et al. in 1953.<sup>23</sup> Other major fluoridation programmes followed the first community programme for water fluoridation instituted at Grand Rapids; in the USA in Newburgh in 1945<sup>24</sup>, and in Evanston, Illinois in 1946;<sup>25</sup> in Canada in Brantford and Ontario in 1945;<sup>26</sup> in the Netherlands in 1953;<sup>27</sup> in New Zealand in 1954<sup>28</sup>; in the United Kingdom in 1955<sup>29-31</sup>, and in the German Democratic Republic

in 1959.<sup>32</sup> The outcomes of these programmes were published mainly in the 1950s and 1960s. As a result, many community water fluoridation programmes were introduced in the largest cities of the USA, including Indianapolis (1951), San Francisco (1952), Philadelphia (1954), Chicago (1956), New York (1965), Dallas (1966), and Detroit (1967). The average cost of water fluoridation in the USA has been estimated at the level of 1US\$ per person per year.<sup>33</sup> Worldwide, extensive fluoridation programmes have also been introduced in Australia, Brazil, Chile, Colombia, Canada, Hong Kong Special Administrative Region of China, Ireland, Israel, Malaysia, New Zealand, Singapore, the United Kingdom, and elsewhere. More recently, new programmes have been introduced in large conurbations in the south and west of the USA, including Los Angeles (in 1999), Las Vegas (in 2000), Sacramento (in 2000), and San Antonio (in 2002).

Systematic reviews consistently conclude that water fluoridation reduces the prevalence of dental caries, i.e. the percentage of the population with decayed, missing and filled primary teeth (dmft)/Decayed, Missing due to caries, and Filled permanent Teeth (DMFT) > 0 and reduces the incidence of dental caries. There is no credible evidence that water fluoridation is associated with any adverse health effects. Water fluoridation has benefits in addition to those associated with the use of fluoride toothpastes alone.

In order to properly implement water fluoridation programmes a central water distribution system is indispensable. In addition, the full support of the top health authorities and of the government is essential; some countries have secured laws, decrees or regulations. Adequate budget for the initiation and maintenance of programmes is

**Table 1.** Dental caries severity in selected countries before implementation of automatic fluoridation for prevention of dental caries<sup>3</sup>

Country	Automatic Fluoridation			DMFT 12-years	Year of implementation
	Water	Salt	Milk		
<b>Brazil</b>	X			2.8	1953
<b>Bulgaria</b>			X	3.1	1988
<b>Canada<sup>1</sup></b>	X			2.1	1945
<b>Chile<sup>2</sup></b>	X			2.6	1996
<b>Chile Codegua</b>			X	3.23 dmft@6years of age	1994
<b>Colombia</b>		X		2.3	1997
<b>Costa Rica</b>		X		2.5	1987
<b>Cuba</b>		X		1.5	2000
<b>Czech Republic</b>		X		2.5	1994
<b>France</b>		X		1.2	1986
<b>Germany</b>		X		0.7	1991
<b>Honk Kong</b>	X			0.8	1961
<b>Ireland</b>	X			1.1	1957
<b>Israel</b>	X			1.66	1970
<b>Jamaica</b>		X		1.1	1987
<b>South Korea</b>	X			2.08	1978
<b>New Zealand</b>	X			1.4	1954
<b>Macedonia</b>			X	3.03	2009
<b>Malaysia</b>	X			1.6	1957
<b>Mexico</b>		X		2.0	1989
<b>Russian Federation</b>			X	2.9	1994
<b>Singapore</b>	X			1.0	1958
<b>Switzerland</b>		X		0.86	1955
<b>Thailand</b>			X	1.9	2000
<b>United Kingdom</b>	X			0.7	2003
<b>St Helens, UK</b>			X		1993
<b>United States</b>	X			1.16	1945
<b>Uruguay</b>		X		2.5	1992

<sup>1</sup> Ontario

<sup>2</sup> Metropolitan area

indispensable to ensure sustainability.

### 3.2. Salt fluoridation

One of the objections to water fluoridation is that it limits consumers' choice. If the public water supply is fluoridated, a consumer has few practical alternatives other than to purchase bottled drinking-water that does not contain fluoride. One of the attractions of fluoridated salt is that it can be sold alongside a non-fluoridated alternative. Salt is consumed by virtually all populations, the amount consumed is constant, and an overdose is virtually excluded. In countries of the Americas decrees, regulations or standards

emanated from health authorities require that salt for human consumption be fluoridated. Salt fluoridation has been used successfully for over 55 years. The fluoride addition is inexpensive and techniques for addition in various settings have been developed and these are accessible to small and large processors. When most salt for human consumption is fluoridated, the effectiveness of salt fluoridation approximates that of water fluoridation. Fluoridated salt is available in certain countries that do not have identified programmes. The first studies on the effects on the incidence and prevalence of dental caries of fluoride added to

alimentary salt were carried out from around 1965 to 1985 in Colombia, Hungary and Switzerland, with rather similar results to those observed after the introduction of water fluoridation.<sup>34,35</sup> These studies also explain that fluoridated salt reaches the consumer through several channels, including domestic salt, meals at schools, large kitchens, and in bread. In Colombia, Costa Rica, Jamaica, and the Canton of Vaud in Switzerland, most, if not all, of these channels are used; in France and Germany the focus is on fluoridating domestic salt. Jamaica provides another interesting setting, because all salt destined for human consumption in the country has been fluoridated since 1987. Significant development has occurred in the Americas where Colombia, Costa Rica, Jamaica, Mexico and Uruguay have more than 20 years of documented community experience with population coverage up to 98%.<sup>36-38</sup>

Around the world, the concentration of fluoride in salt used ranges from 200 mg/kg to 350 mg/kg, with an optimal concentration of around 250 mg/kg.<sup>39,40</sup> In studies conducted in Hungary the concentration of 350 ppm F was used in all test towns. Caries reduction of 53% to 68% was observed in both temporary and permanent dentitions after 15 years of salt fluoridation.<sup>41</sup> If salt ingestion was reduced concentration of fluoride in salt could be increased to provide the corresponding amount of fluoride to maintain comparable cariostatic effect. One concern expressed misleadingly is that the promotion of the dental benefits of fluoridated salt would be unacceptable and contradictory to public health messages that encourage the reduction of consumption of salt and thus decrease the risk of hypertension. However, populations are not encouraged to consume more salt but limit themselves to a minimal consumption to improve their dental health; rather, the "automatic" or passive effect of fluoridated salt is accepted. In other words, people do not need to change their usual behaviour to benefit. Indeed, reduced consumption of salt could and should be encouraged and, where this is successful, the concentration of fluoride in salt could simply be increased appropriately.

Iodization of salt has been successfully used to prevent iodine deficiency diseases and is now being promoted in all parts of the world. It is emphasized by WHO that iodization and fluoridation of salt should be combined.<sup>40</sup> Coordination between health agencies, salt producers, marketers, distributors, and the community, with inclusion of appropriate epidemiological surveillance systems, is recommended for effective implementation. The cost of implementing a salt fluoridation program varies with the type of equipment available at the processing plant, the method for adding the fluoride compound, cost of the fluoride compound, necessary training of personnel, quality control equipment, and supplies. The cost of the equipment and other inherent costs for initiating a salt fluoridation programme depend on the size

of the processing plants and the amount of salt to be processed. Estimates based on programmes implemented in the Americas indicate that the cost per person per year is approximately US \$0.06.<sup>34</sup>

### 3.3. Milk fluoridation

The fluoridation of milk is another example of an attempt by public health administrators to provide the benefits of fluoride without requiring the consumers to take on particular responsibilities or change their behaviour. The potential of milk as an alternative vehicle for fluoride - primarily to children - was first identified in Switzerland in 1962. Further experience was reported from programmes implemented in Scotland<sup>42</sup>, and in Hungary.<sup>43</sup> Various channels have been used, including programmes distributing milk in kindergartens,<sup>44</sup> and schools,<sup>45,46</sup> and powdered milk and milk-cereal distributed as part of the National Complementary Feeding Programme in Chile.<sup>47</sup> The results of these programmes as well as other ones targeted at children have been summarized by WHO.<sup>48</sup> All studies have emphasized that it is important to start the programme in early childhood to ensure an optimal effect on the deciduous teeth, and to maintain the consumption of milk for at least 180 days per year. Interesting initiatives such as sending school milk home on a Friday evening for consumption over the weekend have been reported in China, where milk consumption has been maintained for more than 300 days per year.<sup>49</sup> To date no milk fluoridation programmes have been targeted at and evaluated in adult populations. Still today, WHO is involved in comprehensive milk fluoridation programmes in several countries such as Thailand and Bulgaria. In Bulgaria, the first community based scheme was introduced in 1988 including some 15,000 children and it reached more than 30,000 children in 2003. WHO reported recently the experience gained from milk fluoridation in Bulgaria<sup>50</sup>; this programme was evaluated through the application of a most advanced study design based on longitudinal surveys and time trend analysis. Fluoridated milk delivered daily in schools in Bulgaria resulted in substantially lower caries development compared with children in schools receiving milk without added fluoride.

The enrollment of children in milk fluoridation programmes increased substantially as programmes were introduced in four other countries. More recently there has been further expansion, particularly in Thailand and Chile. In Thailand about 1 million children are now covered by the national programme. In conclusion, fluoridation of milk can be recommended as a caries preventive measure in children, where the fluoride concentration in drinking water is suboptimal, caries experience in children is significant, and there is an existing school milk programme.<sup>48</sup> Generally, the additional cost of providing fluoridated milk, compared with non-fluoridated milk, is approximately two to three US

dollars per child per year.<sup>34</sup>

### 3.4. Fluoride-containing toothpaste

Toothpaste is probably the most widespread and significant vehicle used for fluoride. Introduced in the late 1960s and early 1970s, their rapid increase in market share was remarkable. The consensus view from high income countries was that the introduction of fluoride-containing toothpastes was the single factor most responsible for the massive reduction in dental caries seen in many countries during the 1970s and 1980s.<sup>51</sup> Furthermore, of the various vehicles for fluoride, toothpaste has been the most rigorously evaluated. Marinho et al.<sup>19</sup> included 74 randomized, controlled clinical trials of good quality in their systematic review of fluoride toothpastes. WHO considers a toothpaste containing 1000-1500 ppm F to be an effective toothpaste; meanwhile, in some low and middle income countries fluoridated toothpaste may contain less fluoride such as 400-500 ppm which is ineffective for the prevention of dental caries.

Accordingly, people should be encouraged to brush their teeth daily with effective fluoride-containing toothpaste, i.e. fluoride recommended at the level of 1000-1500 ppm. It is worth noting that "topical" fluorides such as toothpaste can also have a "systemic" effect when they are inadvertently ingested by young children. Dispensing a pea-sized amount of toothpaste, encouraging parents to supervise tooth brushing by their young children, or the use of toothpastes containing less fluoride by young children are approaches to ameliorating this problem. Countries may recommend toothpastes with low concentration of fluoride, i.e. 500 ppm or less specifically for such young age groups (1-3 years of age).

An important limitation is that the population value of these toothpastes depends upon the behaviour of the individual and the family in purchasing and regularly using the products. Studies of children<sup>52-55</sup> and adults<sup>4,56</sup> have shown that use toothpaste containing fluoride are not uniform and is less likely among underprivileged population groups. In addition, ethnicity plays a significant role in oral hygiene habits.<sup>57</sup> The fall in the incidence of dental caries after the introduction of fluoride into toothpaste formulations, although seen in all social classes, is particularly found in the wealthy social classes; social-class inequality persists in countries with advanced or less advanced oral health systems.<sup>4</sup>

In response to the social inequities found in many parts of the world that are known to impact oral health with consequent disproportional occurrence of dental caries, the WHO Oral Health Programme continue to promote the development and use of "affordable" fluoride-containing toothpaste<sup>58</sup>. "Affordable" toothpaste is one that is available at a price that allows people on a low income to purchase it. Vital elements in the cost of production are the choice and availability of raw materials. Critically, the abrasive agent and the fluoride source should be compatible over time. Precipitated

calcium carbonate is the abrasive agent of choice because of its low cost and ready availability in developing countries. It is experienced companies which can manufacture effective toothpastes that are also of a low cost. However, it remains to be seen whether the marketing of such toothpastes will increase demand and use among low-income groups. In order to encourage use it might be in the interest of countries to exempt these effective fluoride toothpastes from the duties and taxation that are imposed on cosmetics.<sup>1,34,59</sup>

### 4. WHO policy on the use of fluoride for the prevention of dental caries

The WHO policy on the effective use of fluoride is reflected in four World Health Assembly Resolutions: WHA22.30 (1969) and WHA28.64 (1975) on fluoridation and dental health; WHA 31.50 (1978) on fluoride for prevention of dental caries, and the most recent WHA60.17 (2007): "Oral Health: Action Plan for Promotion and Integrated Disease Prevention". The 2007 Resolution urges Member States to ensure that populations benefit from appropriate use of fluoride<sup>14</sup> and the statement reads as follows:

*(4) for those countries without access to optimal levels of fluoride, and which have not yet established systematic fluoridation programmes, to consider the development and implementation of fluoridation programmes, giving priority to equitable strategies such as the automatic administration of fluoride, for example, in drinking-water, salt or milk, and to the provision of affordable fluoride toothpaste;*

Today about 450 million people benefit from fluoride<sup>4</sup>. The WHO Oral Health Programme continues to emphasize the importance of public health approaches to the effective use of fluorides for the prevention of dental caries and the Programme is involved with support, guidance, and practical assistance to several countries.

**Table 1** summarizes the baseline data on dental caries severity at 12 years of age reported to the WHO Global Oral Health Data Bank [CAPP]<sup>3</sup> from countries that have implemented automatic fluoridation programmes (water, salt or milk). It is recognized that fluoride-containing toothpaste may be available in these countries although, data on demand and regularity of use in all countries are not available.

#### 4.1. WHO guidance

Where the incidence and prevalence of dental caries in the community is high to moderate, or where there are firm indications that the incidence of caries is increasing, an additional source of fluoride (water, salt or milk) should be considered. Water fluoridation using fluoride at a concentration of 0.5-1 mg/l is the method of choice if the country (or area of the country) has a moderate level of economic and technological development. A central water system, a municipal water supply reaching a large population, trained



water engineers, and a favorable public opinion are essential factors<sup>14,34,59</sup>.

WHO has issued a publication on inadequate or excess fluoride prepared within the context of preventing disease through healthy environments; this document focuses on the sources of exposure to fluoride and health effects<sup>60</sup>. Dental enamel fluorosis should be monitored periodically to detect increases in or higher-than-acceptable levels of fluorosis. Action, such as adjusting intake of fluoride from water, salt, milk or other sources, should be taken when the prevalence of fluorosis is found to be excessive. It is highly recommended to calculate the community fluorosis index (CFI) using data generated from examinations of renal excretion undertaken by calibrated examiners as part of epidemiological studies to assess whether occurrence of unsightly fluorosis constitutes a public health problem warranting increasing consideration. WHO produced in 2014 a manual on the assessment of renal fluoride excretion in community prevention programmes for oral health<sup>61</sup>. This manual informs on practical procedures in measuring exposure to fluoride from existing fluoridation programmes. It complements the WHO "Oral Health Surveys - Basic Methods 2013"<sup>62</sup> which provides guidelines for obtaining epidemiological information about the population level of dental caries and the prevalence of enamel fluorosis. Salt fluoridation may be relevant to countries where the technical facilities for water fluoridation are not available. It is required that salt production and distribution can be controlled.

Salt fluoridation is an effective alternative that has the advantage of allowing consumer choice; this may be important in certain countries or cultures. An overview of some practical aspects relating to the implementation of salt fluoridation programmes has been published<sup>39,40</sup>.

Milk fluoridation is particularly used for promoting oral health in children. WHO published a comprehensive manual<sup>48</sup> on milk fluoridation which highlights the rationality of milk as a vehicle for the administration of fluoride; the manual details the biological basis, the opportunities for integration with other national or community programmes on diet and nutrition, development of community and school health programmes, challenges in practical implementation, and monitoring and evaluation of programmes. The evidence on the use of milk fluoridation is outlined in this manual and further supported by country experiences. A global report has revealed that the school is a unique platform for fluoride administration, particularly when programmes are organized according to the WHO Health Promoting Schools Project<sup>63,64</sup>.

WHO convened an Expert Committee in 1993 to provide authoritative information about the role of fluoride in the promotion of oral health throughout the world<sup>59</sup>. In 2016, a similar group of experts published an update of the research on fluoride and oral health and the findings are reported in a special issue of the journal *Community Dental*

*Health*<sup>34</sup>. It reviews the effect of fluoride from biological, clinical and public health perspectives. The document focuses on the presence of fluoride in the environment; fluoride metabolism and excretion; fluoride in teeth and bone; biomarkers of fluoride exposure; dental caries prevention and enamel fluorosis; fluoridated drinking water, salt and milk; topical use of fluoride, and fluoride-containing toothpaste. Based on the modern conception of evidence for public health the report emphasizes the effectiveness and appropriateness of different fluoride application forms in communities and specifies the practical impact of implementation of combined administration of fluoride. In addition, this publication summarizes the experiences from the use of fluoride around the globe. Such update information is highly relevant to countries which are in process of introducing fluoride programmes or to those countries engaged in adjustment of programmes.

### 5. The need for further research

Continuous research is vital to advance the use of fluoride for oral health in countries. It is important to maintain and foster a programme of public health research that might seek to:

- update our information on the cost-effectiveness and cost-benefit of water, salt and milk fluoridation against a background of the now widespread use of fluoride-containing toothpastes;
- continue to develop and update our knowledge of the health effects of ingested fluoride;
- further develop affordable techniques for the removal of fluoride from the public water supply in communities where natural concentrations of fluoride are above the guideline value of 1.5 mg/l set by WHO<sup>65</sup>;
- better understand the public perception of dental enamel fluorosis and, increment efforts to educate the community so that it is well understood that enamel fluorosis is not a disease and that mild forms are preferable to the devastating effects of dental caries; and
- evaluate the effects of the introduction of affordable fluoride-containing toothpastes on purchase and use by the public.

Research on the prevention of dental caries through the use of fluoride is urgently needed in low and middle income countries.

It is well recognized from research undertaken in high income countries that population wide automatic fluoridation measures are most effective and equitable strategies for the prevention of dental caries; however, it remains to clarify to what extent the implementation of fluoridation programmes is possible in low and middle income countries and whether similar health results may be obtained. In addition, the social inequalities in dental caries prevalence are substantial in all countries and further evidence is needed on how to break the gap between rich and poor population groups through effective use of fluoride.

## Acknowledgments

The author declare no conflict of interest related to this study. There are no conflicts of interest and no financial interests to be disclosed.

## REFERENCES

1. The world oral health report 2003. Geneva: WHO; 2003. Available from: [http://www.who.int/oral\\_health](http://www.who.int/oral_health)
2. Petersen PE. Oral health. In: Heggenhougen K, Quah S, editors. International Encyclopaedia of Public Health. Vol. 4. San Diego: Elsevier, Academic Press; 2008. p. 677-685.
3. World Health Organization. WHO Global Oral Health Data Bank. Geneva: WHO; 2015. Available from: [http://www.who.int/oral\\_health](http://www.who.int/oral_health)
4. Kwan S, Petersen PE. Oral health: equity and social determinants. In: Blas E, Kurup AS. Equity, social determinants and public health programmes. Geneva: World Health Organization; 2010. p.159-176.
5. Petersen PE. Sociobehavioural risk factors in dental caries: International perspectives. *Community Dent Oral Epidemiol.* 2005;33(4):274-279.
6. Petersen PE, Baez RJ, Lennon MA. Community-oriented administration of fluoride for the prevention of dental caries: A summary of the current situation in Asia. *Adv Dent Res.* 2012; 24(1):5-10.
7. Petersen PE, Phantumvanit P. Toward effective use of fluoride in Asia. *Adv Dent Res.* 2012; 24(1):2-4.
8. Petersen PE, Phantumvanit P. Perspectives in the effective use of fluorides in Asia. *J Dent Res.* 2012;91(2):119-121.
9. Zhu L, Petersen PE, Wang HY, Bian JY, Zhang BX. Oral health knowledge, attitudes and behaviour of children and adolescents in China. *Int Dent J.* 2003;53(5):289-298.
10. Zhu L, Petersen P, Wang H, Bian JY, Zhang BX. Oral health knowledge, attitudes and behaviour of adults in China. *Int Dent J.* 2005;55(4):231-241.
11. Petersen PE, Kwan S, Zhu L, Zhang BX, Bian JY. Effective use of fluorides in the People's Republic of China - A model for WHO Mega Country initiatives. *Community Dent Health.* 2008;25(4 Suppl 1):257-267.
12. Jones S, Burt BA, Petersen PE, Lennon MA. The effective use of fluorides in public health. *Bull World Health Organ.* 2005;83(9):670-676.
13. Featherstone JD. The science and practice of caries prevention. *J Am Dent Assoc.* 2000;131(7):887-899.
14. Petersen PE. World Health Organization global policy for improvement of oral health - World Health Assembly 2007. *Int Dent J.* 2008;58(3):115-121.
15. Petersen PE, Lennon MA. Effective use of fluorides for the prevention of dental caries in the 21st century: the WHO approach. *Community Dent Oral Epidemiol.* 2004;32(5):319-321.
16. McDonagh M, Whiting P, Bradley M, Cooper J, Sutton A, Chestnut I et al. A systematic review of public water fluoridation. York: The University of York NHS Centre for Reviews and Dissemination; 2000. Report 18, Appendix K, p. 235. Available from: <http://www.york.ac.uk/inst/crd/fluores.htm>
17. McDonagh MS, Whiting PF, Wilson PM, Sutton AJ, Chestnut I, Cooper J et al. Systematic review of water fluoridation. *BMJ.* 2000;321(7265):855-859.
18. Demos LL, Kazda H, Cicuttini FM, Sinclair MI, Fairley CK. Water fluoridation, osteoporosis, fractures – recent developments. *Aust Dent J.* 2001;46(2):80-87.
19. Marinho VCC, Higgins JPT, Logan S, Sheiham A. Fluoride toothpastes for preventing dental caries in children and adolescents (Cochrane Review). The Cochrane Library, Chichester, UK: John Wiley & Sons Ltd; 2004. Available from: <http://www.update-software.com/abstracts/ab002278.htm>
20. Marinho VCC, Higgins JPT, Logan S, Sheiham A. Fluoride mouth rinses for preventing dental caries in children and adolescents (Cochrane Review). The Cochrane Library, Chichester, UK: John Wiley & Sons Ltd; 2004.
21. Ripa LW. A half-century of community water fluoridation in the United States: review and commentary. *J Public Health Dent.* 1993;53(1):17-44.
22. Dean HT, Arnold FA, Jay P, Knutson JW. Studies on mass control of dental caries through fluoridation of the public water supply. *Public Health Reports (1896-1970).* 65(43):1403-1408.
23. Arnold FAJ, Dean HT, Knutson JW. Effect of Fluoridated Public Water Supplies on Dental Caries Prevalence: Seventh Year of Grand Rapids-Muskegon Study. *Public Health Reports (1896-1970).* 1953;68(2):141-148.
24. Ast DB, Smith DJ, Wacks B, Cantwell KT. Newburgh-Kingston caries-fluorine study XIV. Combined clinical and roentgenographic dental findings after ten years of fluoride experience. *J Am Dent Assoc.* 1956;52(3):314-325.
25. Blayney JR, Hill IN. Fluorine and dental caries. *J Am Dent Assoc.* 1967;74(2):225-302.
26. Hutton W, Linscott B, Williams D. Brantford fluorine experiment; interim report after 5 years of water fluoridation. *Can J Public Health.* 1951;42(3):81-87.
27. Kwant GW, Houwink B, Backer Dirks O, Pot TJ. Artificial fluoridation of drinking-water in the Netherlands; results of the Tiel-Culemborg experiment after 16 1/2 years. *Neth Dent J.* 1973;80(9 suppl):6-27.
28. Ludwig TG. The Hastings Fluoridation Project V - dental effects between 1954 and 1964. *N Z Dent J.* 1965; 61(285):175-179.
29. Medical Research Council. Working Group Report: water fluoridation and health. London: MRC; 2002. Available from: [http://www.mrc.ac.uk/index/public-interest/public-news-4/public-news\\_archive/public-news-archive\\_sep\\_oct\\_02/pdf-publications-water\\_fluoridation\\_report.pdf](http://www.mrc.ac.uk/index/public-interest/public-news-4/public-news_archive/public-news-archive_sep_oct_02/pdf-publications-water_fluoridation_report.pdf)
30. Ministry of Health Scottish Office Ministry of Housing and Local Government. The conduct of the fluoridation studies in the United Kingdom and the results achieved after five years. London: HMSO; 1962. Reports on Public Health and Medical Subjects No. 105.
31. Department of Health and Social Security Scottish Office Welsh Office. The fluoridation studies in the United Kingdom and the results achieved after eleven years. London: HMSO; 1969. Reports on Public Health and Medical Subjects No. 122
32. Künzel W, Fischer T, Lorenz R, Brühman S. Decline of caries prevalence after the cessation of water fluoridation in the former East Germany. *Community Dent Oral Epidemiol.* 2000;28(5):382-389.
33. United States Department of Health and Human Services Centers for Disease Control and Prevention. Recommendations for using fluoride to prevent and control dental caries in the United States. *Morb Mortal Wkly Rep.* 2001;50. Available from: [www.bfsweb.org](http://www.bfsweb.org)
34. O'Mullane DM, Baez RJ, Jones S, Lennon MA, Petersen PE, Rugg-Gunn AJ, Whelton H, Whitford GM. Fluoride and Oral Health. *Community Dent Health.* 2016;33(2):69-99.
35. Marthaler TM. Overview of salt fluoridation in Switzerland since 1955, a short history. *Schweiz Monatsschr Zahnmed* 2005;115(8):651-655.
36. Burt BA, Marthaler T. Fluoride tablets, salt fluoridation, and milk fluoridation. In: Fejerskov O, Ekstrand J, et al., editors. *Fluoride in dentistry.* 2nd ed. Copenhagen: Munksgard; 1996.
37. Estupinan-Day SR, Baez R, Horowitz H, Warpeha R, Sutherland B, Thamer M. Salt fluoridation and dental caries in Jamaica. *Community Dent Oral Epidemiol.* 2001;29(4):247-52.
38. Warpeha R, Beltran-Aguilar E, Baez R. Methodological and biological factors explaining the reduction in dental caries in Jamaican school children between 1984 and 1995. *Pan Am J Public Health.* 2001;10(1):37-44.
39. Marthaler T. Practical aspects of salt fluoridation. *Schweiz Monatsschr Zahnmed.* 1983;93(12):1197-1214.
40. Marthaler TM, Petersen PE. Salt fluoridation - an alternative in automatic prevention of dental caries. *Int Dent J.* 2005; 55(6):351-358.

41. Toth K. Caries prevention by domestic salt fluoridation. Budapest: Akademiai Kiado; 1984.
42. Stephen KW, Boyle IT, Campbell D, McNee S, Boyle P. Five-year double-blind fluoridated milk study in Scotland. *Community Dent Oral Epidemiol.* 1984;12(4):223-229.
43. Banoczy J, Zimmermann P, Hadas E, Pinter A, Bruszt V. Effect of fluoridated milk on caries: 5 year results. *J R Soc Health.* 1985;105(3):99-103.
44. Pakhomov GN, Ivanova K, Moller IJ, Vrabcheva M. Dental caries-reducing effects of a milk fluoridation project in Bulgaria. *J Public Health Dent.* 1995; 55(4):234-237.
45. Legett BJ, Jr, Garbee WH, Gardiner JF, Lancaster DM. The effect of fluoridated chocolate-flavored milk on caries incidence in elementary school children: two and three-year studies. *ASDC J Dent for Child.* 1987; 54(1):18-21.
46. Woodward SM, Ketley CE, Pealing R, West J, Lennon MA. School milk as a vehicle for fluoride in the United Kingdom. An interim report. *Community Dent Health.* 2001;18(3):150-156.
47. Mariño R, Villa A, Guerrero S. A community trial of fluoridated powdered milk in Chile. *Community Dent Oral Epidemiol.* 2001;29(6):435-442.
48. Bánóczy J, Petersen PE, Rugg-Gunn AJ (Editors). *Milk fluoridation for the prevention of dental caries.* Geneva: World Health Organization; 2009.
49. Bian JY, Wang WH, Wang WJ, Rong WS, Lo EC. Effect of fluoridated milk on caries in primary teeth: 21-month results. *Community Dent Oral Epidemiol.* 2003;31(4):241-245.
50. Petersen PE, Kwan S, Ogawa H. Long-term evaluation of the clinical effectiveness of community milk fluoridation in Bulgaria. *Community Dent Health.* 2015;32:199-203.
51. Bratthall D, Hansel-Petersson G, Sundberg H. Reasons for the caries decline: what do the experts believe? *Eur J Oral Sci.* 1996; 104(4):416-422.
52. Mansbridge JN, Brown MD. Changes in dental caries prevalence in Edinburgh children over three decades. *Community Dent Health.* 1985;2(1):3-13.
53. Steele J, Lader D. *Children's dental health in the United Kingdom, 2003. Social factors and oral health in children.* London: Office for National Statistics; 2004. Available from: <http://www.statistics.gov.uk/cci/nugget.asp?id=1000>
54. Petersen PE. Oral health behaviour among 6-year-old Danish children. *Acta Odontol Scand.* 1992;50(1):57-64.
55. Petersen PE, Danila I, Samoila A. Oral health behavior, knowledge, and attitudes of children, mothers, and schoolteachers in Romania in 1993. *Acta Odont Scand.* 1995;53(6):363-368.
56. Christensen LB, Petersen PE, Krusturup U, Kjoller M. Self-reported oral hygiene practices among adults in Denmark. *Community Dent Health.* 2003;20(4):229-235.
57. Sundby A, Petersen PE. Oral health status in relation to ethnicity in the Municipality of Copenhagen, Denmark. *Int J Paediatr Dent* 2003;13(3):150-157.
58. Adyatmaka A, Sutopo U, Carlsson P, Bratthall D, Pakhomov G. School-based primary preventive programme for children. Affordable toothpaste as a component in primary oral health care. Experience from a field trial in Kalimantan Barat, Indonesia. Geneva: World Health Organization; 1998.
59. World Health Organization Expert Committee on Oral Health Status and Fluoride Use. *Fluorides and oral health. WHO Technical Report Series No. 846.* Geneva: World Health Organization; 1994.
60. World Health Organization. *Inadequate or excess fluoride: a major public health concern.* Geneva: WHO Public Health and Environment; 2010.
61. World Health Organization. *Basic Methods for Assessment of Renal Fluoride Excretion in Community Prevention Programmes for Oral Health.* Geneva: WHO; 2014.
62. World Health Organization. *Oral Health Surveys-Basic Methods (5th Edition).* Geneva: WHO; 2013.
63. World Health Organization. *Oral health promotion: an essential element of a health-promoting school. WHO information series on school health, document eleven.* Geneva: WHO; 2003.
64. Jürgensen N, Petersen PE. *Promoting oral health of children through schools - Results from a WHO global survey 2012.* *Community Dent Health.* 2013; 30(4):204-218.
65. *Guidelines for drinking-water quality. 3rd ed. Recommendations.* Geneva: World Health Organization; 2004. Available from: [http://www.who.int/water\\_sanitation\\_health/dwq/gdwq3/en/](http://www.who.int/water_sanitation_health/dwq/gdwq3/en/)

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## Questions

### **Given a global perspective, are the problems related to dental caries are largely solved now?**

- a. Dental caries continues to be a major public health problem to countries across the world and is now increasing rapidly in developing countries;
- b. Because of dentistry, dental caries is now a limited problem to people around the globe;
- c. Essentially, we have no effective strategies to tackle the burden of dental caries among people;
- d. The burden of dental caries is more or less of same magnitude in Eastern Europe as in Western Europe.

### **Is fluoride is of great benefit to avoid dental caries?**

- a. Yes, years of research have shown high scientific evidence of fluoride for the prevention of dental caries;
- b. Fluoride is harmful to the health of people and should be avoided;
- c. It is helpful that we have information on the internet on the negative impact of fluoride;
- d. People will suffer from dental caries no matter what.

### **What is the recommendation made by WHO in relation to fluoride?**

- a. The use of fluoride should be restricted because it is unhealthy;
- b. The use of fluoride is a cost-effective approach for public health;
- c. The use of fluoride-containing toothpaste is good but the fluoride concentration does not matter;
- d. Children and pregnant women should avoid fluoride for the prevention of dental caries.

### **Do we have to accept social inequalities in dental caries?**

- a. In dentistry we have no effective means to reduce the health gap between poor and wealthy people;
- b. Automatic fluoridation (water, salt or milk) is a most equitable approach which is recommendable in public health;
- c. Social inequality is not of concern to dentistry; we should just take proper care of our patients;
- d. If poor or low educated people just cleaned their teeth properly, they would have a dental status comparable to the standard of wealthy and highly educated people.