WATER FLUORIDATION AND ORAL HEALTH IN MALAYSIA: A REVIEW OF LITERATURE

Abdul Karim F[1,2], Yusof ZYM[2], Mohd Nor NA[2].
[1]Oral Health Programme, Ministry of Health Malaysia, Level 5, Block E10, Parcel E, Precinct 1, Federal Government, Administrative Centre, 62590 Putrajaya, Malaysia
[2]Department of Community Oral Health and Clinical Prevention, Faculty of Dentistry, University of Malaya, 50603 Kuala Lumpur, Malaysia

Correspondence:
Dr Nor Azlida Mohd Nor
Department of Community Oral Health and Clinical Prevention,
Faculty of Dentistry,
University of Malaya,
50603 Kuala Lumpur, Malaysia
Phone number: +603 79674805
Email: azlida@um.edu.my

Abstract

Information regarding water fluoridation (WF) in Malaysia has been substantially documented, but is scattered in various government publications and may be lost to the stakeholders. This paper is a review of water fluoridation in Malaysia and its effect on oral health: a history of WF in Malaysia, the current policy, the evidence of its effectiveness, the challenges and the future directions. A search for relevant physical and electronic documents of WF in Malaysia resulted in the identification of 70 documents for review. WF was gazetted as national policy with an optimal fluoride level of 0.7 parts-per-million (ppm) in 1972, with a reduction of the level to 0.5 ppm in 2005. Evidence showed that WF effectively reduced population dental caries while fluorosis was not a prevalent public health concern. Strong collaboration between stakeholders and the extensive network of piped water supplies resulted in 80% of the population receiving WF in 2013. However, the coverage was reduced to 74.1% in 2018, largely due to the cessation of WF in Pahang. The key challenges in WF included a lack of funding, weak legislation, use of reverse osmosis water filtration system, difficulty to maintaining an optimal level of fluoride in the water, and lack of local data on the impact of WF cessation on oral health, and its cost-effectiveness. This review will provide dental health professionals with scientific evidence on WF and oral health in Malaysia and assist them in answering relevant questions about WF raised by the public.-

Keywords: *Dental Caries, Fluorosis, Malaysia, Review, Water Fluoridation*

Introduction

The discovery of fluoride in caries prevention is attributed to the investigations carried out on the high concentration of natural fluoride in the water (1). It was discovered that fluoride protects against caries through its topical action after the teeth have erupted (2). When fluoride is present in an acidic solution surrounding the enamel crystal, it inhibits mineral loss. In the presence of fluoride during remineralisation, it is adsorbed onto the crystal surface and attracts calcium and phosphate ions to form a new mineral, with stronger resistance to acid dissolution (2, 3). Thus, this dynamic process resulted in the prevention of the onset and the progression of caries as well as the reversal of early lesions (3).

Caries was a serious health problem in the USA before water fluoridation (WF) was introduced in the mid-1940s. Following the fluoridation of water, there was a major decline in caries among children in the USA (4, 5). Owing to its effectiveness, WF was named as one of the ten greatest public health achievements of the 20th century by the Surgeon General of the USA (6). By 2012 more than 370 million of the global population in 27 countries were exposed to fluoridated water. Some of the countries with extensive WF programme are Singapore, Hong Kong, Australia, New Zealand, and the USA (7).

A vast body of evidence supported the effectiveness of WF in caries prevention (8-12). Analysis of studies conducted after 1974 indicated that WF is effective over and above

the use of fluoridated toothpaste and other fluoride modalities (10). In a more recent study in Australia, living in a non-fluoridated area remained a significant factor for caries development in children despite the presence of fluoridated toothpaste and fluoride supplements (13). Furthermore, exposure to WF has slowed down the caries progression that occurred in enamel pits and fissures despite the use of fissure sealants (14).

Despite being effective against dental caries and safe at a low fluoride level in the water supply, WF continues to be one of the most debated public health measures. Opposition to WF, coupled with its political and legal complexities, has resulted in the discontinuation of WF in several countries (9) such as in Finland (15) and Korea (16). The opponents of WF claimed that fluorosis was a sign of fluoride toxicity and they focused mostly on the aesthetic effects of a severe type of fluorosis even though most dental fluorosis is presented in the mild form (10, 11). Also, the prevalence of moderate to severe fluorosis was found to be very low in optimally fluoridated areas (17). Some authorities have reported that it may not be possible to achieve effective fluoride-based caries prevention without some degree of dental fluorosis (7). Another tactic often used by anti-fluoridation groups is associating fluoridated drinking water with bone cancer. However, this claim is unfounded. A recent case-control study showed that the risk of having osteosarcoma among individuals exposed to WF was low (18). Furthermore, various reviews reported insufficient evidence to support the adverse effects of fluoride on health as claimed by opponents of WF (7, 10, 11).

Similarly, in Malaysia, there were episodes where WF had been stopped in certain areas after the programme was launched in 1972 (19). The dental authorities faced various challenges in maintaining WF in several states and were struggling to convince other stakeholders to initiate or reinstitute WF in some areas. The snapshots of WF development at the state and national levels can be very beneficial for the decision-making process and to inform the general population of the importance of WF in the current situation. The information regarding WF in Malaysia, however, although substantially documented, is scattered in various government publications and many of these documents are unknown to important stakeholders. Therefore, a summary of the key evidence about WF in Malaysia is important. Thus, this paper aimed to review the history of WF programme and oral health in Malaysia, current policy, evidence of effectiveness, side effects, and its challenges and future directions. This article will provide a summary of scientific evidence on WF in Malaysia and assist dental professionals in scholarly dialogues on WF raised by the public.

Materials and Methods

This review is part of a larger WF study in Malaysia and received ethical approval from the Medical Research and Ethics Committee of the Ministry of Health (MOH) Malaysia [NMRR-18-3309-44638] and Medical Ethics Committee, Faculty of Dentistry, University of Malaya [DFC01902/0002]. Permission to conduct the study was obtained from the Oral Health Programme, MOH, Malaysia.

This review focused on searching for documents related to WF in Malaysia from various sources. First, an online search for government reports, guidelines, legal documents, and others was conducted on the official webpages of MOH Malaysia, the Oral Health Programme of MOH Malaysia, the National Water Service Commission, and the National Audit Department. Second, an online search was also conducted in Medline, Google, Malaysian Thesis Online website, other relevant government websites, and universities' repositories to identify published local studies related to WF and fluoride use. The keywords used were "fluorine", "fluoride", "WF" and/or "caries" and/or "fluorosis" and/or "quality of life" and/or Malaysia. No strict inclusion criteria were applied. All study designs were included to capture all possible data. Finally, the hard copy of reports and documents related to WF were retrieved from the Oral Health Programme in MOH Malaysia with permission. No publication date restriction was imposed on online and hand searched documents. Both English and Malay articles and documents were included in this review. All documents were assessed and reviewed accordingly, and the relevant data were analysed descriptively and discussed.

Discussion

A total of 72 documents related to WF in Malaysia were included in this review (Figure 1). The documents included published article journals, government documents and reports, and other related sources.

History of WF in Malaysia

The implementation of WF in Malaysia started in 1969 after the success of a caries prevention programme with WF in Johor (20, 21). Johor Baharu has received WF since 1957 at 0.7 parts-per-million (ppm) fluoride. The first fluoridation study conducted in Johor in 1946 indicated that children in Johor Baharu who had been exposed to WF since birth had 60% fewer caries than children who had not been exposed to WF (20). This finding had led to the establishment of the Committee of Fluoridation of Public Water Supplies in West Malaysia by the Minister of Health in June 1969 with the task to assess the feasibility of implementing WF in West Malaysia. This committee comprised of 15 members, including the Director-General of Medical Services, the Director of Dental Services, Director of Water Works, and a Senior Nutrition Officer (21). The basis for the decision was due to the widespread of population dental caries where more than 90% of children were affected, good network of public water supplies (21, 22), low dentist/dental nurse to patient ratio of 1:15000 with 70% unmet treatment needs, and low levels of naturally occurring fluoride in the water supplies across West Malaysia. Based on the committee's recommendation, WF was eventually gazetted as a national policy by the cabinet of ministers on 25th April 1972 (21, 23). The milestones of WF in Malaysia is shown in Figure 2.

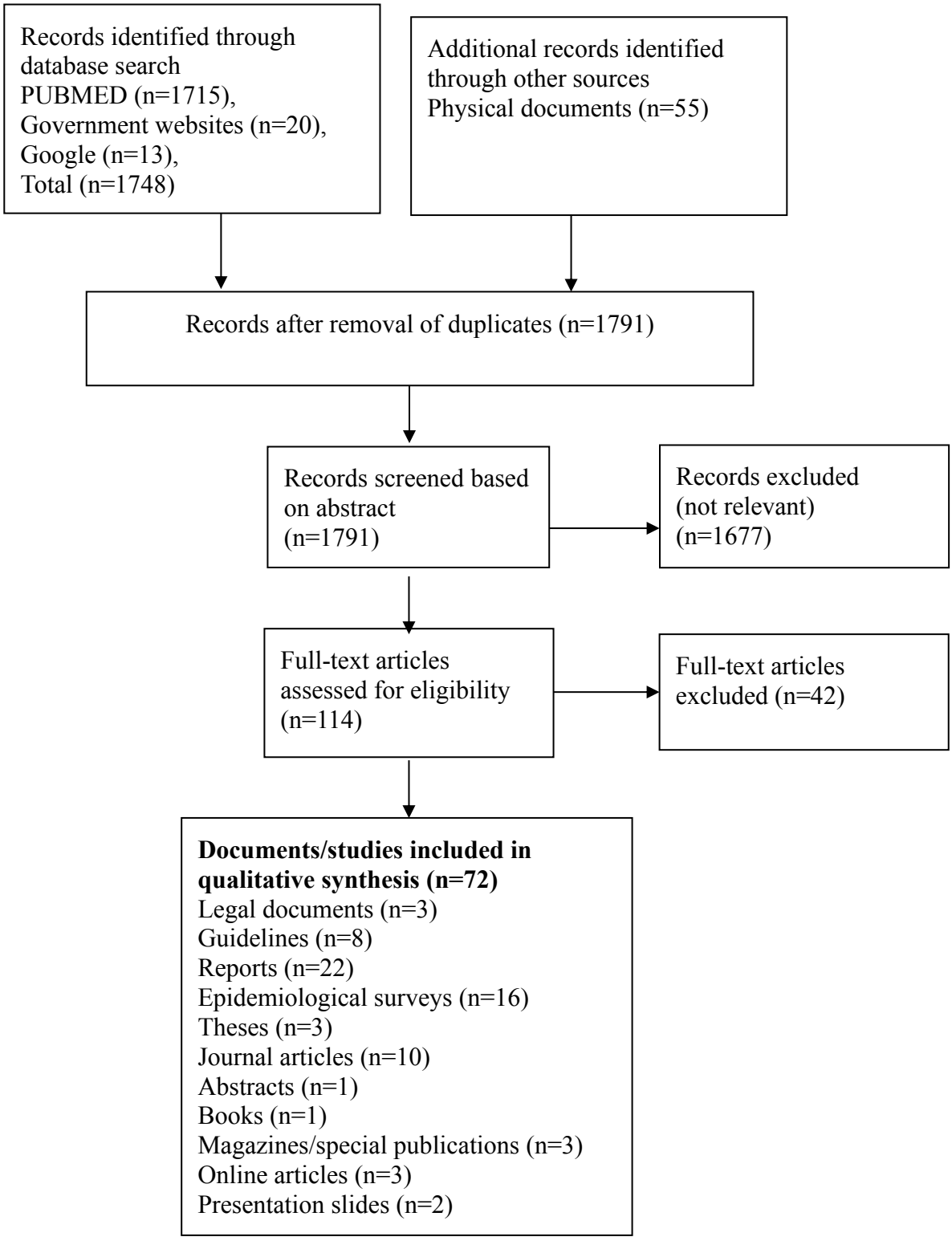

Figure 1: Flow diagram of studies included in the review

At the beginning of WF implementation, MOH was given the mandate to operate the programme while the state governments were informed of any decision made related to WF in their respective states (24). During that time, the fluoride level was set at 0.7ppm. The decision was made after taking into consideration the higher water consumption pattern of the population due to the hot climate, and the effectiveness of WF against caries at the similar fluoride level in Singapore (21). Under the safety level of fluoride, the compound has been listed as one of the parameters in the water supplies needed to be monitored regularly under the National Drinking Water Quality Surveillance Programme that was launched in 1983 (25-27).

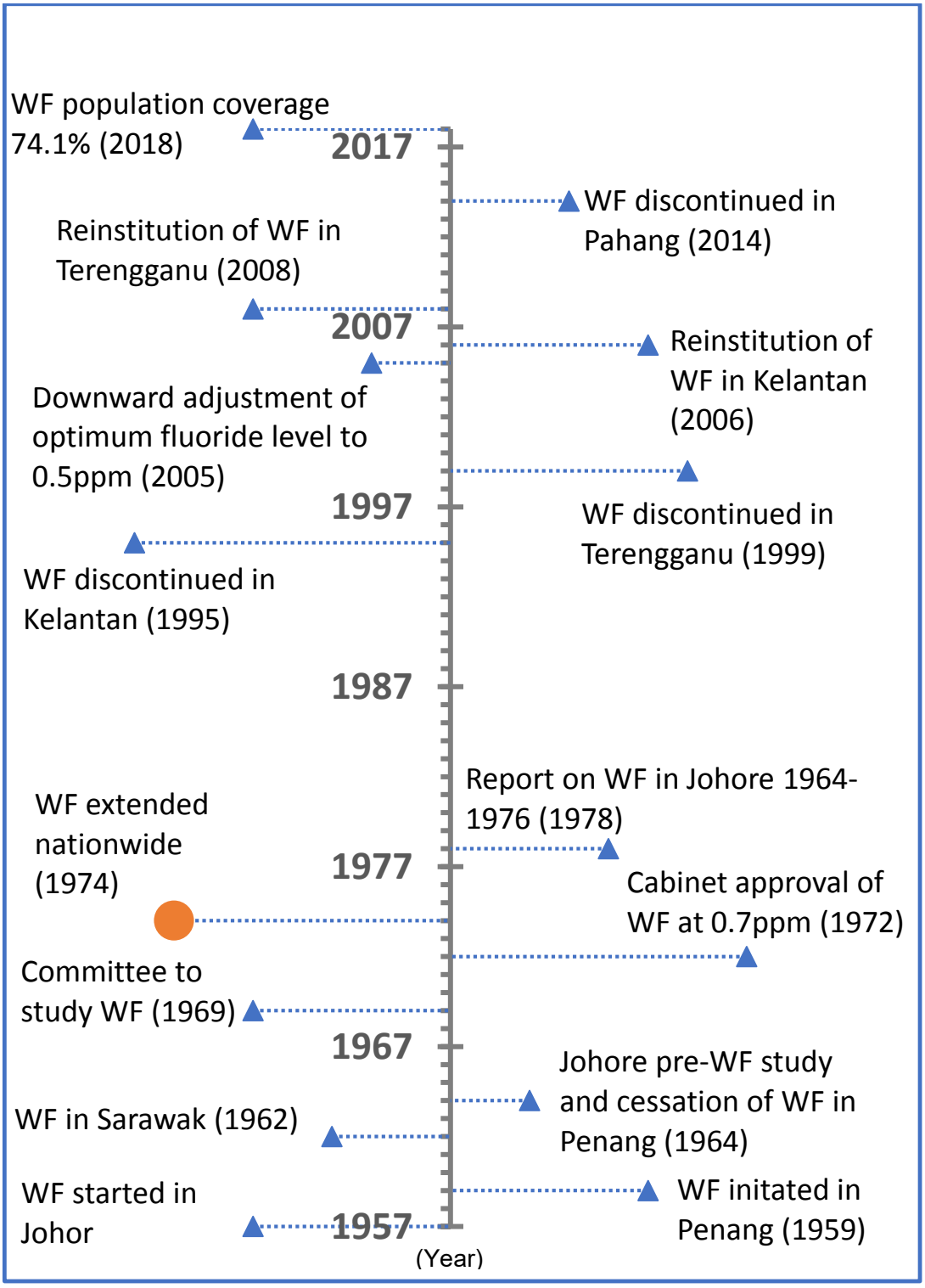

Figure 2: Chronological milestone of WF in Malaysia (courtesy of Oral Health Programme, Ministry of Health, Malaysia) (19)

Since the implementation in 1972, the coverage of WF in the country had grown exponentially. About 69.1% or 17.7 million of the population in Malaysia had gained access to WF in 2005 (14). Gradually, the coverage of WF had increased to the highest point percentage (80%) among Malaysians in 2013 (19). The success of WF in Malaysia is the result of good collaborations among various agencies such as the Public Health Department of Ministry of Health, Ministry of Science, Technology and Innovation, states governments, water treatment plant companies and water supply board (23).

However, the WF coverage showed a declining trend after 2013. This was mainly due to the dramatic drop in WF coverage in the state of Pahang, bringing the national WF coverage down to 75.7%, or approximately 24.3 million of the total population in 2017. In 2018, the population coverage had declined to below the national target of 75% for the first time since 2008 (29). However, the declining trend was attenuated by a moderate increase in the population receiving WF in the states of Kelantan and Sabah (Figure 3). The implementation of WF in Sabah, however, has been weak due to the problem with fluoride feeders in the water treatment plants since it started in 1996 with the maximum population coverage reaching only 9% of the total population in 2013. However, other possible reasons, such as weak implementation, was not mentioned in the reviewed documents (19, 30-39).

There is an imbalance between WF and water pipeline coverage among the Malaysian population. In 2017, 30.6 million people or 95.5% of the total population had access to piped water supplies (40). Nevertheless, due to technical problems such as lack of funding to purchase fluoride compound, breakdown of fluoride feeders, poor maintenance of WF equipment (19), more than 26% or 6.3 million of the population were deprived of WF despite having piped water supplies. Majority of them lived in Sabah, Pahang, and Sarawak (19, 40).

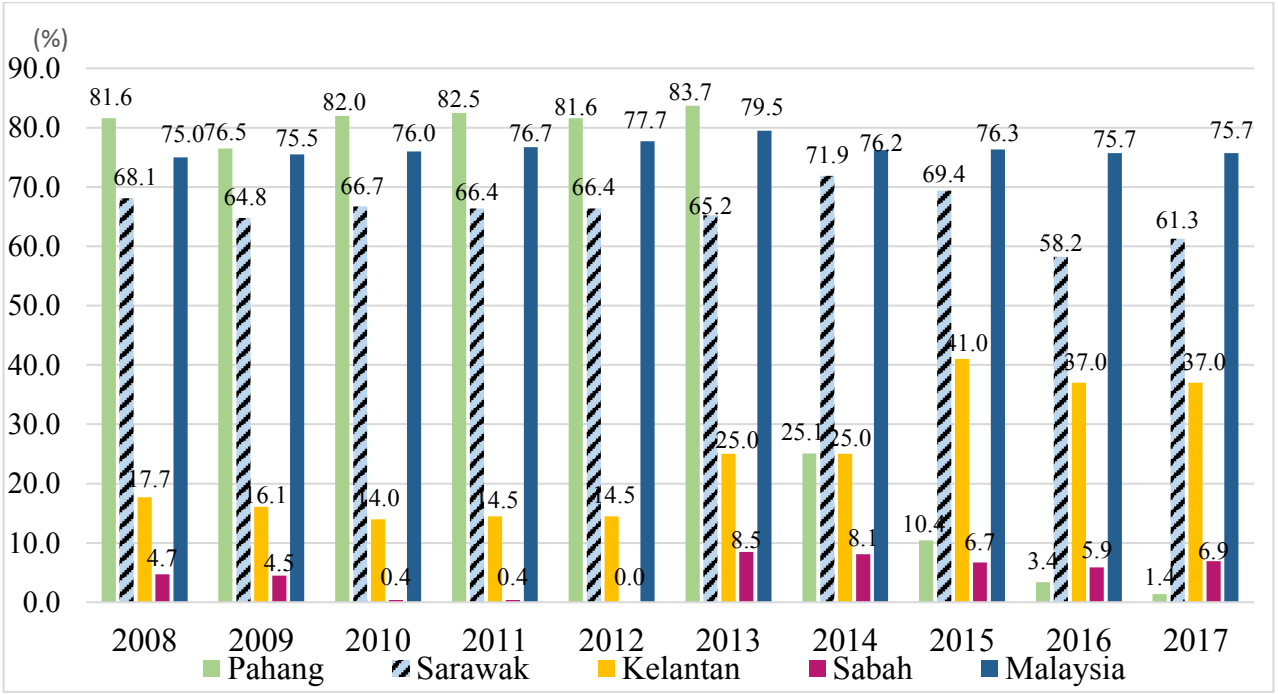

Figure 3: Comparison of WF coverage in selected states with the national average from the year 2008-2017

Cessation of WF in several states in Malaysia

The first WF cessation took place in Penang in 1964 after the programme had been running since 1959. The encrustation problem in the water piping system, which might be caused by fluoride in the water was cited as the main reason for the WF cessation. Later, a chemical analysis indicated that the main compound responsible for the encrustation was silica. However, the restriction on adding fluoride into public water supplies was not lifted until the 1970s (23, 41). In 1998, the population coverage of WF in Penang increased to 94.8% (30).

In recent years, more episodes of WF cessation took place in several other states namely Kelantan (1995), Terengganu (1999), and Pahang (2014) due to several reasons, i.e. change of political party that ruled the state government, privatisation of water treatment plants, lack of funding, technical issues, and fear of adverse effects from WF (Table 1). However, WF had resumed in Terengganu in 2012, and water treatment plants in Kelantan had gradually reinstituted the WF programme possibly due to effective lobbying by the dental authorities (19, 36-39). In Pahang, poor management of state-owned water treatment

company, i.e. *Pengurusan Air Pahang* (PAIP), had affected the WF programme. The company had recorded financial losses for three consecutive years, from 2015 to 2017 (42). As a result, the company had not been able to purchase fluoride compounds since 2012, and by 2014, almost all water treatment plants in Pahang had stopped WF.

Ironically, WF cessation and low WF coverage occurred mainly in the less affluent states (40) where caries level was high (19), and the population caries prevention is mostly needed. For example, in Sabah, the percentage of caries-free among primary schoolchildren in 2017 was only 8.9% while in Kelantan it was 16.9%, rendering them with the poorest oral health status in the country (19). The details of the low WF coverage and histories of WF cessation in the states are summarised in Table 1.

Table 1: Summary of key issues in states with low coverage of WF or with WF cessation experience

State	Summary of findings
Pahang	WF has been discontinued gradually since corporatisation of the state Water Supply Department in 2012, starting with water treatment plants in Bera and Temerloh. Only two of 53 water treatment plants with a fluoride feeder supplied WF in 2017. In 2018, it was estimated that only 0.9% of the population received WF.
Sabah	In 1994, only one of the water treatment plants in Sabah had a fluoride feeder. By 1998, 11.5% of the population benefited from WF. However, WF coverage dropped gradually until it stopped in 2012 despite the State Cabinet Committee's approval to reinstitute WF on October 6 2010. In addition, more than 30% of the rural population did not have access to piped water supplies.
Kelantan	WF had ceased operation in October 1995 due to political power shift and privatisation of water treatment plants. Population coverage was 50% before WF cessation. WF was reinstituted in Pasir Mas and Machang in 2006. In 2017, there were three water treatment plants equipped with a fluoride feeder. Percentage of population using public water supplies in 2017 was lower (68.0%) than other states due to the high use of other water sources such as well water (81). The Kelantanese reported having poor perception towards piped water quality which may have contributed to low use of piped water (82).
Sarawak	Sarawak implemented WF in 1959. Since 2014, WF coverage had reduced gradually to 58.2% in 2016. Four of the 89 water treatment plants were privatised. Only 35 water treatment plants were equipped with a fluoride feeder. The leading cause of WF cessation in several water treatment plants was due to lack of funding. Additionally, Sarawak has a higher percentage of the population living in rural areas with no piped water supplies. Their main source of water came from wells and rain catchments.
Terengganu	In 1998, WF coverage was 81.1%, but it was stopped completely in 1999 due to a change in the local government and privatisation of water treatment plants. Negotiations among the state Oral Health Division, the water provider company, and the state government led to the reinstitution of WF in Setiu district in 2008. In 2016, all water treatment plants were equipped with a fluoride feeder and were fully operational. Nonetheless, the supply of an optimal fluoride level is poor.

Note: The findings are generated from the Oral Health Programme Annual Reports 1998, 2008-2018, and the MOH Malaysia Annual Report 2018

Related data on WF in Malaysia

1. Caries reduction

WF in Malaysia is associated with caries reduction based on the totality of evidence from epidemiological surveys and cross-sectional studies. The first decline in caries experience was seen in Johor in a series of pre- and post-WF studies conducted between 1964 to 1976. The findings showed an average caries reduction of 58% in the permanent teeth across all age groups, while the rate of caries-free increased by three-folds, after seven to eight years of WF (Table 2). Although there was a lack of study on WF, it is noteworthy to mention that the reduction in caries in areas with WF was attributed largely to WF as fluoridated toothpaste was not commonly used until the late 1970s to early 1980s (20).

Since the first dental epidemiological survey conducted in 1971, the percentage of caries-free among 6-, 12- and 16-year-old children had increased by two to five folds since the first dental survey in 1971 (Figure 4). Caries severity in the permanent teeth among 12- and 16-year-old children had reduced to 78.9% and 55.8% respectively over the past 40 years (22, 53-57). Moreover, the need for restorative treatment among 12-year-old children had reduced significantly from 21.0% in 2007 to 14.8% in 2017 while the need for preventive treatment had increased slightly which reflected the changing trend in caries progression and severity (55, 57).

Also, caries reduction was observed in both WF and non-WF areas which were attributed to various factors such as improvements in the living environment, socioeconomic status, level of education, exposure to WF and other sources of fluoride, and extensive coverage of the school dental service. The available evidence shows that the levels of caries were much higher in the non-WF than the WF areas (55, 57).

In 2015, 71.3% of 5-year-old children had caries in the deciduous teeth, with the mean number of teeth affected

Table 2: Findings on dental caries, fluorosis and quality of life among schoolchildren in Malaysia from various cross-sectional studies

Author(s) & year	Fluoride level (ppm) & area(s)	Sample size/ age groups	dft/dmft (S.D)	DMFT (S.D)	Caries-free prevalence (%) (DMFT=0)	Fluorosis prevalence (%) & index used	Quality of Life
Dental Division Ministry of Health Malaysia, 1964-1968 (pre-WF)	0.7/ Johor Baharu	N=1638/ 7 9 11	 6.1 (3.2) 2.3 (2.1) 0.7 (1.2)	 1.0 (1.3) 2.0 (1.7) 3.1 (2.8)	 55.5 26.2 17.7	-	-
	0.25-0.35/ four districts in Johor	N=4547/ 7 9 11	 6.9 (3.2) 3.1 (2.5) 0.7 (1.3)	 2.4 (1.6) 3.5 (2.2) 4.8 (3.3)	 18.4 8.9 7.9	-	-
Dental Division Ministry of Health Malaysia, 1973-1976 (post-WF)	0.7/ four districts in Johor (newly WF)	N=4686/ 7 9 11	 3.8 (2.5) 2.2 (1.9) 0.6 (1.1)	 0.6 (0.9) 1.6 (1.8) 2.4 (2.1)	 75.3 34.2 19.4	-	-
Dental Division Johor, 1986	0.7/ Johor	N=1522/ 12	-	2.0 (2.1)	31.0	81.2/DDE	-
	<0.4/ Johor	N=866/ 12	-	2.8 (2.5)	20.7	56.0/DDE	
Sujak *et al.*, 1997	0.7/ Penang	N=1074/ 16	-	-	-	63.5/DDE	Regression model indicated having fluorosis was not a significant predictor for psychosocial impact
Oral Health Division Ministry of Health Malaysia, 1997	0.7 to <0.4 Peninsular Malaysia, Sabah and Sarawak	N=12230/ 6 12 16	 4.1 (3.5) - -	 - 1.9 (2.3) 3.3 (3.4)	 - 39.1 24.5	- - WF: 67.4/DDE Non-WF: 35.8/DDE	-
Oral Health Division Ministry of Health Malaysia, 1999	0.7 Penang, Selangor, Kuala Lumpur and Johor	N=2153/ 16-17	-	1.3 (2.0)	52.4	74.7/ Dean's>0 Questionable: 12.4 Very mild : 40.1 Mild: 17.8 Moderate: 4.2 Severe: 0.2	41.5% of the respondents were dissatisfied due to caries. Having mild fluorosis associated with higher satisfaction ($p<0.05$)
	<0.4 Sabah	N=756/ 16-17	-	4.2 (3.6)	17.6	14.2/ Dean's>0 Questionable: 11.2 Very mild: 2.5 Mild: 0.4 Moderate: 0 Severe: 0	
Esa and Razak, 2001	0.7 Klang, Selangor	N=1519/ 12-13	-	-	-	32.8/ Dean's≥2 Questionable: 13.2 Very mild: 25.7 Mild: 5.6 Moderate: 1.4 Severe: 0.1	-

Table 2: Findings on dental caries, fluorosis and quality of life among schoolchildren in Malaysia from various cross-sectional studies (continued)

Author(s) & year	Fluoride level (ppm) & area(s)	Sample size/ age groups	dft/dmft (S.D)	DMFT (S.D)	Caries-free prevalence (%) (DMFT=0)	Fluorosis prevalence (%) & index used	Quality of Life
Tan *et al*., 2003	0.7 Selangor	N=1343/ 10-11	-	-	-	58.7/ Dean's≥2 Very mild: 35.6 Mild: 7.6 Moderate: 7.6 Severe: 0.9	-
Mohd. Nor *et al*., 2003	0.7 Kuala Pilah, Negeri Sembilan	N=431/ 16-17	-	-	-	27.8/ Dean'>0 Questionable: 11.1 Very mild: 7.0 Mild: 4.6 Moderate: 4.9 Severe: 0.2	16.1% had psychosocial impact from fluorosis
Shaharuddin *et al*., 2003/ 2004	0.29±0.18/ Sabah, Kelantan & Terengganu	N=147/ 12-13	-	-	-	31.6 (TSIF>0)	-
Yussof *et al*., 2008	0.7/ Kuala Lumpur	N=957/ 10-11	-	-	-	88.6/DDE	-
Abd Mutalib *et al*., 2013	0.5 Penang, Selangor, Kuala Lumpur and Johor	N=466/ 16	-	1.0	59.0 (95%CI: 54.5-63.5)	82.4/ Dean's>0 Questionable: 6.5 Very mild: 67.5 Mild: 20.1 Moderate: 5.7 Severe: 0.3	Odds ratio for oral impact with caries[a]: 1.6 (95%CI: 1.3-2.1) without caries: 0.6 (95%CI: 0.5-0.8) with FEO: 0.5 (95%CI: 0.4-0.6) without FEO: 2.2 (95%CI:1.6-2.8)
	<0.4/ Sabah and Kelantan	N=497/ 16	-	3.7	21.7 (95%CI: 18.1-25.4)	8.4/ Dean's>0 Questionable: 42.9 Very mild: 52.4 Mild: 2.4 Moderate: 2.4 Severe: 0	
Mohd. Nor *et al*., 2015	0.5/ Negeri Sembilan	N=607/ 9 12	3.5 (3.0)* 1.0 (1.3)*	0.4 (1.0)* 0.5 (1.0)*	75.4 74.5	Dean's>0 39.3 44.6	-
	<0.4/ Kelantan	N=548/ 9 12	5.9 (3.3) 1.4 (1.5)	0.7 (1.2) 1.3 (1.8)	59.8 46.5	8.9 10.3	-

CI: Confidence Interval
DDE: Developmental Defects of Enamel index (Values shown are from diffused opacities category)
FEO: Fluoride Enamel Opacities
TSIF: Tooth Surfaces Index of Fluorosis
dmft: decayed, missing and filled teeth in deciduous dentition
DMFT: decayed, missing and filled teeth in permanent dentition
SD: standard deviation
[a]Using the Malay version of Child Oral Impact on Daily Performances (85)
*p-value<0.05 for differences between same age group in WF and non-WF areas

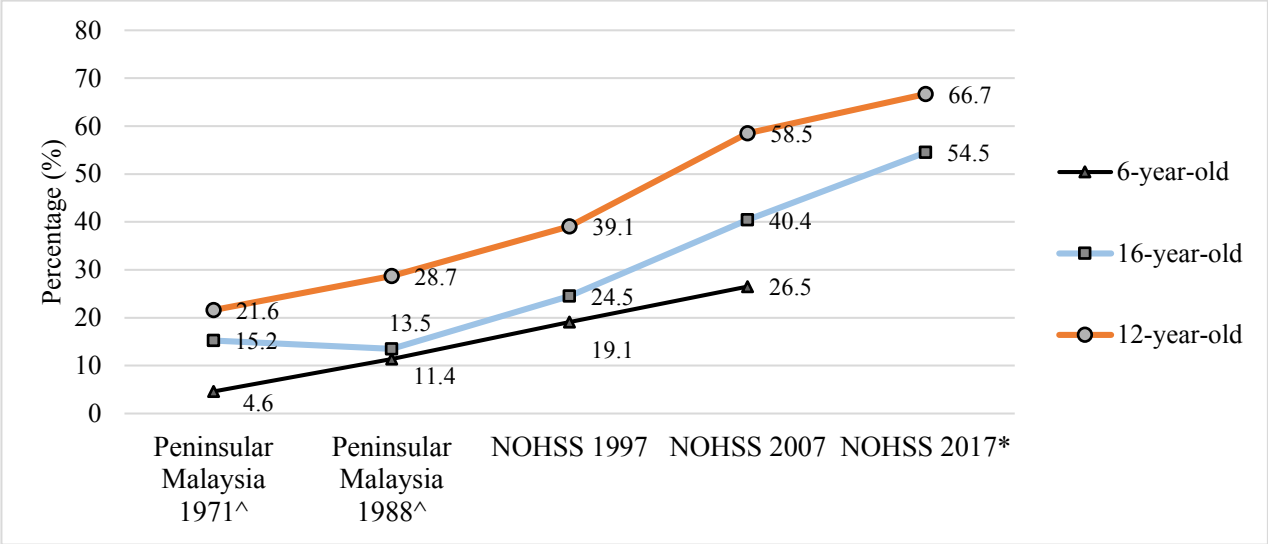

Figure 4: Percentage of caries-free among 6- (dmft=0), 12- and 16-year-old (DMFT=0) children in Malaysia

dmft: decayed, missing and filled teeth in deciduous dentition
DMFT: decayed, missing and filled teeth in permanent dentition
NOHSS: National Oral Health Survey of Schoolchildren
^Dental Epidemiological Survey of Schoolchildren in Peninsular Malaysia (excluding Sabah, Sarawak & Federal Territory of Labuan)
*Value for 16-year-old is adopted from Oral Health Programme, MOH Malaysia as presented during Asian Conference of Oral Health Promotion for Schoolchildren (ACOHPSC) in Penang (20th September 19)

was 4.83 (95% CI: 2.51-3.52). Caries reduction in primary teeth was minimal over the past 20 years mainly in rural areas which might be associated, among other things, with lower socioeconomic status and higher sugar consumption among the toddlers (58-60). Among the adults, caries remained unchanged over the years, with almost 90% of the population affected. This was due to a higher percentage of adults in the working-age group (35 to 44 years) who retained more teeth than those in 1971 (61-64).

In Pahang, the percentage of primary school children with caries-free teeth had declined from 37.6% in 2013 to 31.3% in 2019 after WF cessation in 2014. In the WF state of Perak, the caries-free teeth among primary school children increased by two per cent within the same period (19, 36). In Terengganu, although the caries prevalence continued to decline despite five years of WF cessation (1999 to 2004), caries prevalence of the permanent teeth among 12-year-old children in 2004 (52%) was higher than those of the same age who resided in WF areas in Johor (26%) (65).

2. Fluorosis

Two national surveys on fluoride enamel opacities were conducted in 1999 and 2013 to re-evaluate the benefits and risks of WF in light of the increased population exposure to other sources of fluoride. Both surveys involved 16-year-old children who were life-long residents in WF and non-WF areas. The authors found that caries experience was lower in WF areas than that in non-WF areas in both studies, and the reverse was observed for caries-free teeth. The association was found to be significant in the latter study (Table 2) (43, 44).

In the same surveys, the findings demonstrated an increase in the prevalence of dental fluorosis in WF areas from 74.7% in 1999 to 82.4% in 2013 with the majority of the lesions fell into “very mild” and “mild” categories assessed using the Dean’s index. However, fluorosis prevalence in non-WF areas was relatively low (Table 2) (43, 44). Findings from other similar local studies showed varying degrees of fluorosis assessed using Dean’s index and Tooth Surface Index of Fluorosis, and diffused opacities assessed using Developmental Defects of Enamel index (Table 2). However, the comparison of findings between the studies was not possible due to the different indices used to assess fluorosis. Nevertheless, the totality of evidence showed that the prevalence of fluorosis and diffused opacities was consistently higher in WF areas than non-WF areas (Table 2) (45-51). Before WF and the introduction of fluoridated toothpaste, the prevalence of fluorosis in Malaysia was almost non-existence (22).

3. Oral health-related quality of life (OHRQoL)

Despite the relatively higher prevalence of fluorosis in the WF areas, the impact of the condition on the individual’s quality of life was reported in two studies (Table 2) (48, 52). Based on the studies, it was found that higher satisfaction on aesthetic appearance was more prevalent among children with very mild or mild fluorosis than children without fluorosis. Furthermore, children with fluorosis who were caries-free reported significantly lower OHRQoL scores (better OHRQoL) than children without fluorosis who subsequently suffered from dental caries (Table 2). Based on the findings, there was a greater severity of impact on the quality of life among the children

associated with dental caries in non-WF areas than with the prevalence of fluorosis in WF areas. Overall, the authors concluded that WF is relevant and provides oral health benefits as the primary caries prevention method at the population level (44).

Adjustment for the optimal fluoride level in the water

In the late 1990s, there was concern regarding high exposures to fluoride from different sources due to the increasing prevalence of dental fluorosis in the population (43). The Malaysian dental authorities were compelled to assess this finding for the possible contribution of fluoride exposure from multiple sources (47).

A study was conducted in 2005 to assess the total fluoride intake among children in WF areas and its relationship with fluorosis. The findings showed that children with fluorosis were significantly associated with higher fluoride exposure from drinking water than children without fluorosis (47). Based on the optimal fluoride level derived from plotting caries against fluorosis in the study (0.45 ppm), and taking into account the higher amount of water consumption in the tropical climate of Malaysia, a decision was made to reduce the optimum level of fluoride in the water from 0.7 ppm to 0.5 ppm in 2004. The acceptable range was set at 0.4-0.6 ppm while the maximum acceptable range of fluoride in the water was maintained at 1.5 ppm (23, 47, 66).

Later in 2015, a study was carried out to evaluate the effectiveness of the adjusted fluoride level on caries prevention and dental fluorosis. The findings showed that caries prevalence among children exposed to WF at 0.5 ppm throughout their life was significantly lower than children who lived in non-WF areas. Moreover, although not statistically significant, the prevalence of fluorosis was lower among children exposed to 0.5 ppm fluoride throughout life (31.9%) than children exposed to fluoride at mixed levels of 0.7 ppm and 0.5 ppm throughout life (38.4%). It was concluded that the adjustment of fluoride level to 0.5 ppm had a similar impact with 0.7 ppm in caries preventive-effect and dental fluorosis (67).

Current policies on WF

A national policy endorsed by The Malaysian Dental Council has recommended WF at 0.5ppm as the sole systemic fluoride modality in the country due to the various benefits to population's oral health (68). Meanwhile, a call was made for rigid monitoring and continuous research of optimal fluoride levels in the water supply, given the increasing exposure of the population to other sources of fluoride (69). Aligned with the council's recommendation, the Oral Health Programme has listed the expansion of WF particularly into the rural areas as one of the major strategies for achieving higher caries-free rates among the schoolchildren as stated in the National Oral Health Plan 2011-2020. Besides dental caries indicators, the prevalence of fluoride enamel opacities is monitored periodically to assess the risk-benefit trade-off about WF (69, 70).

According to the Water Services Industry Act 2006 (Act 655) under Chapter 2, Section 41 clause (1), adding fluoride into the public water supplies is made mandatory for all water treatment plants in the country except in Sabah and Sarawak (71). The two states have autonomous power over matters about water supplies and services, including WF, which has a huge impact on its implementation (72). All water treatment providers are required to ensure the fluoride level in treated water complies with the fluoride levels of 0.4-0.6 ppm, as stated in the National Standard for Drinking Water Quality (23, 26). Regular monitoring of fluoride levels at the reticulation points are conducted by the district health personnel and the Department of Chemistry. Surveillance by the Oral Health Programme is also in place, and the level of conformance to the optimal level of fluoride in the water is monitored monthly (73).

Challenges of WF programme in Malaysia

1. Quality of evidence on WF effectiveness at the local level

All of the data included in this review were from the survey and school dental service records whose evidence were considered of low quality. Nevertheless, these data are valuable for reporting population oral health trends and in setting future policies. Assessing WF effectiveness is often a complex endeavour due to the nature of the WF itself. It is an intricate population-based intervention confounded by various factors such as socioeconomic status, exposure to other sources of fluoride and caries preventive modalities (74). As such, to build a strong case for WF, robust evidence of effectiveness from a study with an appropriate design will be needed. Several cross-sectional studies have been conducted to evaluate the effectiveness of WF against caries (43, 44, 47, 67). However, as with most WF research, the prospective study design was not used as it is resource-intensive. Furthermore, the population studied was mostly school-aged children, thus leaving a vacuum in the body of evidence on the impact of WF on the adult population's oral health.

Additionally, there is also an urgent need for evidence on the cost-effectiveness of WF. The available data are outdated and only limited to cost estimation of per capita cost of fluoride compound (RM0.18) and recurrent expenditure per head of population served per year (RM0.45) in Johor in 1996 which did not reflect the savings resulted from the implementation of WF (24). The impact of WF cessation on dental caries, fluorosis, and quality of life among Malaysian is also poorly understood.

2. Maintaining optimal fluoride level in the public water supply

Currently, conformance to the optimal fluoride level in the public water supply remains a challenge in several states

such as Terengganu and the Federal Territory of Labuan although the population coverage of WF was high (19). Kuthy *et al.* (1985) (75) explained that fluoride level reading in water is mainly influenced by the source of water, the competence level of the operators and the tenure period of staff. The operator's competence in the process of dosing fluoride compounds into the fluoride feeders is important as the procedures require technical knowledge obtained from proper training and availability of comprehensive manuals or guidelines (76).

The breakdown of fluoride feeders, inadequate laboratory equipment (77), and low supply of fluoride compounds (36) were often cited as the main reasons for suboptimal fluoride levels. Several public water treatment plants had poor laboratory facilities and were unable to conduct fluoride level testing efficiently (78). Failure to continuously monitor fluoride levels in water treatment plants may result in sub-optimally fluoridated water circulating in the distribution system.

3. Occupational safety for water treatment plant operators

Issues regarding safety in handling fluoride compounds were raised in the past by the water authorities. Lack of awareness regarding the toxicity of fluoride among staff and lack of supervision were among the main concerns (79). Personnel in water treatment plants should be educated regarding the health consequences of direct inhalation or ingestion of fluoride compound, and their health should be monitored regularly (80). Safety measures should be put in place when handling fluoride compounds such as the use of special protective clothing with positive pressure breathing apparatus, safe access for compound delivery, and a safe storage area with good ventilation (81).

4. Use of household water filter with the reverse osmosis system

The use of household water filters has increased in recent years due to the negative perceptions of the quality of the water supply. However, concerns have been raised about the use of the reverse osmosis water filters because these filters can remove between 87 to 93% of fluoride in the water (82-74). Based on data from the national oral health survey of adults in 2010, more than 40% of the population used at least one water filter at home. Among those, less than 10% used water filters with the reverse osmosis system (64). In another study conducted five years later, 59.1% of the respondents reported usage of household water filter, but the types of water filter were unknown (51). Alarmingly, the reverse osmosis filtration system had dominated the water purifier market in the country in 2018 with "Coway" labelled as the leading brand (85). The use of household water filters, particularly those with the reverse osmosis system may pose a threat to the WF for caries prevention which warrants further investigation.

5. Privatisation and funding for WF

The Privatisation Policy introduced in 1983 resulted in more than 60% of the water treatment plants operated by private companies (39). Privatisation poses a problem when WF is not included in the concession agreement between the water treatment plant companies and the government. This is because WF is funded by the government for public water treatment plants only while the cost of WF in private water treatment plants is borne by the company (23). As a consequence, the water provider companies may refuse to fund WF, which leads to WF cessation. In Kelantan and Sabah, WF ceased due to the reason aforementioned despite the respective state governments intention to increase WF coverage (86, 87). WF in Pahang was stopped due to a similar situation and further aggravated by the poor financial status of the water provider company (42).

Nevertheless, privatisation had not caused problems in WF in other states such as Selangor, Negeri Sembilan, and Johor primarily because the water treatment plants were involved in the Water Service Industry Restructuring exercise conducted by a government-linked company, *Pengurusan Aset Air Berhad* (PAAB). Under this exercise, ownership of water assets is separated from the operation of water treatment plants, allowing for further development and proper maintenance of water assets. In contrast, the water provider companies will focus solely on the operation of water treatment plants. This, in return, provides financial sustainability for the water provider companies and improves water supply quality to the users (88). Nonetheless, there may be other factors that contributed to the success in these states that entail further investigation. Therefore, the notion that privatisation is disadvantageous to WF may be misleading as it can be beneficial to WF if conducted efficiently.

Public water treatment plants in Perak, Sabah and Sarawak receive funds from the federal government for WF. However, government funding has declined over the years, putting constraints on the WF programme (19, 36). It is imperative to note that changes in government commitment towards WF funding may dictate the success or failure of future WF as has been seen in Australia (89) and the United States of America (90). According to the Federal Constitution of Malaysia, the state governments may choose to assist in WF funding but not obliged to do so (91).

Although financial issues are often raised by relevant authorities, the argument to support the monetary value of the WF programme often rely on international evidence. There is a lack of local evidence on the cost-effectiveness of WF in Malaysia and will be a subject for future research.

6. Legislation of WF

In Malaysia, there is no specific action to legislate WF. The existing Water Services Industry Act 2006 (71) does not state the maximum acceptable values for all chemical

parameters including fluoride whose maximum acceptable value is stated in the National Standard for Drinking water as a legally acceptable value. Furthermore, more weightage is given to parameters related to bacteriological quality, chemical toxicity of the water, and residual chlorine, leaving fluoride in the lower rank of significance (25). The clause about regulation does not discreetly disclose the agencies responsible for the enforcement of the law (71). Owing to the complexity and ambiguity of the existing legislation, the enforcement of regulation about water quality is difficult.

7. Inter-sectoral collaboration

In Malaysia, the success of WF is attributed to the excellent partnership between the water provider companies, the MOH, the Ministry of Energy Science Technology Environment and Climate Change, the Public Works Department, and the state authorities. WF is often discussed in meetings such as the National Technical Meeting on Drinking Water Quality that involves various relevant agencies (23). Also, the development and review of the National Oral Health Plan 2011-2020 that steers the nation oral health agenda including WF were conducted in consultation with members from the dental fraternity, other relevant stakeholders from the ministries, non-government organisations, academia, industries and consumer groups. Resolutions were issued calling for higher priority in stakeholder engagement, collaborations and partnerships (69, 92).

Nevertheless, conflicting interests between the stakeholders may result in WF cessation such as in Pahang or use of WF funds for other public health activities and clinical preventive programmes which happened in Sabah and Sarawak (36). Little is discussed in the reviewed documents regarding the state of collaboration among the stakeholders where the implementation of WF is poor. Understanding the factors that contributed to the breakdown of collaboration between the stakeholders is vital in the effort to reinstate and expand WF.

8. Anti-fluoridation activities

WF opposition activities came up in a few states such as Penang and Sabah led by the Consumers Association of Penang (CAP). The CAP is well-known for being vocal on various issues that affect the larger society. The narrative was consistent with other anti-fluoridation movements around the world; fluoride is toxic, WF is mass medication, WF violates human rights, and fluoride causes cancer and other ill health effects including fluorosis (93).

In 1995, a group of public engineers demanded WF to be stopped. The group claimed that WF was not critical for caries prevention as the same effect can be achieved by using fluoridated toothpaste, citing examples from other countries that had stopped WF (79).

In the late 1990s, fluoride content in toothpaste has become a subject of intense debate in the local newspapers. Various individuals and organisations voiced out their fears that fluoride may be dangerous to children, and fluoridated toothpaste was not be labelled adequately. Following the events, the Oral Health Programme has recommended additional mandatory labelling for fluoridated toothpaste in January 1998 (30, 94).

The Internet, particularly social media and websites, provide the mainstream platforms for anti-fluoridation activities to reach a wider audience rapidly (95). In 2015, a Malaysian celebrity started to post comments regarding the danger of fluoride and encouraged the society to abandon the use of toothpaste containing fluoride on Facebook which gained quite a traction among the detractors and supporters of fluoride (96).

Over the years, anti-fluoride or fluoridation activities arose occasionally. The activities were mostly sporadic, and therefore, may not pose a significant threat to WF. Nevertheless, opponents of WF may congregate to form a highly organised movement that may have the power to influence decision-making about WF. Hence, there is a heightened need for preparation to refute the claims made by the opponents.

Conclusion

Based on the available evidence, WF is shown to be effective in preventing dental caries among schoolchildren in Malaysia. However, similar evidence on the adult population was lacking. The main challenges of WF include maintaining the optimal fluoride level in the public water supply, privatisation of water treatment plants, lack of funding, legislation of WF, an increasing number of water filter users, and anti-fluoridation activities. These factors act as barriers to continue and expand WF in Malaysia. High-quality local evidence on the caries preventive effect of WF is needed to continue the support and justify funding for WF.

Acknowledgement

We would like to thank the Director-General of Health Malaysia for his permission to publish this article. This study is supported by the Faculty Research Grant, University of Malaya (Grant No: GPF003E-2018).

Competing interests

The authors declare that they have no competing interests.

References

1. Dean HT, McKay FS. Production of mottled enamel halted by a change in common water supply. Am J Public Health Nations Health. 1939;29(6):590-6.
2. Ten Cate JM, Featherstone JD. Mechanistic aspects of the interactions between fluoride and dental enamel. Crit Rev Oral Biol Med. 1991;2(3):283-96.
3. Featherstone JD. Prevention and reversal of dental caries: role of low level fluoride. Community Dent Oral Epidemiol. 1999;27(1):31-40.

4. Murray JJ. Fluorides in Caries Prevention. 3rd Ed. Bristol: John Wright & Sons Ltd. 1991.
5. Whelton HP, Spencer AJ, Do LG, Rugg-Gunn AJ. Fluoride revolution and dental caries: evolution of policies for global use. J Dent Res. 2019;98(8):837-46.
6. Centers for Disease Control and Prevention. Achievements in public health, 1900-1999: fluoridation of drinking water to prevent dental caries. MMWR. 1999;48(41):933-40.
7. O'Mullane DM, Baez RJ, Jones S, Lennon MA, Petersen PE, Rugg-Gunn AJ*, et al.* Fluoride and oral health. Community Dent Health. 2016;33(2):69-99.
8. Slade GD, Grider WB, Maas WR, Sanders AE. Water fluoridation and dental caries in U.S. children and adolescents. J Dent Res. 2018;97(10):1122-8.
9. Spencer AJ, Do LG, Ha DH. Contemporary evidence on the effectiveness of water fluoridation in the prevention of childhood caries. Community Dent Oral Epidemiol. 2018;46(4):407-15.
10. McDonagh MS, Whiting PF, Wilson PM, Sutton AJ, Chestnutt I, Cooper J*, et al.* Systematic review of water fluoridation. BMJ. 2000;321(7265):855-9.
11. Iheozor-Ejiofor Z, Worthington HV, Walsh T, O'Malley L, Clarkson JE, Macey R*, et al.* Water fluoridation for the prevention of dental caries. Cochrane Database Syst Rev. 2015;2015(6):CD010856.
12. McLaren L, Singhal S. Does cessation of community water fluoridation lead to an increase in tooth decay? A systematic review of published studies. J Epidemiol Community Health. 2016;70(9):934-940.
13. Do LG, Ha DH, Spencer AJ. Factors attributable for the prevalence of dental caries in Queensland children. Community Dent Oral Epidemiol. 2015;43(5):397-405.
14. Maupomé G, Shulman JD, Clark DC, Levy SM, Berkowitz J. Tooth-surface progression and reversal changes in fluoridated and no-longer-fluoridated communities over a 3-year period. Caries Res. 2001;35(2):95-105.
15. Seppä L, Kärkkäinen S, Hausen H. Caries in the primary dentition, after discontinuation of water fluoridation, among children receiving comprehensive dental care. Community Dent Oral Epidemiol. 2000;28(4):281-8.
16. Cho HJ, Jin BH, Park DY, Jung SH, Lee HS, Paik DI, *et al.* Systemic effect of water fluoridation on dental caries prevalence. Community Dent Oral Epidemiol. 2014;42(4):341-8.
17. Pretty IA, Boothman N, Morris J, MacKay L, Liu Z, McGrady M, *et al.* Prevalence and severity of dental fluorosis in four English cities. Community Dent Health. 2016;33(4):292-6.
18. Kim FM, Hayes C, Burgard SL, Kim HD, Hoover RN, Douglass CW, *et al*. A case-control study of fluoridation and osteosarcoma. J Dent Res. 2020;99(10):1157-64.
19. Ministry of Health Malaysia. Annual report 2017: Oral Health Programme, Ministry of Health, Malaysia. Putrajaya: Oral Health Programme, Ministry of Health, Malaysia. 2019. Available at: http://ohd.moh.gov.my/images/pdf/annual_rpt/annual_rpt17.pdf. Accessed 20 December 2019.
20. Ministry of Health Malaysia. Report on the fluoridation projects in the state of Johor Malaysia 1964-1976. Johor Baharu: Dental Division, Ministry of Health, Malaysia. 1978.
21. Ministry of Health Malaysia. Report of the committee appointed to inquire Into and report upon the fluoridation of public water supplies in West Malaysia. Kuala Lumpur: Dental Division, Ministry of Health, Malaysia. 1977.
22. Ministry of Health Malaysia. Dental epidemiological survey of school children in West Malaysia, August 1970 - May 1971: a report of Dental Epidemiological Survey Committee, Ministry of Health. Kuala Lumpur: Dental Services Division, Ministry of Health, Malaysia. 1972.
23. Ministry of Health Malaysia. Implementation of water fluoridation programme in Malaysia. Putrajaya: Oral Health Division, Ministry of Health, Malaysia. 2006. Available at: http://ohd.moh.gov.my/images/pdf/xtvtnsop/Implementation-of-Water-Fluoridation-Programme-in-Malaysia-2006.pdf. Accessed 29 October 2019.
24. Norain A, Norlida A. Water fluoridation-a public health approach in caries prevention in Malaysia 2009. Paper presented at: Symposium Pengurusan dan Peroditan Industri Air. November 2-3, 2009. Shah Alam, Selangor. Available at: https://www.audit.gov.my/index.php/en/2012-10-04-09-18-28/simposium-seminar/115-department-activities/264-simposium-pengurusan-pengauditan-industri-air. Accessed 25 October 2019.
25. Ministry of Health Malaysia. National programme on drinking water quality surveillance. Kuala Lumpur: Drinking Water Quality Surveillance Unit, Division of Engineering Services, Ministry of Health, Malaysia. 1983.
26. Ministry of Health Malaysia. National standard for drinking water quality. Putrajaya: Engineering Services Division Ministry of Health, Malaysia. 2004. Available at: http://www.gunungganang.com.my/pdf/Malaysian-Policies-Standards-Guidelines/Standards/National%20Drinking%20Water%20Quality%20Standard.pdf. Accessed 20 October 2019.
27. Ministry of Health Malaysia. Buku Panduan Pengawalan Mutu Air Minum. Kuala Lumpur: Drinking Water Quality Surveillance Unit, Division of Engineering Services, Ministry of Health, Malaysia. 1987.
28. Ministry of Health Malaysia. Milestones in dentistry: Oral Health Programme, Ministry of Health Malaysia. Putrajaya: Oral Health Programme, Ministry of Health, Malaysia. 2019. Available at: http://ohd.moh.gov.my/images/milestones2019.pdf. Accessed 23 November 2019.
29. 29.Ministry of Health Malaysia. Annual report Ministry of Health Malaysia 2018. Putrajaya: Ministry of Health, Malaysia. 2018. Available at: http://www.

moh.gov.my/index.php/pages/view/58?mid=19. Accessed 31 December 2019.
30. Ministry of Health Malaysia. Annual report 1998: Oral Health Division, Ministry of Health, Malaysia. Kuala Lumpur: Oral Health Division Ministry of Health, Malaysia. 1998.
31. Ministry of Health Malaysia. Annual report 2008: Oral Health Division, Ministry of Health, Malaysia. Putrajaya: Oral Health Division, Ministry of Health, Malaysia. 2009.
32. Ministry of Health Malaysia. Annual report 2009: Oral Health Division, Ministry of Health, Malaysia. Putrajaya: Oral Health Division, Ministry of Health, Malaysia. 2010.
33. Ministry of Health Malaysia. Annual report 2010: Oral Health Division, Ministry of Health, Malaysia. Putrajaya: Oral Health Division Ministry of Health, Malaysia. 2011.
34. Ministry of Health Malaysia. Annual report 2011: Oral Health Division, Ministry of Health, Malaysia. Putrajaya: Oral Health Division, Ministry of Health, Malaysia. 2012.
35. Ministry of Health Malaysia. Annual report 2012: Oral Health Division, Ministry of Health, Malaysia. Putrajaya: Oral Health Division, Ministry of Health, Malaysia. 2013.
36. Ministry of Health Malaysia. Annual report 2013: Oral Health Division, Ministry of Health, Malaysia. Putrajaya: Oral Health Division, Ministry of Health, Malaysia. 2014. Available at: http://ohd.moh.gov.my/images/pdf/annual_rpt/annual_rpt13.pdf. Accessed 29 October 2019.
37. Ministry of Health Malaysia. Annual report 2014: Oral Health Division, Ministry of Health, Malaysia. Putrajaya: Oral Health Division, Ministry of Health, Malaysia. 2015. Available at: http://ohd.moh.gov.my/images/pdf/annual_rpt/annual_rpt14.pdf. Accessed 29 October 2019.
38. Ministry of Health Malaysia. Annual report 2015: Oral Health Programme, Ministry of Health, Malaysia. Putrajaya: Oral Health Programme, Ministry of Health, Malaysia. 2016. Available at: http://ohd.moh.gov.my/images/pdf/annual_rpt/annual_rpt15.pdf. Accessed 29 October 2019.
39. Ministry of Health Malaysia. Annual report 2016: Oral Health Programme, Ministry of Health, Malaysia. Putrajaya: Oral Health Programme, Ministry of Health, Malaysia. 2018. Available at: http://ohd.moh.gov.my/images/pdf/annual_rpt/annual_rpt16.pdf. Accessed 29 October 2019.
40. Department of Statistics, Malaysia. Household income and basic amenities survey report 2016: Table 4-basic amenities (general). Putrajaya: Department of Statistics Malaysia. 2016. Available at: https://newss.statistics.gov.my/newssportalx/ep/epFreeDownloadContentSearch.seam?cid=37065 (login required). Accessed 30 November 2019.
41. Ishak AR, Nasruddin J, Raja Latifah RJ. Fluorida dan Kesihatan Pergigian. Kuala Lumpur: Jabatan Penerbitan Universiti Malaya. 1988.
42. National Audit Department Malaysia. Laporan ketua audit negara: pengurusan aktiviti/kewangan jabatan/agensi dan pengurusan syarikat negeri Pahang 2017. Putrajaya: National Audit Department Malaysia. 2017. Available at: https://www.audit.gov.my/images/pdf/2018/LKAN2017Siri1/6.Pahang.pdf. Accessed 1 October 2019.
43. Ministry of Health Malaysia. Fluoride enamel opacities in 16-year-old school children. Putrajaya: Oral Health Division, Ministry of Health, Malaysia. 2001.
44. Abd Muttalib K, Abdullah N, Tan E, Che Salleh N, Ismail N, Jaafa N*, et al*. Fluoride enamel opacities in 16-year-old schoolchildren in Malaysia 2013. Putrajaya: Oral Health Division, Ministry of Health, Malaysia. 2018.
45. Dental Division Johor. Epidemiological survey of developmental defects of dental enamel in Johor 1986. Johor Bahru: Dental Division Johor, Malaysia. 1987.
46. Esa R, Razak IA. Dental fluorosis and caries status among 12-13 year-old school children in Klang district, Malaysia. Annals Dent Univ Malaya. 2001;8(1):20-4. Available at: https://ejournal.um.edu.my/index.php/adum/article/view/7415. Accessed 25 January 2020.
47. Tan B. Fluorosis and fluoride exposure among Malaysian schoolchildren. Thesis. Kuala Lumpur, Malaysia: University of Malaya. 2003.
48. 48. Mohd Nor M, Sheiham A, Tsakos G. Psychological impacts of dental fluorosis among Malaysian school children. Dent J Malays. 2008;29(1):20-4. Available at: https://www.mda.org.my/mdj/archieve/2008-01/2008-Vol29-Issue1.pdf. Accessed 25 January 2019.
49. Yusoff N, Jaafar N, Razak IA, Chew YY, Ismail N, Bulgiba AM. The prevalence of enamel opacities in permanent teeth of 11-12-year-old school children in Kuala Lumpur, Malaysia. Community Dent Health. 2008;25(1):55-8.
50. Shaharuddin M, Kidahus M, Sumarlan S, Kamil Y, Ismail Y, Firuz R*, et al.* Dental fluorosis (DF) and its relationship with fluoride levels in drinking water in three states in Malaysia. Res J Med Sci. 2010;4(1):20-4.
51. Mohd Nor NA. The impact of downward adjustment of fluoride concentration in the Malaysia public water supply on dental caries and fluorosis. Thesis. Cardiff, United Kingdom: Cardiff University. 2017.
52. Sujak SL, Abdul Kadir R, Dom TN. Esthetic perception and psychosocial impact of developmental enamel defects among Malaysian adolescents. J Oral Sci. 2004;46(4): 221-6.
53. Ministry of Health Malaysia. Dental epidemiological survey of school children in Peninsular Malaysia 1988. Kuala Lumpur: Dental Services Division, Ministry of Health, Malaysia. 1988.

54. Ministry of Health Malaysia. National oral health survey of schoolchildren 2007 (NOHSS 2007) 6-year-olds: Oral Health Division, Ministry of Health Malaysia. Putrajaya: Oral Health Division, Ministry of Health, Malaysia. 2009.
55. Ministry of Health Malaysia. National oral health survey of schoolchildren 2007 (NOHSS 2007) 12-year-olds. Putrajaya: Oral Health Division, Ministry of Health, Malaysia. 2010.
56. Ministry of Health Malaysia. National oral health survey of schoolchildren 2007 (NOHSS 2007) 16-year-olds. Putrajaya: Oral Health Division, Ministry of Health, Malaysia. 2010.
57. Ministry of Health Malaysia. National oral health survey of schoolchildren 2017, oral health status of 12-year-old schoolchildren. Putrajaya: Institute of Public Health National Institute of Health, Ministry of Health, Malaysia. 2018.
58. Ministry of Health Malaysia. National oral health survey of pre-school children 1995. Kuala Lumpur: Oral Health Division Ministry of Health, Malaysia. 1995.
59. Ministry of Health Malaysia. The national oral health survey of preschool children 2005 (NOHPS 2005): oral health status and treatment needs. Putrajaya: Oral Health Division, Ministry of Health, Malaysia. 2007.
60. Ministry of Health Malaysia. National oral health survey of pre-school children 2015. Putrajaya: Oral Health Programme, Ministry of Health, Malaysia. 2017.
61. Ministry of Health Malaysia. Dental epidemiological survey of adults in the Peninsular Malaysia September 1974-April 1975: a report of the survey conducted by the Dental Division, Ministry of Health, Malaysia. Kuala Lumpur: Dental Division, Ministry of Health, Malaysia. 1978.
62. Ministry of Health Malaysia. Dental epidemiological survey of adults in Malaysia 1990. Kuala Lumpur: Oral Health Division, Ministry of Health, Malaysia. 1993.
63. Ministry of Health Malaysia. National oral health survey of adults 2000 (NOHSA 2000): oral health status, impacts and treatment of Malaysian adult. Kuala Lumpur: Oral Health Division, Ministry of Health, Malaysia. 2004.
64. Ministry of Health Malaysia. National oral health survey of adult 2010. Putrajaya: Oral Health Division, Ministry of Health, Malaysia. 2013.
65. Norlida A, Wan M. Effects of cessation of WF in Kelantan and Terengganu on caries experience. Abstract. Compendium of Abstracts 2005: Research Projects and Publications of Oral Health Personnel Ministry of Health Malaysia, Putrajaya: Oral Health Division, Ministry of Health, Malaysia. 2006:31.
66. Tan B, Razak I, Foo L. Fluorosis prevalence among schoolchildren in a fluoridated community in Malaysia. Community Dent Health. 2005;22(1):35-9. Available at: https://www.ncbi.nlm.nih.gov/pubmed/15819114. Accessed 11 October 2019.
67. Mohd Nor NA, Chadwick BL, Farnell DJ, Chestnutt IG. The impact of a reduction in fluoride concentration in the Malaysian water supply on the prevalence of fluorosis and dental caries. Community Dent Oral Epidemiol. 2018;46(5):492-9.
68. Malaysian Dental Council. Position statement: use of fluorides in Malaysia. Putrajaya: Malaysian Dental Council. 2009. Available at: http://mdc.moh.gov.my/uploads/fluorides.pdf. Accessed 20 October 2019.
69. Ministry of Health Malaysia. National oral health plan for Malaysia 2011-2020. Putrajaya: Oral Health Division, Ministry of Health, Malaysia. 2011. Available at: http://ohd.moh.gov.my/images/pdf/nohp20112020.pdf. Accessed 19 October 2019.
70. Ministry of Health Malaysia. Health indicators 2018: indicators for monitoring and evaluation of strategy health for all. Putrajaya: Ministry of Health, Malaysia. 2018. Available at: http://www.moh.gov.my/index.php/pages/view/58?mid=19. Accessed 25 October 2019.
71. Government of Malaysia. Water Services Industry Act 2006 (Act 655). Putrajaya: Attorney General Chamber, Malaysia. 2006. Available at: https://www.span.gov.my/document/upload/66ILUPtM99inqSJ4o7YLUgOrK4IrZtOq.pdf. Accessed 12 November 2019.
72. Government of Malaysia. Federal Constitution, Ninth Schedule (Article 74, 77), Legislative List, List I, II, IIA and III. Putrajaya: Attorney General Chamber, Malaysia. 2010. Available at: http://www.agc.gov.my/agcportal/uploads/files/Publications/FC/Federal%20Consti%20(BI%20text).pdf. Accessed 25 October 2019.
73. Ministry of Health Malaysia. Addendum for guidelines on implementation of water fluoridation programme in Malaysia. Putrajaya: Oral Health Division, Ministry of Health, Malaysia. 2015.
74. Rugg-Gunn A, Spencer A, Whelton H, Jones C, Beal J, Castle P, *et al*. Critique of the review of 'Water fluoridation for the prevention of dental caries' published by the Cochrane Collaboration in 2015. BDJ. 2016;220(7):335-40.
75. Kuthy RA, Naleway C, Durkee J. Factors associated with maintenance of proper water fluoride levels. J Am Dent Assoc. 1985;110(4):511-3.
76. Muhd Firdaus M, Nurliana O, Abd Karim F. Laporan lawatan sambil belajar oleh Pelajar Penang International Dental Collage (PIDC) ke Loji Rawatan Air Gunung Semanggol 2019. Parit Buntar, Kerian: Pejabat Kesihatan Pergigian Daerah Kerian, Bahagian Kesihatan Pergigian Negeri Perak. 2019.
77. National Audit Department Malaysia. Audit on water: water quality management in Malaysia September 2012. National Audit Department Malaysia. 2012.
78. Md Wahid MN. Kajian pengurusan kualiti air minum seluruh negara. Paper presented at: Symposium Pengurusan dan Peroditan Industri Air. Shah Alam, Selangor. November 2-3, 2009. Available at: https://www.audit.gov.my/index.php/ms/2012-10-04-09-18-28/simposium-seminar/115-aktiviti-jabatan/264-

simposium-pengurusan-pengauditan-industri-air. Accessed 25 October 2019.
79. Ministry of Health Malaysia. Laporan status program pemfluoridaan 1995. Kuala Lumpur: Oral Health Division, Ministry of Health, Malaysia. 1996.
80. Petersen P, Baez R, Lennon M. 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.
81. Ferrada J, Hightower J, Begovich J. Compilation of requirements for safe handling of fluorine and fluorine-containing products of uranium hexafluoride conversion. ORNL. 2000
82. Law BB. The usage of domestic water filtration systems in Malaysia. Bachelor dissertation. Bachelor of Civil Engineering. Queensland: University of Southern Queensland. 2005. Available at: https://core.ac.uk/download/pdf/11034725.pdf. Accessed 19 October 2019.
83. Loh K, Yaacob H, Andan H, Omar S, Jamaludin M. A study of the effect of home water filtration systems on fluoride content of drinking water in Johor. Dent J Malays. 2011;33(2). Available at: https://mda.org.my/mdj/archieve/2011-02/2011-AStudy.pdf. Accessed 25 November 2019.
84. Kamil NAFM, Bahari M, Akhbar NA, Mizad M. Evaluation of fluoride concentration in water filter system for households. Int J Integr Eng. 2018;10(2). Available at: https://publisher.uthm.edu.my/ojs/index.php/ijie/article/view/2639. Accessed 13 December 2019.
85. TechSci Research. Coway continues its dominance in Malaysia water purifiers market. 2018. Available at: https://www.techsciresearch.com/news/3128-coway-continues-its-dominance-in-malaysia-water-purifiers-market.html. Accessed December 12, 2019.
86. Ministry of Health Malaysia. Laporan status program pemfluoridaan 1996. Kuala Lumpur: Oral Health Division, Ministry of Health, Malaysia. 1997.
87. Ministry of Health Malaysia. Laporan status program pemfluoridaan 1998. Kuala Lumpur: Oral Health Division, Ministry of Health, Malaysia. 1999.
88. Pengurusan Aset Air Berhad. Annual report 2017. 2017. Available at: http://www.paab.my/annual-report/annual-report-2017/. Accessed 12 November 2019.
89. Sivaneswaran S. The revival of water fluoridation in the state of New South Wales, Australia, in the 21st century. Community Dent Oral Epidemiol. 2012;40(Suppl 2):65-70.
90. 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.
91. Government of Malaysia. Federal constitution chapter 3-distribution of financial burden. Item 82. (a), (b). Putrajaya: Attorney General Chamber, Malaysia. 2010. Available at: http://www.agc.gov.my/agcportal/uploads/files/Publications/FC/Federal%20Consti%20(BI%20text).pdf. Accessed 25 October 2019.
92. Ministry of Health Malaysia. National oral health plan (2011-2020) symposium: mid-term review of national oral health plan. Bulletin Oral Health Division: News Letter of the Oral Health Division, Ministry of Health Malaysia. 2016. Available at: http://ohd.moh.gov.my/images/pdf/ebuletin/ebuletin-dec2016.pdf. Accessed 22 October 2019.
93. Idris SM. Stop fluoridation of Malaysian, Sabah water supply. 2010. Available at: https://www.malaysiakini.com/letters/152010. Accessed 13 November 2019.
94. Ministry of Health Malaysia. Laporan status program pemfluoridaan 1997. Kuala Lumpur: Oral Health Division, Ministry of Health, Malaysia. 1998.
95. Mertz A, Allukian M. Community water fluoridation on the Internet and social media. J Mass Dent Soc. 2014;63(2):32-6.
96. Abang N. Kongsi keburukan fluorida dalam ubat gigi, Afddlin Shauki buat para doktor gigi tampil kongsi pendapat. 2015. Available at: https://beautifulnara.com/kongsi-keburukan-fluorida-dalam-ubat-gigi-afdlin-shauki-buat-para-doktor-gigi-tampil-kongsi-pendapat/. Accessed 29 January 2020.