The Impact of Changing Fluoride Concentrations in the Water Supplies in the Maltese Islands on Caries Prevalence in 12-Year-Old Maltese Schoolchildren

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Abstract
This paper outlines the changes in the water supply system in the Maltese Islands and in fluoride concentration and the impact that this has had on the prevalence of dental caries in 12-year-old schoolchildren. It describes how over the past decades, the Maltese Islands (which comprise two main islands, Malta and Gozo) have seen changes in the water supply system, from one purely dependent on underground water which was naturally fluoridated, to one heavily dependent on desalinated seawater produced by reverse osmosis plants. This has led to the decline in the levels of fluoride in the water supply that was present naturally. Before the introduction of reverse osmosis water into the water supplies, fluoride levels in Malta averaged 0.6 ppm. In 2005, the level of fluoride in the Maltese Islands was 0.4 with a concentration of 0.15 ppm in Malta, with two-thirds of the island having undetectable amounts, and 0.65 ppm in Gozo. This may have had an impact on oral health. Since 1968, the prevalence of dental caries in 12-year-old Maltese children has seen a dramatic fall, in line with other industrialised nations, However, one study has suggested that the fall has not been smooth and between 1986 and 1995 caries prevalence in Maltese 12-year-olds appeared to rise in parallel with the changes in the fluoride content of the water supply. Nevertheless, since 1995, the decline in caries prevalence has again continued in both Malta and Gozo. It is possible that fluoride has become available through other sources, one of which may be dentifrices, the import of which increased by more than twenty-fold between 1980 and 2003.

Key Words: Water Fluoridation, Dental Caries, Prevalence, Fluorosis, Reverse Osmosis, Dentifrices

Background information: Malta

The Maltese archipelago consists of three inhabited islands, Malta, Gozo and Comino *(Figure 1)*. In 2009, the population of the Maltese Islands totalled 412,970, of whom 31,295 lived in Gozo [1].

There is no clear dichotomy of urban and rural areas in Malta. The climate is warm with mild wet winters and hot dry summers. Rain falls only for short periods, generally between September and April and averages 57.8 cm per year.

Water Fluoridation

The beneficial effect of a fluoridated water supply to reduce the prevalence of dental caries is no longer a matter of debate [2-5]. Fluoridation of domestic water supplies has been shown to be effective in reducing the prevalence of dental caries by numerous observational and interventional studies conducted worldwide over the last 50 years. These studies are remarkably consistent in demonstrating substantial reductions in caries prevalence as a result of water fluoridation. Prior to 1980, when caries prevalence was high, the modal percentage reduction in caries was 40-49% in primary teeth and 50-59% in permanent teeth [6]. However, when these studies were performed, fluoride toothpaste and other sources of delivering fluorides were rarely used [7]. Studies conducted in the 1980s demonstrated that the range of reduction in caries prevalence in fluoridated as compared with non-fluoridated communities was no longer of the same magnitude; there was 20-40% less decay in fluoridated communities [8]. A review of Canadian studies also found a smaller average difference of 25%, for example a difference of 0.73 Decayed Missing Filled Surfaces (DMFS) between children residing

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Figure 1. *Map of the Maltese islands*

in fluoridated and non-fluoridated communities [9]. This change is believed to be due to the increased availability of a variety of fluoride products, including dentifrices, mouthrinses, supplements, and professionally applied gels and solutions. An additional explanation for the decreased difference in caries prevalence in fluoridated versus non-fluoridated communities is the "halo" effect—the presence of fluoride in beverages and foods that are processed in fluoridated communities and consumed in fluoride deficient-communities [8,10].

The relationship between dental caries and water fluoridation was not so clear-cut in the 1990s [11]. The magnitude of the beneficial effects of water fluoridation appears to have decreased as the pattern of dental caries has changed and as fluoride has become more widely available from a range of sources. However, it still produces the traditional benefits in communities where caries prevalence is high and availability of alternative fluoride vehicles is low [12]. A significant reduction of 21-40% was found in a study in Ireland [13], even with the ready availability of fluoride toothpastes and where the overall caries prevalence had declined.

Findings of a secular decline in the prevalence of caries in non-fluoridated communities should not be interpreted as meaning that water fluoridation is no longer necessary. Caries reductions are greatest where water fluoridation is used and topical fluorides, especially dentifrices, are also available, as demonstrated in Ireland. In every county surveyed, caries decreased between 1964 and 1984 [14], but the decrease was consistently greater in those communities in the same county where the schoolchildren were exposed to both communal fluoridated water and topical fluoride (most frequently via toothpaste) [15].

The optimal range of community water fluoridation (optimal with respect to near maximal dental caries prevention and minimal risk of enamel fluorosis) varies and depends on fluid consumption according to the annual average of the maximum daily air temperature. Failure to make adjustment for this factor may result in a higher prevalence of fluorosis in warmer climates. The optimum caries-protective effect of different fluoride concentrations has been demonstrated in hot climatic zones (0.6 ppm) and in cold zones (1.0-1.2 ppm).

However, these standards are not appropriate for all parts of the world such as the tropical and subtropical areas. Thus the level of 1.0 ppm should be viewed as an upper limit, even in a cold climate, and 0.5 ppm, now used in Hong Kong and recommended in the Gulf States, may be a more appropriate lower limit [16] *(Table 1).* In the light of more recent evidence, the optimum level of fluoride in dinking water has been revised downwards to between 0.6 and 0.8 ppm [17].

By 1990, over 210 million people lived in fluoridated areas throughout the world [6], 40 million of whom are served by water that is naturally fluoridated at a concentration of 0.7 ppm or higher. The crucial requirement for community water fluoridation is a well-established, centralised, piped water supply.

Water fluoridation has been under continuous attack by the anti-fluoridation lobby, and has been questioned in Australia, Canada, Denmark, and the Netherlands by some dentists who have suggested that "water fluoridation is no longer necessary" [8].

The Maltese Islands currently have no official policy on the fluoridation of water, because it was considered that the fluoride found naturally in the water supply, which averaged 0.6 ppm in the past decades, did not need any special treatment. However, as more and more drinking water is produced from seawater via a process of reverse osmosis, this policy may need to be revised in view of the impact on the prevalence of dental caries.

Fluoride Dentifrices

There is now increasing evidence that the decline in the prevalence of dental caries recorded in most industrialised countries can be attributed to the widespread use of fluoridated toothpastes. Rolla *et al.* (1991) [18] stated that "the introduction and wide use of such toothpastes (fluoridated) coincide with the timing of caries reduction". A similar conclusion was drawn in Finland; "the greater availability of fluoride dentifrices has been suggested as the main reason for the decline in caries in adolescents…." [19].

No data are available regarding trends in volume of imports of dentifrices in tubes in the

Table 1. *Recommended Fluoride Concentrations for Average Temperature Ranges (WHO, 1984) [16]*

Annual average of maximum daily air temperatures (°C)	Fluoride concentration mg/L		
	Lower	Optimum	Upper
10.0 - 12.5	0.9	1.2	1.7
12.0 - 14.6	0.8	1.1	1.5
14.6 - 17.6	0.8	1.0	1.3
17.7 - 21.4	0.7	0.9	1.2
21.5 - 26.2	0.7	0.8	1.0
26.2 - 32.5	0.6	0.7	0.8

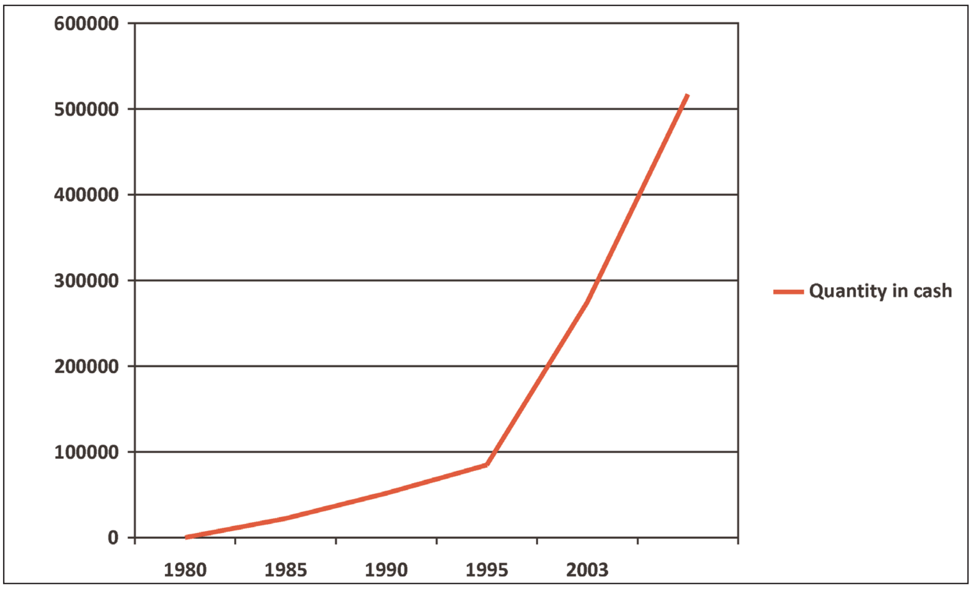

Figure 2. *Imports of dentifrices in Maltese pounds*

Maltese Islands. The only data available show that the amount of money spent on dentifrices has increased more than ten-fold from 1980 to 1995 and doubled from 1995 to 2003, from Lm 274762 to Lm 516784 *(Figure 2).* It is important to note that the data refer to dentifrices in general and not specifically fluoridated toothpastes. Moreover, it is impossible to determine how much of the increase is due to consumption rather than increase in cost. Nevertheless, it is very likely that there has been a real increase in use, considering the twenty-fold increase in expenditure *(Figure 2),* and that most of this toothpaste is fluoridated.

The water supply system

Prior to the late 1980s, the Maltese Islands' water supply was obtained entirely from ground water from boreholes. It contained naturally occurring fluoride. The mean fluoride level in potable water of the Maltese Islands never exceeded a concentration of 1.4 ppm, but certain localities had fluoride levels exceeding 2 ppm.

The ever-growing population, industrial development, agricultural demands, lack of rainwater, together with the expansion of the tourist trade and the increasing standards of hygiene, put more strains on the water supplies. Thus, ground water production became insufficient to meet demand. As a result, the Water Services Corporation (WSC) started converting seawater into high-purity drinking water at reverse osmosis plants and blending it with ground water.

The first reverse osmosis (RO) plant was introduced in Malta in December 1982, but it was not until 1984 that it contributed significantly to the water supplies. Since then, the number of RO plants have increased, resulting in an increased percentage of water coming from the sea. *Figure 3* shows the total water produced from the RO plants from 1986 to 2007. During 2004, the RO plants were upgraded and new installation methods and concepts were incorporated into these new designs in order to address problems of leakages and increase efficiency. This explained the drop in production.

Thus, water from boreholes and the converted seawater is blended. This blended water is stored in the 24 reservoirs in Malta, Gozo and Comino, which have a total capacity of 400,000 m^3. From these reservoirs, the water is redistributed to towns and villages. A few locations may also receive water directly from primary sources, such as boreholes or RO plants. This resulted in variations in the fluoride concentrations of local domestic tap water in some parts of the Maltese islands.

Prior to 2004, Gozo's water supply was from ground water from boreholes, which contained high levels of fluoride ranging from 1 ppm to 2.2 ppm, depending on the distribution system. In 2004, a new system of water distribution was introduced in Gozo. This new system used a collection scheme whereby ground water from all the boreholes was pumped to one reservoir. Part of this ground water was then "polished" in the plant. One part of this

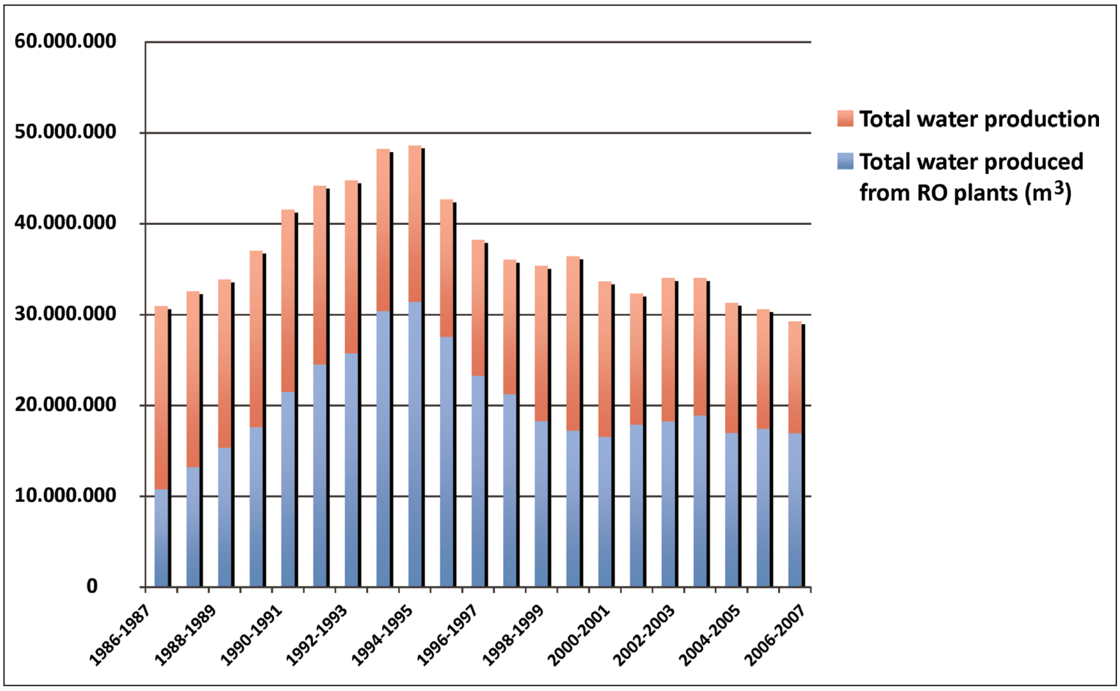

Figure 3. Total annual water production from the Water Services Corporation and from the reverse osmosis plants (m^3)

"polished" water is blended with another two parts of "non-polished" ground water and this mixture is stored in the five water quality zone reservoirs, from where it is pumped to the households in Gozo (WSC). The "polished" water produced by RO plants contains less fluoride than the ground water.

The Water Operations Unit is responsible for all distribution and ground water operations in the Maltese islands. These responsibilities include the Water Quality Zones and the Distribution Control Section. The water supply network is divided into 20 Water Quality Zones in Malta and Gozo. Each zone is linked to a particular reservoir, which is numbered the same as the Water Quality Zones. There are five Water Quality Zones for Gozo (WSC, Institute for Water Technology).

In the Maltese Islands, water for public consumption is required to meet the standards set out in European Union (EU) legislation. The drinking water directive (98/83/EC) puts the limit for fluoride in drinking water at 1.5 mg/l (1.5 ppm) [20]. This directive was transposed into Maltese Law LN 23/2004, which came into force in January 2004 [21]. This was amended by LN 116/2004 [22] due to the introduction of the Annexes. The parameter for fluoride had to be corrected to below 1.5 mg/l in accordance with the relevant legal notice by 31st December 2005.

The WSC performs fluoride analysis as part of its check and audit monitoring in order to meet the requirements of LN 23/2004 and 116/2004. Fluoride levels are analysed at the village points twice a year in Maltese villages and on a monthly basis in the case of Gozo villages. The results are read using ultraviolet/visible (UV/VIS) spectrophotometry.

The WSC is undergoing a Drinking Water Quality Project (funded by the EU), which consists of the refurbishing and upgrading the existing RO plants to improve the quality of drinking water at the consumer's tap. It is planned to increase the pumping from RO and decrease that from ground water to improve the quality of ground water [23]. This would result in a further reduction in the fluoride concentration in both Malta and Gozo.

During 2006-2007, over 30,306,179 m^3 was produced. This means that the WSC produces around 83,000 m^3 of water every day. Around 40.46% of this water comes from ground water sources (galleries and boreholes) scattered all over the Maltese Islands [23].

Tap water in the Maltese Islands, therefore, now contains less fluoride than is found in naturally occurring ground water obtained from aquifers due to the blending that takes place with water from RO plants.

Fluoride Concentration

In the past, the Maltese Islands had natural fluoride present in the water supply, at an average level of 0.6 ppm. The latest reports on the fluoride content of the public water supply in Malta show that the level of fluoride is now below 0.2 ppm *(Figure 4)*. This has dropped from a mean value of around 0.6 ppm in 1968. Such a concentration may be considered as a lower limit of optimum during the summer months, when an average temperature of around 32° C is recorded *(Table 1)*. The fluoride levels in most local drinking water in Malta have dropped to concentrations that are insufficient for the prevention of dental caries.

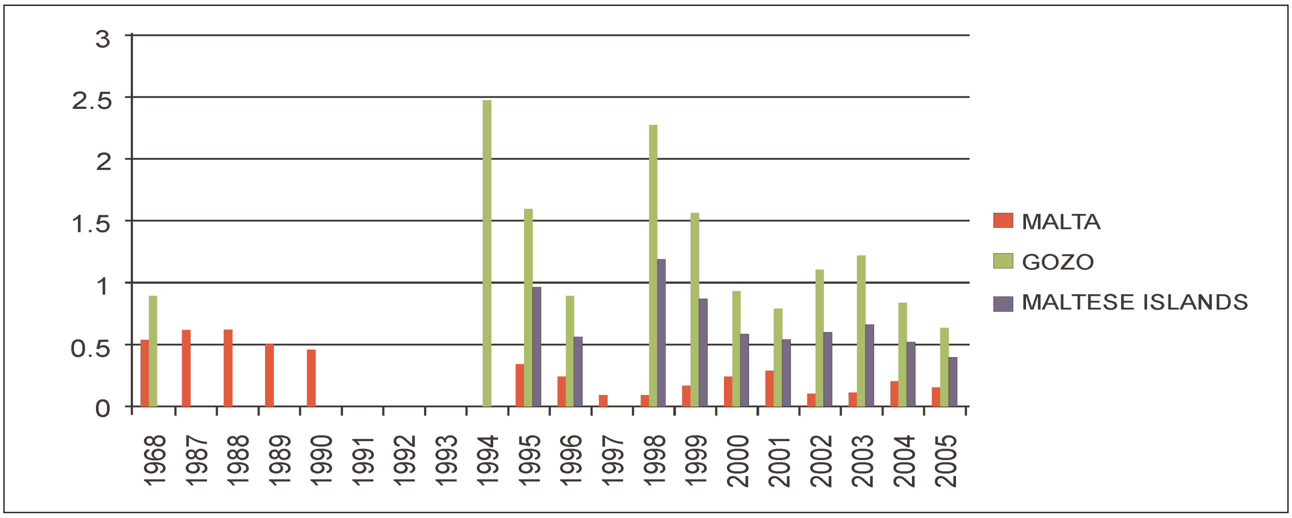

Figure 4. *Fluoride concentrations in the Maltese Islands*

Gozo, on the other hand, had levels of fluoride that ranged from 0.8 to 2.5 ppm. Since the introduction of its RO plant in 2004, the "polished" water contains less fluoride than the ground water and the mean fluoride concentration for the different parts of the island now averages 0.65 ppm *(Figure 4),* thus meeting the drinking water directive 98/83/EC, which puts the limit for fluoride in drinking water at 1.5 ppm [20].

Dental Fluorosis

Evidence of dental fluorosis had been found among some schoolchildren in Gozo in 1964 [24]. However, no data were ever collected or presented during that period. The first documented data on dental fluorosis were in 1986, when Möller carried out a pathfinder survey in Malta and Gozo [25]. *Table 2* shows the distribution and severity of dental fluorosis in 12-year-old children in Malta and Gozo in 1986.

Table 2. *Levels of Dental Fluorosis in 12-Year-Old Children in 1986: Percentage of Persons Affected (According to the Modified Dean's Index)*

Level of fluorosis	Malta	Gozo
Normal	62.4	46.3
Questionable	3.4	23.8
Very mild	15.9	15.0
Mild	14.6	8.8
Moderate	2.1	5.0
Severe	0.8	0.0

At that time, in Malta 62% of children were recorded as having normal enamel whereas in Gozo only 46.3% of children were recorded as having normal enamel. There would appear to have been more fluoride in Gozo water as the level of questionable fluorosis was higher at 23.8% compared to 3.4% in Malta. However, it was only in Malta that children had severe levels of fluorosis, albeit that only 0.8% of children were affected.

Möller (1987) suggested that there was, at the time, a public health problem with regards to dental fluorosis in Gozo [25]. A score of >0.6 was recorded using Dean's index [2], exceeding the normal threshold scores of 0.4-0.6. However, Möller (1987) also suggested that possibly other enamel opacities could have been mistakenly classified as dental fluorosis [25].

Further data collected by Vassallo and Portelli in 2004 showed that 21% of all 12-year-old children examined in Malta and Gozo had signs of staining attributable to fluorosis on one or more of their maxillary anterior teeth and of these children, only 19% were aware of the staining [26]. In Gozo, 15% of the 12-year-old children examined had marks attributable to fluorosis [26].

A recent study [27] showed that dental fluorosis prevalence in Gozo is low in the permanent dentition of 12-year-olds and the majority of the fluorosis present is of a mild form. In fact, the 12-year-old children were also not aware of the aesthetic changes on their central incisors associated with dental fluorosis. This study used the Thylstrup Fejerskov (TF) index [28] and the results showed that 13.8% of the children had a TF score of 1 or more. *Table 3* shows the TF scores.

The conclusions from this study showed that the systemic source of dental fluorosis, which is present in Gozo, was not solely tap water, as had been previously assumed.

Dental Caries

Overall, the data available show that the caries prevalence in the Maltese Islands is low. The prevalence of dental caries is and has been lower among the 12-year-old Gozitan schoolchildren, than it is among their Maltese counterparts *(Figure 5).*

From 1968 to 1986, the mean DMFT in 12-year-old children in Malta dropped from 2.3 to 1.56. However, the results of a survey in 1995 [29] suggested that between 1986 and 1995 caries prevalence had increased from 1.6 to 1.8 DMF-T in 12-year-olds. Then, from 1995 to 2004 it decreased from 1.8 to 1.4 [26,29].

It is interesting to note that a similar increase occurred in other countries where water fluoridation was discontinued. In Antigo, Wisconsin, where water fluoridation was started in 1949 but discontinued in November 1960 and not reinstated until October 1965, the caries prevalence increased remarkably (by about 100%) between 1960 and 1966 (DMFT increased from 1.7 to 2.9) [30].

Table 3. *Thylstrup Fejerskov Scores in 12-Year-Old Children in Gozo*

Age	TF Score 0	TF Score 1	TF Score 2	TF Score 3	TF Score 4	TF Score 5
12 years	83.30%	5.90%	2.82%	2.56%	0.77%	0.26%

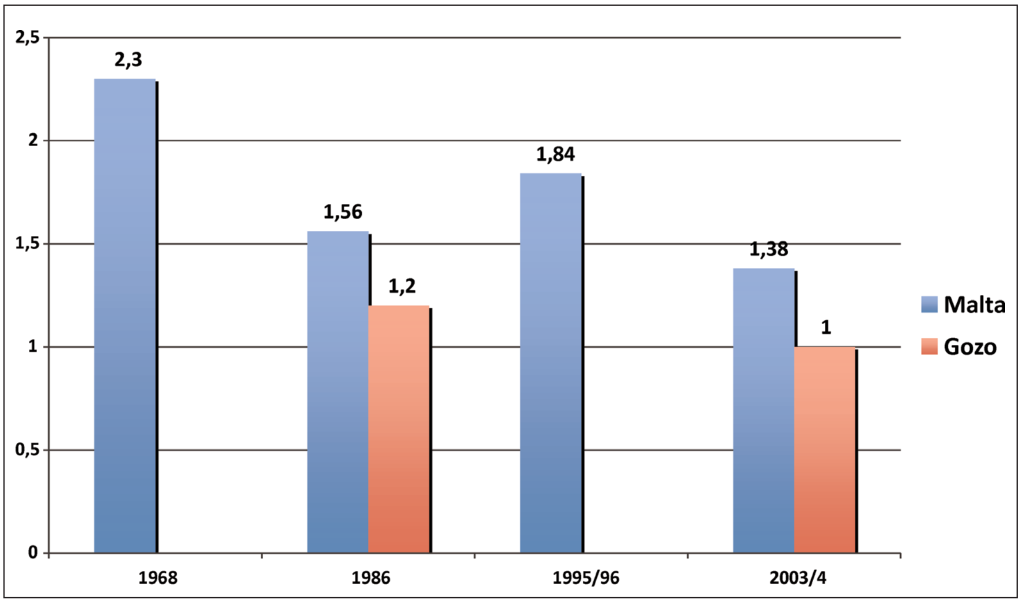

Figure 5. *Trends in dental caries prevalence in 12-year-olds in terms of mean DMFT in Malta and Gozo*

Mansbridge (1969) [31] reported that after cessation of the fluoridation scheme in Kilmarnock, in 1962, the prevalence of caries increased in children aged 3-7 years. By 1968, the proportion of children free from decay approximated to the pre-fluoridation level of 1956 and to that of the control children in Ayr. Similarly, in Wick, Scotland, which started water fluoridation in 1969 but stopped it in 1979, the caries prevalence in five- to six-year-old children increased by 27% between 1979 and 1984, despite a national decline in caries and increased availability of fluoride dentifrices [3]. Similarly, the prevalence of dental caries has increased in Stanraer, Scotland, since the withdrawal of water fluoridation [32]. Nevertheless, even if water fluoridation is stopped, there can still be beneficial long-term effects. A study carried out in Okinawa, Japan, on the caries experience of 18-22-year-old subjects, 13 years after water fluoridation had been discontinued, showed that missing teeth and advanced carious lesions occurred less frequently in the subjects who had fluoridated water compared to the control group. There was also significantly lower caries prevalence on the free smooth and approximal surfaces. However, the overall DMFT differences were small and non-significant [33]. In the Dutch town of Tiel, where the fluoridation of drinking water was discontinued in 1973, the caries experience (DMFS) of 15-year-old children increased between 1968/1969 and 1979/1980 by 18% (from 10.8-12.7) and decreased by 26% (to 9.6) in the following years. After cessation of water fluoridation, caries prevention had been continued with school-delivered F-tablet distribution and other measures, such as individual use of fluoride dentifrices [34].

The question as to whether water fluoridation would have had an additional benefit if it had been continued cannot be answered, as there are no remaining communities with fluoridated water in the Netherlands [35].

Direct evidence suggesting that a reduction in the optimum concentration in fluoride in community water supplies would significantly alter DMFT is scant. In 1991, the Working Group of the National Health and Medical Research Council of Australia found no data to estimate directly the consequences of reducing water fluoride concentration below 1 ppm [36]. This organisation extrapolated from historical data and concluded that dental caries would increase by 10-15% overall and much more for high-risk persons, within 5-10 years following a reduction in fluoride concentration from 1.00 ppm to 0.5 ppm. However, Lo *et al.* (1990) found that dental caries continued to decline in 6-12-year-old children in Hong Kong despite a small reduction in the concentration of fluoride in the water from 0.8 ppm to 0.6 ppm in 1978 [37].

Considering that the clinical effectiveness of water fluoridation in the reduction of dental caries in both the primary and permanent dentition is around 50%, the magnitude of the increase of caries levels in Malta in 1995 was not so great. This suggests that a factor (or factors) operating independently of this population measure is likely to be responsible. The control of sugar is undoubtedly an important issue in the prevention of caries. Thus it is possible that sugar may have had an impact, but this has not been investigated. The other reason that may explain why the caries prevalence has not increased so dramatically is the greater availability of fluoride in the oral environment, particularly the increasing use of toothpastes (most of which were fluoridated), which have shown more than a tenfold increase from 1980 to 1995 *(Figure 2).*

The decline in the DMFT in Malta from 1995 to 2004 is in keeping with reports that have confirmed a decline in dental caries in children in the developed and developing countries during this period [38-42]. This has been attributable, in part, to the widespread use of fluoride-containing dentifrices, now regarded as both clinically effective and socially acceptable, making them the best form of intervention for the prevention of caries [43]. Thus the increased expenditure on dentifrices could also explain the statistically significant decline in DMFT from 1995 to 2004.

Over a period of 17 years, the DMFT in Gozo has declined from 1.2 to 1.0 ppm. The decline is not statistically significant *(Figure 5)* but the impact of the introduction of the desalinated seawater had not yet had an impact.

Conclusion

From 1968 to 2004, the caries levels in the Maltese Islands have declined in parallel with other countries. In 1995, the caries levels in Malta appeared to have increased slightly at the same time as a reduction in the fluoride levels of the public water supplies in Malta from 0.6 ppm to 0.1 ppm. This increase might have been due to a number of factors, including sugar consumption, which have not been investigated, and/or the maintenance of ambient fluoride levels through other vehicles. Over this time period, available data suggest that fluoride from (mainly) dentifrices has replaced the loss of fluoride from the Maltese water supplies, as previously concluded by Marthaler (1990) [7].

Caries prevalence and fluorosis levels need to be monitored regularly in order serve as a guide for developing a fluoride strategy for the Maltese Islands.

References

1. National Statistics Office Malta (NSO). *Demographic Review 2009*. Malta: NSO; 2010.

2. Dean HT, Arnold FA Jr, Elvove E. Domestic water and dental caries, additional studies of the relation of fluoride domestic waters to dental caries experience in 4425 white children aged 12-14 years, of 21 cities in 4 states. *Public Health Report* 1942; **57**: 1155-1179.

3. Stephen KW, McCall DR, Tullis JI. Caries prevalence in northern Scotland before, and 5 years after, water defluoridation. *British Dental Journal* 1987; **163**: 324-326.

4. Pitts NB, Evans DJ, Pine CM. British Association for the Study of Community Dentistry (BASCD) diagnostic criteria for caries prevalence surveys—1996/97. *Community Dental Health* 1997; **14**(Suppl 1): 6-9.

5. Stephen KW, Macpherson LMD, Harper G W, Stuart RAM, Merrett MCW. A blind caries and fluorosis prevalence study of school children in naturally fluoridated and non-fluoridated townships of Morayshire, Scotland. *Community Dentistry and Oral Epidemiology* 2002; **30**: 70-79.

6. Murray JJ, Rugg-Gunn AJ, Jenkins GN. *Fluorides in Caries Prevention*. 3rd ed. Oxford: Wright; 1991.

7. Marthaler TM. Clinical effects of various fluoride methods and programmes. In: Ekstrand J, Fejerskov O, Silverstone LM, editors. *Fluoride in Dentistry*. Copenhagen: Munksgaard; 1988.

8. Newbrun E. Effectiveness of water fluoridation. *Journal of Public Health Dentistry* 1989; **49**(spec iss): 279-289.

9. Lewis DW, Banting DW. Water fluoridation: current effectiveness and dental fluorosis. *Community Dentistry and Oral Epidemiology* 1994; **22**: 153-158.

10. Ripa LW. A half-century of community water fluoridation in the United States: Review and commentary. *Journal of Public Health Dentistry* 1993; **53**: 17-44.

11. Ismail AI, Shoveller J, Langille D, MacInnis WA, McNally M. Should the drinking water of Truro, Nova Scotia, be fluoridated? Water fluoridation in the 1990s. *Community Dentistry and Oral Epidemiology* 1993; **21**: 118-125.

12. Horowitz HS. The future of water fluoridation and other systemic fluorides. *Journal of Dental Research* 1990; **69**(spec iss): 760-764.

13. O'Mullane, D.M. The future of water fluoridation. *Journal of Dental Research* 1990; **69**(spec iss), 756-759.

14. O'Mullane DM, Clarkson J, Holland T, O'Hickey S, Whelton H. *Children's Dental Health in Ireland, 1984*. Dublin: Stationery Office; 1986.

15. O'Mullane DM, Clarkson J, Holland T, O'Hickey S, Whelton H. Effectiveness of water fluoridation in the prevention of dental caries in Irish children. *Community Dental Health* 1988; **5**: 331-344.

16. World Health Organization (WHO). *Fluorine and Fluorides*. Environmental Health Criteria 36. Geneva, Switzerland: WHO; 1984

17. Department of Health and Children of Ireland. *Report of the Forum on Fluoridation*. Dublin: Government of Ireland; 2002.

18. Rolla G, Almeida Cruz R. Clinical effect and mechanism of cariostatic action of fluoride-containing toothpastes: a review. *International Dental Journal* 1991; **141**: 171-174.

19. Vehkalati M. Ryotomaa T, Helminen S. Decline in dental caries and public oral health care of adolescents. *Acta Odontologica Scandinavica* 1991; **49**: 323-328.

20. European Drinking Water Directive. Council Directive 98/83/EC, on the quality of water intended for human consumption. *Official Journal of the European Communities* L 330, 05/12/1998 pp. 0032-0054.

21. Legal Notice 23 of 2004 under the Food Safety Act (Act No. XIV of 2002). Quality of Water Intended for Human

Consumption Regulations. *Government Gazette of Malt*a 2004; **17**; 531-520.

22. Legal Notice 116 of 2004 under the Food Safety Act (Act No. XIV of 2002). Quality of Water Intended for Human Consumption (Amendment) Regulations. *Government Gazette of Malta;* **17**: 549.

23. Water Services Corporation Malta: 2006. Accessed via: http://www.wsc.com.mt/

24. Vassallo A. The water supply problem in Malta. *Journal of the Royal Institute of Public Health and Hygiene* 1965; **28**: 248-258.

25. Möller IJ. Report on a Visit to Malta. EURO MAT/ORH 001 3017H. Copenhagen: World Health Organization Regional Office for Europe; 1987.

26. Vassallo P, Portelli JM. Report on the National Oral Health Survey for the Maltese Islands; 2004.

27. Vento Zahra E. *Dental Fluorosis in Gozo* [Thesis: MSc Public Health Medicine]. Malta: University of Malta; 2007.

28. Thyslstrup A, Fejerskov O. Clinical appearance of dental fluorosis in permanent teeth in relation to histologic changes. *Community Dentistry and Oral Epidemiology* 1978; **6**: 315-328.

29. Galea H. Malta: Annual Report 1995. Malta: Department of Dentistry; 1996

30. Lemke CW, Doherty JM, Arra, MC. Controlled fluoridation: the dental effects of discontinuation in Antigo, Wisconsin. *Journal of the American Dental Association* 1970; **80**: 782-786.

31. Mansbridge JN. The Kilmarnock studies. Appendix to: *The Fluoridation Studies in the United Kingdom and Results Achieved After 11 Years*. London: HMSO; 1969.

32. Kobayashi S, Kawasaki K, Takagi O, Nakamura M, Fujii, N, Shinzato M, *et al*. Caries experience in subjects 18-22 years of age after 13 years' discontinued water fluoridation in Okinawa. *Community Dentistry and Oral Epidemiology* 1992; **20**: 81-83.

33. Konig, K.G. Feasibility of the combined use of fluorides. Journal of Dental Research 1990; 69 (special Issue): 801-804.

34. Kalsbeek H, Kwant GW, Groeneveld A, Backer Dirks O, Van Eck AAMJ, Theuns HM. Caries experience of 15-year-old children in the Netherlands after discontinuation of water fluoridation. *Caries Research* 1993; **27**: 201-205.

35. National Health and Medical Research Council. *The Effectiveness of Water Fluoridation*. Canberra: Australian Government Publishing Service; 1991.

36. Lo ECM, Evans RW, Lind OP. Dental caries status and treatment needs of the permanent dentition of 6-12-year-olds in Hong Kong. *Community Dentistry and Oral Epidemiology* 1990; **18**: 9-11.

37. Bolin A-K, Bolin A, Koch G. Children's dental health in Europe: caries experience of 5- and 12-year-olds from eight EU countries. *International Journal of Paediatric Dentistry* 1996; **6**: 155-162.

38. Bolin A-K. Children's Dental Health in Europe: An epidemiological investigation of 5- and 12-year-old children from eight EU countries. *Swedish Dental Journal Suppl* 1997; **122**: 1-88.

39. Attwood D, Blinkhorn AS. Trends in dental health of ten-year-old school children in south-west Scotland after cessation of water fluoridation. *Lancet* 1988; **2**: 266-267.

40. Anderson RJ. Changes in dental caries experience of 12-year-old school children in two Somerset schools: a review after an interval of 30 years. *British Dental Journal 1995*; **179**: 125-129

41. World Health Organization (WHO). *Educational Imperatives for Oral Health Personnel: Change or Decay?* WHO Technical Report Series no.794. Geneva, Switzerland: WHO 1990.

42. Seki M, Yamashita Y. Decreasing caries prevalence in Japanese preschool children is accompanied with a reduction in mutans streptococci. *International Dental Journal* 2005; **55**; 100-104

44. Selwitz RH, Ismail AI, Pitts NB. Dental Caries. Seminar. *Lancet* 2007; **369**: 51-59.