# CHANGE IN FLUORIDE CONTENT OF MALTESE TAPWATERS: IMPLICATIONS FOR ORAL HEALTH

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## ABSTRACT

Dietary intake of fluoride is believed to be largely derived from drinking water. In Malta, tapwater presently contains less fluoride than is found in naturally occurring ground water obtained from aquifers. Over 55% of water production comes from reverse osmosis and such water is practically fluoride-free. Before the introduction of reverse osmosis water into the water budget, fluoride levels measured from 10 different tapwaters averaged 0.51 ppm F-. Now, fluoride contents measured from 19 tapwater sources average 0.21 ppm F- and more than a third of these sources are practically fluoride-free. The incidence of dental caries in Malta has so far been low according to international standards. We suggest that the lowering of the fluoride level in the water supplies may favour an escalation in the incidence of tooth decay in future.


## INTRODUCTION

Many substances when absorbed by living organisms in very small amounts may be essential to life while exposure to larger doses may evoke severe signs of intoxication. The element fluorine falls in such a category of essential trace elements. In adults a minimum of 0.5 mg/day is required for survival, the optimum range being from 2 to 10 mg/day. An intake of 10 to 20 mg/day however results in toxicity and doses higher than this may even be lethal (1). Although some fish may contain as much as 100 mg/kg of fluorine and tea may even have twice this concentration, most foods usually contain very little fluorine, typically less than 10 mg/kg (2). The total intake of the substance is thus normally considered to be derived from drinking water. Water containing 1.0 ppm fluoride is regarded as a "high fluoride" water. This concentration of fluoride is believed to prevent dental caries without having harmful effects on health (3). At concentrations of 2 ppm or higher, fluorine in drinking water is known to have deleterious effects on health. Chronic dental fluorosis (mottled enamel) appears when waters containing 2 ppm or more are ingested during the first eight years of life. Ingestion of waters containing fluorine at concentrations higher than 8 ppm may lead to a symptomatic osteosclerosis. Crippling fluorosis may appear in rare instances of excessive industrial exposure to fluorides or where natural waters contain very high fluoride concentrations (4).

Fluorine, as the fluoride ion F-, is found in both surface water and ground waters. The natural concentration of the element in ground water depends on such factors as the geological, physical and chemical characteristics of the water-supplying area, the consistency of the topsoil, the porosity and permeability of the aquifer rocks and the pH and temperature of the water. In Malta, only about 38% of water production is presently obtained from ground water aquifers. A very small amount of the water demand, less than 1%, is occasionally obtained from surface water which is collected and treated in four water treatment plants. Four distillers at the Marsa power station produce about 6% of daily requirements. Over 55% of drinking water is generated from sea water by three reverse osmosis plants which between them produce about 30 million litres of water per day. Most of these primary production sources supply water directly to a complex system of reservoirs connected by a network of conduits and from these reservoirs the water is redistributed to towns and villages. Some locations may also actually receive water directly from primary sources such as boreholes or reverse osmosis plants.

Hence, variations or trends in the fluoride concentrations of local domestic tapwaters have to be seen in this perspective of a system of water sources that is both complex and variable in time.

## METHODS

In this work we analysed a number of waters for their fluoride content. The samples were collected over a short period during December 1987 and January 1988 and analysed shortly afterwards. These waters were chosen from different sources, namely, primary production points (boreholes, pumping stations, springs, purification plants), storage points (reservoirs, blending rooms) and domestic supplies from various towns and villages. Sea water from a point about 1 km offshore Valletta was also analysed. The chloride content and total hardness for all the samples were also determined. Besides these samples, other waters were analysed as follows: rain water; bottled "mineral water" both of local origin and imported.

Standard methods of analysis were adopted for all the parameters measured. Fluoride was measured by the Megregian-Maier technique which is based on the reaction between fluoride ions and a zirconium-alizarin monosulphonate lake. Standards in the range 0.00 to 2.00 ppm F- were run with the samples and the absorbance of the dye lake was measured at 530 nm using a double beam Shimadzu/Bausch and Lomb Spectronic 210UV spectrophotometer. Deionised water was used in the reference cell and as solvent for all the standards. Waters containing more than 800 ppm chloride were diluted before analysis for fluorine in order to eliminate analytical interferences. Total hardness, defined as the sum of the calcium and magnesium concentrations and expressed as $CaCO_3$ equivalent in ppm, was determined by complexometric titration. Chloride content was determined by argentometric titration.

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**Table 1**

TABLE 1: ANALYSIS OF WATERS DERIVED FROM DIFFERENT SOURCES

| Production Point[a] | Depth/m | Aquifer Rock[b] Formation | F ppm | Total Hardness ppm | Cl ppm |
|---|---|---|---|---|---|
| Wied Bordi BH | 118 | LCL | 0.21 | 260 | 180 |
| Tal-Hlas PS | 33 | GL | 0.22 | 560 | 960 |
| Tat-Torba BH | 110 | GL | 0.30 | 340 | 340 |
| Ta' Qali PS | 110 | GL | 0.40 | 980 | 2200 |
| Naxxar Res.BH | 122 | LCL | 0.48 | 760 | 1600 |
| Hal Mann BH | 96 | GL | 0.50 | 240 | 140 |
| Ta' Bakkja PS | 110 | GL | 0.72 | 580 | 1020 |
| Ta' Qali II BH | 132 | GL | 0.75 | 320 | 220 |
| Gozo Pipeline | - | - | 0.69 | 320 | 380 |
| Torri Cumbo WTP | - | - | 1.00 | 500 | 340 |
| RO Plant,Lapsi | - | - | nd[c] | 80 | 380 |
| RO Plant,Tigne | - | - | nd | 50 | 280 |
| RO Marsa,Marsa | - | - | nd | 50 | 340 |
| Dist.£1,PWRS | - | - | nd | nd | nd |
| Dist.£4,PWRS | - | - | nd | nd | nd |

a BH = borehole; PS = pumping station; PWRS = power station; WTP = water treatment plant (surficial water).
b LCL = Lower Coralline Limestone; GL = Globigerina Limestone
c nd = not detected; detection limit for fluoride = 0.02 ppm F

**Table 2**

TABLE 2 ANALYSES OF WATERS DERIVED FROM DIFFERENT RESERVOIRS

| Storage Reservoir | F ppm | Total Hardness ppm | Cl ppm |
|---|---|---|---|
| Ta' Qali Res. | 0.48 | 500 | 940 |
| Luqa Res. | 0.17 | 400 | 1040 |
| Blending Rm PWRS | 0.15 | 160 | 410 |
| Wier Rm Ta' Qali | 0.54 | 440 | 920 |
| Mercieca Res. | 0.48 | 420 | 1060 |
| St Maria Res. | 0.38 | 460 | 960 |
| Sea water | 1.37 | 6600 | 21600 |

**Table 3**

TABLE 3 FLUORIDE CONTENT (PPM) OF DOMESTIC TAPWATER IN DIFFERENT AREAS

| | Dec 1983[a] | May 1984[a] | Jan 1988[b] |
|---|---|---|---|
| Floriana | 0.30 | 0.40 | 0.30 |
| Valletta | 0.30 | 0.60 | 0.30 |
| Sliema | 0.70 | 0.60 | nd |
| St Paul's Bay | 0.60 | 0.60 | 0.30 |
| Mellieha | 0.65 | 0.60 | 0.31 |
| Rabat | 1.00 | 0.80 | 0.48 |
| Dingli | 0.45 | - | 0.54 |
| Zurrieq | 0.30 | 0.40 | nd |
| Qrendi | 0.20 | 0.40 | nd |
| Mqabba | 0.10 | 0.60 | - |
| Luqa | - | - | nd |
| Paola | - | - | nd |
| Zejtun | - | - | nd |
| Marsascala | - | - | 0.22 |
| Ghaxaq | - | - | nd |
| Birkirkara | - | - | 0.38 |
| Laqxija | - | - | 0.26 |
| Iklin | - | - | 0.26 |
| Gzira | - | - | 0.26 |
| Ghajn Tuffieha | - | - | 0.33 |

a Data taken from Moller (5)
b This work

## RESULTS

Table 1 presents the fluoride concentrations found in waters produced from the various primary sources. The table also includes total hardness and chloride concentrations of these waters.

Table 2 shows similar data for waters sampled from storage or blending reservoirs as well as data on the sea water sample analysed.

Table 3 gives the fluoride concentrations in several domestic tapwaters obtained from different localities and compares them with earlier published results. Two samples of rain water collected from Santa Venera during a rain storm in November 1987 were found to contain an average fluoride content of 0.16 ppm and a chloride content of 20 ppm. Four brands of imported bottled "mineral water" and two locally produced brands were analysed. The imported waters contained respectively 0.40 ppm F (one brand) and 0.10 ppm F (the other three). One local brand contained 0.10 ppm F while the fluoride content of the other product was below our detection limit which we estimate to be 0.02 ppm F.

## DISCUSSION

In Malta, ground water is produced from two main aquifers namely, the Perched Water Table (Upper Water Table) and the Main Sea Level Water Table (Lower Water Table). Rain water percolating down through the Upper Coralline Limestone and Greensand Formations is trapped by the impervious Blue Clay stratum and it then spreads out and collects as the upper table. The lower water table is formed by similar infiltration of rain water through exposed older formations (the Globigerina and Lower Coralline Limestone) and exists in a lenticular form floating on denser underlying salt water. Faults and fissures serve to connect these water tables in various places.

The ground water samples analysed in this work were obtained from a series of boreholes and pumping stations (water galleries) located on a north-south trend extending from Naxxar to Siggiewi and exclusively tapping the Sea Level Water Table. Insofar as these samples accurately describe the quality of the water in this major aquifer, we can see that ground water from this source contains fluorine in concentrations which vary from about 0.2 to 0.8 ppm. This variation in values reflects such factors as (i) local differences in the concentration of fluorine-bearing minerals in the limestones; (ii) different residence times of the waters in the aquifer and (iii) mixing of different waters within the aquifer through joints and fissures in the rock. No doubt, a fraction of the fluorine in ground water originates from sea water which intrudes into the water table and mixes with the fresh water by diffusion.

However, using the chloride concentrations in the ground water samples as an indicator of the extent of sea water admixture, it can easily be shown that more than 99% of the fluorine in all the samples examined must originate from the rock matrix itself. It is likely that detrital minerals such as the fluoroapatites, ubiquitous in marine sedimentary rocks, are the major contributors of fluorine to Malta's ground water. No attempt, however, was made to identify the presence of fluorine-bearing minerals in local limestones.

At this point we refer to the fluorine content of the rain water samples examined. Here again, in view of the chloride content of the rain water, we calculate that only 0.8% of the fluorine in this water could have originated from sea spray contamination. We speculate that the major source of fluorine in rain water is airborne pollutants probably originating from coal firing at the Marsa power plant. This is supported by the observation of fine black particles (of soot?) found present in the rain water collected.

A working definition of tapwater is any natural or artificially produced water or mixture of waters which is certified as potable by the water authority and which is supplied to users by means of a mains system. Tapwater samples were collected from four series of localities which were each fed from an independent reservoir, the latter being the Santa Maria reservoir at Ta' Qali and the Naxxar, Qrendi and Fiddien reservoirs, respectively. As Table 3 shows, the levels of fluoride ions in all tapwaters analysed ranged from less than 0.02 ppm, our limit of detection, to 0.54 ppm with a mean value of 0.21 ppm F. These fluoride concentrations are, in general, quite lower than those found naturally in ground waters produced from boreholes or water galleries. Furthermore, the mean value of fluoride concentrations measured in tapwaters during December 1983 and May 1984, taken together, is 0.51 ppm F. Thus, on average, tap water fluoride concentrations produced at the beginning of 1988 were smaller by a factor of about 59% from their values in late 1983/early 1984. Moreover, for a number of localities, e.g. Sliema, Qrendi and Zurrieq, the fluoride water content is now practically negligible.

This substantial reduction in fluoride concentration in drinking water is a direct consequence of the production of nearly fluoride-free reverse osmosis water which was introduced in 1984. At present, three such plants are in operation and a fourth one, at Cirkewwa, has recently been completed. Hence, the present contribution of reverse osmosis water to the total water budget of these islands is destined to increase even further. Other factors which may lead to a reduction in the share which ground waters make towards the total water budget are (i) an increase in salinity of the ground water due to sea water intrusion: already the chlorides from most producing points are quite high in concentration and (ii) an increase in nitrate (or pesticide or herbicide residue) concentration due to aquifer contamination from agricultural irrigation waters.

According to published trade statistics, the consumption of bottled "mineral water" may be substantial. However this water appears to have little potential of increasing total dietary fluoride intake since most of the brands examined were quite low in fluoride.

Fluoride levels in most local drinking waters may drop to concentrations which could be insufficient for maintaining oral health. It appears from this work that already a number of domestic water supplies may have an extremely low fluoride content. Such a situation if sustained or further worsened by a continued fall in fluoride levels, will presumably have a negative effect on oral health which may manifest itself in the near future. Past epidemiological studies (6 - 8) have indicated that the severity of dental caries in the permanent dentition in Malta ranked at a low level according to international standards. If the fluoride contribution of drinking water to the total fluorine requirement is indeed dominant, as currently believed, then such a situation in the state of oral health with respect to dental caries may well change for the worse.

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## REFERENCES

1 Frieden E. (ed): Biochemistry of the Essential Ultratrace Elements, New York, Plenum Press 1984, pp 1-15.

2 World Health Organization: Guidelines for Drinking-Water Quality, Volume 2, Health Criteria and Other Supporting Information, World Health Organization, Geneva, 1984, p. 101.

3 Jenkins G.N.: The Effects of Trace Elements on the Calcified Tissues, in Cohen B and Kramer IRH (eds): Scientific Foundation of Dentistry, London, W. Heinemann Medical Books Ltd., 1976, pp.376-382.

4 World Health Organization: Technical Report Series No. 146, Expert Committee on Water Fluoridation, Geneva, 1958, pp.9-16.

5 Moller I.J.: Oral Health in Malta, Report on a Visit to Malta 16-19 December 1987, Copenhagen, W.H.O. Regional Office for Europe, 1987, p.26.

6 Moller I.J.: Oral Health Situation and Planning of National Oral Health Pathfinder Survey, Copenhagen, W.H.O. Regional Office for Europe, 1985, p.2.

7 Galea H.: The dental health of seven year old children in Malta's state-run primary schools. St. Luke's Hospital Gazette 1971; 6: 126 - 133.

8 Olivieri-Monroe C.: A study of the oral health of Maltese school children. Br Dent J. 1968; 124: 177 - 182.