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Fluoride content of tank water in Australia

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ABSTRACT

The aims of this study were to: (1) analyse the fluoride content of tank water; (2) determine whether the method of water collection or storage influenced fluoride content; and (3) survey participant attitudes towards water fluoridation. Plastic tubes and a questionnaire were distributed through dentists to households with water tanks in Victoria. A midstream tank water sample was collected and fluoride analysed in triplicate using ion chromatography. All samples (n = 123) contained negligible amounts of fluoride, with a mean fluoride concentration of <0.01 ppm (range: <0.01 to 0.18 ppm). No statistically significant association was found between fluoride content and variables investigated such as tank material, tank age, roof material and gutter material. Most people did not know whether their tank water contained fluoride and 40.8% preferred to have access to fluoridated water. The majority thought fluoride was safe and more than half of the respondents supported fluoridation. Fluoride content of tank water was well below the optimal levels for caries prevention. People who rely solely on tank water for drinking may require additional exposure to fluoride for optimal caries prevention.

Key words: Fluoride; water tanks, water fluoridation; rainwater

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INTRODUCTION

Water fluoridation has been lauded as one of the ten most important public health successes of the twentieth century due to its preventive effects on dental caries[1]. Since the inclusion of fluoride in Australian water supplies a dramatic decrease in the caries experience of children and adults has been seen.[2, 3] Recent data show that lifetime exposure to fluoridated water by Australian adults aged 17-35 years reduced their caries experience by 23-25 per cent compared to those without any exposure.[4, 5]

While 93% of Australian households have access to reticulated water[6] and approximately 90% of Australians have access to fluoridated drinking water there are those especially in the rural and remote regions who do not have access and rely on water from other sources such as bottled water, rivers, creeks, dams, bore water, well water, grey water or rain water.

Studies have investigated the fluoride content of bottled waters and shown that they typically contain low levels of fluoride.[7, 8] Bore water contains variable levels of fluoride that depends on the nature of the rocks and prevalence of fluoride-bearing minerals.[9] Tank water has been investigated in less detail. In fact, there is only a single study in the literature that reports on the fluoride content of tank water. In 1987, Woods[10] examined the fluoride content of cement (n=24) and galvanised iron water tanks (n=26) and found that the fluoride content in these tanks was 0.59 ppm and 0.14 ppm respectively. Despite this finding, authors often make the assumption that rainwater stored in a tank does not contain fluoride.[11] As a consequence, recommendations are made regarding fluoride exposure based on these assumptions. Additionally, World Health Organization publications on fluoride in drinking water do not comment on the fluoride concentration in tank water.[9]

Tank water fluoride content is an increasingly important issue as Australian data show that since 1994 there has been an increase in the number of water tanks being installed.[6] In 2007, despite 93% of Australian households supposedly having access to reticulated water,

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19.3% reported sourcing water from rainwater tanks.[6] This comprised of 11.2% and 33.5% of households in and outside of capital cities respectively.[6] Therefore, given the increase in water tank usage, it was decided that a more recent investigation into the fluoride content of tank water should be undertaken.

The aim of this study was to: (1) analyse the fluoride content of tank water; (2) determine whether the method of water collection or storage influences the fluoride content; and (3) survey participant attitudes towards water fluoridation.

MATERIALS AND METHODS

This research had ethical approval from The University of Melbourne Human Research Ethics Committee (#1034988). Fifty dentists were selected from the Australian Dental Association database based on their practice location and invited to participate by telephone; 22 agreed to participate in this study. Packs containing questionnaires, 15 mL plastic tubes and return reply paid envelopes were sent to participating dentists across Victoria to distribute to patients who met the inclusion criteria of having a water tank used for eating and drinking. A total of 123 samples of tank water returned from around Victoria were collected along with accompanying questionnaire for analysis.

Questionnaire

The questionnaire consisted of two parts. The first was designed to determine the variants of the water tank; this section was divided in four subsections: roof, gutter, tank and water filter. Participants were asked to record the materials and age of each. Questions that were not answered or ambiguous were excluded from the analysis. The second part was designed to assess knowledge and attitudes towards fluoride and was based on a previous study by Tsurumoto *et al.*[12] Participants were asked five questions related to fluoride and were asked whether they agreed, disagreed or did not know. Another five questions related to

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attitudes towards fluoride asked participants to rate each statement on a 5-point Likert scale from 1-strongly agree to 5-strongly disagree.

Collection and analysis

Participants were asked to collect a midstream water sample from their water tank without the use of their water filter in the test tube provided. The fluoride content of the returned water was determined using Ion Chromatography (ICS-3000, Dionex) after filtering the samples through a 0.22 micron membrane to remove debris.[13] Each sample was analysed in triplicate and the amount of fluoride determined through comparison with a standard curve determined with 7 standards between 0.01 ppm and 2 ppm fluoride. Ion chromatography was used due its accuracy at measuring minute concentrations up to parts per billion compared to using an ion-specific fluoride electrode. Results below 0.01 ppm were below the lowest point on the standard curve and for analysis were set to 0 ppm. Tap water collected from the Melbourne Dental School was analysed each time tank water samples were analysed (n = 36).

Statistical analyses

Questionnaire and fluoride data were analysed using SPSS version 17 (Statistical Package for the Social Sciences, SPSS Inc.). The geographic location that the water sample was from was grouped by postcode into four regions of Victoria, Australia for analysis: (1) Grampians and Loddon Mallee; (2) Southern region and Gippsland; (3) Barwon South Western regions; and (4) Hume. Fluoride content of the tank water was also analysed in relation to the various tank, gutter and roof parameters. Differences between groups were tested using One-way Analysis of Variance with the level of significance set at $\alpha = 0.05$.

RESULTS

A total of 123 water samples and completed questionnaires were returned. Geographically, 27 samples were obtained from the Grampians and Loddon Mallee region; 34 from the Southern region and Gippsland; 32 from Barwon South Western region; and 30

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from the Hume region. The types of water tanks that water was obtained from is shown in Table 1 and 2. Water tanks were most commonly constructed from plastic or concrete, with the concrete tanks being significantly older than the plastic tanks ($p < 0.001$) (Table 1). In fact, 75% of tanks aged 10 years or less were plastic whereas 92% of tanks 21 years or older were constructed from concrete. There was no significant differences between tank age and capacity ($p = 0.18$) (Table 1). A water filter was used by 23% of participants and the majority were carbon or particulate filters.

All of the water samples examined contained trace amounts of fluoride as a fluoride peak was visible on all chromatograms, although in many cases this was below the level of the lowest standard. The mean fluoride concentration of all water tank samples was <0.01 ppm (n = 123, range: <0.01 – 0.18 ppm). The distribution of these values is shown in Fig 1. There were no significant differences between the fluoride content of the water collected from the different geographical regions ($p = 0.82$). The fluoride content of the Melbourne fluoridated reticulated water tested each time water samples were analysed was 0.89 ± 0.04 ppm (n = 36, range: 0.80 - 0.96 ppm).

The influence of a variety of variables such as tank material, tank capacity, and tank age on tank water fluoride content is shown in Table 2. The mean fluoride concentration in tanks constructed from different materials ranged from <0.01 to 0.02 ppm, but there were no significant differences between material types ($p = 0.58$). Additionally, there were no significant associations between mean fluoride concentration and tank capacity ($p = 0.68$), tank age ($p = 0.11$), whether the property was connected to town water ($p = 0.49$), roof material ($p = 0.98$), roof age ($p = 0.47$), whether the roof was painted ($p = 0.10$), gutter material ($p = 0.06$), or gutter age ($p = 0.85$).

The attitudes of the participants towards fluoride is shown in Table 3. The majority of participants thought that fluoride was safe, and a safe way of preventing tooth decay, with only 14% disagreeing or strongly disagreeing. The majority of participants thought that their

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tank water did not contain fluoride (64.5%). Participants were well aware of that other means of applying fluoride existed and that most toothpastes contained fluoride. Only 40.6% of participants responded that they would prefer to have access to fluoridated drinking water despite 74.6% responding that fluoride was a cheap way of preventing tooth decay and the relatively small number who disagreed with fluorides' safety.

DISCUSSION

Fluoride content of tank water

The water contained in tanks can come from one of four sources: 1) atmospheric water that falls as rain; 2) surface water (creeks, rivers, dams) that can be pumped into the tank from a local source or supplied by trucks; 3) groundwater supplied by underground pumps; or 4) recycled water such as grey water. This study was limited to an assessment of rainwater tanks.

Rainwater has the opportunity to be contaminated at various stages along its collection path. If the uptake of fluoride into the water is considered it could occur via airborne pollution containing fluoride, fluoride-containing materials such as soil and dust that may be resting on the roof catchment surface, or the leaching of ions from the roof material, the gutter material, material in the tank or the tank material. Previously it has been shown that pesticides have been found in collected rainwater,[14] ions have been shown to leach from roofing materials[15] and that this can change with the age of the roof.[16] This study sought to investigate the availability of fluoride in tank water and whether it was related to a variety of water collection and geographic parameters.

Sources of airborne fluoride can be volcanic eruptions, release of hydrogen fluoride gas and fluoride salts into the air from seawater, bushfires, coal-fired barbeques, cigarette smoke, insecticides, fertilisers, some timber preservation finishes, wind-blown dusts from the weathering of soil or rocks, aluminium smelting, clay brick manufacturing, and electricity

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production.[17] Therefore, trace amounts of fluoride can be expected in tank water as was seen in the results of this study (Fig 1). Although many samples contained less than 0.01 ppm fluoride, the presence of a peak at the fluoride retention time was present on all of the chromatograms. Samples were taken from various regions around Victoria to ascertain possible geographic variations. The Hume region has a rich agricultural industry and Gippsland has a number of coal-fired power stations, so it was hypothesised that these two regions may have different levels of airborne fluoride with this being reflected in tank water. However, no differences in the concentration of fluoride in the water tanks from these different areas was detected. This may be due in part to the environmental protection agency monitoring airborne fluoride around such industrial sites to ensure that their emissions do not exceed levels set to protect vegetation, grazing animals and humans.[17]

Rainwater collected from roof catchments is not pure[15] as it can be contaminated by material present on the roof. When galvanised-iron roof catchments were compared to concrete tiles significantly more zinc was found in the water from the iron roof indicating that ions could be leached from the roof material.[15] Some outdoor paints contain fluoropolymers so fluoride may be present in some roof and gutter coatings. Therefore, in this study roof and gutter material, age and whether they were painted was assessed. None of these variables were found to be significantly associated with the fluoride content of the tank water (Table 2). This may be attributable to the relative inertness of the fluoropolymers.[18] Acid rain has previously been shown to increase the leaching of ions from roof materials[15] however this is infrequent in Australia[19] so may minimise the likelihood of chemical movement from the roof into the tank. Additionally, the use of first flush diverters which are in common use in Australia can reduce the contamination of the tank water with material from the roof and gutter.

It is also possible that the tank material may leach out ions into the water[10]. Fluoride may be released from a variety of materials such as concrete due to the presence of fluoride

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in cement.[20] In contrast, steel and plastic were not expected to leach fluoride due to fluoride not being present in these materials. During manufacturing of fibreglass, fluoride present in the material is emitted in the forms of hydrogen fluoride (HF) and silicon tetrafluoride (SiF4). This is particularly the case in textile fibreglass. The greater the fluoride emission during manufacturing, the lower the expected fluoride leaching during use.[21] This study found no effect of water tank material, age, or volume on the fluoride content of the stored water (Table 2). Participants were instructed to collect their water samples without the use of their water filter. It is assumed that this was the case but since the majority of these were carbon or particulate filters they would have had little influence on fluoride levels even if used [22].

The results of this study do not agree with the results of Woods (1987) who found that the mean fluoride concentration of water from galvanised iron tanks was 0.14 ppm and cement tanks was 0.59 ppm.[10] Both of these values are much higher than the <0.01 ppm figure found in both of these tank types in this study (Table 2). This discrepancy may be attributable to a variety of factors. Firstly, the availability of environmental fluoride from pollution, pesticides, fertilizers, etc may have decreased over the last 30 years. It is also possible that the use of fertilizers and insecticides containing fluoride, which may contaminate tank water due to crop dusting, may have been more widely used in the New South Wales region sampled by Woods[10] compared with Victoria. Another possible explanation is that the building materials of water tanks may have changed resulting in less leaching of fluoride ions. This study found that there was a significant relationship between tank age and material ($p < 0.001$) indicating a shift in buying patterns, with concrete tanks being historically favoured and plastic tanks being more recently favoured. In fact, of the concrete tanks analysed only 3 (6%) were less than 10 years old. The leaching of fluoride from concrete may decrease as the tank ages so the study by Woods may have examined more recently placed concrete tanks. Alternatively, the chemical composition of tank building materials may have changed leading to reduced fluoride leaching. The differences may also

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be related to annual rainfall. Victoria in 2010 recorded flooding rains and the wettest year since 1974[23], while 1986 was a dry year with approximately half the annual rainfall of 2010. This may have had an effect on the fluoride content of the tank as the dry weather in 1986 may have required the delivery of water taken from fluoridated supplies to restock low water tanks. The wetter weather in 2010 may also have cleaned contaminants from the roof and diluted fluoride levels within tanks. Finally, the differences may also be explained by the use of first flush diverters, which may have been less common in the 1980's leading to increased contamination of the water tanks.

While the majority of the water from tanks contained low levels of fluoride (< 0.01 ppm) there were three tanks that contained more than 0.1 ppm fluoride (Fig 1). This fluoride may have originated from any of the sources described above or may be due to the refilling of water tanks by fluoridated water supplied by trucks.

The target fluoride concentration in reticulated water in Australia is between 0.7 to 1.0 ppm[24] and all samples of the Melbourne tap water analysed in our study were within this range. Unfluoridated surface water may contain some fluoride (<0.1 - 0.5 ppm) depending on the type of soil and rock through which the water drains whereas groundwater from deeper wells may contain higher levels (1 - 10 ppm).[24] Therefore, if tanks are supplemented with reticulated water or groundwater, then the fluoride concentration of tank water would be higher than rainwater alone. The minimal concentration required for a protective effect against caries is approximately 0.5 ppm.[24] The mean fluoride concentration of tank water determined in this study was <0.01 ppm and the highest concentration was 0.18 ppm, which is well below both the minimal and optimal level. Therefore, people using this water for eating and drinking will not be receiving the oral health benefits of water fluoridation.

Attitudes towards fluoride

The majority of the people surveyed (64.5%) did not believe that their tank water contained fluoride which was supported by the results of this study. This still leaves quite a

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large percentage of the community that are unaware that their drinking water may not contain fluoride at levels sufficient to influence the initiation and progression of dental caries. Despite the majority of respondents believing that water fluoridation is a cheap way of preventing tooth decay (74.6%) only 40.8% would prefer to have access to fluoridated drinking water. This may be due to feelings against fluoride or potentially more general feelings towards treated reticulated water that may have fluoride added amongst other things. Approximately 60% of respondents thought that fluoride was safe.

The questions asked in this study were based on those posed to users of metropolitan tap water in Melbourne in 2007 by Tsuromoto *et al.*[12] In general the responses to questions about "there are other ways to apply fluoride apart from tap water", that "most toothpastes contain fluoride" and that "if I brush my teeth I do not need water fluoridation" all had a similar pattern of responses as those in the 2007 study. Public opinion regarding the safety of fluoride had increased from the 2007 levels from 33.3% to 68.6% of respondents agreeing or strongly agreeing that "water fluoridation is a safe method for preventing tooth decay".[12] There was also an increase from 43.8% to 51.6% of respondents agreeing or strongly agreeing that "fluoride should be added to drinking water to reduce tooth decay".[12] This may be attributable to the Australian governments' recent push to increase the percentage of the community having access to fluoridated water with an accompanying public awareness campaign.

CONCLUSION

Fluoride levels in tank water were negligible and were well below the optimal level of fluoride necessary for caries prevention. The rural populous which rely solely on tank water for eating and drinking may require additional exposure to fluoride for optimal caries prevention. A significant proportion of the rural population remains unsure or unaware of the

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benefits of fluoride and water fluoridation. Better rural community education about the effects of fluoride would be advantageous for current and future populations.

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FIGURE LEGEND

Figure 1. Distribution of tank water fluoride concentration

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Table 1. Tank age by material and capacity

		Tank Age (years)			
		0 - 10	**11 - 20**	**21+**	**P value**
Tank material (4 unknown)	Total	48	33	38	< 0.001
	Plastic	75.0%	27.3%	0%	
	Concrete	6.3%	33.3%	92.1%	
	Galvanised steel	12.5%	24.2%	2.6%	
	Fibreglass	6.3%	15.2%	2.6%	
	Other	0%	0%	2.6%	
Tank capacity (L) (9 unknown)	Total	47	31	36	0.18
	0 - 10 000	34.0%	45.2%	19.4%	
	10 001 – 30 000	36.2%	25.8%	33.3%	
	30 001+	29.8%	29.0%	47.2%	

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Table 2. Mean fluoride concentration by variables surveyed in questionnaire

		n	Mean fluoride concentration (ppm)	Standard deviation	P value
Tank material	Plastic	45	0.01	0.03	
	Concrete	49	0.01	0.02	
(3 unknown)	Galvanised steel	16	<0.01	0.01	0.58
	Fibreglass	9	0.02	0.06	
	Other	1	<0.01	n/a	
	Total	120	0.01	0.03	
Tank capacity	0 - 10000	37	0.01	0.03	
(L)	10001 – 30000	37	0.01	0.01	0.68
	30000+	40	0.01	0.03	
(9 unknown)	Total	114	0.01	0.02	
Tank age	0 - 10	50	0.01	0.03	
(years)	11 - 20	34	0.02	0.04	0.11
	21+	38	<0.01	0.01	
(1 unknown)	Total	122	0.01	0.03	
Access to town	Yes	27	0.01	0.02	
water	No	96	0.01	0.03	0.49
	Total	123	0.01	0.03	
Roof material	Galvanised steel	103	0.01	0.02	
	Ceramic	9	0.01	0.01	
(2 unknown)	Concrete	6	0.01	0.01	
	Tin	1	0.02	n/a	0.98
	Cement	1	<0.01	n/a	
	Galvanised iron	1	0.02	n/a	
	Total	121	0.01	0.02	
Roof age	0 - 10	29	<0.01	0.01	
(years)	11 - 20	24	0.01	0.03	
	21 - 30	31	0.01	0.01	0.47
(5 unknown)	31+	34	0.01	0.01	
	Total	118	0.01	0.02	
Roof painted	Yes	56	<0.01	0.01	
	No	64	0.01	0.03	0.10
(3 unknown)	Total	120	0.01	0.02	
Gutter	Uncoated steel	37	0.01	0.01	
material	Painted steel	56	0.01	0.02	
	Painted aluminium	9	0.03	0.06	
(2 unknown)	PVC	4	0.01	0.01	0.06
	Uncoated galvanised steel	14	<0.01	0.01	
	Unpainted aluminium	1	<0.01	n/a	
	Total	121	0.01	0.02	
Gutter age	0 - 10	43	0.01	0.03	
(years)	11 - 20	34	0.01	0.03	
	21 - 30	28	<0.01	0.01	0.75
(2 unknown)	31+	16	0.01	0.01	
	Total	121	0.01	0.02	

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Table 3. Attitudes and knowledge towards fluoride

Statements	Total (n)	Response options (%)				
		Agree		Don't know		Disagree
My tank water contains fluoride	121	2.5		33.1		64.5
There are other ways to apply fluoride apart from tap water	120	89.2		8.3		2.5
Most toothpastes contain fluoride	121	92.6		1.7		5.8
Water fluoridation is a cheap way of preventing tooth decay	122	74.6		15.6		9.8
I would prefer to have access to fluoridated drinking water	120	40.8		22.5		36.7
		Strongly agree	**Agree**	**Neither**	**Disagree**	**Strongly disagree**
Fluoride is safe	121	14.0	45.5	26.4	7.4	6.6
Fluoride is added to tap water in many countries to reduce tooth decay	122	28.7	51.6	13.9	3.3	2.5
If I brush my teeth I do not need water fluoridation	121	5.8	14.0	24.8	40.5	14.9
Water fluoridation is a safe method for preventing tooth decay	121	16.5	52.1	17.4	7.4	6.6
Fluoride should be added to drinking water to reduce tooth decay	122	20.5	31.1	32.8	7.4	8.2

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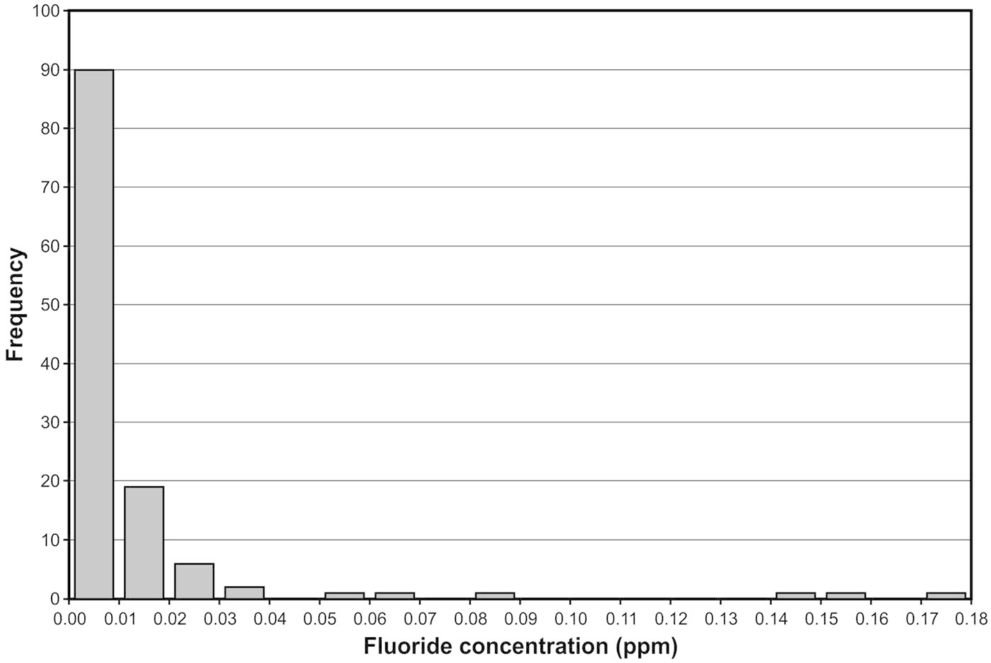

Distribution of tank water fluoride concentration
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