Water Fluoridation: Questions and Answers

This more detailed technical resource has been prepared by NSW Health to assist communities and professionals understand the process of fluoridation, the evidence supporting the benefits of fluoridation and the evidence cited to support claims made about harms associated with fluoridation.

Contents

Fluoride and water fluoridation – the basics

What is fluoride?

Fluorine is an element, the 9th in the periodic table. Fluorine is highly reactive and naturally found only in a form combined with other elements (a compound). When fluorine gains an electron (when it combines with other elements) it is called fluoride or the fluoride ion and is abbreviated F^- (F minus). It is this form of fluoride that is found in fluoridated water. Fluoride compounds are abundant in the earth's crust and found in rocks and soils, salt and sea water. Fluoride in water exists in the dissociated form, i.e. the fluoride ion. Fluoride in water is colourless, odourless and tasteless.

What is water fluoridation?

Water fluoridation is the process of adding fluoride to a water source so that the level of fluoride in the water reaches the recommended level of fluoride for good dental health.

How much fluoride is added to the water?

In NSW fluoride is added to the water supply at a level of 1 milligram per litre (mg/L) in line with the National Health and Medical Research Council recommendations. One milligram per litre is 1 part per million. The National Health and Medical Research Council recommend a fluoridation range of 0.6-1.1 mg/L. This range is to allow lower fluoridation levels in warmer parts of Australia where a person's water consumption may be higher and replicates a similar recommendation in the United States. The *Australian Drinking Water Guidelines* allows a maximum level up to 1.5 parts per million.

How long has NSW had water fluoridation?

Fluoride has been added to water supplies in NSW commencing with Yass in 1956. In NSW alone there are more than 50 years of experience providing effective and safe water fluoridation.

How many people in NSW have access to fluoridated water?

Approximately 96% of the NSW population has access to fluoridated water – one of the highest levels of fluoridation in Australia. (NSWHealth 2013) Not all councils or water utilities fluoridate their water supply and not all people in NSW have a reticulated (public) water supply to their home. For example, some people get drinking water from other sources such as water tanks and private bores.

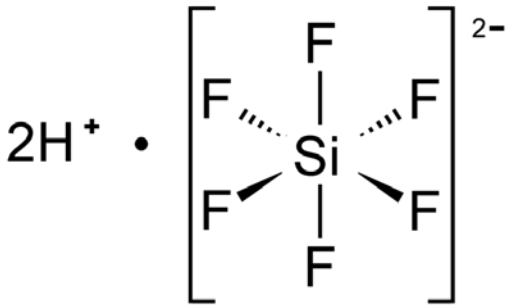
How fluoride is added to the water supply – legalities, technical issues, quality assurance

What is the legal mechanism for fluoridation of a water supply in NSW?

The addition of fluoride to public water supplies in NSW is controlled by the NSW *Fluoridation of Public Water Supplies Act 1957*. Under the Act a water utility cannot start fluoridation of public water supplies without an approval or direction from the Director General of NSW Health. A water utility makes either an application to the Director General to fluoridate the water supply or seeks a direction from the Director General. Once fluoridation has started, a water utility cannot stop fluoridating the water without the Director General revoking the approval or direction.

What chemicals / compounds are used to fluoridate the water supply?

The three main fluoride compounds used are sodium fluoride (NaF), hydrofluosilicic acid or hexafluorosilicic acid (H_2SiF_6) and sodium silicofluoride (Na_2SiF_6). All of these compounds fully mix (dissociate) in water. An example reaction for hydrofluosilicic acid is given below.



Hydrofluosilicic acid

Hydrolysis in water yields six fluoride ions and silicon dioxide.

$SiF_6^{2-} + 2\ H_2O \rightarrow 6\ F^- + SiO_2 + 4\ H^+$

What are the sources of fluoride compounds?

The most common fluoride compounds used in NSW are sodium silicofluoride for large water supplies, and sodium fluoride for medium to small water supplies. Six water treatment plants in NSW currently use hydrofluosilicic acid. Hydrofluosilicic acid, sodium silicofluoride and sodium fluoride are commonly sourced from phosphate fertilizer manufacturers. Fluorapatite is an important mineral, composed of calcium, fluoride and phosphate, commonly used as source material for the fertiliser industry. When phosphate is removed from rock, an extra step in the refining process may be taken to collect fluoride.

What standards must be met for water fluoridation?

NSW Office of Water approves the design, procurement and installation of all fluoridation plants to ensure compliance with the *Code of Practice for Fluoridation of Public Water Supplies (2011)*. Under the NSW Fluoridation Code of Practice water utilities are required to use a suitable chemical specification for the fluoridating chemical and the American Waterworks Association standard is set as a minimum. In the Code of Practice suggested specifications are included for three of the main fluoride chemicals. All finished water is tested daily to ensure correct fluoride dosing and drinking water is sampled throughout NSW to ensure compliance with *Australian Drinking Water Guidelines*.

What are the results of fluoride testing of public water supplies?

Sampling for fluoride testing is done either downstream and close to the dosing point or at points in the water distribution system as part of the NSW Health Drinking Water Monitoring Program. From **January to December 2012** the following results were available:

- **In regional NSW** 94% of the 31,317 water samples analysed daily at the treatment plant and reported to NSW Health were within the required range of 0.9 - 1.5 mg/L. The results ranged from 0 – 1.79 mg/L. The median result was 1.0 mg/L with a standard deviation of +/-0.11. Only 3 results were above 1.5 mg/L. The Code of Practice and NSW Health provide response protocols to be followed when results are above the guideline

value. The 467 drinking water samples from fluoridated supplies submitted to the NSW Health Forensic and Analytical Science Service (the state testing laboratory) were within a range from 0.05 to 1.35 mg/L. The median result was 0.98 mg/L with standard deviation of +/- 0.21.

- **For Sydney Water Corporation**, 99% of the 2800 samples analysed and reported to NSW Health were within the required range of 0.9-1.5 mg/L. No results were above 1.5mg/L. The results ranged from 0.05 to 1.21 mg/L. The median result was 1.02 mg/L with a standard deviation of +/- 0.05.
- **For Hunter Water Corporation**, 91% of the 2293 samples analysed and reported to NSW Health were within the required range of 0.9-1.5 mg/L. No results were above 1.5mg/L. The results ranged from 0.03 to 1.12 mg/L. The median result was 0.97 mg/L with a standard deviation of +/- 0.19.

Are there trace contaminants in fluoride compounds?

Trace contaminants or impurities (such as heavy metals) occur in fluoridation compounds typically at low levels. The NSW *Code of Practice for Fluoridation of Public Water Supplies* stipulates that any impurities in the fluoridation compound shall not result in non-compliance with the National Health and Medical Research Council's *Australian Drinking Water Guidelines*. Fluoride compounds are diluted with drinking water many thousand-fold to achieve 1 mg/L of fluoride[1]. To ensure that heavy metals are kept to a very low level in drinking water a maximum % by weight in lead equivalent is specified in the Code. The Code also advises that regular full chemical analysis of fluoridating compounds should be obtained by the water supply authority from the manufacturer. This testing should include assessment for levels of heavy metals.

Is fluoridated water monitored for the presence of trace contaminants?

Through the NSW Health *Drinking Water Monitoring Program*, all public water utilities monitor the chemical quality of water to ensure compliance with the *Australian Drinking Water Guidelines*. The chemical qualities of public water supply systems in NSW, which receive fluoridation, are monitored on a monthly basis. This includes tests, for example lead, arsenic and cadmium.

What are the results of chemical testing of drinking water?

In 2012 calendar year there were 1669 chemical analyses of water performed and reported to NSW Health from fluoridated and non-fluoridated supplies in regional NSW. Three illustrative results for heavy metals follow. For arsenic the guideline value is 0.01 mg/L, the average level found was 0.0009 mg/L, results ranged from 0.0005 to 0.0070 mg/L and all results were below the Australian Drinking Water guideline level. The guideline level for mercury is 0.001 mg/L, the average level found was 0.0001 mg/L, results ranged from 0.00005 to 0.0003 mg/L and all results were below the guideline value. For lead the guideline value is 0.01 mg/L, the average level found was 0.0012, the results ranged from 0.0005 to 0.0570 and there were five exceptions above the guideline level. Exceptions above the guideline value for lead occasionally occur and often relate to plumbing materials containing trace amounts of lead and samples taken without flushing.

[1] For example, hydrofluosilicic acid at 20% w/w needs to be diluted 160,000-fold to achieve 1mg/L

Can all public water supplies be fluoridated?

About three years ago a simple, safe and low cost sodium fluoride saturator system was developed, meaning many smaller water supplies can now be economically fluoridated. To date, the smallest water supply fluoridated in NSW is the Mendooran water supply, serving 400 people. For a number of small water supplies (serving less than 400 people) there may be a lack of suitable staff available locally to operate the fluoridation plant. This is taken into account when determining if a water supply can be fluoridated.

Dental caries

What is dental caries or tooth decay?

Dental caries or dental decay is a disease caused by the interplay of many factors including the presence of bacteria, resistance of enamel, refined sugars and carbohydrates in the diet, and behaviour. Bacteria in the mouth or plaque break down food containing sugar resulting in acid production. Repeated episodes, over time, result in the destruction of the tooth enamel.

How does fluoride prevent tooth decay?

Fluoride predominantly has a topical action and probably exerts its effect through fluoride ions in plaque and saliva assisting remineralisation of demineralised tooth enamel. Fluoride incorporated into tooth enamel pre-eruption also plays a role (Singh and Spencer 2004). Frequent exposure to low levels of fluoride in the oral cavity is important for prevention of decay (Featherstone 1999).

Why is tooth decay a problem?

Dental health is fundamental to one's overall health. A healthy mouth enables a person to eat, speak and socialise without pain or discomfort. Dental decay is the most common health problem of any type in Australia. Recently, dental conditions have been documented to be the highest cause of acute preventable hospital admissions in Australia. Each year in NSW during the five year period 2007-8 to 2011-12 there were on average just over 1500 hospital admissions for children less than 4 years for dental procedures to remove or restore teeth as a result of dental caries. Tooth decay and other dental pathology can result in important disability. In the NSW Adult Health Survey in 2005, 27% of respondents over the age of 75 reported they were missing all their natural teeth.

How is dental caries measured?

Dental caries can occur in either the deciduous (baby) teeth or the permanent teeth. Dental caries is best measured through surveys using standardised ways of examining and reporting. The most common measure employed in surveys is the number of decayed, missing or filled teeth per child and summary results are expressed as an average. For deciduous teeth the abbreviation is dmft (lower case) and for permanent teeth the abbreviation is DMFT (upper case). Deciduous teeth begin to be replaced by permanent teeth at age 5 or 6 and are usually all lost by age 12; all permanent teeth except for wisdom teeth generally have erupted by 12 years. Consequently children aged around 5 and 12 are commonly examined in surveys. Surveys will often report the number and proportion of children with no decay (dmft or DMFT = 0). Some surveys will also report the number of

decayed missing and filled teeth in the 10% of children with the worst dental caries (NHMRC 2007).

How much tooth decay is there in the community?

In the survey of Australian Child Dental Health Survey in 2007 on average there were 2 decayed missing or filled teeth per child (dmft = 1.95) and over half of children (54%) aged 6 had no dental caries. In the same survey in 2007 12 year-old children had on average around 1 decayed, missing or filled teeth (DMFT = 0.95) and 39% had no decay (Mejia, Amarasena et al. 2007).

How much tooth decay is there by State?

In the Australian Child Dental Health Survey 2007 the Northern Territory and Queensland had the highest prevalence of dental caries in 5 to 6 year-olds. NSW was the state with the highest proportion of children with no decay.

Table 2.4: Caries experience in the deciduous teeth of 5 to 6 year old children by state/territory, 2007

	Decayed teeth (d)		Missing teeth (m)		Filled teeth (f)		dmft	
State/territory	Mean	CI	Mean	CI	Mean	CI	Mean	CI
NSW	1.09	0.96–1.22	0.10	0.06–0.13	0.34	0.28–0.39	1.53	1.36–1.70
Qld	1.68	1.48–1.89	0.11	0.06–0.16	0.68	0.55–0.82	2.47	2.19–2.74
WA	0.97	0.88–1.05	0.05	0.03–0.07	0.49	0.44–0.55	1.51	1.40–1.62
SA	1.10	1.05–1.14	0.17	0.15–0.19	0.74	0.71–0.78	2.01	1.95–2.07
Tas	1.15	1.07–1.22	0.36	0.32–0.40	0.70	0.66–0.75	2.21	2.11–2.31
ACT	0.72	0.60–0.84	0.04	0.02–0.06	0.61	0.50–0.72	1.37	1.20–1.54
NT	2.57	2.11–3.03	0.14	–0.01–0.28	1.04	0.66–1.42	3.75	3.11–4.38
Australia	**1.26**	**1.18–1.34**	**0.11**	**0.09–0.13**	**0.52**	**0.47–0.56**	**1.88**	**1.78–1.99**

Note: Results from Victoria are excluded due to lack of access to the data.

Australian Dental Health Survey 2007

In the permanent dentition the highest prevalence of dental caries was found in Queensland.

Table 2.5: 12 year old caries experience in the permanent dentition by state/territory, 2007

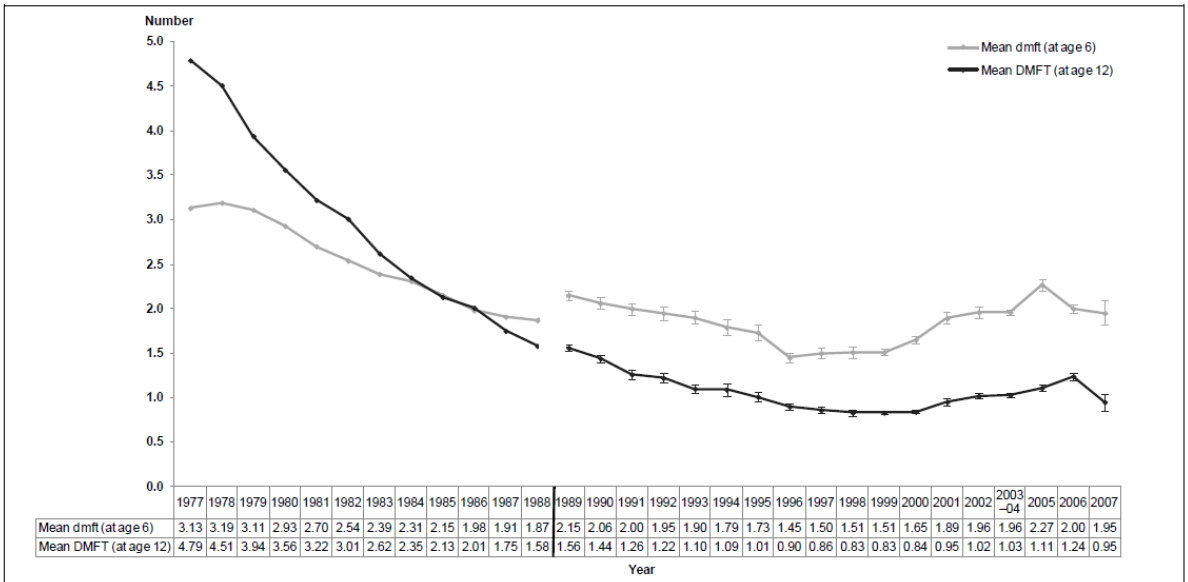
	Decayed teeth (D)		Missing teeth (M)		Filled teeth (F)		DMFT	
State/territory	Mean	95% CI	Mean	95% CI	Mean	95% CI	Mean	95% CI
NSW	0.42	0.35–0.50	0.03	0.01–0.04	0.30	0.25–0.35	0.75	0.65–0.85
Qld	0.69	0.48–0.91	0.07	0.00–0.17	0.56	0.44–0.67	1.32	1.02–1.63
WA	0.40	0.31–0.50	0.07	0.04–0.10	0.41	0.34–0.48	0.84	0.73–0.95
SA	0.40	0.37–0.43	0.02	0.02–0.03	0.51	0.48–0.53	0.93	0.88–0.97
Tas	0.46	0.41–0.52	0.10	0.07–0.13	0.54	0.49–0.59	1.10	1.02–1.19
ACT	0.23	0.16–0.30	0.03	0.01–0.04	0.55	0.45–0.64	0.80	0.68–0.92
NT	0.32	0.17–0.46	0.11	0.00–0.25	0.31	0.16–0.45	0.74	0.44–1.03
Australia	**0.49**	**0.42–0.56**	**0.05**	**0.02–0.08**	**0.42**	**0.38–0.46**	**0.95**	**0.85–1.05**

Note: Results from Victoria are excluded due to lack of access to the data.

Australian Dental Health Survey 2007

What have been the trends in dental caries in Australia?

In 1977, 6 year-old children had on average 3.13 decayed missing or filled teeth. Between 1977 and the mid 1990s the average number of teeth in 6 year-olds affected by caries halved (it was 1.45 in 1996), but has increased a little since then. In 1977 12 year-old children had on average 4.79 permanent teeth affected by dental caries. This declined more than five-fold by 1998 to reach a minimum of less than an average of 1 tooth affected by caries (DMFT = 0.85) but since then a small upward trend has been apparent (Mejia, Amarasena et al. 2007).



	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003–04	2005	2006	2007
Mean dmft (at age 6)	3.13	3.19	3.11	2.93	2.70	2.54	2.39	2.31	2.15	1.98	1.91	1.87	2.15	2.06	2.00	1.95	1.90	1.79	1.73	1.45	1.50	1.51	1.51	1.65	1.89	1.96	1.96	2.27	2.00	1.95
Mean DMFT (at age 12)	4.79	4.51	3.94	3.56	3.22	3.01	2.62	2.35	2.13	2.01	1.75	1.58	1.56	1.44	1.26	1.22	1.10	1.09	1.01	0.90	0.86	0.83	0.83	0.84	0.95	1.02	1.03	1.11	1.24	0.95

Note: From 1977 to 1988, data are from the Australian School Dental Scheme evaluation. From 1989 data are from the Child Dental Health Survey.

Figure 3.1: Mean dmft (at age 6) and DMFT (at age 12), Australia, 1977 to 2007

Australian Dental Health Survey 2007

Are there variations in dental caries in NSW?

The NSW Child Health Dental Survey documents some important variations by area health service (old boundaries). There was a three-fold variation in the number of decayed missing and filled teeth of 5/6 year-olds from 2.75 in North Coast to 0.91 in South Eastern Sydney.

Table 8: 5 and 6 year old children - decayed, missing and filled teeth and dmft index by Area Health Service

AHS	Number of children	Decayed (d)		Missing (m)		Filled (f)		dmft	
		Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM
SSWAHS	313	1.08	0.10	0.06	0.03	0.34	0.05	1.48	0.13
SESIAHS	257	0.51	0.07	0.03	0.03	0.37	0.06	0.91	0.10
SWAHS	323	1.36	0.11	0.11	0.04	0.30	0.04	1.77	0.13
NSCCAHS	304	0.70	0.08	0.02	0.01	0.27	0.04	0.99	0.10
HNEAHS	255	0.93	0.10	0.06	0.01	0.21	0.04	1.20	0.11
NCAHS	215	1.94	0.15	0.17	0.04	0.64	0.09	2.75	0.19
GSAHS	236	1.56	0.11	0.31	0.07	0.29	0.04	2.16	0.14
GWAHS	192	1.81	0.12	0.33	0.06	0.52	0.06	2.66	0.16
NSW	**2,095**	**1.09**	**0.04**	**0.10**	**0.01**	**0.34**	**0.02**	**1.53**	**0.05**

NSW Child Dental Health Survey 2007

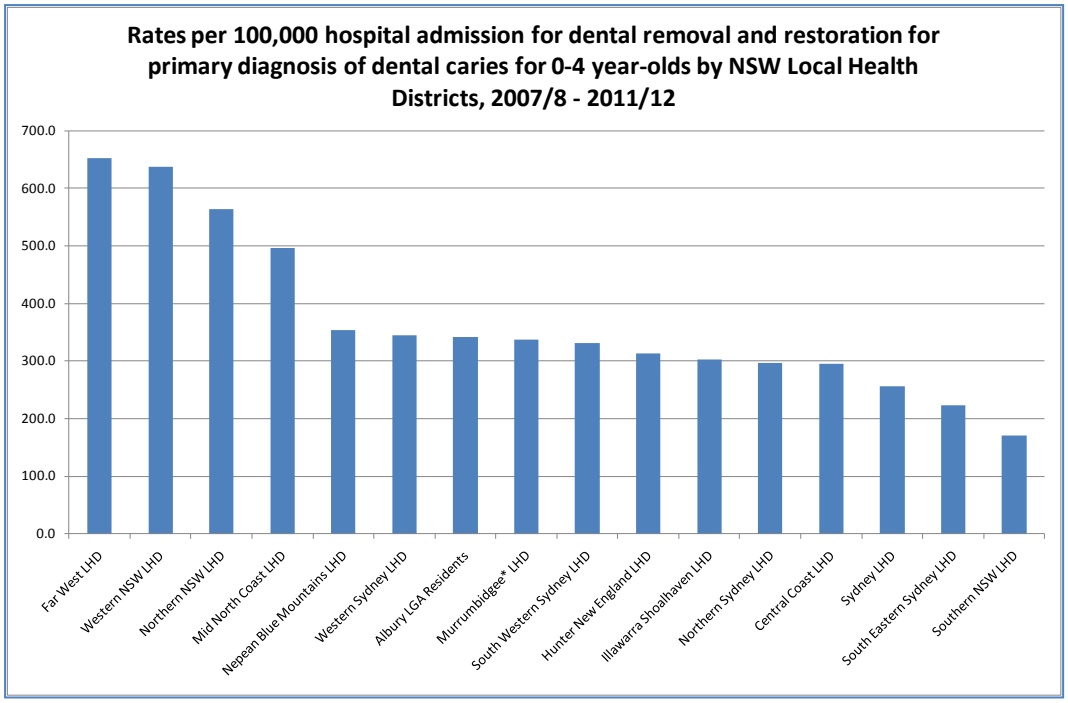
In 11/12 year-olds there was a two-fold variation in the number of decayed missing and filled teeth from 1.07 in North Coast to 0.44 in Hunter New England (COHS 2009).

Table 11: 11 and 12 year old children – decayed, missing and filled teeth and DMFT index by Area Health Service

AHS	Number of children	Decayed (D)		Missing (M)		Filled (F)		DMFT	
		Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM
SSWAHS	345	0.46	0.05	0.03	0.01	0.19	0.03	0.69	0.06
SESIAHS	299	0.29	0.04	0.00	0.00	0.37	0.04	0.66	0.06
SWAHS	381	0.54	0.04	0.03	0.01	0.31	0.03	0.88	0.05
NSCCAHS	364	0.31	0.04	0.02	0.01	0.34	0.04	0.68	0.05
HNEAHS	292	0.20	0.03	0.04	0.01	0.20	0.03	0.44	0.04
NCAHS	254	0.66	0.06	0.04	0.01	0.38	0.05	1.07	0.08
GSAHS	263	0.34	0.04	0.02	0.01	0.48	0.04	0.83	0.06
GWAHS	220	0.49	0.04	0.02	0.01	0.46	0.04	0.96	0.06
NSW	**2,418**	**0.40**	**0.02**	**0.02**	**0.00**	**0.31**	**0.01**	**0.74**	**0.02**

NSW Child Dental Health Survey 2007

There are also variations in the rate of admission to hospital for dental procedures where the principal diagnosis is dental caries. Variations may be due to Aboriginality, remoteness, low socio-economic status, dental practice and unavailability of fluoridated drinking water.



Source: NSW Inpatient Statistics

Benefits of fluoridation

Is there any evidence to support fluoridation of water supplies?

The benefit of fluoridation is the prevention of dental caries (tooth decay). There have been many, many studies examining the effect of fluoride in drinking water on dental caries reflecting the long history of fluoridation. Some of these studies have been of higher quality than others. There has been one substantial official review of the evidence in Australia: the National Health and Medical Research Council's *A Systematic Review of the Efficacy and Safety of Fluoridation* (NHMRC 2007). The NHMRC review builds on an earlier very thorough review by the NHS Centre for Reviews and Dissemination at the University of York - *A Systematic Review of Public Water Fluoridation* completed in 2000 (McDonagh, Whiting et al. 2000). Both these reviews had similar scope, adopted very similar methods of evaluating the evidence, and included only higher quality studies. Both reached the same conclusions. The NHS York Review and the NHMRC Review both found that on average when children in the same community were surveyed before and after fluoridation of the water supply there was on average a 14.3% improvement in the proportion of children with no dental decay (i.e. % dmft or DMFT = 0). The average reduction in number of decayed, missing or filled teeth was 2.61. Cohort studies that follow the same children over time have also found fewer new instances of dental decay in children in a newly fluoridated area compared with an unfluoridated area. (Hardwick, Teasdale et al. 1982) In 14/22 studies of communities where fluoridation was stopped there was an increase in dental caries compared with a control community.

Do surveys in Australia support the effectiveness of fluoride in drinking water?

In the NSW Child Dental Health Survey of 2007 (Centre For Oral Health Strategy 2009) approximately 15% of children (total sample size 7,975) were from non-fluoridated areas. In 5 and 6 year-olds the numbers of decayed, missing and filled teeth in fluoridated areas was

1.4 and in un-fluoridated areas it was 2.62. In 11 and 12 year olds the DMFT score in fluoridated areas was 0.71 and in un-fluoridated areas it was 0.98. When this survey data was analysed controlling for differences in the number of Aboriginal people, concession card holders and children with non-English speaking parents the number of decayed missing and filled teeth was still significantly different between fluoridated and non-fluoridated areas.

Do before and after studies in Australia support the use of fluoridation?

The Blue Mountains was fluoridated in 1992 and dental surveys were carried out in schools in 1993 (before fluoridation could have had any important effect) and 2003 after 10 years of fluoridated water supply (Evans, Hsiau et al. 2009). There were 525 children (with lifelong residence) surveyed in 1993 and 731 in 2003. In 5-8 year-olds the proportion of children with any caries declined from 56% to 27% and in children with any decayed missing or filled teeth (i.e. excluding those children with no caries) there was a significant decline from an average of 4.22 dmft to 2.48 dmft. In the permanent teeth of 8-11 year-olds there was a smaller decline from 35% to 12% in the proportion of children with caries and a decline from 2.21 DMFT to 1.73 DMFT. In a comparison community in the Hawkesbury that had been fluoridated since 1968 the level of caries was lower at baseline in 1993 and there was almost no decline in caries over the same period.

Does fluoridated water benefit people from lower socio-economic backgrounds?

Large studies of NSW data show a gradient of dental caries by socio-economic status. Children from residential areas with low SEIFA scores (Socio-Economic Index for Areas) have higher numbers of decayed missing and filled teeth than children from high SEIFA score areas (Armfield 2005). Fluoridation appears to be equally effective in lowering tooth decay in low SES and high SES areas (Armfield 2005, Armfield 2008).

Does fluoridation benefit adults?

Australian adults have a substantial burden of dental disease: 60% NSW adults surveyed in 2004-6 visited the dentist in the previous 12 months (Sivaneswaran 2009). Australian research suggests that adults born before widespread fluoridation (and so not exposed to fluoride as young children) have fewer decayed, missing or filled teeth if they were exposed to fluoridated water as adults (Slade, Sanders et al. 2013). There is some evidence that adults exposed to high levels of naturally fluoridated water have a lower prevalence of an adult condition - root caries (Stamm, Banting et al. 1990).

Do randomised controlled trials support the fluoridation of the water supply?

Randomised controlled trials randomly allocate individuals to an intervention and a control group and compare the effects in these two groups. Randomised trials are commonly used to evaluate the effects of individual treatments. There are many randomised trials of topical fluoride treatments (toothpaste, varnish, sealants) and they unequivocally provide support for the benefits of fluoride. The NHMRC review (reporting the results of a Cochrane review) found that the proportion of caries prevented varied from between 21% and 40% for various topical fluoride treatments compared with placebo (varnish > mouth rinse >toothpaste >gel) (NHMRC 2007). The randomised trails of individual fluoride treatments provide high quality evidence that supports the effectiveness of fluoride as a preventive agent. Many public health interventions that are designed to be delivered to groups of people rather than individuals (fluoridating the water supply, advertising campaigns, putting in cycle paths to increase physical activity) are difficult to evaluate using randomised

controlled trials. Although there are no randomised controlled trials of fluoridation of the water supply, there have been other well-designed studies as detailed and summarised in the NHMRC's *A Systematic Review of the Efficacy and Safety of Fluoridation*.

Can fluoride be delivered in ways other than through the water supply?

In some parts of the world fluoride is added as a supplement through salt or through milk. For example salt fluoridation is practised in Jamaica, Columbia and the Swiss Canton of Vaud. Fluoride is added to milk in parts of Bulgaria, Chile and Peru. In some cases alternative methods of fluoridation are chosen because of technical issues with the water supply in, for example, remote rural areas. (Anonymous) The NHMRC reviewed the evidence for milk and salt fluoridation and found that the evidence for milk fluoridation was of lower quality than that for water fluoridation but generally supported a reduction in dental caries. No studies of salt fluoridation were of acceptable quality and the NHMRC were unable to make a judgement about the efficacy of this form of supplementary fluoridation (NHMRC 2007).

What has happened in countries that have not fluoridated their water supply?

Many developed countries around the world, particularly in Europe, have not fluoridated their water supply, or have fluoridated their water supply and then ceased fluoridation or in some cases used an alternative form of supplementary fluoridation. Some of these largely unfluoridated countries have reported steep declines in dental caries that parallel declines seen in largely fluoridated countries (Marthaler 2004). Dental caries is related to many factors including diet – particularly sugar and carbohydrate exposure, oral hygiene, bacterial mouth flora, access to fluoridated toothpaste, and other sources of fluoride. Fluoridation of the water supply is not the only factor. However, as discussed previously, in studies where it has been introduced a reduction in dental caries is seen.

Consequences of too much fluoride

Dental fluorosis

Dental fluorosis is a discolouration of teeth and is a recognised side-effect associated with excess fluoride exposure. Its effects on teeth occur just prior to eruption. Teeth develop from birth to approximately six to eight years of age. In its mildest (and most common) form dental fluorosis manifests as barely noticeable whitish marks on teeth. Dental fluorosis can be more severe, resulting in staining and pitting of the teeth. The NHMRC systematic review looked at the evidence from many studies that measure the prevalence of fluorosis in children's teeth with different levels of fluoride in the water. They compared supplies with little fluoride and optimally fluoridated water supply (0.8-1.2 mg/L). They estimated that the risk of fluorosis of 'aesthetic concern' (>=TF 3) was four-fold higher in optimally fluoridated supplies and that the prevalence of fluorosis of 'aesthetic concern' (that could be expected in optimally fluoridated water supplies) was around 4-5% (NHMRC 2007). Fluorosis at mild levels (TF 1 or 2) may be unnoticed and may be perceived to be more aesthetically pleasing than normal teeth but when fluorosis is moderate (TF score 3) it is perceived as less pleasing (Do and Spencer 2007).

Skeletal fluorosis

Skeletal fluorosis occurs in individuals with excessively high levels of fluoride exposure, and is endemic in several parts of the world including India, China, parts of the Middle East and

Africa, where water supplies have naturally occurring fluoride levels much higher than those recommended in Australia. It is rarely described outside these areas and some authors have suggested that crippling skeletal fluorosis in endemic areas may be due to other nutritional factors (Kaminsky, Mahoney et al. 1990). The Institutes of Medicine in their 1997 report were only able to locate five case reports of 'crippling' skeletal fluorosis over a 35 year period in the United States (IOM 1997). The National Research Council (2006) documented a further case with an estimated daily exposure above 37 mg/day from tea and well water.

Fluoride exposure is Australia

Do we get too much fluoride?

The simplest answer to this question is the prevalence of dental fluorosis is very low so Australian children are not exposed to too much fluoride. The NSW Children's Dental Survey in 2007 found that 3.8% of children aged 11-12 years in fluoridated areas had fluorosis of 'aesthetic concern' (a TF index of 3 or greater) in their permanent teeth (Centre For Oral Health Strategy 2009). A fluorosis index of 3 indicates that there are cloudy white patches on the teeth. Teeth with a TF index of 3 are not functionally impaired.

Are there guideline values for fluoride intake?

The Institutes of Medicine in the United States in 1997 produced tolerable upper limit guidelines ranging from 0.7 mg/day for infants less than 6 months to 10 mg/day for children >8 years and adults (IOM 1997). These values were chosen to protect against dental fluorosis in children and skeletal fluorosis in adults. Australia and New Zealand nutrient reference values for fluoride are highly similar (NHMRC 2006). These values are given in the table below.

Population subgroup	Upper Limit (mg/day)
Infants 0-6 months	0.7
Infants 7-12 months	0.9
1-3 years	1.3
4-8 years	2.2
9-13 years	10.0
14-18 years	10.0
Adults 19 years including pregnant women	10.0

What are the main dietary sources of exposure to fluoride?

Fluoride is present in some foods at low levels. Some examples include seafood and some teas. However, the principal source in fluoridated areas is drinking water and beverages made with drinking water. In Australia total dietary exposure to fluoride was considered in 2009 by Food Standards Australia and New Zealand in the assessment of an application by a manufacturer to voluntarily add fluoride to bottled water (FSANZ 2009) Using dietary modelling data they estimated that the suggested upper limits for fluoride dietary intake would generally be exceeded for average weight formula-fed infants and older infants with a mixed diet when drinking water was fluoridated to 1 mg/L. A smaller proportion of children aged between 2 and 8 years would also exceed the suggested dietary upper limit value. Older children and adults would almost never exceed the suggested dietary limit.

Although some infants and children may get more dietary fluoride than recommended, the consequences of this are limited, because, as discussed above, the prevalence of dental fluorosis remains low.

What about non-dietary sources of fluoride?

The average exposure to fluoride has probably increased since the widespread availability of fluoridated toothpaste and other fluoride products. There are also pharmaceutical sources of fluoride, small sources in the air and pesticides containing fluoride. There are no Australian estimates of total dose of fluoride from all sources. The Environment Protection Agency (EPA) in the United States have estimated the total dose by age for the United States population assuming exposure to an averagely fluoridated drinking water supply (0.87 mg/L) and 90th centile (i.e. high) water consumption (USEPA 2010). The estimates included all sources including food and beverages, toothpaste, dental procedures, pharmaceuticals, soil ingestion and air. The US document concluded that some children up to the age of 7 years may be exposed to higher amounts of fluoride than recommended. Fluoride toothpaste is an important source in children up to the age of 7 who ingest more toothpaste than older children. This analysis also shows that drinking water is still a very important source of fluoride.

What protections are there to prevent against too much fluoride?

The risk for dental fluorosis of the permanent teeth is related to fluoride exposure from birth to 8 years and this is the more critical time for caution about excess fluoride exposure. The National Health and Medical Research Council *Australian Drinking Water Guidelines* established a health guideline value (upper limit) of 1.5 mg/L based on protecting against dental fluorosis. Teeth of young children are further protected by the use of low strength fluoride toothpaste in Australia which became common in the 1990s. According to recommendations made in a consensus workshop in 2006 toothpaste should not be used until age 18 months, from 18 months to 5 years reduced fluoride toothpaste containing 0.4 - 0.55 mg /g of fluoride should be used and only a small pea-sized amount placed on the brush. Full strength toothpaste (1mg/g) should not be used until age 6 (Health 2006). These recommendations probably led to a halving of dental fluorosis (Spencer and Do 2008).

Is bottle-feeding safe?

Infants should be exclusively breast-fed for the first six months of life (NHMRC 2012). However, this is not always possible. Bottle-fed infants may be exposed to fluoride through water used to prepare formula and, to a much smaller extent, in infant formulae. Studies in the United States (Marshall, Levy et al. 2004), Australia (Riordan 1993) and a systematic review (Hujoel, Zina et al. 2009) suggest that bottle-feeding and / or early weaning is a risk factor for dental fluorosis. In the United States the prevalence of dental fluorosis is higher than in Australia, and official statements in the US suggest making up powdered infant formula with low fluoride content water is an option that should be considered by parents (Berg, Gerweck et al. 2011, CDC 2013). In Australia, Food Standards labelling requirements for fluoride in infant formula have led to dry powdered infant formulae having low fluoride content (Clifford, Olszowy et al. 2009). In addition the measures outlined above to prevent too much fluoride exposure from toothpaste in early childhood appear to be effective in reducing the prevalence of fluorosis. The National Health and Medical Research Council considers that it is safe to use fluoridated drinking water to make up infant formula. (NHMRC 2007). A consensus statement on the use of fluoride in Australia also concluded

that infant formula is safe when made up with fluoridated drinking water (Australian Research Centre for Population Oral Health 2006).

Claims about harms of fluoridated water

Are there any risks of bone fracture?

Around 99% of fluoride in the body resides in bone. It is incorporated within the bone matrix in a modified form of hydoxyapatite crystal (fluoroapatite). There has been long-standing interest in fluoride effects on bone including use as a pharmaceutical agent at high doses to promote bone mineral density. There have been many studies investigating whether there is an increase in bone fractures at levels of fluoride exposure found in drinking water. The National Health and Medical Research Council in 2007 in their systematic review of studies concluded that there is no clear association between water fluoridation in the optimal range and hip fractures or other fractures (NHMRC 2007). This was also the conclusion of the NHS York review in 2000 (McDonagh, Whiting et al. 2000). The US National Research Council in their publication *Fluoride in Drinking Water* also examined the risk of fracture and was specifically concerned with any risks at a range of 2-4 mg/L because of the range of fluoride exposure in some naturally fluoridated areas of the United States. They considered that at these higher ranges of exposure particularly at lifetime exposures to drinking water at 4 mg/L there may be an increase in fracture rates (National Research Council 2006). This result, although of interest, is not of relevance in the Australian context where natural fluoride occurring at high levels in the water supply is rare.

Are there any risks of kidney disease?

The kidneys are responsible for eliminating fluoride from the body and the ability of people with impaired kidneys to eliminate fluoride is lower. Kidney Health Australia (www.kidney.org.au) state there is limited evidence that persons with advanced kidney disease who ingest substances with high concentrations of fluoride (for example certain dental treatments or some teas) may be at risk of skeletal fluorosis. They recommend prudent avoidance. Kidney Health Australia also state that there is no evidence that consumption of optimally fluoridated water causes chronic kidney disease or poses any risks for people with established chronic kidney disease.

In the case of dialysis, fluoride concentrations in the final feed water to the dialysis machine must comply with established water guidelines, and be less than 0.2 mg/L. The dialysis water must be deionised (free of electrically charged particles) to ensure it is able to filter the dialysis patient's blood appropriately. This issue relates to all electrically charged particles, not just fluoride. Dialysis machines use reverse osmosis to remove fluoride and other electrically charged particles.

Are there risks of cancer associated with fluoridating the water?

The NHMRC in their systematic review examined studies reporting the effect on cancer incidence (all cancers and bone cancers) in populations exposed to different levels of fluoride. They used the NHS 'York' review as their base analysis. The summary of the evidence from both the York review and the NHRMC review was that the studies were of

lower quality and there was no convincing evidence of any effect. (McDonagh, Whiting et al. 2000), (NHMRC 2007).

Fluoride has effects on cells responsible for bone formation and there have been some specific investigations into a possible relationship between fluoride exposure and bone cancer. A study by Bassin (Bassin, Wypij et al. 2006) reported a 5-fold increase in risk of osteosarcoma in optimally or highly fluoridated areas compared with areas that had low fluoride by comparing the exposures of 103 cases with 202 controls from the same orthopaedic hospitals . Other case-control studies have not found this association (Kim, Hayes et al. 2011), (Moss, Kanarek et al. 1995). Case-control studies are liable to certain biases (errors) and the United States National Research Council in their commentary on the Bassin study were concerned that controls may not have been selected so that their exposure to fluoride could be compared with the exposure of osteosarcoma cases. In a recently published analysis of variation in osteosarcoma in the US Levy (Levy and Leclerc 2012) found no evidence of variation in the rate of osteosarcoma by the fluoridation status by State. In previous studies of incidence of bone cancer there does not seem to be an increase in incidence after fluoridation over time that we would expect to see if fluoride in drinking water was truly associated with an increase in osteosarcoma or other bone cancer. Osteosarcoma is a very rare cancer that occurs in teenagers and then again in people over the 50. In NSW in the 5 years between 2004 and 2008 there were 11 osteosarcomas in children reported to the cancer registry in NSW.

Can people be allergic to fluoride?

It is highly unlikely that fluoridated water causes allergic reactions or allergy-like symptoms. The range of symptoms typically reported is not typical of allergic conditions. Because fluoride is already present in many food sources it seems unlikely that additional exposure to fluoride in water could be a trigger for allergic symptoms. The evidence considered by the National Research Council (2006) in *Fluoride in Drinking Water* in their discussion of allergy was scant.

Does fluoride lower intelligence?

Studies have examined Intelligence Quotient (IQ) scores in children exposed to significantly higher fluoride levels than those used in Australia – the majority in China. A 2012 review of previous studies (Choi, Sun et al. 2012) suggested the possibility of an adverse effect on children's neurodevelopment. Studies reported differences in IQ between communities with different levels of fluoride in the water supply. Each study reviewed had major deficiencies that limit the conclusions that can be drawn. Most studies were small, measurement of intelligence was sometimes non-standard, and some important other factors that could explain differences in intelligence were not taken into account. Importantly the low fluoride control groups often had exposures comparable to fluoride in drinking water in Australia and the high fluoride groups exposures up to 10 times higher than that allowed in drinking water in Australia. There is no reason to believe the reported effects would be associated with optimally fluoridated drinking water.

Can fluoride affect the thyroid gland?

Very early in the history of investigation of dental fluorosis and its link to excess fluoride in drinking water in the United States there were observations of goitre (enlarged thyroid) in children. There have been various reports since of a link between fluoride exposure and

goitre or other thyroid dysfunction. This subject was reviewed by the U.S. National Research Committee and it appears there is an absence of good evidence that fluoride exposure is related to thyroid dysfunction or is associated with goitre at levels found in drinking water and independent of other factors. Many studies were from developing countries with relatively high fluoride levels. Even well reported studies such as that of Joost (Jooste, Weight et al. 1999) simply report prevalence of goitre and fluoride levels in water in different communities. There may be effects of fluoride on the thyroid in conditions of iodine deficiency or at high levels of fluoride exposure perhaps in the presence of other factors. There appears to be no clinical effects on the thyroid that could be ascribed to the low level fluoride exposure in Australia.

Can fluoride affect the pineal gland?

There has also been interest in possible effects on the pineal gland (in the brain) because calcium is sometimes deposited in the pineal gland and fluoride binds with calcium. There have been investigations into various functions that could be partly governed by the pineal gland and fluoride exposure (e.g. possible associations with early menarche). Studies (for example variation in age of onset of menarche) have been too simple to draw any conclusions.

Society making decisions

Is water fluoridation ethical?

Whether a public health measure is ethical can be viewed in many different ways and some common considerations include benefits, harms, costs, fairness and individual rights. The ethical perspective that many public health and other policy-making bodies adopt is a utilitarian perspective. This perspective supports a decision as ethical if there is more benefit than harm. This perspective tolerates some harm to some people if the overall benefit is greater. This perspective is problematic if important harms accrue to certain groups in the community and not others. Fluoridation is an intervention with benefits across all age ranges and only a single established side effect: dental fluorosis. This side effect is minor, cosmetic and accrues in the children who directly benefit from the caries-preventing effects of fluoride. Justice perspectives are also important in ethical decision-making. Everyone who has access to a water supply that is fluoridated has access to this public health measure. This includes people with the poorest dental health such as disadvantaged people and Aboriginal people. Often these people have limited access to dental services and basic dental items such as toothbrushes and fluoridated toothpaste.

Is individual consent required to fluoridate?

Some people argue that fluoride is a medical treatment and that individual free and informed consent is required and that this is denied them when a decision is made to fluoridate an entire community. Reference is sometimes made the Universal Declaration on Bioethics and Human Rights and Bioethics which in Article 6 states that any preventive, diagnostic or medical therapeutic intervention is only to carried out with prior free and informed consent (UNESCO 2005). The view of most public health bodies is that fluoridation is not an individual therapeutic intervention and individual free and informed consent is not required. Fluoridation is not individually prescribed or recommended and side effects are restricted to a minor cosmetic condition (dental fluorosis). Fluoridation is more closely

related to a supplementation or fortification of foods, such as the addition of iodine to salt, and folate to bread. The framework for decisions about fortification of foods for public health benefit includes safeguards for proper process and proper consultation. For fluoridation and other similar public policy decisions ethical tests are met by transparent government processes, community consultation and engagement.

Is water fluoridation cost-effective?

A recent Australian study (Cobiac and Vos 2012) shows that extension of fluoridation to un-fluoridated urban communities (>1000 people) is not only cost-effective (good value for the health gain achieved) but is cost saving. For each $1 million invested in capital and maintenance over an assumed 15 year life of a water treatment plant there would an estimated direct saving of $7 million (range 5-20) in avoided treatment costs associated with dental caries. For each $1 million in investment there would be prevention of pain and suffering amounting to 285 disability adjusted life years (DALYs). The study assumed fluoridation only benefited children and did not include the costs of hospital admission – so potentially the benefits and savings may be higher (Cobiac and Vos 2012). However, Cobiac and Vos probably underestimated the costs of fluoridation in smaller urban communities. Recent experience in NSW indicates that the cost of a fluoridation plant to service small communities can be modest. For example the fluoridation plants for Braidwood (pop. 1500) and Currandooly (pop. 3000) each cost around $70,000. The policy decision in NSW that communities pay only ongoing costs and not capital costs means that the direct cost to communities is exceptionally low.

Are people in NSW in favour of water fluoridation?

The NSW Population Health Survey is an ongoing telephone survey of the health of people who live in NSW. The survey is done to assess changes over time in self-reported health behaviours, health status and health service use. The survey collects data from approximately 12,000 NSW residents annually. From 2005 to 2008 the survey included questions to assess the level of community support for water fluoridation ('Do you agree with adding fluoride to your public water supply to prevent tooth decay?'). In 2008, 87% of adults surveyed were in favour of fluoridating public water supplies. People in urban areas were more likely to support water fluoridation (90%) than people in rural areas (82%) (2009). The questions were removed from the health survey after 2008 as there had been little change in the level of community support for water fluoridation since 2005. An independent survey conducted in 2005 found equally strong support for fluoridation of the water for communities that receive water from Rous Water (Ballina, Byron, Lismore and Richmond Valley) – 62% in favour of fluoridation, and only 22% not in favour.

Can fluoride be added to salt or milk or bottled water?

As stated previously, the NHMRC reviewed the evidence for milk and salt fluoridation and found that the evidence for milk fluoridation was of lower quality than that for water fluoridation but generally supported a reduction in dental caries. No studies of salt fluoridation were of acceptable quality and the NHMRC were unable to make form a judgement about the efficacy of this form of supplementary fluoridation (NHMRC 2007). Following an application by a manufacturer the Food Standards Authority of Australia and New Zealand (FSANZ) approved fluoride as an additive to packaged water in 2009 at levels between 0.6 and 1.0 mg/L. Although it has been suggested that bottled water could form an alternative source of fluoride overall consumption of fluoride is low and in the

accompanying risk assessment commissioned by FSANZ annual consumption of still packaged water in 2006 only amounted to 14 litres per person (FSANZ 2009). The general concern with all other forms of supplementation (as an alternative to fluoridating the water supply) is that total exposure and frequency of exposure will be insufficient to prevent dental caries and that some groups in the population in particular will be worse off.

Why can't people who want fluoride just use toothpaste?

As discussed in a previous section there is high quality evidence that fluoride containing topical treatments such as toothpaste reduce dental caries. The effect of fluoridation of the water supply appears to provide additional protection over and above the use of fluoride containing toothpaste and brushing. Further it provides protection to all irrespective of their access to dental treatments, socio-economic background, and health behaviour.

Effects on the environment

Can fluoridated water be used in organic farming?

Fluoride is a naturally occurring element. Fluoride is present naturally in water sources and soil, as well as in some commonly consumed foods such as tea. Fluoride is present in some water supplies at similar concentrations to fluoridated drinking water. Under the Australian Certified Organic Standard 2010 Version 1.0, Annex III, drinking (potable) water is permitted as a conventional (non-certified) ingredient (see http://www.bfa.com.au/Portals/0/ACO_2010_Standard_full.pdf)

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