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Nutrient Reference Values for Australia and New Zealand
Including Recommended Dietary Intakes

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FLUORIDE

BACKGROUND

Fluoride is a normal constituent of the human body, involved in the mineralisation of both teeth and bones (Fairley et al 1983, Varughese & Moreno 1981). The fluoride concentration in bones and teeth is about 10,000 times that in body fluids and soft tissues (Bergmann & Bergmann 1991, 1995). Nearly 99% of the body's fluoride is bound strongly to calcified tissues. Fluoride in bone appears to exist in both rapidly- and slowly-exchangeable pools. Because of its role in the prevention of dental caries, fluoride has been classified as essential to human health (Bergmann & Bergmann 1991, FNB:IOM 1997).

Ingestion of fluoride in the pre-eruptive development of teeth has the effect of reducing caries due to uptake of fluoride by enamel crystallites and formation of fluorohydroxyapatite which is less soluble than hydroxyapatite (Brown et al 1977, Chow 1990). The post-eruptive effect on reducing caries is due to reduced acid production by bacteria and increased enamel remineralisation in acidogenic challenge (Bowden 1990, Hamilton 1990, Marquis 1995). Fluoride also has a unique ability to stimulate new bone formation and as such has been used as an experimental drug for the treatment of osteoporosis (Kleerekoper & Mendlovic 1993) although results have been variable depending on site assessed and the outcome measured (Kroger et al 1994, Riggs et al 1990, Sowers et al 1986, 1991).

Because of the low natural levels of fluoride in some water supplies and high levels of dental caries, many authorities worldwide, including Australia and New Zealand, have permitted, or instigated, fluoridation of water supplies. Although this has met some opposition, partly because of the potential health or dental effects that include fluorosis, the NHMRC concluded that a concentration of 1 mg/L secures most of the caries preventive effect available from fluoridated water, while maintaining minimal contribution of water fluoride to dental fluorosis in children and that there was no evidence of adverse health effects attributable to fluoride in communities exposed to a combination of fluoridated water (1 mg/L) and contemporary discretionary sources of fluoride (NHMRC 1991).

Not all Australian water supplies are fluoridated, notably those in parts of Queensland such as Brisbane. Concentrations in fluoridated areas are within the range identified by the NHMRC as safe and effective, varying from 0.6 mg/L in Darwin to 1.1 mg/L in Hobart. In New Zealand, the Ministry of Health (MOH) has recommended fluoridation of water supplies since the 1950s as the most effective and efficient way of preventing dental caries in communities receiving a reticulated water supply. In the Drinking Water Standards 2000, fluoridation is recommended at a level of 0.7–1.0 mg/L in drinking water. Around 85% of the New Zealand population is on what the government considers to be satisfactorily safe community water supplies in terms of fluoride content. Another 5% of the population are on community water supplies. Some of the larger centres without fluoridated water supplies currently are Whangarei, Tauranga, Wanganui, Napier, Nelson, Blenheim, Christchurch, Timaru and Oamaru.

The World Health Organization states in a review of chronic disease and diet that evidence that both locally applied and systemic fluoride are preventive for dental caries is convincing (WHO 2003).

One of the concerns expressed about fluoridation of the water supply relates to increasing rates of fluorosis in children seen in some communities over the same period as fluoridation has been practised. Dental fluorosis is a biomarker of over-exposure to fluoride among young children and results in a mottling of teeth. Recent research in Australia among children not exposed and exposed to water fluoridation indicated prevalences of 19% and 34%, respectively (Puzio et al 1993). However, Kumar et al (1989) have shown that the increases in fluorosis in other communities have been greater in areas with non-fluoridated water supplies and are likely to be due to increased intake of fluoride from supplements and ingestion from toothpaste and reconstituted infant formula (Osuji et al 1988, Pendrys & Stamm 1990).

Fluoride intake from most foods is low. Foods generally have concentrations well below 0.05 mg/100 g (Taves 1983). However, water in fluoridated areas, as well as beverages, teas, some marine fish and some infant formulas, especially those that are made or reconstituted with fluoridated water,

generally have higher concentrations. Other sources of fluoride include supplements and dental products. Water-soluble fluoride eg sodium fluoride, is nearly completely absorbed. The bioavailability may be reduced by the presence of calcium, magnesium, aluminium, iron or other cations. Absorbed fluoride is rapidly bound to the minerals in bones and teeth. Most of the non-retained or metabolic fluoride is excreted through the kidneys and the remainder via the intestines. In healthy young or middle-aged adults, about 50% of absorbed fluoride is retained and 50% excreted, but young children may retain as much as 80% (Eksterand et al 1994a,b).

Indicators used to assess the requirements for fluoride include prevalence of dental caries, measures of bone mineral content and fluoride balance studies.

1 mmol fluoride = 19 mg fluoride

RECOMMENDATIONS BY LIFE STAGE AND GENDER

Infants	**AI**	**Fluoride**
0–6 months	**0.01 mg/day**	
7–12 months	**0.50 mg/day**	

***Rationale*:** The AI for 0–6 months was calculated by multiplying together the average intake of breast milk (0.78 L/day) and the average concentration of fluoride in breast milk of 0.013 mg/L (Dabeka et al 1986, FNB:IOM 1997) for mothers in areas with fluoridated water. Levels in formulas can vary widely depending on the concentration in the water used to reconstitute it. The AI for 0–6 months was based on extensive documentation about relationships between caries, water concentrations and fluoride intake (FNB:IOM 1997). A level of 0.05 mg/kg/day confers a high level of protection against caries and is not associated with unwanted health effects. Assuming a standard weight of 9 kg, this gives an AI of 0.5 mg/day. Infants living in non-fluoridated areas will not easily achieve the AI for fluoride, so supplements have been recommended based on life stage and level of water fluoridation.

***Special note*:** Australian data have shown that prolonged consumption of infant formulas reconstituted with optimally-fluoridated water beyond 12 months of age could result in excessive amounts of fluoride being ingested during development of the enamel of the anterior permanent teeth and therefore may be a risk factor for fluorosis of these teeth (Silva & Reynolds 1996).

The majority of Australian/New Zealand infant formula manufacturers now control the concentration of fluoride. It is also possible to reduce concentrations by preparing formula using non-fluoridated water such as rain, filtered or spring water from non-volcanic areas in its preparation.

Supplements may be necessary for older infants in non-fluoridated areas. However, it is likely that many older infants and younger children are already ingesting 0.4–0.6 mg fluoride per day from foods, beverages and toothpaste alone (Burt 1992). A study of 60, 11–13 month old New Zealand infants (Chowdhury et al 1990) showed that total intake including fluoride from tablets and toothpastes ranged from 0.093 to 1.299 mg fluoride/day in fluoridated areas and from 0.039 to 0.720 mg fluoride/day in non-fluoridated areas. The fluoride from the diet (food and drink) ranged from 0.089 to 0.549 mg day in the fluoridated areas, and 0.038 to 0.314 mg day in the non-fluoridated areas.

Children & adolescents	AI	Fluoride
All		
1–3 yr	**0.7 mg/day**	
4–8 yr	**1.0 mg/day**	
Boys		
9–13 yr	**2.0 mg/day**	
14–18 yr	**3.0 mg/day**	
Girls		
9–13 yr	**2.0 mg/day**	
14–18 yr	**3.0 mg/day**	

***Rationale*:** The AI for children is based on the requirement of 0.05 mg/kg body weight/day outlined above and adjusted for the standard body weights of 13 kg for 1–3 year olds, 22 kg for 4–8 year olds, 40 kg for 9–13 year olds, 64 kg for boys aged 14–18 years and 57 kg for 14–18 year-old girls. Supplements may be necessary for children in non-fluoridated areas, although the younger children (1–3 years) may already be getting much of their requirement from foods, beverages and toothpaste (Burt 1992).

Adults	AI	Fluoride
Men		
19–30 yr	**4 mg/day**	
31–50 yr	**4 mg/day**	
51–70 yr	**4 mg/day**	
>70 yr	**4 mg/day**	
Women		
19–30 yr	**3 mg/day**	
31–50 yr	**3 mg/day**	
51–70 yr	**3 mg/day**	
>70 yr	**3 mg/day**	

***Rationale*:** The AI for adults is based on the requirement of 0.05 mg/kg body weight/day outlined above and adjusted for the standard body weights of 76 kg for men and 61 kg for women.

Pregnancy	AI	Fluoride
14–18 yr	**3 mg/day**	
19–30 yr	**3 mg/day**	
31–50 yr	**3 mg/day**	

***Rationale*:** There is no evidence that requirements in pregnancy are greater than those of the non-pregnant woman.

Lactation	AI	Fluoride
14–18 yr	**3 mg/day**	
19–30 yr	**3 mg/day**	
31–50 yr	**3 mg/day**	

***Rationale*:** There are no studies of the metabolism of fluoride in pregnancy. Fluoride concentrations in milk are very low and fairly insensitive to differences in the fluoride concentration of maternal drinking water. The AI is not greater than that of women in the non-pregnant, non-lactating state.

UPPER LEVEL OF INTAKE - FLUORIDE

Infants	
0–6 months	**0.7 mg/day**
7–12 months	**0.9 mg/day**
Children and adolescents	
1–3 yr	**1.3 mg/day**
4–8 yr	**2.2 mg/day**
9–13 yr	**10.0 mg/day**
14–18 yr	**10.0 mg/day**
Adults 19+ yr	
Men	**10.0 mg/day**
Women	**10.0 mg/day**
Pregnancy	
All ages	**10.0 mg/day**
Lactation	
All ages	**10.0 mg/day**

***Rationale*:** The UL was set on the basis of moderate enamel fluorosis. A LOAEL of 0.10 mg/kg body weight for infants and children up to 8 years was set on the basis of community studies (Dean 1942, FNB:IOM 1997). A UF of 1 was applied, as the adverse effect is cosmetic rather than functional. For older children and adults, a NOAEL of 10 mg/day was derived based on data on the relationship between fluoride intake and skeletal fluorosis (FNB:IOM 1997, Leone et al 1954, 1955, McCauley & McClure 1954, Schlesinger et al 1956, Sowers et al 1986, Stevenson & Watson 1957). A UF of 1 was selected, as there are no signs of symptomatic skeletal fluorosis at this level of intake. No data exist to show increased susceptibility in pregnancy or lactation, so the same UL was adopted.

REFERENCES

Bergmann KE, Bergmann RL. Salt fluoridation and general health. *Adv Dent Res* 1995; 9:138–43.

Bergmann RL, Bergmann KE. Fluoride nutrition in infancy – is there a biological role of fluoride for growth? In: Chandra RK, ed. *Trace elements in nutrition of children II.* Nestle Nutrition Workshop Series, Vol 23. New York: Raven Press, 1991. Pp 105–17.

Bowden GH. Effects of fluoride on the microbial ecology of dental plaque. *J Dent Res* 1990;69:653–9.

Brown WE, Gregory TM, Chow LC Effects of fluoride on enamel solubility and cariostasis. *Caries Res* 1977;11:118–41.

Burt BA. The changing patterns of systemic fluoride intake. *J Dent Res* 1992;71:l228–37.

Chow LC. Tooth-bound fluoride and dental caries. *J Dent Res* 1990;69:59–600.

Chowdhury NG, Brown RH, Shepherd MG. Fluoride intake of infants in New Zealand. *J Dent Res* 1990;69:1828–33.

Dabeka RW, Karpinski KF, McKenzie AD, Bajdik CD. Survey of lead, cadmium and fluoride in human milk and correlation of levels with environmental and food factors. *Food Chem Toxicol* 1986;24:913–21.

Dean HT. The investigation of physiological effects by the epidemiological method. In: Moulton FR, ed. *Fluorine and dental health*. Washington, DC: American Association for the Advancement of Science, 1942. Pp 23–31.

Eksterand J, Fomon SJ, Zeigler EE, Nelson SE. Fluoride pharmacokinetics in infancy. *Pediatr Res* 1994a;35:157–63.

Eksterand J. Zeigler EE, Nelson SE, Fomon SJ. Absorption and retention of dietary and supplemental fluoride by infants. *Adv Dent Res* 1994b;8:175–80.

Fairley JR, Wergedal JE, Baylink DJ. Fluoride directly stimulates proliferation and alkaline phosphatase activity of bone-forming cells. *Science* 1983;222:330–2.

Food and Nutrition Board: Institute of Medicine. *Dietary Reference Intakes for calcium, phosphorus, magnesium, vitamin D and fluoride*. Washington DC: National Academy Press, 1997.

Hamilton IR. Biochemical effects of fluoride on oral bacteria. *J Dent Res* 1990;69:660–7.

Kleerekoper M, Mendlovic DB. Sodium fluoride therapy of postmenopausal osteoporosis. *Endocrinol Res* 1993;14: 312–23.

Kroger H, Alhava E, Honkanen R, Tuppurainen M, Saarikoski S. The effect of fluoridated drinking water on axial bone mineral density: a population-based study. *Bone Miner* 1994:27:33–41.

Kumar J, Green EL, Wallace W, Carnahan T. Trends in dental fluorosis and dental caries prevalences in Newburgh and Kingston, NY. *Am J Pub Health* 1989;79:565–9.

Leone NC, Shimkin MB, Arnold FA, Stevenson CA, Zimmerman ER, Geiser PB, Lieberman JE. Medical aspects of excess fluoride in a water supply. *Publ Hlth Rep* 1954;69:925–36.

Leone NC, Stevenson CA, Hilbish TF, Sosman MC. A roentgenologic study of a human population exposed to high-fluoride domestic water: a ten-year study. *Am J Roentg* 1955;74:874–85.

Marquis RE. Antimicrobial actions of fluoride for oral bacteria. *Can J Microbiol* 1995;41:955–64.

McCauley HB, McClure FJ. Effect of fluoride in drinking water on the osseous development of the hand and wrist in children. *Pub Hlth Rep* 1954;69:671–83.

Ministry of Health. No date. Frequently Asked Questions about Fluoridation http://www.moh.govt.nz/moh.nsf/wpg_Index/About-Fluoridation and http://www.moh.govt.nz/moh.nsf/0/de19679af662e1d0cc256e3e0071744a?Open Document.

National Health and Medical Research Council The *effectiveness of water fluoridation*. Canberra: Commonwealth of Australia, 1991. (Note: this document was rescinded on 14 March 2002).

Osuji OO, Leake JL, Chipman ML, Nikiforuk G, Locker D, Levine N. Risk factors for dental fluorosis in a fluoridated community. *J Dent Res* 1988;67:1488–92.

Pendrys DG, Stamm JW. Relationship of total fluoride intake to beneficial effects and enamel fluorosis. J *Dent Res* 1990;69:529–38.

Puzio A, Spencer AJ, Brennan DS. *Fluorosis and fluoride exposure in SA children*. Adelaide: AIHW Dental Statistics and Research Unit, 1993.

Riggs BL, Hodgson SF, O'Fallon WM, Chao EY, Wahner HW, Muhs JM, Cedel SL, Melton LJ 3rd. Effect of fluoride treatment on the fracture rate in postmenopausal women with osteoporosis. *N Engl J Med* 1990;322:802–9.

Schlesinger ES, Overton DE, Riverhead LI, Chase HC, Cantwell KT. Newburgh-Kingston caries-fluorine study XIII. Pediatric findings after ten years. *J Am Dent Assoc* 1956;52:296–306.

Silva M, Reynolds EC. Fluoride content of infant formulae in Australia. *Aust Dent J* 1996;41:37–42.

Sowers M, Wallace RB, Lemke JH. The relationship of bone mass and fracture history to fluoride and calcium intake: a study of three communities. *Am J Clin Nutr* 1986;44:889–98.

Sowers M, Clark MK, Jannausch ML, Wallace RB. A prospective study of bone mineral content and fractures in communities with differential fluoride exposure. *Am J Epidemiol* 1991;133:649–60.

Stevenson CA, Watson AR. Fluoride osteosclerosis. *Am J Roentg Rad Ther Nucl* Med 1957;78:13–8.

Taves DR. Dietary intake of fluoride ashed (total fluoride) v. unashed (inorganic fluoride) analysis of individual foods. *Br J Nutr* 1983;49:295–301.

Varughese K, Moreno EC. Crystal growth of calcium apatites in dilute solutions containing fluoride. *Calcif Tissue Int* 1981;33:431–9.

World Health Organization. *Diet, nutrition and the prevention of chronic disease. WHO Technical Report Series 196. Report of a Joint WHO/FAO Expert Consultation.* Geneva: WHO, 2003.