9 "Drink lots of clean, safe water": a food-based dietary guideline for South Africa

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Abstract

The purpose of this review is to summarise the literature that supports the importance of the food-based dietary guideline on water consumption. General recommendations for total daily water intake are between 2 and 3.7 l for women and men, 0.7 l for infants aged 0-6 months, 0.8 l for infants aged 7-12 months, 1.3 l for children aged 1-3 years, and 1.7 l for children aged 4-8 years. Water recommendations for the elderly and people who are involved in exercise or hard physical labour may be higher and might need special consideration. Water remains one of the primary sources of fluoride, and in areas with low levels, the fluoridation of drinking water is recommended. Defluoridation of water is suggested in areas where water fluoride levels exceed 3 mg/l. There is a paucity of South African data on general fluid intake, but some evidence suggests an increase in the intake of energy-containing beverages and in the demand for bottled water, posing unique challenges relating to weight gain and diabetes incidence, and effects on the environment and chemical leaching, respectively. Water quality remains a concern. Low rainfall, declining fresh water sources and the impact of industrial activity, urbanisation, climate change, deforestation, mining and agriculture add pressure on water bodies. This effect on water quality could lead to water-borne illnesses and disease. Managing the quality of drinking water is of utmost importance, and pertains to the microbiological and chemical safety of water, as well as to the physical and organoleptic qualities of drinking water, which is an important cornerstone for health.

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Introduction

It is a known fact that water is essential to life.[1] The Constitution of the Republic of South Africa states that as a basic human right, each individual has the right to access clean, safe water. This right is potentially threatened by the scarcity of water in the country. The demand for water continues to grow, which could also impact on its quality. South Africa is faced with the challenge of supplying high-quality drinking water to all its people, from those in urban areas to those living in deep rural settings. Water is also essential for sanitation, agriculture, industry, power generation, mining and the tourism industry. Each poses a unique challenge with regard to keeping our drinking water clean and safe.

The purpose of this review is to give a broad overview of recommended water intake in the various categories of the population, and summarise the literature that highlights the importance of a water guideline as part of the South African food-based dietary guidelines (FBDGs). The paper presents current recommendations on general fluid intake and reports pertaining to daily fluid (water and other beverages) consumption trends, highlights South African water statistics, focuses on water quality and water-borne illnesses and disease, and suggests fluid recommendations in people who are at increased risk of dehydration.

Recommended daily fluid intake

Water is an essential nutrient[2] and an important multifunctional constituent of the body, with roles as thermo-regulator, building material of cells in the body, a shock absorber, lubricant, solvent and carrier of various compounds, nutrients and waste products.[3] Water balance and hydration status is precisely regulated by an array of sensitive physiological mechanisms which respond to changes in consumption and losses, and thus changes in plasma osmolarity.[3,4] Fluid output mainly includes insensible losses, sweat, urine and faecal loss. Total fluid intake includes fluid consumed as beverages (milk, tea, coffee, juice, sweetened beverages and water, the optimal beverage),[5] water in food, and also the small volumes that are created through the breakdown of body tissue and food oxidation.[4] Current requirements, recommended intake and guidelines are based on the retrospective recall of water intake from food and beverages in order to meet the nutritional adequacy needed for healthy non-institutionalised individuals.[1,3]

Nutritional authorities around the world have established general guidelines for daily water intake which are guided by the dietary habits of the specific population. It is assumed that water from food contributes 20-30% to the adequate intake of total water (boiled cabbage contains 93.4 g water/100 g; watermelon contains 91.8 g water/100 g and brown bread contains 39 g water/100 g),[6] and that water from beverages contributes 70-80%.[3]

The World Health Organization (WHO)[7] advises a total water intake of 2.2 l/day for women and 2.9 l/day for men in average conditions, while the Food and Nutrition Board's dietary reference intakes recommend an adequate intake of water of 2.7 l/day and 3.7 l/day for women and men, respectively, including 2.2 l/day and 3 l/day from beverages, respectively.[6] The Australian and New Zealand adequate intake for total water is 2.8 l/day for women and 3.4 l/day for men, including a fluid intake from beverages of 2.1 l/day for women and 2.6 l/day for men.[8] According to the European Food Safety Authority, daily water intake of 2 l for women and 2.5 l for men is considered to be adequate. Thus, the recommended intake of daily water and beverages varies between 2 l and 2.8 l for women, and between 2.5 l and 3.7 l for men (Table I).[9]

In comparison to recommendations for adults, the fluid requirements for infants and young children are higher in relation to body weight, because of the limited capacity of their kidneys to handle the renal solute load, their higher percentage of body water and their larger body surface area per unit of body weight.[10] Exclusive breastfeeding meets the fluid requirements of an infant for the first six months of life.[11] The Food and Nutrition Board's dietary reference intakes recommends a total water adequate intake of fluid of 0.7 l/day for infants aged 0-6 months (assumed to be from human milk), 0.8 l/day for infants aged 7-12 months (assumed to be from human milk, complementary food and beverages), 1.3 l/day for children aged 1-3 years, and 1.7 l/day for children aged 4-8 years.[6]

Table I: Various recommendations pertaining to total daily water intake for adults

Nutritional authoritative body	Males	Females
World Health Organization: Total water* (litres/day)[7]	2.9	2.2
Food and Nutrition Board: Adequate intake of total water** (litres/day)[6]	3.7(3)***	2.7(2.2)***
Australian Government: Adequate intake of total water**** (litres/day)[8]	3.4 (2.6)*****	2.8(2.1)*****
European Food Safety Authority: Adequate intake of total water****** (litres/day)[9]	2.5	2

* Fluid consumed as water, other beverages, water in food and water from the metabolism of food
** All water contained in food, beverages and drinking water
*** Total beverage intake, including water
**** Food and fluids
***** Fluids, including plain water, milk and other drinks
****** Water from beverages, including drinking water, and food moisture

These guidelines pertain to a healthy population in standard circumstances and under average conditions, and need to be adjusted for cases that fall outside of the set criteria.

Special considerations in individuals at increased risk of dehydration

Dehydration is defined as the loss of water to the extent that normal physiological functions become negatively affected. Dehydration can potentially occur in any individual in varying circumstances. This can be because of inadequate water intake, fluid losses associated with normal metabolism and a failure to replenish the water, or high-performance activities or illnesses if water or physiological fluid losses are not replenished. Mild dehydration does not disturb homeostasis and the water is easily replenished. Severe dehydration, especially of a chronic nature, disrupts homeostasis and thereby results in a number of symptoms associated with dehydration. High-risk population groups for dehydration include babies and older children, the elderly and other individuals who fail to replenish water and physiological fluid losses (Table II).

Fluid requirements of the elderly

Dehydration is a common problem in older adults, and is associated with increased morbidity and mortality.[13,14] Inadequate fluid intake can have far-reaching consequences, such as death, and those who survive can face medical consequences, such as urinary tract infections, bowel obstruction, delirium and cardiovascular complications.[13] Dehydration in this age group is accounted for by certain anatomical and physiological changes that take place as people age, and which affect their ability to maintain a normal fluid balance. The kidneys decrease in size, renal blood flow declines, and glomerular filtration rate (GFR) decreases. Other causes of dehydration include a decline in total body water and changes in hormonal control and thirst sensation.[14,15]

Table II: Clinical signs of dehydration[12]

Type of dehydration	Clinical signs
Extracellular	Arterial hypotension, especially orthostatic Tachycardia
	Hypotonia of ocular globes
	Sunken fontanelles (infants)
	Concentrated urine
	Weight loss
	Persistent skinfolds
Intracellular	Altered thirst
	Mucosal dryness
	Occasional fever
	Arterial ischaemia
	Neuropsychiatric symptoms

The adult kidney reaches its maximum size and blood flow by the age of 30, and shrinks by 30-40% by the age of 90, while the GFR falls to 70-90 ml/minute by the age of 80, compared to 100-125 ml/minute at 40 years of age.[14,16] As the size of the kidney declines, so does its ability to form concentrated urine, which may affect the maintenance of the fluid and electrolyte balance. This change leads to the production of diluted urine, irrespective of the hydration status of the individual.[16] This deficiency of the renal system puts the elderly at high risk of water and sodium loss.[16]

Total body water decreases with age,[13] accounted for by the loss of muscle that is typically seen in the elderly.[15] Water is estimated to contribute to 60% of body weight in young adults, and decreases to 40% of body weight in the elderly. Any small decrease in body weight puts an older person at higher risk of dehydration than it does a younger person.[13] Thirst, a self-regulatory mechanism against dehydration, diminishes in the elderly.[13] The inability to sense thirst leads to poor voluntary fluid intake. Fear of incontinence may also be a factor in the decline in fluid intake.[3,12] The decrease in food intake is also associated with water deficit.[12]

The risk of dehydration increases as adults become dependent on others because of to immobility, frailty, visual problems, reduced alertness, dementia, or any other cognitive alterations that lessen the ability to communicate.[16,12] The presence of fever, diarrhoea, vomiting and swallowing difficulties also predisposes the elderly to dehydration.[12] Other risk factors include having more than four chronic medical conditions, taking more than four medications, using diuretics, abusing laxatives, using sedatives and experiencing chronic infections.[12,16,17] Medications such as angiotensin-converting enzyme inhibitors and nonsteroidal anti-inflammatory drugs, commonly used by the elderly, should be used with caution, as they have the potential to reduce GFR.[16] Dehydrated elderly persons are also unable to regulate body temperature, because of their inability to insulate their bodies in excessive heat. Sweat production decreases, and this puts them at a risk of heat stress and exhaustion, which can eventually lead to death.[18]

There are no standardised methods for the clinical assessment of dehydration.[19] However, diagnosis is made based on a combination of physical signs and symptoms which have unfortunately been found to be less specific in the older generation.[16] Physical, rather than biochemical, parameters have been found to be more reliable in diagnosing dehydration. Vivanti et al[3] reported no differences in blood or urinary biochemistry levels between patients who were and were not considered to be clinically dehydrated.[19] The study reported a marked and statistically significant reduction in systolic blood pressure on standing in the dehydration group, and a difference in body mass index of 7.5 kg/m^2 between the well-hydrated and the dehydrated groups.[19] Knight and Minaker, quoted in the work authored by Larson,[16] state that the most significant sign of volume depletion is acute weight loss, defined as weight loss of 3% or greater. Thus, weight needs to be closely monitored on a regular basis in order to detect any changes.[19] Common complaints associated with dehydration include weakness, fatigue, muscle cramps, sunken eyes and dizziness.[16] More severe dehydration may cause chest pain, abdominal pain and confusion. Although affected by medication, in some diseases such as diabetes, mouth breathing and dryness of the tongue and the mucous membranes may be indicative of dehydration, and are easily measured in a clinical setting. Skin turgor, with its weaker precision because of loss of subcutaneous fat and skin elasticity,[14,16] may also be used to assess fluid status in the elderly. It is recommended that skin turgor is tested on the inner thigh or sternum.[16]

Education plays an important role in good fluid management and the prevention of dehydration in the elderly.[16] Older people who are independent in their activities should be educated on the importance of increasing fluid intake and not to wait until they are thirsty before they drink water. Nurses and caregivers of the elderly should encourage sufficient intake by regular prompting throughout the day, while offering and positioning beverages and foods that contain water within reach, especially for those with disabilities.[15] The elderly should be encouraged to drink frequently rather than drink large quantities at a time, since gastric distension quickly decreases thirst sensation.[12] Drugs that suppress thirst disturb thermoregulation or fluid balance, (e.g. diuretics and laxatives) should be reconsidered or their dose reduced.[18]

Fluid requirements during hard physical labour and exercise

During hard physical labour and exercise, there is an increase in the metabolic rate, which, combined with working muscles, leads to an increase in body temperature. Depending on environmental conditions (e.g. temperature, humidity and sun and wind exposure), as well as the type of clothing worn, the rise in body temperature during exercise or manual work can be substantial (2-3°C).[20] Heat-loss mechanisms are stimulated to help maintain body temperature and prevent a rise in core body temperature. The body cools itself mostly through sweating in hot environmental conditions, defined as an ambient temperature > 30°C, which results in body water losses.[21] Body water loss can be more than 3 l a day in adults, especially when hard physical labour or exercise is performed in a hot environment.[22] Even though thermoregulatory responses in children are different to those in adolescents and adults, when corrected for body mass, generally children experience similar water losses during exercise to those of adolescents and adults.[23] Apart from body water, sweat also contains electrolytes, of which sodium and chloride are the most abundant.[24] Thus, appropriate replacement of lost body water and electrolytes is important during extended periods of hard physical labour and exercise to prevent the development of dehydration (which refers to the loss of body water) and hyperhydration (consuming more fluid than sweat losses), as well as hyponatraemia, all of which can have a negative influence on work, exercise performance and health.[25] Individuals who are most at risk of increased body temperature include athletes of all ages, military personnel and industrial workers, but this does not exclude anyone else who is exposed to hot and humid environments over prolonged periods.[26,27]

Dehydration has been associated with decreased cognitive and mental performance, heat illnesses, skeletal muscle cramps and increased consequences of rhabdomyolysis.[25,28] The level of dehydration at which these health and performance-related consequences occur depends on environmental conditions (i.e. a hot and humid environment versus a cold environment), the individual's tolerance to dehydration, sweating rates, sweat electrolyte concentration and the exercise or work task, and varies between 2% and 7% of body weight.[25,29] There are insufficient available data on dehydration levels and performance or health consequences in children and adolescents, but as little as 1% body weight loss may impair endurance performance.[30,31]

Symptomatic hyponatraemia can occur when plasma sodium levels fall to ~ 130 mmol/l. Individual tolerance of 109-125 mmol/l has been reported. Dilutional encephalopathy and pulmonary oedema can develop and, as hyponatraemia progresses, severe cerebral oedema with seizures and death may result.[32] The first documented report of exercise-associated hyponatraemia was at the Comrades Marathon in the early 1970s.[33] Exercise-associated hyponatraemia can occur when active individuals fail to replace sodium losses in sweat, or drink large volumes of (hyperhydrating) water or hypotonic beverages, often referred to as dilutional hyponatraemia. Dilutional hyponatraemia is more prevalent in recreational marathon runners who run slowly and sweat less, and in those who drink too much water and other hypotonic beverages before, during and after a race.[34,35] Increased sodium losses seem to be more prevalent in elite endurance athletes, individuals with cystic fibrosis and those whose occupational activities include hard physical labour in hot environments.[36-38] Common symptoms of hyponatraemia are sometimes confused with those pertaining to dehydration, such as headaches and vomiting. This resulted in the misdiagnosis of American soldiers who were advised to drink large volumes of water.[38]

Dietary sources of fluid include drinking water and other beverages and food that contain water. The availability of water for absorption, distribution and retention in the body depends on the presence of various ingredients in foods and beverages that are consumed, since some accelerate water absorption (e.g. salt and carbohydrates), while others may have a diuretic effect (e.g. caffeine and alcohol).[39] However, research has shown that the consumption of caffeinated beverages, such as tea and coffee, can add to the daily water balance in individuals who are used to ingesting these beverages. Acute increases in urine output only occur in individuals who are not accustomed to regular consumption of caffeinated beverages, and water should not be seen as the only beverage that can contribute to an individual's daily fluid needs.[4]

During meals, most people can restore body water and electrolyte losses that took place through sweating.[25] Similarly, ingesting a meal and water after dehydration due to exercise (2% body weight) has been shown to promote water balance.[40] Electrolytes, particularly sodium, are an important ingredient in any recovery meal or beverage after dehydration (> 2% body weight) has occurred. Electrolytes accelerate the recovery of plasma volume and total body water by encouraging fluid retention in the kidneys, as well as preventing the development of hyponatraemia.[25,41]

Various studies[41] have been conducted on active individuals to identify the most effective rehydration technique to optimise thermoregulation and prevent more than 2% body weight loss due to sweat loss. The general consensus is that water is the beverage of choice when manual work and exercise is performed for less than two hours in temperate conditions, and when little body weight loss occurs.[41] However, sodium should be added to water when a substantial amount of body weight has been lost (> 2% body weight), when an individual has lost more than 3-4 g of sodium in his or her sweat, and when the exercise lasts for longer than two hours.

It is unadvisable to drink according to a fixed drinking regimen, as this can result in overdrinking and hyponatraemia.[42] However, to drink only in accordance with thirst can result in dehydration in certain occupational or sports situations. Therefore, it is recommended that people who sweat a lot because of manual work or sport-related activities should develop an individualised hydration strategy to ensure health and the preservation of performance and productivity. The main goal should be to limit body mass loss to less than 2%, but people must also be cautioned not to drink so much that weight gain is achieved during hard physical labour and exercise, since this can result in hyponatraemia.[43]

Current trends in daily water, beverage and fluid consumption

Beverage consumption and weight status

Beverage consumption has changed over the past century and has resulted in a significant increase in energy intake from energy-containing beverages.[1] Patterns in beverage consumption appear to vary in age groups and populations. A French study reported that energy from beverages represented 10% of daily energy intake.[44] Carbonated drinks are mostly consumed by adolescents, followed by children and adults, who consume 169 ml/day, 114 ml/day and 92 ml/day, respectively. Water intake represented approximately 50% of the total daily beverage intake of 1 046 ml in children, 1 111 ml in adolescents, 1 306 ml in adults, and 1 197 ml in the elderly (over 55 years of age).[44] Data on energy-giving beverage intake per capita in the American population from the US National Food Consumption Survey showed a net increase in consumption. Intake increased from 250 ml to 442 ml, and 201 ml to 474 ml, in children and adults respectively, between 1977 and 2005.[1]

A growing body of evidence is focusing on the impact of energy-containing beverages on health and disease. Results from a study by Tam et al[45] showed a higher carbohydrate intake from soft drinks and cordials in children who were obese or overweight, and that soft drinks and cordial intake was associated with excess weight gain in early adolescence. Similarly, findings by Welsh and Dietz indicated that the consumption of sugar-sweetened soft drinks was positively associated with energy intake, weight gain and the incidence of diabetes.[46] A meta-analysis[47] investigated the impact of drinking water with meals on total energy intake. The change in total energy intake was compared in situations where meals were accompanied by water, other beverages or having nothing to drink. No significant increase in total energy intake was found when non-nutritive sweetened drinks and water were consumed prior to or with a meal. However, when sweetened beverages were consumed, instead of water, prior to or with a meal, the energy intake increased by 7.8%. Furthermore, when water was replaced with milk or juice, there was a tendency for increased total energy intake, but more studies are needed to verify this. The conclusion is that water consumption with meals has the potential to play an important role in the reduction of daily energy intake, and thus could be pivotal in preventing overweight and obesity in the long term.[47] However, some findings do not support this hypothesis. In the National Health and Nutrition Examination Survey (NHANES), Kant et al showed no relation between water intake, energy intake and body mass index.[48]

South African data on the consumption of beverages are limited. A study by Van Zyl et al showed soft drinks to be the most popular beverage consumed by young adults with meals (56%), while 13.8% consumed fruit juice, 7% flavoured bottled water and 7.6% unflavoured water.[49] However, it is not clear what the contribution of beverages is to daily energy intake. More research is needed in this regard.

Bottled water versus tap water

The demand for bottled water has been increasing worldwide, making it the fastest growing segment of the non-alcoholic beverage market in the world.[50] South Africa is no exception. The bottled water industry is estimated to be expanding at an average of 22.5% per year.[51] Reasons for the increase in bottled water consumption are not straightforward, and surveys report diverse results.[52] Results from most studies that have investigated possible reasons for bottled water preference indicate dissatisfaction with tap water, health risk concerns, taste, purity, convenience, cost, the quality of water sources and perceived health benefits.[50,51,53]

However, bottled water raises concerns. Consumers seem to be apprehensive about possible links between plastic bottles and cancer, as well as about the impact of empty bottles on the environment.[54] Recently, various studies have investigated chemical leaching from different types of water-packing materials. Key factors that could lead to chemical leaching into the water include temperature, bottle reuse and bottle type.[55-57] The migration of bisphenol A (BPA) from polycarbonate bottles into the water was evaluated by Le et al.[55] The results showed the migration of BPA into the water at room temperature, which increased 55-fold when the bottles were exposed to boiling water. Schmid et al investigated the transfer of organic substances from polyethylene terephthalate (PET) bottles under solar water disinfection conditions. Concentrations of 0.046 µg/l di(2-ethylhexyl) adipate (DEHA) and 0.71 µg/l di(2-ethylhexyl) phthalate (DEHP) were reportedly found in the water; 10% less than guideline values. DEHA and DEHP levels were far below maximum safe dosages, and the carcinogenic risk of DEHP was distinctly below the maximum contaminant levels of the US national primary drinking water standards.[58]

Andra et al investigated the effect of temperature, ultraviolet exposure and bottle reuse on the leaching of antimony and bromine from reused PET and polycarbonate containers. The frequency of bottle reuse showed a linear increase in antimony leaching, but the concentrations did not pose a serious health risk according to acceptable intake estimates, as was the case with the leached bromine concentrations.[57] However, acceptability dose estimates for oral ingestion of organobrominated plasticisers have not been established. Similarly, results from a study by Al-Saleh et al[56] showed low levels of phthalates in bottled water after investigating the presence thereof in branded bottled water under different storage conditions. Levels of DEHP in the samples also did not exceed the maximum established limits.[56]

Results from these studies show that levels of the leaching compounds were below relevant guidelines and regulations. However, there are no regulatory levels for some of the substances. Because of the total burden of these substances, related to multiple exposures from different sources, additional research on the potential leaching of organic chemicals from water-packing materials, and the resultant health effects, is warranted.[55,57]

Studies that assessed the quality of bottled water indicated that bottled water generally complied with drinking water legislation.[59] A Norwegian study determined the microbial quality and nutritional aspects of five of the country's leading brands of bottled water and reported that the water met standards of hygiene, as no named pathogens and indicator organisms that had been specified for testing were found. Indigenous yeasts and species associated with opportunistic infections were observed, but were not considered to constitute primary pathogens.[52,60] Güler evaluated maximum contaminant levels in Turkish bottled drinking water against the manufacturers' labels and governmental regulations. The results showed that a significant number of the bottled water contained elements such as sodium, chloride, sulphide, fluoride and heavy metals above the maximum allowed concentrations.[60] A South African study[59] included a random survey on the microbial quality of bottled water, and reported that no total and faecal coliform bacteria, enterococci, *Costridium perfringens,* bacteriophages or enteric viruses were detected in any of the 10 different water products that were tested over three months, on three different occasions. However, two of the 10 bottled water samples did not meet the requirements set by the South African Bureau of Standards (SABS) for heterotrophic plate count bacteria. Subsequently, the quality of bottled water in South Africa has been placed under official regulation by the Department of Health.[61]

Fluoride and drinking water

Fluoride is a natural element that is found in different concentrations in drinking water and soil.[62-64] It is beneficial to both bone and dental development in human beings. The American Dietetic Association position statement reaffirms that fluoride is an important element for mineralised tissue in the body.[65] Optimum fluoride intake plays a key role in the development of tooth enamel. However, excessive intake interferes with the normal formation of tooth enamel and bones, which consequently increases the risk of dental fluorosis.[63,66] On the other hand, a low intake in childhood may be a causal factor for dental caries in later years.

An adequate intake of fluoride from infancy to adulthood ranges from 0.01 - 3 mg/day. The tolerable upper limit is 0.7 mg/day in infancy and 10 mg/day in adulthood, irrespective of gender. The optimum intake of fluoride in children is in the range of 0.05-0.07 mg/kg/day.[67] Continual use of fluoride at levels of more than 8-20 mg/day may cause tooth loss and bone changes in the form of exostosis.[68] The SABS specifies that the ideal concentration of fluoride in water that is suitable for lifelong consumption is 0.7 mg/l, with an upper limit of 1.5 mg/l. This level has been shown to decrease the level of tooth decay by approximately 60%.[63,69,70]

Sources of fluoride include:

- Fluoridated drinking water
- Natural fluoride-rich water reservoirs, streams and groundwater
- Fluoridated salt
- Food that is prepared with fluoride-rich water
- Topical fluoride application sources, such as fluoride mouth rinses, dentrifices, gels and foams
- Fluoride-rich beverages, such as tea and agricultural products.[62,63,71-73]

The consumption of five or more bags of non-herbal tea can increase fluoride levels. Some tea infusions, especially decaffeinated varieties, expose children to a high risk of fluorosis if consumed as the primary source of hydration.[74]

There are several benefits to consuming fluoride in optimal levels in water and food, and from the topical application of fluoridated dentrifices, oral rinses, gels and foams.[64,75] The consumption of fluoride during tooth development makes the enamel more resistant to later acid attacks. The result is stronger tooth enamel throughout life. High levels of fluoride in the mouth (dental plaque and saliva) remineralise tooth enamel areas which have been decalcified by acid. This process of remineralisation results in the early reversal of dental caries.[62,66,71]

Systemic fluoride benefits the teeth before birth and up to 12 years of age. However, pre-eruptive fluoride is no longer considered to be the major mechanism by which fluoride provides the best protection against dental caries.[72,73] Adults who consume fluoridated water have a lower prevalence of dental decay. Van Wyk and Van Wyk[76] showed a 22.7% decrease in the prevalence of dental caries in 12-year-old children over a 20-year period, partly attributed to the widespread use of fluoridated toothpaste in South Africa.

The topical application of fluoride is said to have a positive effect in the post-eruptive tooth. This was shown to be independent of systemic effects in preventing dental caries.[72] The recommended levels needed to achieve maximum protection from dental caries are 0.5-1 mg/l.[73] Dental fluoride supplementation is only recommended in children who are at high risk of developing caries because of a deficiency of fluoride in the drinking water,[77] as the risk of developing dental fluorosis from excessive consumption of other sources of fluoride, other than that found in water,[64] should be kept in mind.

The Centers for Disease Control and Prevention and the South African Dental Association regard the fluoridation of water as one of the 10 most important public health strategies of the twentieth century.[63,64] Kroon and Van Wyk[76] showed that the fluoridation of water in South Africa is still a viable strategy for the prevention and reduction of the prevalence of dental caries. The cost of water fluoridation is estimated to be R1 per person per year.[63] Community water fluoridation even reaches disadvantaged sections of the population. However, if the risk of dental caries is high, fluoridation of water alone cannot provide full protection against the onset of caries.[63,64,69] The South African Department of Health recommends the fluoridation of public water to not more than 0.7 ppm[2]. This initiative is supported by organisations such as the South African Dental Association, the WHO, the South African Medical Research Council and the Nutrition Society of South Africa.[63] Although fluoridation of public water is recommended, legislation has been halted pending further research by water companies, municipalities and the public. Municipalities are concerned about the cost and technical issues, while the public is apprehensive about major long-term health problems. Thus, to date, South Africa does not have artificially fluoridated water.[70,78]

On the other hand, high levels of fluoride in drinking water can lead to dental fluorosis and the development of skeletal fluorosis. The threshold for severe dental fluorosis is believed to be 2 mg/l. Another threshold for dental fluorosis is the consumption of drinking water that contains more than 1 mg/l of fluoride during permanent teeth calcification. However, African countries have not yet established the threshold for dental fluorosis.[70,78]

Fluoride in drinking water is not the only causal factor of dental fluorosis. Studies that were conducted in African countries, such as Tanzania, Sudan and Nigeria, showed a high prevalence of dental fluorosis, although the populations consumed fluoride levels as low as 0.5 mg/l in the drinking water. This was partially attributed to increased consumption of tea and the use of fluoride-containing trona.[79] A study that was conducted in the main Ethiopian Rift region, where there is high fluoride levels of 7.8-18 mg/l in the groundwater, indicated a 100% prevalence of fluorosis.[79] The levels far exceed the WHO standard of fluoride in drinking water of 1.5 mg/l,[69] and the No-Observed-Adverse-Effects-Level level of 0.06 mg/kg/day.[70] In determining the fluoride content of commercially available bottled water, Ayo-Yusuf et al[80] reported irregularities with the labelling, as some samples had fluoride concentrations < 0.3 ppm, while others had higher concentrations > 0.3 ppm. Some brands had a higher concentration of fluoride than was indicated on the label.

In South Africa, a great variation exists in fluoride levels in drinking water that is supplied by municipalities.[81] In a study of two South African rural sites, one with a low fluoride level of 0.19 mg/l and the other with a high fluoride level of 3 mg/l, there was a 49% prevalence of fluorosis in the low-fluoride area, compared with 96% in the high-fluoride area.[82] The prevalence of dental fluorosis in South African communities, such as the North West province, which depends largely on groundwater for drinking water purposes, is as high as 97%.[68] Many sources of water (groundwater and ocean) in provinces such as Limpopo, North West, Northern Cape, Western Cape and KwaZulu-Natal, require partial defluoridation. Processes such as reverse osmosis or activated alumina treatment can be employed, and have been shown to reduce the level of fluoride by 12 mg/l in potable and drinkable water. Defluoridation is recommended if the fluoride level exceeds 3 mg/l.[68,81]

Fluoride also plays an integral role in bone density. There is controversy when considering appropriate fluoride levels. Some studies have demonstrated a high incidence of bone fractures at four times the level of fluoride, while others have indicated no effect.[82] Fluoride levels of 9-23 mg/l/day for four years showed an increase in bone density. An optimal fluoride level in drinking water (1 mg/l) was associated with no benefit of increased bone mineral density. Thus, fluoride levels that are optimal in drinking water are not protective of bone health, and higher levels may increase the risk of dental and skeletal fluorosis.[82]

A healthy mouth enables an individual to socialise and eat without embarrassment.[79,83] Annually, more than 50 million school hours are lost because of oral health problems.[81] Consequently, children's performance at school and their success later in life is affected.[84,85]

South African water statistics: access and intake

South Africa is a water-scarce, semi-arid country, with a growing demand for water. The provision of clean, safe water has a key role to play in reaching a number of the Millennium Development Goals, such as eradicating extreme poverty and hunger, reducing childhood mortality, improving maternal health, combating HIV/AIDS, malaria and other diseases, and ensuring environmental sustainability. Approximately 88% of the South African population has access to basic water service levels,[86] while 73.2% of households have access to free basic water services.[87] Unfortunately, 5.7-million people[86] do not have water security (i.e. water that is sufficient, safe, acceptable, accessible and affordable).[88]

Very few South African studies have been conducted that have specifically investigated water and total fluid intake. Bourne and Seager[2] reported mean tap water intake to be 2.19 l in the white population, 1.26 l in the coloured population, and 1.4 l per day in the black population in Cape Town.

Water quality, water-borne illness and disease

Human health is affected by poor water quality, which has a negative ripple effect on agriculture, industry and the economy at large. South Africa's water quality is regulated by a myriad of policies and legislation,[86] but the quality of water is becoming a cause for concern. The quality of South Africa's fresh water resources is declining because of increased pollution from industry, urbanisation, deforestation, mining, agriculture and power generation. The problem is further exacerbated by outdated and inadequate water and sewage treatment plant infrastructure, as well as unskilled operators. A growing body of literature reports that health-threatening microorganisms, toxic metals and organic compounds are present in the aquatic environment.[86]

Industrial development has had a negative impact on water quality, as many industrial processes produce wastes that contain hazardous chemicals, which may be discharged into sewers, rivers and wetlands.[86] Long-term mining has a degrading impact on the environment, because of contamination of surface water, sediment and soil which contains heavy metals, such as mercury and radioactive uranium.[90] A number of small studies have shown the exposure of drinking water to heavy metals, such as uranium and mercury, in pockets of mining communities in parts of South Africa, and have alluded to possible health-related implications, such as cancer.[91] Other factors that threaten water quality include salination (man-made processes that increase the salinity of a water system), eutrophication (the excessive growth of algae) and human-induced acidification due to industrial effluents, mine drainage and acid rain.[86] Acid mine drainage remains a current concern,[92] and will continue to contribute to an increased concentration of dissolved salt, metal ions and radionuclides in stressed river and reservoir systems. The low pH values in acid mine drainage increase the solubility of trace metals locked up in the sediment, resulting in their release into overlaying water.[86]

Water quality is further compromised because of the discharge of inadequately treated sewage that emanates from urban areas because of incomplete, broken, overloaded and mismanaged sewage treatment plants.[86,93] Unsafe water and the lack of sanitation are key risk factors for a number of diseases.[69] Several recent studies have reported the occurrence of pathogenic microorganisms in water sources. Authors report viral quantities above recommended limits in treated waste water effluent that is produced by waste water treatment plants. Microorganisms, such as *Escherichia coli, Salmonella typhimurium, Listeria, Cryptosporidium, Giardia* and *Vibrio cholerae,* have been found in treated effluent, making them a public health concern.[93-95] The 2011 Green Drop report states that "Waste water treatment is the first barrier in a multi-barrier system of ensuring public and environmental health".[96]

The burden of disease in the country in 2000, attributable to unsafe water and lack of sanitation, was estimated by Lewin et al.[97] The 13 434 deaths attributable to unsafe water, sanitation and hygiene accounted for 2.6% of total deaths in the country.[97] Unsafe water was regarded as the seventh largest risk factor of the total burden of disease in the country in the year 2000, not taking into account the poor quality of waste water treatment services, as shown by the Green Drop reports.[96,98]

The Blue and Green Drop programmes were instituted by the Department of Water Affairs in 2008 as an incentive-based regulation programme to encourage municipalities to improve quality levels in the drinking water and waste water management. Results from the Blue Drop water (drinking water) annual reports show an increase in water systems that achieved Blue Drop scores higher than 50% [2009 (45.5%); 2010 (47%) and 2011 (58.7%)], and thus a decrease in the number of Blue Drop scores below 50%.[99] In the Green Drop report, when evaluating waste water management, an increase in the number of assessed treatment systems was reported. However, a negative trend was observed, with a decline in the number of systems that scored more than 50% (49% vs. 44% in 2009, compared to 2010/2011). High priority needs to be given to continuing to improve access to safe and sustainable sanitation and water facilities.[97]

Conclusion and recommendations

Water is a critical nutrient, which is involved in many diverse bodily functions. Insufficient intake leads to dehydration, which is detrimental to health. Therefore, it is important to include a water guideline in the South African FBDGs.

Statistics on water and fluid consumption, and patterns, in normal and special-care groups in South Africa, are limited, meaning that further research is warranted. South Africa must identify areas with insufficient fluoride levels in drinking water, and recommend the appropriate treatment thereof.

Lastly, it is recommended that access to safe and sustainable sanitation and water facilities should receive high priority, since it is a key factor in addressing the hurdles that prevent the country from achieving the Millennium Developmental Goals.

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