

WATER – THE NEGLECTED NUTRIENT

L T Bourne, J R Seager

Water is an essential nutrient and is the most pervasive compound in the human body. This paper describes typical water requirements and processes affecting homeostasis, and it explores practical issues relating to obtaining safe water.

The US National Research Council recommended water intake is 1 ml/kcal energy expenditure for adults. This equates to 2.9 l/day for men and 2.2 l/day for women under average conditions. Children require 50% more water per kcal energy expenditure. Water loss occurs via the lungs, sweat glands and kidneys. Total sweat loss is usually 500 - 700 ml/day but can reach 8 - 12 l/day.

Mean tap water intakes in Cape Town have been recorded as 2.19 l/day for whites ($N = 1\ 680$, ≥ 1 year old), 1.26 l/day for coloureds ($N = 1\ 088$, ≥ 1 year old) and 1.4 l/day for blacks ($N = 1\ 415$, ≥ 5 years old). Two litres per person per day remains a useful approximation for exposure to elements in water for local use.

The 1996 census reported that less than half the population of South Africa has an indoor water supply. In Port Elizabeth 20% of the city population was using communal water supplies (standpipes) in 1996 and 11% of these were more than 200 m from the home. Carrying and storing water impacts on both quantity and quality of water used. Such contamination contributes to the heavy burden of infectious intestinal disease (20% of deaths, in children aged 1 - 5 years). Women should be targeted in interventions since they play a critical role in water carrying, child care, and food preparation.

The guideline to 'drink lots of clean, safe water' is a unique but very important one for South Africans, living in such a hot and relatively dry climate. Water is the most pervasive compound in the human body. Most biochemical reactions occur in water, and water is an active participant in those reactions. If nothing is taken in, a person dies of thirst more quickly than of hunger.

Water is essential to life. No other substance is as widely involved in as many diverse functions of the human body as

Health and Development Research Group, Medical Research Council, Tygerberg, W Cape

L T Bourne, BSc, MSc, PhD

J R Seager, BSc Hons, PhD

water. A water deficiency manifests rapidly, and symptoms occur with as little as 1% hypohydration. In a 70-kg person, 1% hypohydration is equivalent to 700 ml of water loss or a loss of 0.7 kg of body mass due to sweating. With continued dehydration, the cardiovascular, respiratory, and thermoregulatory systems are compromised, and complete water deprivation leads to death in a matter of days. Water plays a key role in maintaining homeostasis of the internal environment for optimum function of cells.¹

This internal environment – body fluid with associated cations and anions enveloping cells – remains relatively constant despite the diversity of cells and cellular functions. The most easily appreciated roles of water in the human body are to provide a medium for transport of blood components, to dissolve and pass nutrients from blood to cells, to provide a medium for intracellular reactions to take place, and to transfer metabolic products to the blood for redistribution or elimination via the urine.¹

Water is, however, more than just a nutrient – it is a major component of the thermoregulatory system of the body. Water absorbs heat where it is generated and dissipates it over the fluid compartment of the body, minimising the risk of localised damage to enzymes or structural proteins by heat. Once the heat of chemical reactions has been transferred to body fluid, it is routed to the surface of the skin where it is dissipated by convection, radiation, conduction or evaporation.¹

REQUIREMENTS AND GUIDELINES FOR FLUID CONSUMPTION

The aim of the guideline is to provide information on hydrating the body optimally, except in the presence of abnormalities such as renal malfunction and heart failure. Dehydration of as little as 1% decrease in body weight results in impaired physiological and performance responses.^{2,4} Mild dehydration is often described as a 1 - 2% loss of body weight caused by fluid losses. It affects a wide range of cardiovascular and thermoregulatory responses.^{5,7} Dehydration in excess of 3 - 5% of body weight decreases endurance and strength^{6,8} and is the primary cause of heat exhaustion.⁹

Water is an essential nutrient because it is required in amounts that exceeds the body's ability to produce it. Even without perspiration (sensible losses) the normal daily body turnover of water is approximately 4% of total body weight in adults and the percentage is higher in children. In a 70 kg adult this is equivalent to 2 500 - 3 000 ml/day.¹⁰ Water loss from the lungs and skin (insensible losses) are responsible for half of the total turnover.¹¹ Insensible losses are sensitive to environmental conditions and can be increased at higher temperatures, high altitude and low humidity. Losses from stool and urine account for the rest of the total losses.

The human requirement for water is related to metabolism and highly variable. Insensible losses may vary widely, yet

there must be a minimal amount available to maintain a tolerable solute load by the kidneys. The US National Research Council¹¹ recommends fluid intake of 1 ml/kcal energy expenditure for adults living under average conditions of energy expenditure and environmental exposure. For average males, this is the equivalent of 2 900 ml fluid per day, and for average females 2 200 ml fluid per day. For the dependent elderly (who cannot live independently) requirements can be calculated more precisely using the following formula:

100 ml/kg for the first 10 kg body weight, and 50 ml/kg for the remaining kilograms of actual body weight. A pregnant woman requires approximately 30 ml extra fluid per day and a fully lactating woman requires 750 - 1 000 ml/day above the basic recommendation. The average recommendation for children is 1.5 ml/kcal energy expenditure per day.

The primary controller of hydration status in human beings is thirst. Unfortunately, the threshold for induction of thirst occurs when a person is already dehydrated to a level of 0.8 - 2% loss of body weight.^{12,13} This emphasises the need to hydrate the body regularly, preferably with tap water or tap water-based drinks. However, it must be borne in mind that caffeine-containing drinks such as coffee, and alcoholic drinks, have a diuretic effect. Taste influences hydration and beverage choice in adults and children.^{14,15} This highlights the need for tap water to be acceptable to consumers in terms of its potability, i.e. taste, odour and appearance.

AVENUES OF WATER GAIN AND LOSS

Water loss is influenced strongly by activity level and resultant sweat loss. The ambient environment can further influence water loss through sweat, urine and respiratory routes.

The primary source of daily water intake in humans is fluid consumption. The fluid content of food also contributes greatly to daily water balance, although this may not be universally appreciated. The combined water intake for fluids and foods consumed at meal times is the normal route for maintaining fluid balance. More than 50 years ago Rothstein *et al.*¹⁶ first pointed out the importance of eating and drinking at meal times to restore fluid balance. Although it is possible to maintain fluid balance when meals are skipped, it requires a conscious effort to drink fluids at regular intervals, since drinking invariably decreases during busy periods (when water loss is likely to be greater) and increases during periods of rest. Activity generally accentuates a gap in fluid balance, whereas leisure reduces it.¹⁶

Exercise can markedly alter not only the total fluid output, but also the relative contributions of various avenues of water output. Water is lost through the skin from both cutaneous (insensible) and sweat (sensible) losses. Insensible loss is small compared with potential sweat loss. The amount of water lost from the skin is proportional to the amount of heat generated.¹⁷

Respiratory water loss (via the lungs) is approximately equal to the amount produced by metabolism. Exercise can increase respiratory water loss to 2 - 5 ml/minute.¹⁸ Respiratory water loss also varies with climate, decreasing in hot humid weather and rising in cold climates or at high altitudes, where the cold inspired air contains little moisture and the ventilatory rate is faster.¹⁹

Although faeces contain approximately 70% water, faecal excretion in the absence of diarrhoea is relatively small because of the efficient resorption of water from the digested matter in the jejunum and colon. Diarrhoea or vomiting can increase normal daily water loss through stools from 100 ml/day to 10-50 times that amount.¹⁹

The most variable and quantitatively most important routes of water loss in humans are the sweat glands and kidneys. Sweat rates of 1 - 2 l/hour are common in athletes working at moderate to high rates of energy expenditure.^{20,21} The volume of water lost through sweat depends on several factors including work load, temperature, relative humidity, hydration status, and degree of prior heat acclimation.^{20,21} Total sweat loss is usually 500 - 700 ml/day, but can be as much as 8 - 12 l/day.²² The kidney has the ability to regulate water loss in the urine by increasing the tubular resorption of water (as in exercise or with inadequate water intake). Although water conservation by the kidney is an important homeostatic mechanism, the total quantity of water that can be conserved is relatively small compared with sweat loss during exercise.

PHYSIOLOGICAL AND PATHOLOGICAL BACKGROUND

The long-term physiological and pathological implications of less than ideal intakes of water have been thoroughly described by Kleiner²³ who pointed out that new research indicates that fluid consumption in general, and water consumption in particular, can have an effect on the risk of urinary stone disease, cancers of the breast, colon and urinary tract, child and adolescent obesity, mitral valve prolapse, salivary gland function and overall health in the elderly.

Urinary stone disease

Stone prevalence is higher in populations with low urinary volume²⁴⁻³² and increased concentrations of all stone-forming salts. Risk of stone formation increases with urine volumes of less than 1 l/day. When fluid intake is increased to allow for urinary volumes of more than 2 - 2.5 l/day, without any changes in diet or other pharmacological intervention, recurrences of all types of stones can be prevented in a large number of patients.^{24,27-29}

According to Hughes and Norman,²⁷ persons at risk for urinary stone formation should consume at least 250 ml fluid with each meal, as well as between meals, before bedtime and

when they get up at night to void. This pattern will ensure that fluid intake is spread throughout the day and that urine is not concentrated. Patients with stones should also increase their fluid intake in hotter weather and after vigorous exercise.

Cancer

Several studies have discovered a direct correlation between the quantity of fluid consumed and the incidence of certain cancers.³³⁻³⁶ In Israel, Bitterman *et al.*³³ found that patients with urinary tract cancer (bladder, prostate, kidney, testicle) consumed significantly smaller quantities of fluid compared with healthy control subjects. No association with specific beverages was found. In Hawaii, Wilkens *et al.*³⁶ showed that total fluid intake and intake of tap water in particular, had a strong inverse dose-response relationship to risk of lower urinary tract cancer (bladder, renal pelvis, ureter) among women. The association was stronger among smokers than non-smokers.

Similar findings have been made regarding colon and breast cancer. In a population-based case-control study of the association between food grouping and colon cancer in Seattle,³⁴ researchers identified a strong inverse dose-response relationship between water intake, measured as glasses of water consumed per day, and risk of colon cancer among women. Women who drank more than five glasses of water a day had a 45% decreased risk of colon cancer versus those who consumed two or fewer glasses per day (odds ratio (OR) for > 5 glasses/day v. ≤ 2 glasses/day = 0.55, 95% confidence interval (CI) = 0.31 - 0.99, *P* = 0.004). Among men there was a 32% decrease in risk with increasing water consumption (> 4 glasses/day v. ≤ 1 glass/day), although it was not statistically significant.³⁴

In a letter to the editor, Stookey and colleagues³⁵ announced the results of their hospital-based, case-control pilot study of the protective effect of drinking water on breast cancer risk. Water drinking was strongly, inversely, and significantly associated with breast cancer risk.

Obesity

People often report that drinking fluids helps them feel fuller and eat less. The LEARN programme,³⁷ a behavioural weight-control programme, suggests that participants 'drink a lot of water to take the edge off hunger'. The results of two studies may indicate that this is true in both adult and child populations.^{38,39} Levine⁴⁰ reviewed the role of liquid intake as a factor in childhood obesity and disease. She makes several important points, including the suggestion that replacing soft drinks in the diet with milk and water would help with weight control and greatly improve the overall health of the child and adult populations in the USA.

These studies therefore illustrate that insufficient water intakes can have pathological sequelae, and in some cases

additional water intake can be used in therapeutic interventions.

FLUID INTAKES OF THE SOUTH AFRICAN POPULATION

In South Africa, two studies in Cape Town¹⁰ have ascertained fluid intakes. Utilising the 24-hour recall method, mean total tap water intake for whites aged 1 year and over ($N = 1\ 680$) was 2.19 l/day, while that for coloured South Africans ($N = 1\ 088$) was 1.26 l/day.¹⁰ In a separate study, but using the same methodology, mean fluid intake for blacks ($N = 1\ 415$) aged 5 years and upwards was found to be 1.4 l/day.¹⁰ It was concluded that the 'traditional' 2 l/head/day which tends to be reported in the literature for calculation of the exposure to elements in water remains a useful approximation for local use. This 2-litre figure has been used by the World Health Organisation (WHO)¹¹ and the Environmental Protection Agency.¹²

PUBLIC HEALTH PROBLEMS RELATED TO WATER INTAKE IN SOUTH AFRICA

Considerable efforts have been made to supply South African households with water, particularly since 1994. However, according to the 1996 census¹³ there is still some way to go, with certain primarily rural provinces lagging behind in terms of providing taps inside residential dwellings. For example, in the Northern Province only 18% of households have taps inside dwellings, while in the Eastern Cape and the North West the proportion of households with indoor water is somewhat larger (25% and 31%, respectively). In contrast, however, the Western Cape (76%) and Gauteng (68%) reflect what can be attained, although in both these provinces the populations are highly urbanised. It is, however, incorrect to assume that all urban populations are adequately supplied with water. A recent study in metropolitan Port Elizabeth found that 20% of the population is reliant on communal taps and 11% of these are more than 200 m from the home.¹⁴ By population group, black South Africans have the least adequate water supplies, with only 36% of households having taps inside dwellings as opposed to 68% of coloured and 100% of white and Indian households.

Although taps inside dwellings are ideal (in terms of sanitation), this can be misleading, as access to a tap on site, or access to a public tap may go a long way towards alleviating household risk in terms of water. The national population distribution by water source is reflected in Fig. 1, which indicates that although only 45% of households have a tap inside the dwelling, as many as a further 17% have access to a tap on site, and 20% to a public tap. If one accepts that any tap-borne water is purified at some central location, at least 17.5% of households do not use centrally purified water.

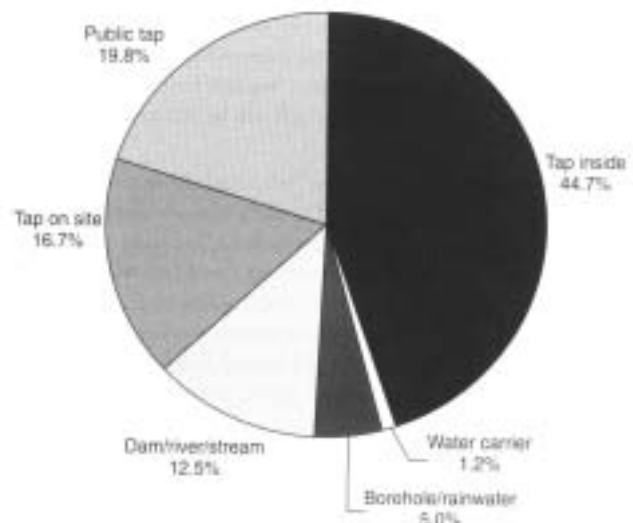


Fig. 1. National distribution of main water source (source: Statistics South Africa¹⁵).

LOCAL WATER-RELATED DISEASES

Apart from the basic metabolic demand for water as indicated above, water is a potential source or carrier of various pathogens. Potentially water-related diseases include the following: (i) water-borne diseases such as gastroenteritis, dysentery and cholera; (ii) water-washed diseases (i.e. transmission resulting from lack of adequate amounts of water or inadequate hygiene) such as shigellosis; and (iii) water-mediated diseases (i.e. water plays a role in the life cycle of the pathogen or one of its hosts) such as schistosomiasis or malaria.

According to the atlas of diarrhoeal diseases in South Africa¹⁶ ill-defined intestinal infections (diarrhoeal diseases) form the vast bulk (95.25%) of water-related disease. In South Africa 20% of deaths in the 1 - 5-year-old age range are caused by infectious intestinal diseases.¹⁶ This raises concerns regarding the handling of water by child minders. Primary prevention of diarrhoeal disease is based on interruption of the faecal-oral transmission of causative agents, and requires behavioural and environmental interventions such as sanitary waste disposal, adequate clean domestic water supplies, refuse removal and improved personal and food hygiene. Many of these objectives are outlined in the Reconstruction and Development Programme.¹⁷

Evidence from the microbiological study of water quality in households in Port Elizabeth¹⁸ suggests that faecal contamination of water occurs at various points in the chain of usage. Taps are contaminated by dirty hands, and animals when in the open air, storage containers may provide incubation sites for pathogenic organisms and drinking vessels may be washed in dirty water or contaminated during storage.

Consequently, it was concluded that mechanisms for ensuring that water supplies remain safe (up to and including the point of consumption) must go beyond mere water quality guidelines and include health and hygiene promotion, including facilitating factors, which will help consumers to obtain and use clean water.

Additional evidence from the Port Elizabeth study⁴⁹ also indicates that contamination of household water supplies is not restricted to informal housing areas, but also occurs in formal housing with supposedly adequate water and sanitation. The adverse consequences of contaminated water such as diarrhoea appear, however, to be more common in poorer communities. Mechanisms for this effect are not known but probably relate to poorer nutritional status and general environmental and domestic hygiene.

The Department of Water Affairs and Forestry White Paper on Water Supply and Sanitation⁵⁰ provides definitions applicable to the ready provision of a clean, safe water supply. Two of the key definitions are:

Quantity

Twenty-five litres per person per day is considered to be a minimum required for direct consumption, preparation of food, and personal hygiene. It is not considered to be adequate for full, healthy and productive life, which is why it is considered a minimum.⁵⁰

Quality

Once the minimum quantity of water is available, its health-related quality is as important in achieving the goal of a water supply adequate for health. The quality of water provided as a basic service should be in accordance with currently accepted standards, with regard to health-related chemical and microbial contaminants. It should also be acceptable to consumers in terms of its potability (taste, odour and appearance).⁵⁰

Two other important issues included in the White Paper⁵⁰ are distance to the supply since contamination occurs during transport and storage, and reliability of the supply. The latter is a big issue in many of the widely publicised water schemes where poor maintenance and illegal connections have resulted in very poor flow rates. The consequence is people spending long times in queues waiting and contamination of supplies because of polluted groundwater entering pipes.

WHEN IS WATER 'SAFE' FOR USE?

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To ensure that a drinking water supply is safe and does not contain any pathogenic microorganisms, it should be examined for indicators of pollution. It is impossible to test the water supply routinely for all pathogens to water-borne diseases because of the complexity of the testing process and the time and cost related to it. It is preferable to use indicator systems which are able to index the presence of pathogens and related

health risks in water. Ideally, the indicator system should fulfil a number of criteria, including the following:⁵¹ (i) it should be present when the pathogen is present and should be absent in unpolluted water; (ii) it should be present in numbers greater than the pathogen it indicates; (iii) its survival in the environment and resistance to treatment processes should be comparable to that of pathogens; (iv) it should not be harmful to human health; and (v) it should be easy to identify and isolate.

At present there is no absolute indicator which complies with all the above criteria, but the traditional indicators of drinking water quality include the coliform group (including the faecal or thermotolerant coliforms, and more specifically *Escherichia coli*) and the standard or heterotrophic plate count (HPC). As microbial drinking water quality guidelines aim at ensuring both protection of human health and the evaluation of the treatment efficacy, more than one indicator organism is often needed. Some of the indicators specifically address efficacy treatment of water with no, or very little, emphasis on human health (e.g. HPC). The coliform group of bacteria has been used much more than any other indicator group for monitoring drinking water, because it addresses both health and water treatment efficacy objectives.⁵²

An initiative has been developed as a joint venture between the South African Department of Water Affairs and Forestry and the Department of Health in the form of a tier system for evaluating water quality. The basis of this was the definition of five classes of water quality in terms of suitability of the water for drinking-water use, ranging from the ideal (Class 0) to Class 4, which is unacceptable water quality:⁵³

- Water in Class 0 ('Ideal') and Class 1 ('Good') is safe for life-time use.
- Water in Class 2 ('Marginal') may be safe for use under certain conditions but should be regarded with caution. Expert advice should be called upon to determine the real threat to sensitive users.
- Water in Class 3 ('Poor') should be considered unsafe for use and should be treated. The water may be used for short-term emergency supply but only where no alternative supplies are available.
- Water in Class 4 ('Dangerous') should be considered unsafe for use and should be treated. Water in this class is unsafe even for short-term emergency use.

People differ widely in their responses to water quality. What is safe for one person may not be safe for another. Even in the ideal class, there may be a few individuals who show some negative response. Where a few individuals may experience negative effects, these individuals have been identified as 'sensitive groups'. Sensitive groups include people who have particular medical conditions which make them more susceptible to poor water quality.⁵³

ROLE OF HYGIENE

As mentioned above, high levels of water contamination have been found in the home environment even when clean water was supplied. Improvements in water quality alone seem to have little effect on water handling practices and the subsequent contamination of stored water. Basic hygienic practices include hand washing after use of the toilet, and before and after preparing food. Contaminated water can be treated in the home by using household bleach at a concentration of 8 drops : 3.8 l water or by simply boiling it. Consequently beverages such as tea and coffee are 'safe'.

Health education involves much more than conveying simple facts or messages; it aims at getting people to think about their situation, challenge assumptions and work for change. Emphasis is placed on community participation and processes of problem solving, decision-making and empowerment. These are seen as preconditions for communities taking steps to change hygiene behaviours and improve their health.

Particularly crucial in this participation are recognition and utilisation of the key role women play as acceptors, users, managers and educators in matters of water supply and sanitation.⁵⁴⁻⁵⁶ Women influence directly the volume consumed, the quality of the water delivered to the household and the hygiene of eating utensils. In addition, it is women who form a constant link in the chain of contamination from faeces to fingers to food and who can break the chain by latrine use, hand-washing and protection of left-over food. Women therefore, can contribute to both the prevention of and recovery from diarrhoea.

ROLE OF FLUORIDE

Debates regarding the fluoridation of water in South Africa have raged for decades. Dental caries in South Africa remains a major public health problem and up to the present, general scientific consensus both locally and internationally is that benefits to dental health outweigh any potential risks. This has very recently been reviewed by Horowitz⁵⁷ from an international perspective. Current local thinking has been led by Chikte,⁵⁸ who states that 'the Department of Health together with the Department of Water Affairs and Forestry have agreed on regulations whereby provision is made to adjust the fluoride levels of the water supplies in South Africa. The regulations are in the process of legal editing and the countrywide implementation of this primary health measure now becomes imminent.'

A COMMENT ON WORLD TRENDS

During the decade 1981 - 1991 (The International Drinking Water Supply and Sanitation Decade) about 1 600 million

people were supplied with safe water. In spite of this, the WHO estimates that approximately one billion people lack safe water.⁵⁹ The major problem in the developing countries is that new sources of water that can easily be exploited are simply not available. Often additional supplies can only be obtained by diverting water from other uses, such as agriculture. Further development of new sources is technically complex and more expensive than existing projects. Inadequate pricing of water and inefficient billing further complicate the financial situation.

Diarrhoeal diseases remain the leading infectious cause of infant and child morbidity and mortality in developing countries.^{60,61} Diarrhoeal diseases have been found to account for more than one-third of paediatric deaths in most parts of the developing countries.⁶² More recently, incidence estimated using 7 350 cross-sectional surveys in 70 countries has yielded a global median incidence rate of 3.4 episodes per child per year.⁶³ This again raises questions about the actions of child minders.

CONCLUDING REMARKS

The current water supply position in South Africa is that about 12 million people out of a population of approximately 44 million do not have access to an adequate water supply. This means that a formidable task awaits the water supply industry in South Africa in the immediate future. While it is relatively easy to establish treatment plants for large water supplies, treating a large number of isolated groundwater supplies in a rural area, for example, is a major challenge. Priorities that will assist in identifying the supplies to be treated need to be established. The tier system of water quality classification in terms of suitability for drinking water use simplifies the process.

A daily intake of up to 2 l/day of 'safe, clean' water is desirable for optimal hydration, and may be taken in the form of tap water, beverages such as tea and coffee, and other tap water-based drinks. The advent of bottled 'mineral/spring' water in South Africa has made water drinking fashionable among the more affluent groups – despite the absence of safety regulations. The option of choice for the bulk of the population, however, remains the public utility.

Systems for monitoring water quality are currently biased towards measuring water quality in pipelines, which often does not correlate well with quality of water consumed. Suitable health promotion and surveillance systems need to be developed which facilitate consumption of sufficient water of good quality.

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