
2. Basic principles of safe drinking-water supply

Worldwide human freshwater use increased tenfold from 1900 to 2000. Fresh water is used for domestic, recreational, irrigation, livestock support and industrial purposes. The heaviest use is for irrigation, which typically accounts for well over 60%, and industry, which accounts for a further 25%. Aquifers are being rapidly depleted and contamination is a rising threat. There are three main sources for increasing supply of fresh water where it is needed: reuse for multiple purposes, desalination of seawater and brackish (salty) surface water and groundwater, and conservation (avoiding wasteful use and water loss from leaks). Each of these is becoming essential to meet demands in an increasing number of circumstances.

2.1 Water quantity

It has been estimated that the use of at least 20 litres of drinking-water per capita per day represents the minimum quantity required for drinking, food preparation and basic personal hygiene; a quantity higher than 50 litres per capita per day should ensure basic laundry and bathing in addition to the latter uses; quantities beyond 100 litres per capita per day would represent an optimal access and should ensure all the previous uses plus a considerable level of comfort and well-being (Howard & Bartram 2003). With no access to a water source within less than a 30 minute walk to fetch water and come back, consumption is likely to be less than the basic requirement, and hygiene will probably be inadequate. It is important to note, however, that even when optimal supply is achieved, if the supply is intermittent, additional risks to health occur because of the compromised condition of the drinking-water supply, as well as interference with the function of waterborne sanitation systems.

Table 2.1 demonstrates that only a small portion of the daily water needs are required for hydration and consumed as drinking-water. Climate and physical activity, as well as personal factors, affect the daily hydration need.

2.2 Water quality and safety

At least 1.8 million people die every year from diarrhoeal diseases, including cholera; 90% are children under the age of five, mostly in developing countries. WHO estimates that 88% of diarrhoeal disease is attributed to unsafe drinking-water supply, and inadequate sanitation and hygiene. Studies have indicated that

TABLE 2.1 TYPICAL VOLUMES OF FLUID INTAKE (FROM FOOD AND WATER) REQUIRED FOR HYDRATION

Human type	Daily fluid intake required for hydration (litres)			
	Average conditions	Manual labour / high temperature	Pregnancy	Lactation
Female adult	2.2	4.5	4.8	5.5
Male adult	2.9	4.5	NA	NA
Child	1.0	4.5	NA	NA

NA: not applicable.

Source: Howard & Bartram 2003.

improved drinking-water supply reduces diarrhoea morbidity by 6% to 25%, and improved sanitation reduces it by 32%. Hygiene interventions, including education and handwashing, can achieve up to 45% reduction of diarrhoea cases. In the absence of a good-quality drinking-water supply use of household water treatment, such as chlorination with a few drops of bleach at the point of use, can reduce diarrhoea episodes by 39% (see sections 2.3.2 and 17.2) (WHO/UNICEF 2005).

2.3 Public drinking-water supplies

A drinking-water supply system consists of three major elements: source, treatment and distribution to the users. Contamination can occur in any of those segments and the prevention and mitigation of contamination are essential roles of the water supplier, as well as assuring that the water continuously delivered to the consumer's entry point is safe and aesthetically acceptable. Each element in the system has vulnerabilities to be managed. The best protection is the multiple barrier approach, which relies upon a series of barriers from the protection of the source water to multiple treatment processes and distribution system integrity to ensure that potentially harmful contaminants are removed with confidence before they reach the consumer's tap.

The prevention, mitigation and elimination of contamination risks are the key responsibilities of water providers, and regulators in their oversight role. The consuming public also has responsibilities to protect the safety of the water within their dwellings by ensuring the integrity of their piped systems, providing quick repairs when needed and properly storing and using drawn water so as to protect its quality and safety. In the event of usage of non-publicly distributed water, or when the public supply is unreliable or unsafe, users can also take measures to ensure that their water is safe to drink (see section 17.2).

2.3.1 Source water quality and protection

Ground and surface source waters are at risk of contamination from both microbes and chemicals. Chemical contamination occurs sometimes from natural origins (e.g. excess fluoride and arsenic). A water supplier must therefore first under-

stand the composition of its source water and the origin of potential contamination that it could encounter, taking into account seasonal factors. Unprotected surface source waters can receive direct contaminant discharges, as well as surface runoff potentially contaminated by human or animal sanitary wastes, agricultural waste or chemicals (e.g. pesticides runoff and automobile oil from streets). Washing and defecation in streams will be a major contributor to downstream contamination. Groundwaters are often naturally protected by soil overlays; however, some geology is porous and vulnerable to contamination from surface wastes, and also from septic tanks and privies. Unprotected and poorly designed wells and the act of drawing water from open dug wells can increase the risk of contamination.

2.3.2 Water treatment

The water treatment process should be designed to remove or inactivate microbial (bacteria, virus, protozoa), chemical (inorganic, organic) and aesthetic (undesirable taste, odour, colour, turbidity) contaminants. The most basic filtration and disinfection technologies are usually necessary and sufficient to treat surface source waters; disinfection is often sufficient for many groundwaters if they are not subjected to contamination from surface activities. Some organisms (e.g. *Cryptosporidium* protozoa) are especially resistant to disinfection, so source protection (e.g. avoiding runoff from dairy activity) and efficient filtration are necessary where they may be present. The appropriate selection, design and operation of technologies are therefore essential to ensure successful treatment of the specific source water being utilized.

Chemical disinfection processes generate some disinfection by-products that are of at least theoretical concern in some situations. However, the benefits of disinfection far outweigh those concerns, and they should not be an excuse to compromise the essential control of microbial pathogens that cause huge numbers of deaths and illness where they are not managed by the water supplier.

2.3.3 Water distribution

The conventional goal is provision of safe piped water to the taps of all consumers. There are other approaches in use, by necessity, including central standpipes, protected wells and community bottled water. A leaking distribution system increases the likelihood that even safe water leaving the source or treatment facility will become contaminated before reaching the consumer. The distribution system must be designed, managed and maintained to present a minimal level of leakage and be continuously under internal pipe pressure greater than the external hydrostatic pressure. This will ensure delivery of water with reduced losses due to leaks, and minimization of excess growth of pathogenic microorganisms. A certain level of free residual chlorine or chloramine disinfectant will reduce

the risks of recontamination within the distribution system (see also section 3.1.4). Inflows of contaminated water during distribution are major sources of waterborne pathogens and thus waterborne disease.

Case study 2, from an article in the *Guardian Weekly*, provides an example of the drinking-water supply and sewage disposal problems faced by developing world cities. In addition to the factors mentioned, water contamination also occurs in the distribution system because the pipe network is old and the supply is intermittent.

CASE STUDY 2. DRINKING-WATER SUPPLY AND WASTE REMOVAL IN DHAKA

Dhaka is built on a flood plain that has been filled in with rubbish and human waste. When the Buri Ganga River floods many areas are inundated with sewage and industrial pollution. In 2002, the population of Dhaka was 10 million, whereas thirty years before it was 250,000. One quarter of the people of Dhaka live in the most squalid slums, but they cannot legally be supplied with water from the city drinking-water supply. They are assisted by NGOs like Wateraid and Tearfund.

The city needs 1.6 billion litres of water daily to provide for basic needs but only 1.26 billion litres are actually supplied. Nearly all the water (97%) comes from deep underground sources and the water table is being rapidly lowered so the source is not sustainable. The sewage system has a nominal capacity of 120,000 cubic meters per day but the main pipe is out of service. There are many illegal connections to the sewer which discharge industrial waste including heavy metals. This means that the sewage cannot be used for fertilizer or for aquaculture.

Waterborne disease is very common and tens of thousands of children in Dhaka die from this cause each year. Much of the pollution that causes waterborne disease occurs at the household level (~70%), because water is stored in rooftop tanks which are easily contaminated.

Source: *Guardian Weekly* (John Vidal, 11–17 April 2002).
