Water, water, everywhere – But is it safe to drink?

Peter Wyn-Jones

Most of us expect clean water to be on tap, but in many parts of the world there is no piped water. Even in developed countries constant vigilance is necessary if water is not to be a hazard to health.

The provision of clean water is something we in so-called developed countries take for granted; the quality of life is dependent on the quality of water. The need for sufficient quantity of water is self-evident, but the need for clean water has been understood for less than 200 years. This recognition has been linked to a realization that faecal waste must be disposed of in a way that does not jeopardize the provision of clean drinking water. It is a fact not always understood even today in developing countries; township dwellers in South Africa, for example, are impatient for the building of new houses, but do not appreciate that the water supply and sewerage system must come first. This need is recognized by the UK water industry in the support it gives to WaterAid in developing countries. We turn on a tap and out comes water we can drink, or bathe in, or use for cooking. We rarely doubt that, provided we pay our bill, water will be provided, even if it has to be transported hundreds of miles.

ABOVE:
A Victorian illustration of a water shortage in Frying Pan Alley, Clerkenwell, London.
COURTESY PETER WYN-JONES

But that is exactly what has to be done every day in many lands. Piped water supplies are the exception rather than the rule for most of the world, and fetching water from a well is one of the day's tasks for many peoples. Often this water will be of, at best, doubtful quality. But if it is a question of drinking polluted water or watching your child die of thirst then there is no real choice. It is a testament to history, engineering and science that we have a water supply in which we have confidence.

Poor quality water brings various effects, including intoxication with poisonous chemicals and life-threatening infectious diseases. Exposure to such effects may occur through drinking contaminated water, consumption of food grown or prepared in polluted water, or domestic activities in contaminated water necessary because there is no other. It is not only developing countries which face serious problems in the future if use or re-use of water is not carefully controlled in the face of increasing population; developed countries use increasing quantities of water per capita in industrial processes; many ground waters are becoming increasingly contaminated, and replenishment rates are slower than rates of use.

Water in history

Water has figured prominently in history; the City of Jericho owed its survival to the presence of a fresh water spring; the Minoan civilization in ancient Greece built a sewerage system to protect its water supply and the ancient Egyptians realized that contamination of their water supplies by dead dogs and rats was a cause of illness. Two thousand years ago the Roman and Persian Empires transported water in aqueducts; the Roman town of Durnovaria, modern Dorchester, was supplied with water from chalk wells and along an aqueduct from sites upstream on the River Frome.

Cholera

The worst of all waterborne diseases has undoubtedly been cholera. Cholera is a disease easily spread by water and has had major worldwide effects. Cholera outbreaks instigated many developments in water supply and allowed the progress that gave rise to the development of major cities. It first became a common, serious disease in Europe in the 1820s as a result of the increased trade with India. It had such a dramatic effect because of its ease of spread within the crowded and unsanitary conditions of the poor housing in which large numbers of people were obliged to live. The industrial revolution had drawn huge numbers of workers into the newly expanding cities where living conditions were very poor. Polluted drinking water sources, open sewers and polluted rivers combined to encourage the spread of the disease. The poor, without political power and common voice, suffered the greatest hardships and loss of life. Medicine had no effective understanding of the causes of outbreaks of cholera and no method of dealing with the overwhelming symptoms that could kill within a few hours. The first major epidemic in Europe killed over a million people during 1830–1832. Wars and social upheaval throughout the later 1800s led to a succession of further outbreaks.

Progress in microbiology, epidemiology and medicine was stimulated by the need to understand, prevent and treat cholera. In London, outbreaks of cholera in 1832, 1848–1849 and 1853–1854 prompted the formation of local government health boards. In 1847, local water supply companies were required by law to supply pure, wholesome and sufficient water for consumption. During the following years the worst slums were cleared in London, sewers built and water cleaned by slow sand filtration. In 1855 physician John Snow recognized that a larger number of people who used the water pump in Broad Street, Soho, were dying of the disease compared with communities using a different water supply and pump in the neighbourhood. He persuaded the authorities to remove the pump handle to prevent the use of the suspect water supply. The local outbreak was halted and Snow thus demonstrated that the hitherto controversial theory of waterborne disease was indeed a fact, something over which even *The Times* had shown some scepticism:

'*A certain amount of opposition may doubtless be anticipated in all measures of sanitary reform. Cleanliness is highly becoming and supremely beneficial, but it involves some trouble and, what is worse, some expense. There will always be found people to vote against a rate, for whatever purpose levied, but in the long run common sense prevails, and when the reforms are once accomplished everyone testifies to the advantage of the result.*' (Editorial, 3 August 1854)

Problems with cholera remain; the pandemic of 1991 that began in Chile is a graphic demonstration of the great harm that can be done by a combination of social upheaval, deprivation and climate change. It is possible that peasants, fleeing Shining Path guerrilla violence, migrated in huge numbers to the coastal regions. Shellfish and river water were contaminated with *Vibrio cholerae* and transmitted the disease. The river water was also used for irrigating salad crops which then spread both cholera and typhoid, which in turn precipitated the loss of international confidence in Chilean goods and consequently the collapse of the economy. At the same time the *El Niño* phenomenon caused heavy rainfall in Peru and dramatic increases in cholera cases.

Supplying potable water

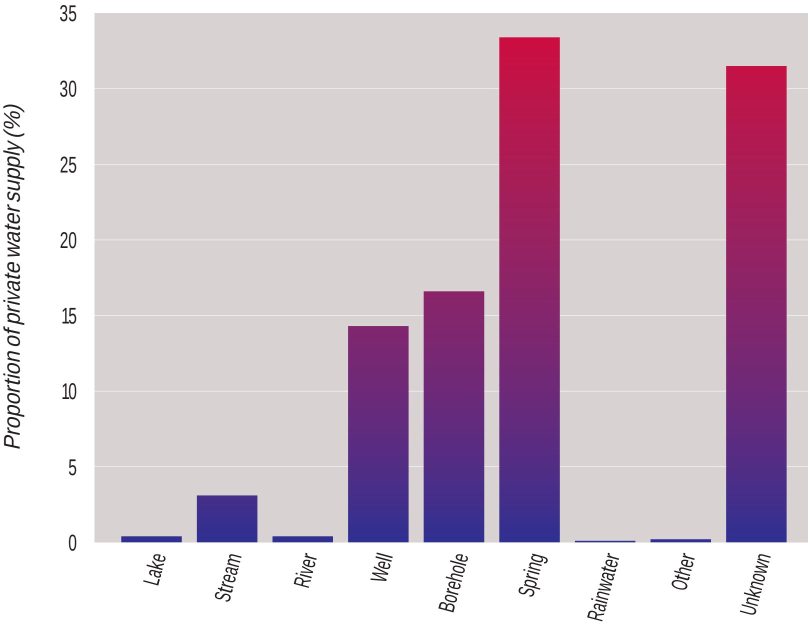
The provision of clean drinking water and adequate waste disposal is always an urgent need in refugee crises or natural disasters. It has been estimated that to prevent illness in an emergency situation there is an estimated requirement of 30–50 litres per person per day for drinking, cooking and washing needs. This starkly contrasts with the typical UK household use of 140 litres of mains potable water per person per day and the US figure of 410 litres per person per day.

In the natural water cycle, rainfall on land accumulates to form streams, rivers and lakes (surface waters), or soaks into the soil and lower rocks (groundwaters), or is taken up by plants. The surface layer of both fresh and marine water bodies evaporates to form water vapour, which in turn becomes rain or snow. Upon this cycle man has imposed a complex network of water abstraction, storage, transportation, usage, disposal and recycling. Abstraction in the UK is from surface waters such as reservoirs of rain run-off, or rivers that may contain wastewater, and also from groundwater. About 35% of UK drinking water is derived from groundwater and may only require disinfection before distribution.

In making water fit to drink (potable), all abstracted source water in the UK is treated to reach the same standard, the level of treatment given being determined by the quality of the source water. Surface reservoir or river water is treated with a coagulant such as ferric sulphate to assist the formation of flocs of organic matter which are removed as the water is passed upwards through primary sand filters. Secondary filters such as fine slow sand filters remove further bacteria and organic matter. Clarified water is disinfected with chlorine or sometimes ozone. The level of chlorine added allows for a residual to be present throughout the distribution system; a typical level would be 1 mg per litre on leaving the treatment works and a level of 0·2 mg per litre at the consumer's tap.

Most water in the UK is supplied by water companies, but about 1% of the population is supplied with water from a private supply. A private water supply is one which is not managed by a statutory water undertaker, and the responsibility for its maintenance and repair lies with the owner or person who uses it. Private supplies may arise from several sources, including springs, boreholes or wells, and may require no treatment (Fig. 1). Springs are the most common type, comprising about a third of private supplies in the UK. The source and its catchment are often poorly protected from access by wild and domestic animals. Improved protection is offered to boreholes and wells but many are old and in need of repair.

Fig. 1. Relative percentages of private water supply sources in the UK



Source: K. Shepherd, PhD thesis, University of Sunderland

Private supplies are differentiated into those used for domestic purposes (Category 1), which are further classified A–F according to the number of people supplied, and those used for other purposes, such as hospitals, camp sites and premises where food and drink are prepared for retail sale (Category 2). The classes within the domestic supplies range from the supply of water to more than 5,000 people down to single premises. A summary of the classification of Category 1 supplies is shown in Table 1.

Table 1. Category 1 private water supplies

Class	No. of people supplied (per day)	Average daily volume (m^3 per day)
A	> 5,000	> 1,000
B	501–5,000	101–1,000
C	101–500	21–100
D	25–100	2–20
E	< 25	< 5
F	Single domestic property	–

Legislation

Legislation to protect the microbiological quality of drinking water is covered by EU Council Directives. Most types of water are covered by Directive 80/778/EEC, the so-called Drinking Water Directive, but this is to be replaced by Directive 98/83/EEC. Water for human consumption includes bottled waters and mineral waters, the latter being governed by regulations different from the Drinking Water Directive. The 1980 Directive included parameters for total and faecal coliforms, enterococci, sulphite-reducing anaerobes and colony counts at 22 and 37 °C. Faecal coliforms are regarded as *Escherichia coli* and UK legislation does not specify numerical values for colony counts. Coliforms must not be detected in 95 % of samples when more than 50 are taken from any one point in a 12-month period. No *E. coli* is permissible. The new Directive will include microbiological parameters and also govern the aesthetic quality of the water and the effectiveness of treatment. Values for coliforms and *E. coli* will remain, though the *Clostridium perfringens* limit will be more stringent. Additionally, in the UK there is now legislation to monitor treatment plants for *Cryptosporidium* oocysts. Following risk-assessment of all treatment works in England and Wales, those designated 'at risk' are required to carry out continuous monitoring to count *Cryptosporidium* oocysts in 1,000 litres of water every 24 hours. It will be a criminal offence to supply water containing more than 10 *Cryptosporidium* oocysts per 100 litres.

Bottled water

The current fashion for buying bottled water has heightened interest in its microbiology. Bottled water other than natural mineral water is governed by the same Directives as mains or private waters. Recognition of water as 'mineral water' is by approval of the source by the relevant local authority, and it must not be altered in any way to affect its microbiological or chemical composition. Bottled waters may contain a variety of micro-organisms, though no potential pathogens are permitted, since survival or even multiplication of organisms may occur on the supermarket shelf. It is sometimes interesting to hear the reasons given for paying for a product microbiologically inferior to that coming out of the tap.

Water-associated disease

Drinking water-associated outbreaks of disease are usually the result of one of four events:

- inadequate removal of organisms during treatment;
- failure in the treatment system so the intended procedures are not carried out;
- failure in the chlorination equipment;
- breaks in the integrity of the distribution infrastructure.

Outbreaks of typhoid, cholera and other bacteria are a thing of the past in developed countries, a reflection of engineering and scientific skills, as well as learning from history. Waterborne disease due to other micro-organisms does occur, however. Viruses have been responsible for a number of drinking water outbreaks worldwide, though less frequently than bacteria or protozoa. Outbreaks due to Norwalk-like viruses (NLVs) are the most widely reported, though the evidence is circumstantial. They include an outbreak at a tourist hotel where sewage had seeped into the borehole water used to supply the hotel through faults in the rock strata. Another outbreak at a mobile home park was the result of sewage gaining access to the well. Contaminated water used in the production of cakes in a bakery is likely to have been the cause of an outbreak of NLV amongst employees and customers in South Wales, and gastroenteritis with a likely viral origin occurred when sewage from a broken pipe contaminated a drinking water supply pipe in Bramham, Yorkshire in 1980 and when sewage contaminated a borehole in Naas in Ireland in 1991. Cruise ships are a favourite haunt of NLVs, which often strike when the vessel is well out to sea and out of reach of any comfort for those affected. Disinfection of the water supply on board and compensation for ruined holidays is an expensive consequence for tour companies.

Inadequate removal of *Cryptosporidium*, and less frequently *Giardia*, and *Toxoplasma* have led to outbreaks when chlorination has been the only barrier used in treatment or sand filters have been contaminated. *Campylobacter* outbreaks are most often associated with wells providing private supplies. These small rural systems are most likely to be contaminated with animal waste. For the same reason *E. coli* O157 outbreaks may be found in rural situations. For example, at a music festival, in a field previously used for cattle grazing, an infection was transmitted through mud and standing water after heavy rain.

All this pales into insignificance, however, when compared with the *Cryptosporidium* outbreak in Milwaukee in 1993 in which over 400,000 people were affected. The authorities knew something was wrong only when alerted by pharmacists who reported rocketing sales of anti-diarrhoea remedies. Outbreaks due to this organism have occurred in the UK and other EU countries, but not on as grand a scale. Initial blame levelled at farmers for allowing slurry to run into rivers which were later used for drinking water abstraction may have been justified in some cases, but molecular typing of *Cryptosporidium* now allows us to see that much of the *Cryptosporidium* in rivers is actually of human, rather than animal origin, and that its source must be sewage treatment plants and non-point sources other than farms.

● The future

The future of drinking water provision lies in continued vigilance against new and known micro-organisms, and in more effective use of our water. The use of 'grey' water, already used for washing, then recycled for similar purposes, is one way of economizing on water treatment costs. More effective detection methods, risk assessment and predictive modelling of risk associated with water use will help to ensure that we use this very valuable resource wisely and with consideration not just for ourselves but for those whose water supply is little more than a stream or a hole in the ground.

● *Peter Wyn-Jones is Convener of the SGM Education Group and Principal Lecturer in Virology & Microbiology at the School of Sciences, University of Sunderland, Sunderland SR1 3SD*
Tel. 0191 515 2520; Fax 0191 515 2531;
email peter.wyn-jones@sunderland.ac.uk