Drinking water quality: new challenges for an old problem

The provision of safe drinking water has been a high priority in public health ever since John Snow removed the handle from the Broad Street pump more than a century ago to quell an epidemic of cholera in London. Today, three main issues surrounding the provision of safe drinking water are emerging. These are: to better define the burden of gastroenteritis attributable to drinking water and the organisms which cause it; to identify those water treatment systems which are cost effective and safe; and to determine the optimal methods for monitoring drinking water to ensure its continuing safety.

True burden of disease
Defining the amount of gastroenteritis that is attributable to drinking water is difficult, especially when cases are widely distributed in time and space. Large outbreaks of gastroenteritis that occur over a short period and in a confined area are usually relatively easy to identify. In the Milwaukee outbreak, for example, an estimated 400 000 cases of diarrhoea occurred over a 14 day period in a single city and were easily visible above the background incidence.1 In contrast, smaller outbreaks involving fewer people, over a longer period, and over a wide geographical area, are more difficult to detect from the background incidence without the use of complex surveillance systems.

What is almost impossible to answer, without a specific aetiological study, is whether water borne gastroenteritis is endemic and hence contributes significantly to the background incidence of disease. Recent research has suggested that much water borne gastroenteritis is endemic and causes a greater burden of disease than that occurring during the highly publicised outbreaks. A Canadian intervention study, for example, found that almost one third of the gastroenteritis occurring outside a known epidemic was attributable to drinking unfiltered water.2 In this study, households were randomised to receive either their normal tap water or bottled water from which all organisms had been removed. Those who received tap water had 30% more gastroenteritis than those who drank bottled water. As participants knew which type of water they were receiving, this may have influenced their reporting of gastrointestinal symptoms, and therefore this type of study will need to be repeated with participants blinded.

This study was conducted in an area that received drinking water which had been treated with a combination of flocculation, chlorination, and sand filtration, and which generally met all water quality standards. In areas where the water quality is substantially worse, a greater proportion of the background incidence of gastroenteritis is likely to be due to drinking water.

Providing drinking water that does not significantly contribute to endemic gastroenteritis among the entire population does not necessarily protect subgroups that are more susceptible to water borne organisms. Patients with HIV infection and AIDS, for example, are at risk of severe and intractable diarrhoea from Cryptosporidium, a parasite which has recently been identified as an important contaminant in drinking water.3 As these patients represent only a very small fraction of the community, local measures, such as the use of specialised water filters in their homes, may be an appropriate preventive measure.4 In contrast, patients taking acid suppressing medication to prevent peptic ulceration are common,5 and have been found to require a lower infective dose of some water borne organisms to develop clinical disease.6 7

Once the true burden of endemic gastrointestinal disease from drinking water has been identified, the next major step is to define the specific organisms responsible. Knowledge of this is important because it will help to identify the water treatment processes which will be most effective. On the basis of the most recent data, newly emerging organisms—including parasites such as Cryptosporidium and viruses such as Norwalk—are likely to be making a greater contribution to water borne endemic gastroenteritis than are bacteria.8 9

Concern about the threat from Cryptosporidium in drinking water, in the wake of the Milwaukee outbreak, led to a major workshop in the United States in 1994 to consider methods to reduce the public health impact of this organism.10

Water treatment processes
Water treatment systems in current use have been primarily developed to control pathogenic bacteria and improve the aesthetic quality of water. Chlorine is highly effective against pathogenic bacteria, but usually has little effect on many parasites found in drinking water.11 The addition of flocculation and deep sand filtration to disinfection systems are used primarily to reduce the turbidity of drinking water, which can bring about a substantial reduction in the number of cryptosporidial cysts, but result in little effect on viruses. Even in water treated with all these methods, and in which all current water quality guidelines are being met, large outbreaks can still occur. Unusual weather conditions may contribute to this, as in the Milwaukee outbreak, which occurred after heavy rains caused increased turbidity and proliferation of cryptosporidial cysts in the water.12

Water treatment is expensive. In some cases, major changes to treatment systems are clearly justified, as it was in Milwaukee where chlorine resistant pathogens were the cause of the problem. In contrast, in some protected water catchment systems, where the quality of the source water is very high after chlorination alone, there may be little to be gained by upgrading the water treatment process. The source and site of microbialological
contamination are also important determinants of the type of water treatment system required. For example, if Cryptosporidium enters the system through a permeable physical barrier such as sand filtration, further upgrading of the system at the level of the source water will have little effect. Before decisions can be made about the most appropriate treatment for a particular water system, it is important to know how many cases of disease are attributable to drinking the water in that system, and what effect the introduction of various water treatment processes is likely to have on reducing this number, so that the cost per episode of human disease prevented can be calculated.

In recent years, concern has been expressed about the safety of some methods used to disinfect and otherwise treat drinking water. Chlorine, for example, is known to react with organic matter within drinking water distribution systems to form low levels of trihalomethanes. There is some epidemiological evidence that trihalomethanes may be carcinogenic in humans. 13 This evidence is not strong, however, as many of the cancer studies were ecological in design with poor indices of exposure relating to water intake and hence have resulted in considerable uncertainty in the ingested dose of trihalomethanes. Recently, the ability of epidemiological methods to detect health effects from low level environmental exposures, often the case in chemical contamination of drinking water, has been seriously questioned. 14 Nevertheless, potential adverse effects from chemical additives used in the provision of drinking water need to be considered in any cost benefit analyses of different water treatment systems.

In some cases, concern over the production of trihalomethanes has caused a scaling down of the amount of chlorine added to drinking water, sometimes with disastrous consequences. In Peru, for example, concern over the carcinogenic potential of trihalomethane concentrations in drinking water led to a reduction in added chlorine, resulting in a serious widespread cholera outbreak. 15

In summary, decisions about the introduction of the most appropriate water treatment system need to take a rational approach, and consider the economic and social costs, and benefits of interventions, aimed at improving water quality in that particular system. We therefore need better methods to assess dose-response relations between different levels of microbiological contamination and adverse health outcomes and to develop appropriate risk assessment models similar to those developed for environmental chemical contamination. 14

Monitoring drinking water quality
Tests for indicator organisms, such as coliforms, have been developed to provide a cheap, simple, and reliable means of routinely testing the quality of drinking water. Tests for indicator organisms, however, have the disadvantage of false positive and negative results. This arises because specific pathogens may occur in the absence of rises in indicator organisms or alternatively indicator organisms may rise in the absence of any pathogen. A significant rise in the turbidity of the source water may also indicate that there is increased risk of microbiological contamination. This was, for example, a good indicator that the source water quality had deteriorated during the massive outbreak of Cryptosporidiosis in Milwaukee, although the treated water met all the required standards during the outbreak. 1

Testing water for specific pathogens on a routine basis would be a very expensive exercise, and one that could not be justified on scientific grounds at present. A single assay for Cryptosporidium, for example, requires large volumes of water when low levels of detection are required, and can cost several hundred dollars to perform. More importantly, however, the relevance to health of such a result is unknown. Cryptosporidium is often found at low concentrations in water samples from cities where no recognised outbreak has occurred. 11 This may indicate that the cysts are not viable or are below the infective dose. An arbitrary detection level of 10–30 oocysts per litre has been set on the basis that recognised outbreaks have usually been associated with higher concentrations than this. 17 If a single sample contains organisms at this level, then the water authority should consider additional sampling, expedited processing of samples, and attention to other characteristics of the performance, of the treatment plant.

An accurate, cheap, and effective means of testing water to ensure that it is safe from all pathogens does not currently exist. It is hoped that new technology that is easier to perform, such as the polymerase chain reaction, will provide the basis for such assays, although the relevance of a positive test in terms of human health needs to be clarified before such tests are routinely advocated.

In summary, the effective prevention of gastroenteritis from drinking water requires a large amount of data which are currently not available. Firstly, we need to know what proportion of endemic gastroenteritis from each specific organism is attributable to drinking water. Armed with this knowledge we then need to know what water treatment systems will remove these organisms and assure that these methods are both safe and cost effective. To ensure that water quality is maintained we need to know what are the most appropriate tests of water quality to perform, and how often and where in the water distribution network water samples should be taken. Finally, there needs to be in place an effective and rapid surveillance system that will minimise the time required to recognise both the background incidence and outbreaks of disease attributable to the drinking water supply. As the provision of safe drinking water can be an emotive issue, it is important that decisions are made on the basis of high quality information that can sustain pressure from groups with vested interests.

In the future, solutions to problems in the quality of drinking water are not likely to be as simple, as measurably effective, or as free from side effects as John Snow removing the handle from the Broad Street pump during the cholera epidemic in London. Nevertheless, this should not deter us from our primary aim of ensuring that high quality and safe drinking water is generally available to everyone.

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