CHAPTER 10

Chemical and physical agents

Chemical contaminants can enter surface waters or be deposited on beaches from both natural and anthropogenic sources. These may be either point sources, such as an industrial outfall or a natural spring, or non-point (diffuse) sources, such as runoff from land. In most cases, there will be significant dilution or attenuation of contaminants, depending on circumstances. In all cases, chemical and physical contamination must be assessed on a local basis.

The potential risks from contamination of recreational water environments by chemical and physical agents are described in this chapter. Chemical and physical agents may also lead to degradation of the aesthetic quality of recreational water environments, which is addressed in chapter 9. Toxins from cyanobacteria and algae, while chemical in nature, are addressed in chapters 7 and 8.

10.1 Exposure assessment

Exposure is one of the key issues in determining the risk of toxic effects from chemicals in recreational waters. The form of recreational activity will therefore play a significant role. Routes of exposure will be direct surface contact, including skin, eyes and mucous membranes, inhalation and ingestion. In assessing the risk from a particular contaminant, the frequency, extent and likelihood of exposure are important parts of the evaluation.

Generally, exposure of skin and mucous membranes is most frequent. For activities involving whole-body contact, the probability that some water will be ingested increases. The skill of the participant in their water recreation activity will be important in determining the extent of involuntary exposure, particularly by ingestion.

Inhalation can be important in circumstances where there is a significant amount of spray, such as in waterskiing or white water canoeing. Generally, however, inhalation is of greater significance in swimming pools and related environments where disinfection is practised (see Volume 2 of *Guidelines for Safe Recreational Water Environments*).

The use of wet suits implies that long periods may be spent in the water. In addition, by trapping water against the skin, the wet suit will create a micro-environment that will enhance the absorption of chemicals through the skin and potentially the development of skin irritation or allergy (see also chapters 7 and 8).

Many substances of potential concern are of low water solubility and will tend to migrate to sediments, where they may accumulate. Where the sediments remain undisturbed, this is of low concern. However, where the sediment is disturbed and

resuspended or where recreational water users are in intimate contact with sediment, then this may contribute to exposure. This can result in increased skin exposure, but little is known of the quantitative movement of chemicals adsorbed on sediment through skin. In general, it is probable that this will make only a minor contribution to overall exposure.

10.2 Hydrogen ion concentration (pH)

pH has a direct impact on the recreational users of water only at very low or very high values. Under these circumstances, pH may have effects on the skin and eyes.

Primary irritation of the skin appears to be linked to high pH, although the mechanism is unclear. It is unlikely that irritation or dermatitis would be caused directly by high or low pH, although these conditions may be exacerbated, particularly in sensitive subjects.

High or low pH may also to and exacerbate irritation of the eye by chemicals. However, no adverse effects on the eye were noted in a study by Basu et al. (1984), who examined the capacity of water from two inland lakes in Ontario, Canada (Clearwater Lake: pH ~4.5, acid neutralizing capacity 40 µeq/litre; Red Chalk Lake: pH ~6.5, acid neutralizing capacity 70 µeq/litre), to cause eye irritation in rabbits and human volunteers.

Water of high pH could have an adverse effect on hair condition by causing the hair fibres to swell and by cleaving the cystine bridges between adjacent polypeptide chains of hair protein. However, the impact will also be dictated by the buffering capacity of the water.

In very soft and poorly buffered waters with an alkalinity of less than about 40 mg of calcium carbonate per litre, pH will be more susceptible to wide fluctuations. In well buffered waters, pH is much less likely to reach extreme values, but the significance of high or low pH for skin reactions and eye irritation will be greater.

10.3 Dissolved oxygen

Dissolved oxygen will not have a direct effect on users, but it will influence microbial activity and the chemical oxidation state of various metals, such as iron. It will be of great importance in preventing the formation of undesirable amounts of hydrogen sulfide. These factors are not a human health concern, but may give rise to aesthetic issues (see chapter 9). These problems will not occur in waters with sufficient dissolved oxygen.

10.4 Chemical contaminants

In general, the potential risks from chemical contamination of recreational waters, apart from toxins produced by marine and freshwater cyanobacteria and algae (chapters 7 and 8), marine animals (chapter 11) or other exceptional circumstances, will be very much smaller than the potential risks from other hazards outlined in chapters 2–5). It is unlikely that water users will come into contact with sufficiently high concentrations of most contaminants to cause adverse effects following a single exposure. Even repeated (chronic) exposure is unlikely to result in adverse effects at the

concentrations of contaminants typically found in water and with the exposure patterns of most recreational water users. However, it remains important to ensure that chemical hazards and any potential human health risks associated with them are recognized and controlled and that users can be reassured as to their personal safety.

For recreational water area users, the dangers of chemical contamination will depend on the particular circumstances of the area under consideration. For example, a fast-flowing upland river, remote lakes or drinking-water reservoir used for recreation will be unlikely to suffer from significant chemical contamination. However, slow-flowing lowland rivers, lowland lakes and coastal waters may be subject to continuous or intermittent discharges and may have suffered from past pollution, which could result in contaminated sediments. Where motorboats are used extensively, chemical contamination of the water by gasoline additives may cause concern. Where a water body used for recreational purposes receives significant wastewater discharges, its chemical constitution and how recreational areas will be influenced should be considered, taking into account both the dilution and dispersion of the discharge.

In general, significant contamination by naturally occurring contaminants is less likely than contamination by industrial, agricultural and municipal pollution, but there may be circumstances where small recreational water bodies containing water from mineral-rich strata could contain high concentrations of some substances. Such waters, however, are more likely to contain metals, such as iron, that may give rise to aesthetic degradation of the water (see chapter 9).

There is a great deal of anecdotal evidence regarding skin rashes and related effects in individuals coming into contact with chemically contaminated water. Except in circumstances of extreme contamination or the presence of algal blooms (covered in chapters 7 and 8), evidence amenable to critical scientific evaluation is not available.

10.5 Guideline values

The chemical quality of recreational waters does not seem to represent a serious health risk for recreational water users, and in most cases the concentration of chemical contaminants will be below drinking-water guideline values. There are no specific rules that can easily be applied to calculate guideline values for chemical contaminants in recreational waters. However, as long as care is taken in their application, the WHO *Guidelines for Drinking-water Quality* (WHO, 1993, 1998) can provide a starting point for deriving values that could be used to make a screening level risk assessment under specific circumstances.

WHO drinking-water guideline values relate to water ingestion and, in most cases, to lifetime exposure. However, drinking-water guidelines may be related to recreational exposure. Mance et al. (1984) suggested that environmental quality standards for chemicals in recreational waters should be based on the assumption that recreational water makes only a relatively minor contribution to intake. They assumed a contribution for swimming of an equivalent of 10% of drinking-water consumption. Since most authorities (including WHO) assume consumption of 2 litres of drinking-water per day, this would result in an intake of 200 ml per day from recreational contact with water.

A simple screening approach is therefore that a substance occuring in recreational water at a concentration ten times that stipulated in the drinking-water guidelines may merit further consideration.

10.5.1 Inorganic contaminants

Most recreational exposure to inorganic contaminants will be by ingestion, with dermal contact and inhalation contributing little to exposure. Based on the assumptions given above, screening values for the ingestion of inorganic contaminants in recreational waters can be calculated from the WHO *Guidelines for Drinking-water Quality* (WHO, 1993, 1998). However, if the corresponding value for a particular inorganic contaminant is exceeded, this does not necessarily imply that a problem exists. Rather, it suggests the need for a specific evaluation of the contaminant, taking into consideration local circumstances and conditions of the recreational water area (see section 10.6). These could include, for example, the characteristics of the typical recreational water user, the degree of water contact of the recreational water activities carried out, effects of winds/currents/tides on contaminant concentration and the chemical form of the inorganic contaminant. For example, the chemical form of metals may significantly affect their solubility and absorption, and this should be taken into account in assessing any potential risks from exposure.

10.5.2 Organic contaminants

There are many organic contaminants that can be present in surface waters as a consequence of industrial and agricultural activity. Many of these substances will primarily be associated with sediments and particulate matter. This is particularly true of substances that are highly lipophilic, such as chlorinated biphenyls.

Skin absorption from contact with sediment is a possibility that cannot be ruled out, however, for most recreational purposes the extent of contact is likely to be small. However, consideration should be given to the likelihood of sediment being disturbed and the possibility of ingestion by some groups, such as infants and small children.

Some small chlorinated molecules (e.g., chloroform or tri- and tetrachloroethene) and hydrocarbons (e.g., toluene) have been shown to be absorbed through skin from water. A study by the US EPA (1992) concluded that the contribution from skin absorption and inhalation could contribute as much again as water ingestion.

As with inorganic contaminants, the WHO *Guidelines for Drinking-water Quality* (WHO, 1993, 1998) can be used as a basis for screening the potential risk from specific organic chemicals. Again, if the screening value for a particular organic contaminant is exceeded, this does not necessarily imply that a problem exists (see section 10.6). Rather, it suggests the need for a specific evaluation of the contaminant, taking into consideration local circumstances and conditions.

10.6 Approach to assessing chemical hazards in recreational waters

1. An inspection of the recreational water area will show if there are any obvious sources of chemical contamination, such as outfalls. These are a problem if they

are easily accessible or if the effluent does not receive immediate and significant dilution. Intelligence on past industry in the recreational area and upstream will give an indication of whether contaminated sediments are likely to be present and also the identity of possible contaminants. Knowledge is required of upstream industry and whether direct or indirect discharges are made to the water.

2. The pattern and type of recreational use of the water need to be carefully considered to determine the degree of contact with the water and if there is a significant risk of ingestion.
3. If it is probable that contamination is occurring and there is significant exposure of users, then chemical analysis will be required to support a quantitative risk assessment. Care should be taken in designing the sampling programme to account for variation in time and water movement. If resources are limited and the situation complex, then samples should first be taken at the point considered to give rise to the worst case; only if this gives rise to concern is there a need for wider sampling.
4. The quantitative risk assessment should consider the anticipated exposure in terms of both dose (i.e., is there significant ingestion?) and frequency of exposure. The WHO *Guidelines for Drinking-water Quality*, which provide a point of reference for exposure through ingestion, with a few exceptions described in the guideline summaries, relate to lifetime exposure.
5. It is important that the basis of any guidelines or standards, which are considered to be necessary, be made transparent. Without this, there is a danger that even occasional or trivial exceedances could unnecessarily undermine users' confidence.

10.7 References

Basu PK, Avaria M, Cutz A, Chipman M (1984) Ocular effects of water from acidic lakes: an experimental study. *Canadian Journal of Ophthalmology*, 19: 134–141.

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