CHAPTER 7

FRESHWATER ALGAE AND CYANOBACTERIA

In freshwaters, the term "algae" refers to microscopically small, in principle unicellular organisms, some of which form colonies and thus reach sizes visible to the naked eye as minute green particles. These organisms are usually finely dispersed throughout the water and may cause considerable turbidity if they attain high densities. "Cyanobacteria" are organisms with some characteristics of bacteria and some of algae. They are similar to algae in size, and unlike other bacteria, they contain blue-green or green pigments and thus perform photosynthesis. Therefore, they are also termed "blue-green algae". In contrast to most algae, many species of cyanobacteria may accumulate to surface scums, often termed "blooms", of extremely high cell density.

Livestock poisonings have lead to the study of cyanobacterial toxicity, and during the past 2-3 decades, the chemical structures of a number of cyanobacterial toxins (‘cyanotoxins’) have been identified and their mechanisms of toxicity established. In contrast, toxic metabolites from freshwater algae have scarcely been investigated, but toxicity has been shown for freshwater species of *Dinophyceae* and *Prymnesiophyceae* (see below). As marine species of these genera often contain toxins, it is reasonable to expect toxic species among these groups in freshwaters as well.

In comparing the relative cause for concern arising from toxic cyanobacteria to that arising from potentially toxic freshwater algae, mechanisms of cell concentrations are a key factor. Although many species of freshwater algae may proliferate quite intensively in eutrophic (excessively fertilised) waters, they do not form dense surface scums as do some cyanobacteria. Toxins they may contain therefore are not accumulated to concentrations likely to become hazardous to human health or livestock. In contrast to cyanobacteria, freshwater algae have not been implicated in cases of livestock or wildlife poisoning. For these reasons, this chapter will focus primarily on health impacts of cyanobacteria.

Some species of cyanobacteria also proliferate in brackish coastal waters, particularly under calm conditions. *Nodularia spumigena* is the most widespread of these organisms, contains toxins and may form surface scums. Brackish waters also harbour toxic algae such as *Prymnesium* (chapter 6).

Many species of cyanobacteria form filaments or colonies, sometimes up to one or two millimetres in diameter. Benthic species inhabit the sediment surface, sometimes forming dense mats.

More detailed coverage of cyanobacteria and human health is available in *Toxic Cyanobacteria in Water* (Chorus and Bartram, Eds, 1999) published by E&FN Spon on behalf of WHO.

7.1 Evidence for Adverse Health Effects caused by Cyanobacteria

Concern of health impairments due to toxic cyanobacteria in recreational waters arises from several sources of information. Observations of lethal poisoning of animals drinking from water with mass developments of cyanobacteria are numerous. The first documented case of a lethal intoxication of livestock caused by drinking of water from a lake heavily infested with cyanobacteria was published in the last century, and cases recorded since include sheep, cattle, horses, pigs, dogs, fish, rodents, amphibians, waterfowl, bats, zebras and rhinoceros (Codd *et al.*, 1989). Dogs have died after grooming accumulations of cyanobacteria out of their fur, or after ingesting beached mats of benthic cyanobacteria. Observations of human deaths through cyanobacterial toxins have been limited to exposure through renal dialysis (Jochimesen *et al.,* 1998), but health impairments are known from numerous anecdotal reports of irritations of the skin and/or mucous membranes, and also from documented cases of illness after exposure through drinking water as well as accidental swallowing or aspiration of scum material (Table 7.2). Other sources of information are toxicological data from animal experiments and data on concentrations of cyanobacterial toxins in waters used for drinking-water abstraction and recreation.

From the 1960s to the end of the 1980s detection of cyanotoxin was primarily performed with the mouse bioassay, chiefly to assess the safety of drinking water supplies. Due to the high cost and few approved laboratories (as well as ethical limitations of applicability), this method is not suitable for large screening or monitoring programs. However, effective methods of chemical analysis are now available for the known toxins, and sensitive immuno-assays as well as enzyme assays have become commercially available for the most important ones (e.g. microcystins and saxitoxin, Table 7.1). These opens new possibilities for screening programs targeted at assessment of the potential risk, as well as for regular surveillance.

Table 7.1 Acute intoxications of humans with cyanobacteria

Cases attributed to cyanotoxins in drinking water	
1931:	USA: a massive Microcystis-bloom in the Ohio and Potomac Rivers caused illness of 5000 - 8000 persons whose drinking water was gained from these rivers. Drinking water treatment by precipitation, filtration and chlorination was not sufficient to remove the toxins (Tisdale, 1931).
1968:	numerous cases of gastrointestinal illness after exposure to mass developments of cyanobacteria were compiled by Schwimmer and Schwimmer (1968).
1975:	endotoxic shock of 23 dialysis-patients in Washington DC is attributed to a cyanobacterial bloom in a drinking-water reservoir (Hindman *et al.,* 1975).
1979:	Australia: Combating a bloom of *Cylindrospermopsis raciborskii* in a drinking water reservoir on Palm Island with copper sulphate lead to liberation of toxins from the cells into the water and thus caused serious illness (with hospitalisation) of 141 persons supplied from this reservoir (Falconer, 1993, 1994).
1981:	Australia: In the city of Armidale liver enzyme activities were elevated in the blood of the population supplied from surface water polluted by *Microcystis* spp. (Falconer *et al.*, 1983).
1985:	USA: Carmichael (1994) compiled case studies on nausea, vomiting, diarrhoea, fever, eye-, ear-, and throat-infections after exposure to mass developments of cyanobacteria.
1993:	China: the incidence of liver cancer relates clearly to water sources and is significantly higher for populations using cyanobacteria-infested surface waters as compared to those drinking groundwater (Yu, 1995).
1993:	Australia: Falconer (1994) estimated that due to toxic cyanobacterial blooms, more than 600 000 person-days are lost for drinking water abstraction annually.
1994:	Sweden near Malmö: illegal use of untreated river water in a sugar factory led to an accidental cross-connection with the drinking water supply for an uncertain number of hours. The river water was densely populated by *Planktothrix agardhii*, and samples taken few days before and a few days after the incident showed these cyanobacteria to contain microcystins. 121 of 304 inhabitants of the village (as well as some dogs and cats) became ill with vomiting, diarrhoea, muscular cramps, nausea (Cronberg *et al.*,1997).

Cases attributed to cyanotoxins in recreational water
1959: Saskatchewan: in spite of a kill of livestock and warnings against recreational use, people did swim in the lake infested with cyanobacteria. Thirteen persons became ill (headaches, nausea, muscular pains, painful diarrhoea). In the excreta of one patient - a medical doctor who had accidentally ingested 300 ml of water- numerous cells of *Microcystis spp.* and some trichomes of *Anabaena circinalis* could be clearly identified (Dillenberg and Dehnel,1960).
1989: England: Ten out of 20 soldiers became ill after swimming and canoe-training in water with a heavy bloom of *Microcystis spp.*; two of them developed severe pneumonia attributed to the inhalation of a Microcystis-toxin and needed hospitalisation and intensive care (Turner *et al.*, 1990). Swimming skills and the amount of water ingested appear to have related to the degree of illness.
1995: Australia: Epidemiological evidence of adverse health effects after recreational water contact from a prospective study involving 852 participants showed elevated incidence of diarrhoea, vomiting, flu symptoms, skin rashes, mouth ulcers, fevers, eye or ear irritations within 2 - 7 days after exposure (Pilotto *et al.*, 1997). Symptoms increased significantly with duration of water contact and density of cyanobacterial cells, but were not related to their content of known cyanotoxins.
Cases due to other exposure routes
1996: Caruaru in Brazil: One hundred and thirty one dialysis patients were exposed to microcystins with the water used for dialysis, 56 of them died. At least 44 of these victims showed the typical common symptoms associated with microcystin, now referred to as "Caruaru Syndrome", and the liver microcystin content corresponded to that of laboratory animals having received a lethal dose of microcystin (Carmichael, 1996).

A number of cases of human injury through cyanotoxins have been documented. Though most involved exposure through drinking water, they demonstrated that humans have become ill - in some cases seriously - through ingestion or aspiration of toxic cyanobacteria (Table 7.1); symptoms were clearly attributable to microcystins in one case of accidental administration of these toxins through renal dialysis (Jochimsen *et al.,* 1998).

The low number of reported cases may be due to lack of knowledge about the toxicity of cyanobacteria, neither patients nor doctors associate symptoms with this cause. Symptoms reported include '*abdominal pain, nausea, vomiting, diarrhoea, sore throat, dry cough, headache, blistering of the mouth, atypical pneumonia, and elevated liver enzymes in the serum, especially gamma-glutamyl transferase'*. (Carmichael, 1995, p9) as well as hay-fever symptoms, dizziness, fatigue, skin and eye irritations; these symptoms are likely to have diverse causes with several classes of toxin and genera of cyanobacteria involved.

7.1.1. Route of exposure

Human health hazards arise from three routes of exposure during recreational water use:

- direct contact of exposed parts of the body, including sensitive areas such as the ears, eyes, mouth and throat, and the areas covered by a bathing suit which may collect cell material;

- accidental uptake of water containing cells by swallowing; and
- uptake of water containing cells by aspiration (inhalation).

Different cyanobacterial metabolites are likely to be involved in evoking symptoms associated with these exposure routes.

Direct contact

Contact irritation has been reported from a number of freshwater cyanobacterial genera after recreational exposure (*Anabaena, Aphanizomenon, Nodularia, Oscillatoria, Gloeotrichia*), though this was not as severe as that from marine algae.

Allergic or irritative dermal reactions of varying severity are known from cyanobacteria as well as from freshwater algae, but have not been documented extensively. Bathing suits and particularly diving suits tend to aggravate such effects by accumulating algal material and enhancing disruption of cells and liberation of cell content. Reports from the United States of America have recorded allergic reactions from recreational exposure, and the cyanobacterial pigment phycocyanin has been shown to be responsible in one case (Cohen and Reif, 1953). In addition, cutaneous sensitization to cyanobacteria has been documented. Severe dermatitis resembling skin burns has been reported from marine bathing in the presence of cyanobacteria dislodged from rocks after storms in tropical seas (Kuiper-Goodman *et al.*, 1998). Skin irritations were a frequent symptom found in an epidemiological study by Pilotto *et al.*, (1997), on health effects after recreational exposure to cyanobacteria. This study showed correlation to cyanobacterial cell density and duration of exposure, but not to microcystin concentrations. It is probable that these symptoms are not due to recognised cyanotoxins listed in Table 7.2, but rather to (currently largely unidentified) substances.

Table 7.2 Cyanobacterial toxins and their acute toxicity

Cyanotoxins	LD_{50} (i.p. mouse) of pure toxin	Taxa known to produce the toxin(s)	mechanism of toxicity
Protein-phosphatase-blockers (cyclic peptides with ADDA)			block protein
Microcystins in general (ca. 60 known congeners)	45->1000 µg/kg	*Microcystis, Planktothrix Oscillatoria, Nostoc*	Phosphatases by covalent binding and
Microcystin-LR	60 (25-125) µg/kg	*Anabaena, Anabaenopsis*	cause haemorrhaging
Microcystin-YR	70 µg/kg	*Hapalosiphon*	of the liver;
Microcystin-RR	300-600 µg/kg		cumulative damage
Nodularin	30-50 µg/kg	*Nodularia spumigena*	may occur
Neurotoxins			
Anatoxin-a (alkaloid)	250 µg/kg	*Anabaena, Oscillatoria, Aphanizomenon, Cylindrospermum*	blocks post-synaptic depolarisation
Anatoxin-a(s) (unique organophosphate)	40 µg/kg	known only from 2 species of *Anabaena*	blocks acetyl-cholinesterase
Saxitoxins (carbamate alkaloids)	10 - 30 µg/kg	*Aphanizomenon, Anabaena, Lyngbya, Cylindrospermopsis raciborskii*	block sodium channels
Cytotoxin Cylindrospermopsin (alkaloid)	2100 µg/kg/ d 200µg/kg/5-6 d	*Cylindrospermopsis raciborskii*	blocks protein synthesis; substantial cumulative toxicity

Uptake

Swallowing or inhalation was the exposure route in most of the documented cases of human illness that have been associated with cyanobacteria (Table 7.1). In contrast to direct contact, uptake of cyanobacteria involves a risk of intoxication by the cyanotoxins listed in Table 7.2. This risk may be estimated from cell density, cellular toxin content and known mechanisms of toxicity. Acute mechanisms of toxicity are well-known for the neurotoxins and microcystins, and some information is available to estimate risks due to repeated or chronic exposure.

7.1.2 Cyanotoxins

Progress in analytical chemistry during the past two decades has enabled the isolation and structural identification of three neurotoxins with somewhat different modes of blocking neuronal signal transmission (anatoxin-a, anatoxin-a(s), and saxitoxins), one general cytotoxin which inhibits protein synthesis (cylindrospermopsin), and a group of toxins termed microcystins which inhibit protein phosphatases. Phosphatase inhibition could in principle also be generally cytotoxic, but microcystins are primarily hepatotoxic because they use the bile acid carrier to pass through cell membranes. These toxins were named after the organism from which they were first isolated, but most of them have been found in a wider array of genera, and some species contain more than one toxin or both microcystins and neurotoxins. Table 7.2 presents an overview of the most important cyanotoxins currently known and their mode of acute action (Turner *et al*., 1990; Sivonen and Jones, 1998; Kuiper-Goodman *et al*., 1998).

Toxins responsible for animal deaths and human injuries have been identified. However, there is considerable evidence that a range of further cyanobacterial metabolites may be relevant to human health and should be evaluated as potential hazards. Further research on toxins and allergens produced by cyanobacteria and various algal taxa is needed for comprehensive risk assessment.

Though the toxins listed in Table 7.2 are assumed to be the substances most significant for human health, it is unlikely that all of the important cyanotoxins have been discovered. Yoo *et al.,* (1995) pointed out that an increasing variety of individual toxins is continually being discovered. Numerous pharmacological working groups are conducting research for pharmacologically active substances, from cyanobacteria (e.g. Falch *et al.,* 1995; Mundt and Teuscher, 1988). Results produced by Fastner *et al.,* (1995), showed that primary rat hepatocytes reacted to microcystins in crude extracts of some strains of cyanobacteria in close correlation to their content of microcystins, but that this reaction was further enhanced by an unknown factor. Oberemm *et al.,* (1997) demonstrated substantial toxicity of cyanobacterial crude extracts to fish eggs, the effects not being due to the content of any of the known cyanotoxins. It is probable that further cyanobacterial metabolites with impact upon human health will be found.

Neurotoxins

Irrespective of somewhat different modes of action, all three neurotoxins (Table 7.2) have the potential to be lethal by causing suffocation: anatoxin-a and a-(s) through cramps, saxitoxins through paralysis. No human deaths associated with recreational use of water are known of. Artificial support of respiration may enable survival. Anatoxin-a(s) is the only known naturally occurring organophosphate cholinesterase-inhibitor and causes strong salivation (s stands for salivation), cramps, tremor, diarrhoea, vomiting and an extremely rapid death within minutes. Saxitoxins and anatoxin-a(s) are among the most neurotoxic substances known. However, evidence is accumulating that in lakes and rivers they are not as frequent as microcystins. This applies especially to anatoxin-a(s): to date it has only been found in a small number of *Anabaena*-blooms in North America**.** Further, concentrations even of these highly toxic substances in scums will scarcely reach levels acutely neurotoxic to a human ingesting a mouthful. In contrast, livestock will drink many litres, and pets - especially dogs - gather scum material in their fur and ingest it through grooming with the tongue.

After ingestion of a sub-lethal dose of these neurotoxins, recovery appears to be complete, and no chronic effects have been observed to date. For these reasons, the neurotoxins are a hazard to be aware of when using waters infested with cyanobacteria for recreation, but on the basis of current knowledge it is reasonable to consider them less dangerous than microcystins or cylindrospermopsin, which may cause ongoing injury.

Microcystins

These are the most frequent and most widespread cyanotoxins. They are cyclic heptapeptides containing a specific amino acid (ADDA) side chain which to date has only been found in microcystins and in nodularin (a cyclic pentapeptide toxin of cyanobacteria from brackish waters). About 60 structural analogues of microcystin are known so far (Rinehart *et al.,* 1994; Sivonen and Jones, 1998). They vary with respect to methyl groups and two amino acids within the ring. This has consequences for the tertiary structure of the molecule and results in pronounced differences in toxicity as well as in hydrophobic/hydrophilic properties. Microcystins block the protein phosphatases 1 and 2a, which are important ‘molecular switches’ in all eukaryotic cells, with an irreversible covalent bond (MacKintosh *et al.,* 1990). Nodularin, produced by the brackish species *Nodularia spumigena*, has a very similar structure and effect to microcystins.

The chief pathway for microcystins into cells is the bile acid carrier, which is found in liver cells, but to a lesser extent also in intestinal epithelia (Falconer, 1993). For vertebrates, a lethal dose of microcystin causes death by liver necrosis within hours up to a few days. Permeability of other cell membranes for microcystins is still controversial. Possibly, hydrophobic structural analogues can penetrate into some types of cells even without the bile acid carrier (Codd, 1995). In addition, Fitzgeorge *et al.,* (1994), published evidence for disruption of nasal tissues even by the common hydrophilic analogue microcystin-LR. Whilst toxicity by oral uptake is generally at least an order of magnitude lower than toxicity by intraperitoneal (i.p) injection, intranasal application in these experiments was equally toxic as i.p. injection, and membrane damage by microcystin enhanced the toxicity of anatoxin-a. This uptake route may be relevant for water sports activities which lead to inhalation of spray and droplets, such as water skiing.

Microcystins are found in most populations of *Microcystis* spp., which frequently form surface scums, and in strains of some species of Anabaena spp, which may also form scums. High microcystin content has further been observed in *Planktothrix* (syn. *Oscillatoria*) *agardhii* and *P. rubescens* (Fastner *et al.,* 1999). However, *P. agardhii* never forms scums, and *P. rubescens* usually does not form them during the bathing season. This reduces the hazard to bathers as compared to the hazard arising from scum-forming species.

Fitzgeorge *et al.,* (1994) demonstrated that microcystin-toxicity is cumulative: a single oral dose showed no increase in liver weight (which is a measure of liver damage), whereas the same dose applied daily over 7 days caused an increase of liver weight by 84 % and thus had the same effect as a single oral dose 16 times as large. This may be explained by the irreversible covalent bond of microcystin to the protein phosphatases and subsequent substantial damage to cell structure (Falconer, 1993). Healing of the liver probably requires growth of new liver cells. Sub-acute liver injury is likely to go unnoticed for two reasons:

- Liver injury only shows externally noticeable symptoms once it is severe.
- Acute dose-response curves for microcystins are steep. Therefore, little acute liver damage may occur up to levels close to severe acute toxicity. In consequence of the lack of apparent symptoms at moderate exposure, this is likely to be continued by persons uninformed of the risk (e.g. for consecutive days of a holiday or hot spell), which will increase the risk of cumulative liver damage.

There are two aspects of chronic microcystin damage to the liver, one is progressive active liver injury (see above and Falconer *et al.*, 1988), the other is the potential for promotion of tumour growth. Tumour-promoting activity of microcystins is well documented, though microcystins alone have not been demonstrated to be carcinogenic. Promotion of mouse skin tumours has been shown after initiation by topical exposure to a carcinogen (dimethylbenzanthracene) followed by ingestion of a *Microcystis aeruginosa* extract (Falconer and Buckley 1989; Falconer and Humpage, 1996). In rat liver studies, the appearance of preneoplastic liver foci and nodules was promoted by pure microcystin-LR in a protocol involving one i.p. dose of diethylnitrosamine and i.p. doses of microcystin-LR over several weeks (Nishiwaki-Matushima *et al.,* 1992). Studies on the mechanism of cell toxicity show that microcystin interferes with cell structure and mitosis, and this may contribute to explaining the tumour-promoting activity (Falconer and Yeung, 1992; Kaja, 1995).

Cylindrospermopsin

This is an alkaloid isolated from *Cylindrospermopsis raciborskii* (Ohlani *et al.*, 1992). It is a general cytotoxin which blocks protein synthesis, the first clinical symptoms being kidney and liver failure. In contrast to the pure toxin, crude extracts of the organism also causes injury to the lungs, adrenals and intestine. Clinical symptoms may only become manifest several days after exposure and cause and effect will therefore often be difficult to relate. Patients intoxicated with cylindrospermopsin via drinking water in an incident in Australia escaped death only through skilled and intensive hospital care (Falconer, 1997). *Cylindrospermopsis raciborskii* is considered to be a tropical and sub-tropical species, but recently it has been reported to form blooms as far north as Vienna (Roschitz, 1996). Substantial populations are reported from north-eastern Germany (Wiedner, *pers. comm.*), and generally it appears to be invading temperate regions (Padisák, 1997). so this toxin may become relevant in temperate zones as well.

7.1.3 Cyanobacterial toxins and toxicity

Toxic cyanobacteria are found world-wide in inland and coastal water environments. Currently, at least 46 species have been shown to cause toxic effects in vertebrates (Sivonen and Jones, 1998). The most common toxic cyanobacteria are:

Microcystis spp.
Planktothrix (syn. *Oscillatoria*) *rubescens*
Planktothrix (syn. *Oscillatoria*) *agardhii*
Anabaena spp.
Aphanizomenon spp.
some *Oscillatoria* spp.
Cylindrospermopsis raciborskii
Synechococcus spp.
Gloeotrichia spp.
Lyngbya spp.
Nostoc spp.
Schizothrix spp.
Synechocystis spp.

and in brackish or marine environments *Nodularia spumigena*.

Toxicity cannot be excluded for further species and genera, and as research broadens and covers further regions over the globe, more toxic species are likely to be found. Therefore, it is prudent to expect a toxic potential in any cyanobacterial population.

Some species contain neurotoxin and microcystin simultaneously. The most common bloom-forming genus, *Microcystis*, is almost always toxic (Carmichael, 1995), but non-toxic strains do occur. Generally, toxicity is not a trait specific for certain species, rather, most species comprise toxic and non-toxic strains. While conditions leading to cyanobacterial proliferation are well established, the physiological or biochemical function of toxins for the cyanobacteria is unknown, and factors leading to dominance of toxic strains over non-toxin ones are poorly understood. Evidence is accumulating for genetic differences between strains containing microcystin and strains without, within taxonomic categories otherwise identified as one-and-the-same species (Dittmann *et al.*, 1997; Rouhainen *et al.*, 1997). Experience with cyanobacterial cultures also shows that toxicity is a fairly constant trait of a given strain (or ‘genotype’), only somewhat modified by environmental conditions.

World-wide, about 75 per cent of the cyanobacterial samples investigated proved to contain toxins. The toxicity of a single bloom may, however, fluctuate rapidly both in time and space. Demonstrations of toxicity of the cyanobacterial population in a given lake do not necessarily imply an environmental or human hazard as long as the cells remain thinly dispersed. Mass developments and especially surface scums pose the risks.

7.1.4 Accumulation of Cyanobacteria and Cyanotoxins

In contrast to true algae, many species of planktonic cyanobacteria posses specialised, intracellular gas vesicles. Stacks of these minute (< 300 nm) proteinaceous hollow cylinders maintain a gas-filled space in the cell which enables the organism to regulate its buoyancy and thus to actively seek water depths with optimal growth conditions. However, regulation of buoyancy by changing the amount of gas in the vesicles is slow. Cells adapted to turbulent mixing by enlarged gas vesicles will take a few days to reduce their buoyancy in order to adapt to more quiescent conditions. Thus, especially when the weather changes from stormy to fine (i.e. mixing conditions in the water from turbulent to strongly stratified), many excessively buoyant cells or colonies may accumulate at the surface. Light winds drive them to leeward shores and bays, where they form scums (Fig. 7.1). In extreme cases, such agglomerations may become very dense and even acquire a gelatinous consistency. More frequently, they are seen as streaks or slimy scums that may even look like blue-green paint or jelly. Such situations may change rapidly, within hours.

Mass aggregations of cyanobacteria have earned the collective term "water blooms", which may be differentiated according to general mass developments of cells throughout the water, and scums floating at the surface. "Blooms" distributed evenly throughout the upper water layer may be dense enough to cause visible discoloration. Scums, however, have frequently been reported to accumulate cells by a factor of 1000 or more; one-million-fold accumulations to pea-soup consistency are observed, and scums of species with substantial amounts mucilage may reach gelatinous consistency.

Scums can be quickly broken by wave action and re-dispersed by renewed wind mixing. However, especially in shallow bays, scum material may take a rather long time to disperse, either as a result of wave wash or, ultimately, disintegration of the cells. Dying and lysing cells release their contents into the water, where pigments may adopt a copper-blue colour. Bacterial decomposition leads to rapid putrefaction of the material. The in-shore deposits are unsavoury, often repulsive, and potentially very toxic.

Whilst agglomerations of cyanobacteria are usually caused by planktonic species in eutrophic waters, benthic mats in oligotrophic waters occasionally also cause problems: these surface-covering mats can grow only in clear water, in which sunlight penetrates to the bottom. During sunny days, their photosynthesis may lead to high rates of oxygen production, causing bubbles which loosen parts of the mats and drive them to the surface. Mats of benthic cyanobacteria washed to the shore and scavenged by dogs have been lethal (Edwards *et al*., 1992), and cattle deaths on Swiss alpine meadows may also be caused by benthic cyanobacteria (Mez *et al.*, 1997, 1998). Though relevant for pets and livestock, the human health impact of these cyanobacteria on beaches will be considerably lower than that of scums in the water. Awareness of the potential toxicity of such beached mats is, however, important because they accumulate along shores of clear waters usually not recognised as potentially producing harmful cyanobacteria or algae.

7.2 Dinoflagellates, chrysophytes, chlorophytes, and other algae

Oshima *et al.,* (1989), isolated and identified three ichthyotoxins (polonicumtoxins A, B, and C) from a dinoflagellate, *Peridinium polonicum*, suspected to be responsible for fish-kills. Toxicity in the mouse bioassay was 1.5 - 2 mg/kg i.e. several orders of magnitude lower than the toxicity of microcystin-LR. The Ames test showed no mutagenicity, but the authors emphasized the need for studies on chronic toxicity to evaluate the potential health risk of these toxins.

Hansen *et al.,* (1994), described a case study of a fish kill in a small Danish lake during an enormous mass development of *Chrysochromulina parva* (614 000 cells/ml) with few other phytoplankton present. The authors considered the total lack of any other detrimental conditions as a strong indication for toxicity of this species, especially as marine species of the genus *Chrysochromulina* contain potent toxins.

Systematic investigation of toxicity of freshwater algae is required, particularly for species related to toxic marine taxa (dinoflagellates, diatoms, haptophytes). However, freshwater algae are considerably less likely to pose recreational health hazards comparable to those of scum-forming cyanobacteria, because algae lack similarly effective mechanisms of accumulation.

7.3 Allergic reactions and other health outcomes after exposure to algae and cyanobacteria

Allergic reactions to algae and cyanobacteria are frequently reported on the level of 'anecdotal evidence' from eutrophic bathing waters and it has been claimed that '*allergic reactions to cyanobacteria are relatively common' (*Yoo *et al.*, 1995, *p77)*. However, these are rarely investigated in scientific studies or published. Among the small number of publications available, Heise (1949, 1951), described ocular and nasal irritations in swimmers exposed to *Oscillatoriaceae*. McElhenny *et al.,* (1962), applied extracts from four different algal species (cyanobacteria and chlorophyceae) as intracutaneous skin tests to 20 non-allergic children, none of which responded, and to 120 children with respiratory allergies, 98 of which showed clear positive reactions to at least one of the test strains. Mittal *et al.,* (1979) tested 4000 patients in India with respiratory allergies, 25 per cent of which showed positive reactions either to chlorophyceae or to cyanobacteria, or to both.

Pronounced skin reactions in response to a bloom of *Uroglena* spp. were observed in a small number of bathers, especially under bathing suits where cells accumulated and partially disrupted during swimming (Chorus, 1993). Frequently, divers complain of dermal reactions to algal material accumulating under their wet suits, which tend to act as a strainer which lets out water, but collects algae between skin and suit. Pressure and friction between fabric and skin leads to cell disruption, liberation of content, and intensified dermal exposure not only to algal cell wall material, but also to substances otherwise largely confined within the cells.

It is important to note that allergic reactions are not confined to cyanobacteria. The substances which provoke these reactions are likely to be others than the cyanobacterial toxins described above. However, allergic reactions require elevated cell densities in bathing water, and in freshwaters, mass developments are most frequently due to cyanobacteria. Further, other groups of algae do not accumulate as surface scums and therefore their metabolites will not occur in comparably high concentrations.

Algae have caused irritative coughs in personnel and patients of a physiotherapeutic unit supplied with coarsely filtered surface water with which it performed underwater massage treatment. For example, in October 1986, a water body was found to contain 4600 to 58 000 cells/ml of the desmid *Staurastrum gracile,* a species that was not effectively eliminated by the filter, and has strong cell walls lined with spine and hook-like structures which may well cause irritations of mucous membranes (Naglitsch, 1988). Whilst this incident may be more of a curiosity than a serious health threat, it does highlight the benefit for management of regular microscopic examination of bathing and therapeutical waters in order to recognise algae as a potential cause of health reactions.

7. 4 How often and in which types of recreational waters are freshwater cyanobacteria and algae likely to cause health risks?

Documented evidence of significant health impairment exists only for cyanobacteria, not freshwater algae. Data from surveys in a number of countries show that toxicity is to be expected in about 75 per cent of all samples containing cyanobacteria (Table 7.3). Generally, the liver-toxic microcystins appear to be more common than neurotoxins, though the latter have caused severe animal poisonings in North America, Europe and Australia. Blooms containing cylindrospermopsin have been reported from Australia, Hungary, Japan and Israel.

Table 7.3. Surveys of frequency of cyanobacterial toxicity

Country	number of sites sampled	% toxic	reference
England	78	70 %	NRA report 1990
Scandinavia	51	59 %	Codd *et al.*, 1989
Finland	188	44 %	Sivonen *et al.*, 1990
Baltic Sea	25	72 %	Sivonen *et al.*, 1989
Wisconsin, USA	102	27 %	Repavich *et al.*, 1990
Netherlands	10	90 %	Leeuwangh *et al.*, 1983
Netherlands	29	79 %	RIZA 1994
Hungary	35	82 %	Törökné-Kozma & Gábor, 1988
Germany (GDR)	6	67 %	Henning and Kohl 1981
Germany 1995-96	80	90 %	Fastner *et al.*, 1998
Denmark	96	72%	Henriksen 1997

Ref Sivonen and Jones, 1998

While a general picture of the frequency of cyanotoxins associated with certain cyanobacterial taxa is emerging, it is less clear which cyanotoxin levels may be expected in recreational waters with cyanobacteria.

Most studies have focussed on the quantity of toxins that the cells of the dominant cyanobacteria contain. If the cell density is known in addition to the toxin content per cell, toxin concentrations per litre of water can be calculated. A few studies have directly addressed concentrations per litre, and sensitive detection methods now allow direct determination of toxin concentrations per litre rather than requiring enrichment of cell material.

Generally, cyanotoxin content of cells can reach levels of several milligrams per gram dry weight (dw). This has been established for microcystins, nodularin, cylindrospermopsin, anatoxin-a and saxitoxins, the maximum being found for nodularin 18 mg/g dw (Sivonen and Jones, 1998). If the biomass of cyanobacteria per litre is known for a given water body, maximum toxin concentrations to be expected can be estimated from such data.

Very few studies have addressed the variability of toxin content in the course of the development of cyanobacterial populations (Benndorf and Henning, 1989; Jungmann, 1995; Kotak *et al.*, 1995; Fastner *et al.*, 1999). Although this knowledge would be important for risk assessment, due to the cumulative toxicity of microcystins (section 7.1.2), hazards are greatest for persons exposed on several consecutive days. For management of recreational waters, a few years of regular investigation of the toxin content of prevalent cyanobacterial blooms may provide information on the variability of toxin content both in time and space. If the toxin content proves to show little variation during several weeks or even months of blooming of certain species, a regional basis for future predictions may be established.

The toxin concentrations per litre of water resulting from cellular content depends entirely upon the cell density. Scum formation is critical in determining cell density. In one study, microcystin concentrations ranged from 0.01 - 0.35 mg/l while the cyanobacteria were evenly dispersed (Fastner *et al.*, 1999), but sampling of shoreline scums of the same water bodies has shown microcystin concentrations of more than 1 mg/l in 7 of 34 samples, and maxima reached 24 mg/l (Chorus *et al.*, 1998).

Some commonly occurring species, such as *Planktothrix agardhii,* never form scums. Maximal microcystin concentrations per litre of water published from these are 0.35 mg/l (Fastner, 1999), but concentrations up to 0.5 mg/l can be calculated for shallow water bodies where population densities of this species may be extremely high.

For practical purposes, the present state of knowledge implies that health authorities should regard any mass development of cyanobacteria as a potential health hazard. Human health risk assessment studies amongst dingy sailors, recreational fisherman, and wind surfers exposed to *Microcystis* and *Gloeotrichia* blooms have however, not identified adverse health effects (Philipp, 1992; Philipp and Bates, 1992; Philipp *et al*., 1992).

7.5 Guidelines Derivation

Approaches to bathing water safety should address the occurrence of cyanobacteria as such, because it is as of yet unclear whether all important cyanotoxins have been identified, and the health outcomes observed after recreational exposure - particularly irritation of the skin and mucous membranes - are probably related to cyanobacterial substances other than the well-known toxins listed in Table 7.2. Additionally, the particular hazard of liver damage by microcystins may be considered. In face of the difficulty of representative quantitative sampling due to the heterogeneous distribution of cyanobacteria in time and space, particularly with respect to scum formation and scum location, approaches should further include addressing the capacity of a water body to sustain major cyanobacterial populations.

Health impairments from cyanobacteria in recreational waters must be differentiated between the chiefly irritative symptoms caused by unknown cyanobacterial substances and the potentially more severe hazard of exposure to high concentrations of known cyanotoxins, particularly microcystins. A single Guideline value therefore is not appropriate. Rather, a series of guideline values associated with incremental severity and probability of health effects is defined at three levels (Table 7.4).

Relatively mild and/or low probabilities of adverse health effects:

For protection from health outcomes not due to cyanotoxin toxicity, but rather to the irritative or allergenic effects of other cyanobacterial compounds, a guideline level of 20 000 cyanobacterial cells per ml (corresponding to 10 µg/L of chlorophyll ‘a’ under conditions of cyanobacterial dominance) can be derived from the prospective epidemiological study by Pilotto *et al.* 1997. Whereas the health outcomes reported in this study were related to cyanobacterial density and duration of exposure, they affected less than 30 per cent of the individuals exposed. At this cyanobacterial density, 2-4 µg/L of microcystin may be expected if microcystin-producing cyanobacteria are dominant, with 10 µg/L being possible with highly toxic blooms (regional differences of microcystin-content of the cells may be substantial). This level is close to the WHO provisional drinking-water Guideline value of 1 µg/L for microcystin-LR (WHO 1998) which is intended to be safe for life-long consumption. Thus, health outcomes due to microcystin are unlikely, and providing information for visitors to bathing sites with this low-level risk is considered to be sufficient.

Additionally, it is recommended that the authorities are informed in order to initiate further surveillance of the site.

Moderate probability of adverse health effects:

At higher concentrations of cyanobacterial cells, the probability of irritative symptoms is elevated. Additionally, cyanotoxins (usually cell-bound) may reach concentrations with potential health impact. To assess risk under these circumstances the data used for the drinking water provisional Guideline Value for microcystin-LR may be applied. Swimmers involuntarily swallow some water while bathing, and the harm from ingestion of bathing water will be comparable with that from a drinking water supply with the same toxin content. A swimmer can expect to ingest 100-200 ml of water in one session, sailboard riders and water skiers probably more.

Table 7.4: Guidelines for safe-practice in managing recreational waters

Guidance level or situation	**How guidance level derived**	**Health risks**	**Typical Actions***
Cyanobacterial scum formation in bathing areas	• Inference from oral animal lethal poisonings • Actual human illness case histories	• Potential for acute poisoning • Potential for long term illness with some cyanobacterial species • Short term adverse health outcomes e.g. skin irritations, gastrointestinal illness	• Immediate action to control contact with scums; possible prohibition of swimming and other water-contact activities • Public health follow up investigation • Inform public and relevant authorities
100 000 cells cyanobacteria /mL *or* 50 µg chlorophyll-a /L with dominance of cyanobacteria	• From provisional drinking water guideline for microcystin LR, and data concerning other cyanotoxins	• Potential for long term illness with some cyanobacterial species • Short term adverse health outcomes e.g. skin irritations, gastrointestinal illness	• Watch for scums or conditions conducive to scums • Discourage bathing and further investigate hazard • Post on-site risk advisory signs • Inform relevant authorities
20 000 cells cyanobacteria/mL *or* 10 µg chlorophyll-a/L with dominance of cyanobacteria	• From human bathing epidemiological study	• Short-term adverse health outcomes e.g. skin irritations, gastrointestinal illness	• Post on-site risk advisory signs • Inform relevant authorities

* actual action taken should be determined in light of extent of use and public health assessment of hazard

A level of 100 000 cyanobacterial cells per ml (which is equivalent to approximately 50 µg/l of chlorophyll-a if cyanobacteria dominate), represents a Guideline value for a moderate health alert in recreational waters. At this level, 20 µg/L of microcystins are likely, if the bloom consists of *Microcystis* and has an average toxin content per cell of 0,2 pg, or 0.4 µg microcystin per µg chlorophyll-a, (up to 50 µg/L of microcystin are possible). Levels may be approximately double if *Planktothrix agardhii* dominates. This level is equivalent to twenty times the WHO provisional Guideline Value concentration for microcystin-LR in drinking water, but would result in consumption of an amount close to the Tolerable Daily Intake (TDI) for an adult of 60 kg consuming 100 ml of water while swimming (rather than 2 L of drinking-water). However, a child of 15 kg consuming 250 ml of water during extensive playing could be exposed to ten times the TDI. The health risk will be increased if the person exposed is particularly susceptible, e.g. because of chronic hepatitis-B. Therefore, cyanobacterial levels likely to cause microcystin concentrations of 20 ug/L should trigger further action.

Non-scum-forming species of cyanobacteria such as *Planktothrix agardhii* have been observed to reach cell densities corresponding to 250 µg/l of chlorophyll-a or even more in shallow water bodies. Transparency in such situations will be less than 0.5 m measured with a Secchi-disk. *Planktothrix agardhii* has been shown to contain very high cell quotas of microcystin (1-2 µg per µg chlorophyll-a) and therefore toxin concentrations of 200 400 µg/L can occur without scum-formation.

An additional reason for increased alert at 100 000 cells/ml is the potential of some frequently occurring cyanobacterial species (particularly *Microcystis* spp. and *Anabaena* spp.) to form scums. These scums may increase local cell density and thus toxin concentration by a factor of one thousand or more in a few hours, thus rapidly changing the risk from moderate to high for bathers and others involved in body-contact water-sports.

Cyanobacterial scum formation presents a unique problem for routine monitoring at the usual time intervals of one or two weeks, because such monitoring intervals are unlikely to pick up hazardous maximum levels. Because of the potential for rapid scum formation at a cyanobacterial density of 100 000 cells/ml or 50 µg/L chlorophyll-a (from scum-forming cyanobacterial taxa), intensification of surveillance and protective measures are appropriate at these levels. Daily inspection for scum formation (if scum-forming taxa are present), and measures to prevent exposures in areas prone to scum formation are the two main options.

Intervention is recommended to trigger effective public information campaigns to educate people on avoidance of scum contact. Furthermore, in some cases (e.g. with frequent scum formation), restriction of bathing may be judged to be appropriate. An intensified monitoring program should be implemented, particularly looking for scum accumulations. Health authorities should be notified immediately.

High risk of adverse health effects

Abundant evidence exists for potentially severe health outcomes associated with scums caused by toxic cyanobacteria. No human fatalities have been unequivocally associated with cyanotoxin ingestion by mouth, numerous animals have been killed by consuming water with cyanobacterial scum material (section 7.1.1). This discrepancy can be explained by the fact that animals will drink higher volumes of scum-containing water in relation to their body weight, whereas accidental ingestion of scums by humans during bathing will typically result in a lower dose.

Cyanobacterial scums can represent thousand-fold to million-fold concentrations of cyanobacterial cell populations. Calculations suggest that a child playing in a *Microcystis* scums for a protracted period and ingesting a significant volume could receive a lethal exposure, although no reports indicate that this has occurred in practice. Based on evidence that a lethal oral dose of microcystin-LR in mice is 5000-11,600 µg/kg body weight, for a child of 10 kg the ingestion of 2 mg of microcystin or less could be expected to cause acute liver injury. Concentrations of up to 24 mg/L of microcystins have been published from scum material. Substantially higher enrichment of scums - up to gelatinous consistency - is occasionally observed, of which accidental ingestion of smaller volumes could cause serious harm. Anecdotal evidence indicates that children, and even adults, may be attracted to play in scums. The presence of scums caused by cyanobacteria is thus a readily detected indicator of a risk of potentially severe adverse health effects for those bathers who come into contact with the scums. Immediate action to control scum contact is recommended for such situations.

The approach outlined in this section does not cover all conceivable situations. Swimmers may be in contact with benthic cyanobacteria after a storm breaks off clumps of filaments, or cyanobacterial mats naturally detach from the sediment and are accumulated on shore lines (Edwards *et al.* 1992). Some marine beaches report widespread problems due to a benthic marine cyanobacterium, *Lyngbya majuscula*, growing on rocks in tropical seas and causing severe blistering when trapped under the bathing suits of swimmers after a storm (Grauer, 1961). This response may be due to acute toxicity, as in the case of *Lyngbya* which can produce irritant toxins. Measures of cyanobacterial cell density will not detect these hazards. Instead, this cyanotoxin hazard calls for critical and well-informed observation of bathing sites, coupled with a flexible response.

Lake Profile

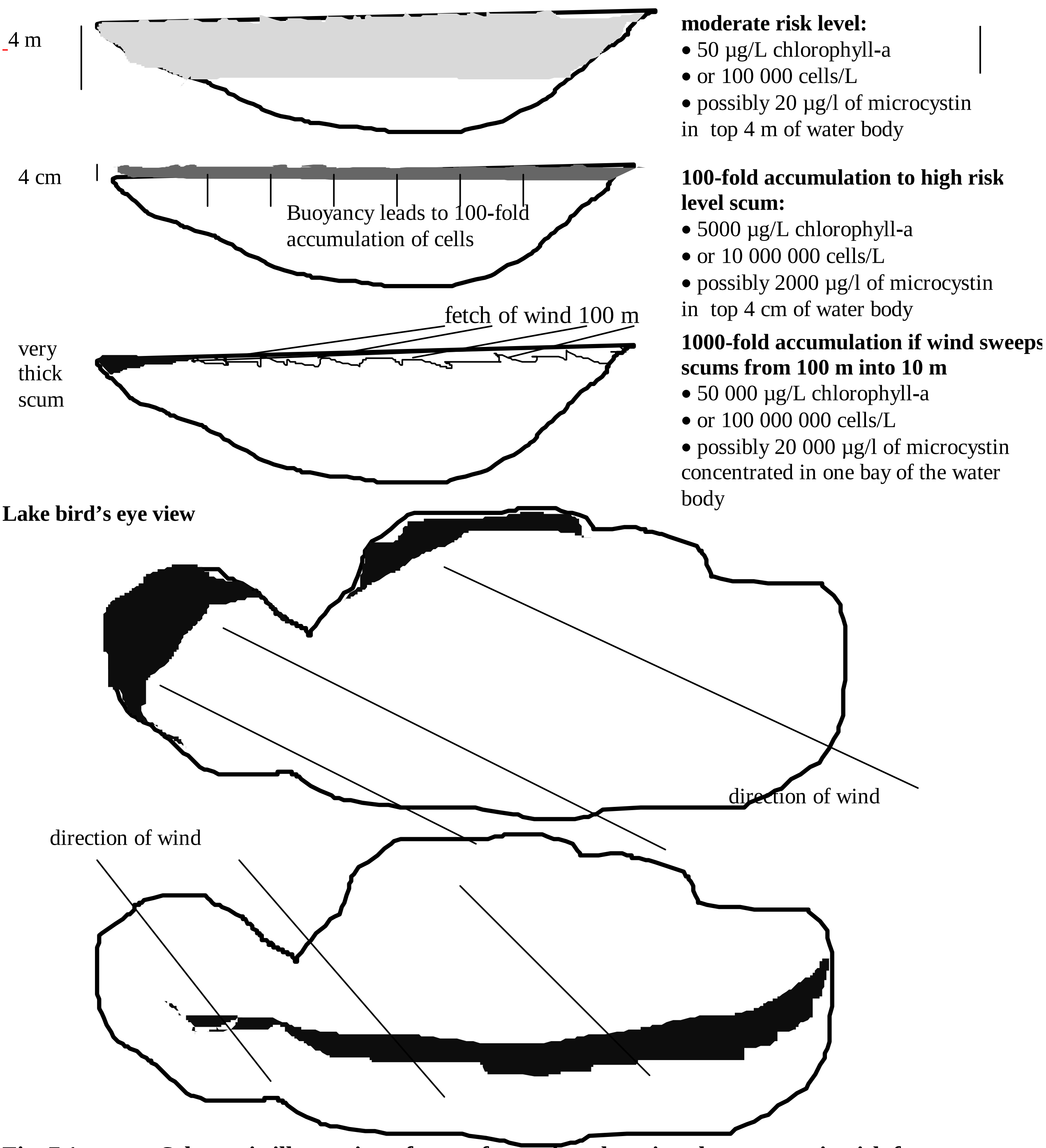

Fig. 7.1 **Schematic illustration of scum-formation changing the cyanotoxin risk from moderate to high**

It is difficult to define 'safe' concentrations of cyanobacteria in recreational water for allergenic effects or skin reactions, as individual sensitivities vary greatly. Aggravation of dermal reactions due to accumulation of cyanobacterial material and enhanced disruption of cells under bathing suits and wet suits may be a problem even at densities below the guidelines described above.

7.6 Management Options

Algal and cyanobacterial toxins are natural substances, but human activity has lead to excessive fertilisation ("eutrophication") of many water bodies, especially during the past three decades. This in turn causes unnatural proliferation of algae and in freshwaters especially of cyanobacteria, and thus has considerable impact upon recreational water quality. In temperate climates cyanobacterial dominance is most pronounced during the summer months, when the demand for recreational water is highest. Eutrophication together with a lack of "avoidance behaviour" may lead to recreational health risks from cyanotoxins.

For purposes of management, it is important to understand that these toxins are chiefly found within the cyanobacterial cells. Liberation into the surrounding water is possible, particularly when cells die and lyse, and differences may occur between toxins and species regarding 'leakage' from intact cells. However, toxin dissolved in water is rapidly diluted and probably also degraded, whereas hazardously high toxin concentrations usually result from accumulation of cell material as scums. Measures for recreational safety should chiefly address cyanobacterial cells containing toxins.

Because adequate surveillance is difficult and immediate management options except precluding or discouraging use, and cancelling water sports activities such as competitions are scarce, a large share of the responsibility for safe practice lies with the users of a bathing site. One major management responsibility of public authorities is therefore provision of adequate public information. Medium- to long-term measures are identification of the sources of nutrient (usually phosphate) pollution and significant reduction of nutrient input in order to effectively reduce not only proliferation of cyanobacteria, but of potentially harmful algae as well.

7.6.1 Short-term measures

The most important short-term measure is adequate information provided to the public on the cyanobacterial risk. Awareness of a potential hazard is not only a prerequisite for avoiding it, but also for understanding symptoms potentially caused by exposure and identifying their cause. Communication of warnings to the public may occur through local news media and by posting warning notices and other means. Communication of cyanobacterial warning notices may be supplemented with additional information on other recreational water quality parameters regularly monitored by the authorities and/or some further information on cyanobacteria.

Differentiation between the degree of water contact in different types of water sports should be included in warning notices. Information on the frequently transient nature and very variable local distribution of scums is important to convey the message that recreational activities are restricted only temporarily and very locally, and that acceptable water quality may be found nearby, e.g. at another site of the same lake.

7.6.2 Long-term measures

The aim of measures to minimise health risks due to toxic algae is not to close bathing sites, but rather the restoration of bathing water quality ideally to transparencies of > 2 m (Secchi disc reading) and absence of cyanobacterial blooms. This can be achieved by keeping total phosphorus concentrations below 0.01 µg/l P, and cyanobacterial densities causing moderate to high risk levels as described in Table 7. 4 are unlikely at total phosphorus concentrations below 0.02 - 0.03 µg/l P. This threshold may be difficult to reach in water bodies with multiple sources of nutrient pollution. However, nutrient sources are locally very variable. Therefore, identifying the chief sources and developing restoration strategies is strongly recommended and may in many cases prove to be more feasible than initially assumed (Chorus and Mur, 1998). Particularly nutrient input from agricultural runoff may in many cases easily be reduced by reducing the application of fertilisers to the actual demand of the crop, or by simple measures such as protection from erosion by planting shrubs along a strip of about 20 m along the shoreline, rather than ploughing and fertilising to the very edge of the water. Health authorities can initiate substantial improvement in such situations.

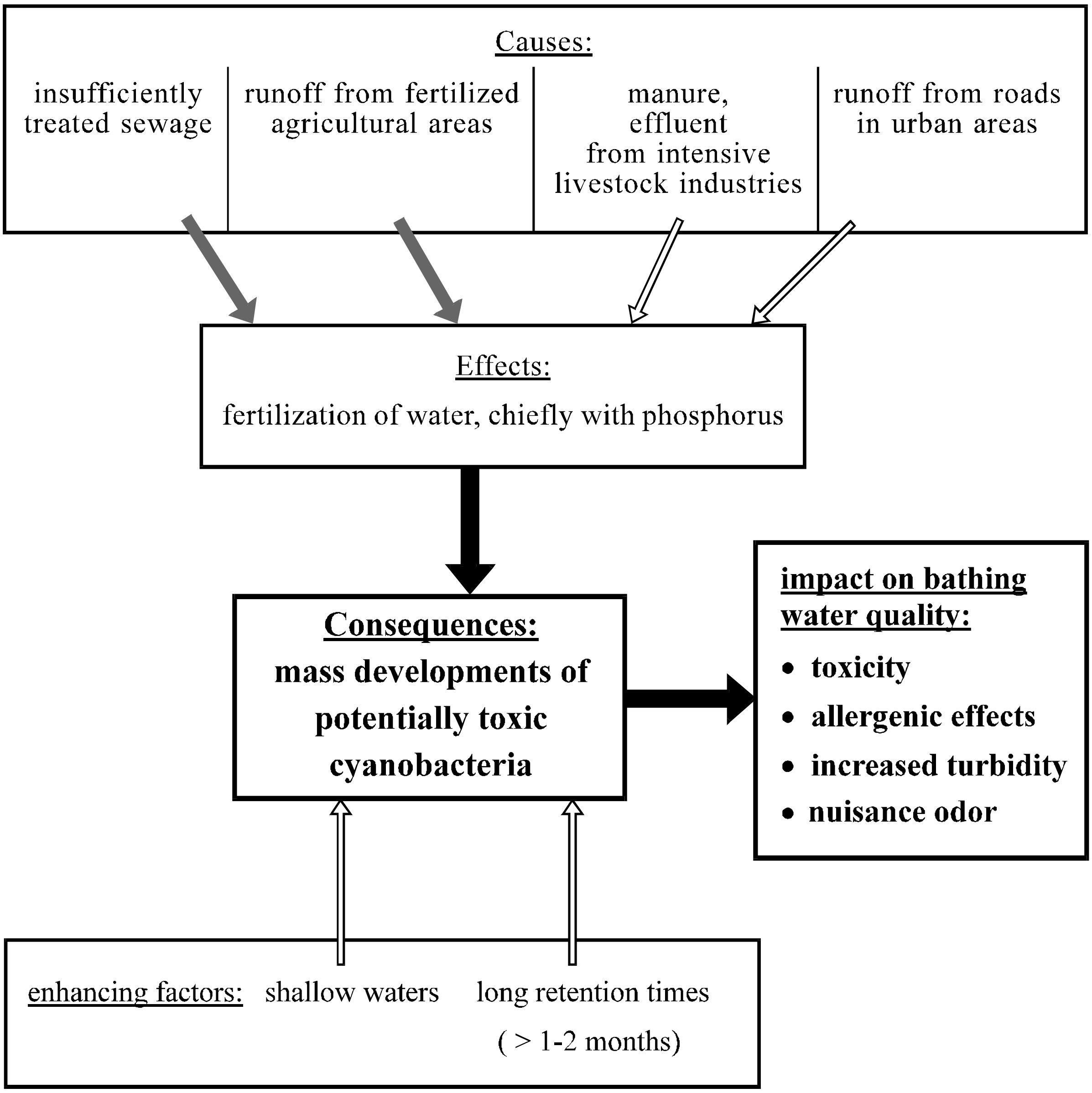

Fig.7. 2 Mass developments of potentially toxic cyanobacteria - causative and enhancing factors, and impact upon bathing water quality

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CHAPTER 8

WELL-BEING AND AESTHETIC ASPECTS

Health, ecological, aesthetic and socio-economic aspects of environmental management are interdependent (WHO, 1983). The aesthetic issues of human concern comprise visual physical changes, moral conduct and sentimental values, and environmental impact assessment of them should include compliance monitoring and impact monitoring (WHO, 1983). The World Health Organisation (WHO) European Charter on Environment and Health, also reported that *"good health and well-being require a clean and harmonious environment in which physical, psychological, social and aesthetic factors are all given their due importance"* (WHO, 1989a, p6). In 1994, the Charter was endorsed by the Ministers of the Environment and the Ministers of Health of the European Members States of WHO in their Helsinki Declaration on Action for the Environment and Health in Europe. The Shorter Oxford Dictionary (Onions, 1973, p36), defines the word, '*aesthetic*' as, '*having an appreciation of the sense of beauty in accordance with the principles of good taste'*. The aesthetic effects of pollutants and other environmental factors occur from their impact on well-being through the senses. All the five senses (sight, smell, touch, taste and hearing) are therefore included in questions about the aesthetic quality of our environment.

Problems associated with the aesthetic quality of recreational waters and bathing beaches (Editorial, 1990; WHO/UNEP, 1991) encompass:

- aesthetic and microbial problems of uncollected refuse and discarded litter in cities (Semple, 1989; Lowry, 1990);
- the mixing and disposal of domestic, general and clinical waste (Walker, 1991);
- concern that European hospital waste has been found in washed up on American beaches (Editorial, 1994);
- the appearance of medical wastes on holiday beaches (Philipp, 1991; Walker, 1991); and
- fears that environmental degradation of our beaches could lead to loss of income from tourism (WHO, 1990; Godlee and Walker, 1991; Philipp, 1992a).

The public also often perceive the quality of recreational water to be very different from actual chemical and/or bacterial quality (Philipp, 1994). Some studies have shown that rivers of good chemical or bacteriological quality have been perceived as poor by the public because of aesthetic pollution (Dinius, 1981; House, 1993). Poor aesthetic water and bathing beach quality may however, also imply poor microbiological/chemical water quality. For example, high incidence rates of self-reported gastro-intestinal illness after bathing in sewage-polluted water have been associated with public perceptions of different items affecting the aesthetic appearance of bathing water quality and bathing beaches (University of Surrey, 1987). The presence of the following items was positively correlated with the likelihood of gastro-intestinal symptoms: discarded food/wrapping; bottles/cans; broken bottles; paper litter; dead fish; dead birds; chemicals; oil slicks; human/animal excrement (particularly dogs/cats/cattle/birds); discarded condoms; discarded sanitary towels.

Other unwanted recreational water contaminants include: algae; jellyfish; seaweed; driftwood; mucilagenic substances; trace metals; pesticides; detergents; flotsam and jetsam (e.g. wooden crates and palettes; cardboard cartons; newspaper; steel drums; plastic containers and foam products; rubber goods such as vehicle tyres; bottles and cans; sludge flocculant or sewage effluent; dead animals; or animal bones; human hair; discarded clothing; hypodermic syringes; needles and other medical wastes; bottle tops; cigarette butts and packets; matchsticks; fish netting and rope ends.

Aesthetic issues are important as public opinion surveys about desirable seaside resort characteristics have found that some 10 per cent of respondents cite the importance of a clean beach (Oldridge, 1992). It has been reasoned that the physical and psychosocial environments of seaside resorts "*should favour the well-being and enjoyment of tourists*" (Giroult, 1990), particularly as pollution problems cause nuisances for tourists as well as for the environment, and tourism should be psychologically beneficial (WHO, 1980).

It is apparent that environmental values and the health of recreational water users are interdependent and that health is a function of, for example, the:

- health and behaviour of visitors and the host tourist-receiving population;
- physical qualities of the natural and built host environment;
- economic well-being of the tourist and host populations;
- understanding of what tourists seek when they travel;
- desire, in its inheritance, of a local population to sustain its cultural, social, emotional, spiritual, aesthetic and lifestyle values and the quality of its natural and built environment; and will act on that heritage.

Environmental quality objectives could be better considered in environmental debates for standards setting (WHO (1989b) and aesthetic standards and indicators for the quality of bathing water and bathing beaches could be usefully developed (WHO, 1990). The need was reinforced in subsequent reports (WHO, 1993;1994a; 1994b). Indeed, monitoring of marine debris has been undertaken around the world for several years. Its purposes (Rees and Pond, 1995) are to:

- provide information on the types, quantities and distribution of marine debris,
- provide an insight into problems and threats associated with an area,
- assess the effectiveness of appropriate legislation and coastal management policies,
- identify sources of marine debris,
- explore public health issues relating to marine debris, and
- increase public awareness of the condition of the coastline.

8.1 Aesthetic Parameters

In considering basic amenity, the general aesthetic acceptability of a water body is expressed in terms of criteria for transparency, odour, aerobic condition, and colour. It has been suggested that values for light penetration, colour, and turbidity should not be significantly increased over natural background (Ministry of National Health and Welfare, Canada, 1992). Safety hazards associated with turbid or unclear water depend on the intrinsic quality of the water itself. Nevertheless, lifeguards and other persons near the water must be able to see and distinguish people in distress and swimmers should be able to see quite well while under water (Ministry of National Health and Welfare, Canada, 1992; see Chapter 2).

Examples of the practical application of these definitions come from the EC and Canada. The EC Directive on Bathing Beach Quality (76/160/EEC) considers aesthetic issues and psychological well-being associated with water exposure as well as biological purity. The directive states that '*it is also desirable that bathing water should be clear, not contain toxic substances or show traces of oil, and should have acceptable taste, odour and colour'* (Council of European Communities, 1976). This assessment is based on fortnightly sampling and visual and olfactory inspection or extraction using an adequate volume and weighing the dry residue. As a guideline value too, fortnightly inspection is also recommended for the absence of tarry residues and floating materials such as wood, plastic articles, bottles, containers of glass, plastic, rubber, waste, splinters or any other substance. It is however, very difficult to establish criteria for oil and grease, as the mixtures falling under this category are very complex. Nevertheless, even very small quantities of oily substances make water aesthetically unattractive (Environment Canada, 1981).

The aesthetic value of recreational waters implies freedom from visible materials that will settle to form objectionable deposits, floating debris, oil, scum and other matter, substances producing objectionable colour, odour, taste or turbidity, and substances and conditions or combinations thereof in concentrations which produce undesirable aquatic life (Ministry of National Health and Welfare, Canada, 1992).

8.1.1 Clarity and colour

It is important that water at bathing and swimming areas be clear enough for users to estimate depth, to see subsurface hazards easily, and to detect the submerged bodies of swimmers or divers who may be in difficulty (see chapter 2). Aside from the safety factor, clear water fosters enjoyment of the aquatic environment. The clearer the water, the more desirable the swimming area (National Academy of Sciences, 1973). The principal factors affecting the depth of light penetration in natural waters include suspended microscopic plants and animals, suspended mineral particles, stains that impart a colour, detergent foams, dense mats of floating and suspended debris, or a combination of these factors.

There are two measures of colour in water - true and apparent. The true colour of natural water is the colour of water from which turbidity has been removed (i.e. filtered water). Natural minerals give *true colour* to water, for example, calcium carbonate in limestone regions gives a greenish colour, ferric hydroxide, red. Organic substances, tannin, lignin, and humic acids from decaying vegetation also give true colour to water (Reid and Wood, 1976).

Apparent colour is an aesthetic quality and cannot be quantified. It is usually the result of the presence of coloured particulates, the interplay of light on suspended particles, and such factors as reflection of the bottom or sky. An abundance of (living) blue-green algae imparts a dark green hue; diatoms give a yellow or yellow-brown colour. There are algae that impart a red colour, and rarely, zooplankton, particularly microcrustaceans, may tint the water red (Reid and Wood, 1976).

The causes of colour in marine waters are not thoroughly understood, but dissolved substances are one of the contributory factors. The blue of the sea is a result of the scattering of light by water molecules, as in inland waters. Suspended detritus and living organisms give colours ranging from brown through red and green. Estuarine waters are not as brilliantly coloured as the open sea; the darker colours result from the high turbidity usually found in such situations (Reid and Wood, 1976).

8.1.2 Oil and grease

In some countries, e.g. Canada, and to help determine maximum limits, it has been reasoned that oil or petrochemicals should not be present in concentrations that can be detected as a visible film, sheen, or discoloration on the surface, be detected by odour or form deposits on shorelines and bottom sediments that are detectable by sight or odour (International Joint Commission, 1977; Ministry of National Health and Welfare, Canada, 1992).

8.1.3 Litter

Beach litter is derived from three main sources: marine, riverine and beach user discards. Visitor enjoyment of any beach would obviously be marred by litter. Clean beaches are one of the prime parameters that are desired by recreational users (Oldridge, 1992). Litter perception will vary with respect to many parameters such as age, social economic status, gender; gross amounts are obviously aesthetically displeasing. The variety of litter found on a beach is considerable.

Litter counts have been considered as possible proxy indicators for the likelihood of gastrointestinal effects associated with swimming. The reliability and validity of these indicators as measures of health protection does however, need to be tested amongst different populations and in different exposure situations (Philipp *et al.,* 1997), and counts by themselves cannot attribute source. Beach surveys for the extent of littering are however, extremely useful as indicators of the need for behavioural change (WHO, 1994b). To be worthwhile in the context of biological research litter counts, as measures of aesthetic quality, and potentially too of biological quality, must be able to:

- classify different levels of beach and water quality and the density of different litter and waste items before and after any environmental improvements (e.g. removal of sewage outfall pipes or fitting of fine mesh screens to them) or cleansing operations;
- be useful when compared with conventional bacteriological and chemical indicators of recreational water and bathing beach quality and of the likelihood of illness, and of well-being, amongst different recreational water and beach user groups;
- differentiate the density of different pollutants deposited by the public on beaches from pollutants that originated elsewhere and were then washed ashore;
- show consistent findings when used in studies of similar population groups exposed to the same pollutant patterns; and
- show a correlation with variations in the human population density of bathing beaches and bathing waters (Philipp, 1992a; IEHO, 1993; Philipp *et al.,* 1997).

8.1.4 Odour

Objectionable smells associated with untreated sewage effluent, decaying organic matter such as vegetation, dead animals or fish, and discharged diesel oil or petrol, can deter recreational water and bathing beach users. WHO, for example in respect of air quality, defines a ‘nuisance threshold’ as the concentration at which less than 5% of the population experiences annoyance for less than 2% of the time (WHO, 1987). Odour thresholds and their association with the concentrations of different pollutants of the recreational water environment have not however, been determined.

8.1.5 Noise

Traffic on nearby roads, trade hawkers, and indiscriminate use of beach buggies, motorbikes, portable radios and hi-fi equipment, motorboats and jet skis can all impact on tranquillity for the beach and water user (Velimirovic, 1990). Yet, some people thrill to noisy activities (Velimirovic, 1990). Mindful of the need for mutual respect (WHO, 1989a), zoning of areas for different activities is often undertaken.

8.2 Psychological aspects

The psychological impact of environmental factors on personal well-being is well-recognised. For example, the WHO definition of health *'represents a balanced* *relationship of the body and mind and complete adjustment to the external environment'* (Howe and Lorraine, 1973). In 1997, WHO drew attention to the recreational values of tourism and their association with mental health. Emphasis was given to the aesthetic aspects, quietness, cleanliness of recreational areas and architecture (WHO, 1997). The principal aesthetic concern is revulsion associated with visible pollution, turbidity, scums or odour. Nevertheless, individuals and populations are not always aware of environmental values they wish to keep, or those that have been lost and could be usefully restored. The subjective, intuitive ideals can be difficult to appraise (Philipp, 1992a; Philipp, 1992b; Philipp, 1998).

To help study environmental values and their association with well-being as a basis for setting standards and guidelines, an arts-science gradient is recognised. It spans artistic, intuitive, inspirational and subjective personal viewpoints and the measurable, objective, deductive, logical and scientific perspective (Philipp, 1998). Initial studies suggest that people react negatively and retreat from the impact on their senses (sight, sound, smell, touch and taste) of some factors. In contrast, they respond positively and resonate with others; personal well-being is associated with a positive response (Philipp *et al.*, 1998). The different sensory inputs stimulate building of images in the mind and the associations, connections and interpretations that give meaning, understanding and purpose to living. WHO has defined "*the quality of life*" as: "*an individual's perception of their position in life in the context of the culture and value systems in which they live and in relation to their goals, expectations, standards and concerns*" (WHOQOL Group, 1995.)

8.3 Monitoring

Trend monitoring with reliable data is useful, particularly as for truly sustainable development "*that meets the needs of the present without compromising the ability of future generations to meet their own needs*" (WHO, 1989c), the demands of inter-generational equity need to be addressed (Shrader-Frechette, 1991). In the UK for example, one series of studies identified a four-fold deterioration in environmental quality during three consecutive years (Philipp *et al.*, 1994). It helped to justify national legislation for tighter controls on discharges from seawater sewage outfall pipes and the removal of screenings for disposal elsewhere, better provision and emptying of litter bins and improved advice for the public (Philipp *et al.*, 1994; Philipp *et al.*, 1997).

The purposes of marine debris monitoring are to:

- provide information on the types, quantities and distribution of marine debris (Williams and Simmons, 1997).
- provide an insight into problems and threats associated with an area (Rees and Pond, 1995)
- assess the effectiveness of appropriate legislation and coastal management policies (Earll *et al.*, 1997),
- identify sources of marine debris (Earll *et al.*, 1997),
- explore public health issues relating to marine debris, (Philipp *et al.*, 1993;1997),
- increase public awareness of the condition of the coastline (Rees and Pond, 1995).

Large scale monitoring programmes often rely on volunteers to survey the beaches and collect data. It is however, not usually possible, with staffing constraints to validate the findings in a sample of locations before the next high tide. Tide changes can too, be accompanied by changes in water currents and wind direction. Nevertheless, reliable data can be collected if comprehensive guidance is given to ensure comparable approaches by different groups of volunteers, and if validated questionnaire methods are used in consistent and uniform ways. Internal cross-checks of such methods have been undertaken and they have confirmed consistency of the data collected (Philipp *et al.*, 1993).

8.4 Management

Questions about aesthetic factors frequently raised for local managerial consideration include:

- Are wastes there?
- What are the local perceptions of them?
- Are they causing aesthetic health problems?
- Could the aesthetic problems be responsible for any economic losses of the local community?
- If present, where are the wastes coming from?
- Can the effects (if any) be stopped?
- Who should control the problems?
- What will it cost and can any loss of environmental opportunity be measured? (Philipp, 1993).

There are many hazards to control in recreational water use areas. Rational use for limited resources and priority ranking for the introduction of preventive measures, should be based on five main questions (Philipp and Hodgkinson, 1994):

- How serious is the problem in terms of the likelihood of death, disability, disease, discomfort, or dissatisfaction?
- How many people are likely to be affected during a year?
- To what extent is an intervention technically feasible and likely to relieve or prevent the problem?
- What does an analysis show for the benefits obtained from the risk, adverse effects of the risk, and the cost implications for different systems of hazard control?
- To what extent is the community likely to accept or adopt the intervention, behaviour or other change required?

8.4.1 Classification Schemes

These schemes are common in many countries and range from use in large scale resorts to undeveloped recreational areas. They were designed to inform the public about assessment of an area’s quality so that an informed choice could be made of recreational areas. Their continued development follows a recommendation of the Second International Conference on Tourist Health (WHO, 1990). The most popular in the European context is the Blue Flag but a number of other rating schemes are prevalent in countries like the UK, e.g. Seaside Awards; Good Beach Guide; Beachwatch. All these schemes look into parameters such as water quality, but none of them assess beach user preferences. Award schemes can have a large influence on tourism e.g. the beach award schemes in the USA (Leatherman, 1997).

8.4.2 Education/Information

Educating the public about litter and health issues relating to the water environment starts at school level but the amount of litter generated is increasing each year. At resort beaches enormous amounts of litter can be found each day which has an economic effect on the region. During 1987 and 1988, beach closures in New York and New Jersey, due to litter accumulation together with the public's perception of degraded beach and water quality cost the local economy several billion dollars (Swanson *et al.*, 1991).

8.4.3 Mechanical Beach Cleaning

This usually involves motorised equipment, utilising a sieve which is dragged through the top layer of the sand and retains the litter but usually cotton buds, cigarettes and other small items pass through. Resort beaches use such equipment because it is fast and provides an aesthetically clean recreational areas for visitors. In areas with for example medical waste, sewage-related debris or other potentially harmful items it reduces health risks because no manual picking up of material is involved. The utilisation of mechanical cleaning at rural beaches is questionable as such cleaning does affect the local ecology (Llewellyn and Shackley, 1996).

8.4.4 Voluntary activities

Volunteers are frequently utilised in recreational areas for example in manually picking up litter, monitoring, lifeguarding, rangers, tree planting, building sea defences, planting marram grass on dunes and other activities. The amount of training given varies from place to place but usually most lifeguards/rangers have at least an elementary knowledge of first aid. Volunteers are usually keen, willing to work, idealistic and well motivated. A cadre of volunteers is a bonus for any recreational area management team.

8.4.5 Economic consequences

Local economies depend on the aesthetic quality of bathing water and beach areas. For example, the upper Adriatic Coast of the Mediterranean sea was hit during the 1989 summer season by a very severe episode of eutrophication which, together with mucilage caused by the production of viscous substances from benthic micro-algae, generated considerable concern amongst tourists about their health. The unpleasant sight of large tracts of this viscous amorphous substance along the shoreline resulted in a large number of beaches along the Italian coastline becoming temporarily unsuitable for bathing (WHO, 1990). As a consequence of this problem, a 40 percent reduction in local tourism was experienced (Philipp, 1992a), and aesthetic considerations alone were sufficient to prevent would-be bathers from entering the water (WHO, 1990). At that time, the following effects were attributed to the loss of proper use from aesthetic pollutants, of the marine environment of the Adriatic Sea for tourists and other economic purposes:

- number of tourist days lost,
- damage to the local tourist infrastructure (hotels, restaurants, bathing resorts, other amenities, etc.),
- damage to tourist-dependent activities (clothing manufacture, food industry, general commerce etc.),
- damage to fisheries activities (stoppage of fisheries, reduction in fish catch, depreciation of the price of seafood),
- damage to fisheries-dependent activities (fishing equipment production and sales, fisheries products, etc.),
- damage to the image of the Adriatic Coast as a recreational resort at both national and international levels (WHO, 1990; Philipp, 1992a).

The direct health care costs of one aesthetic hazard, discarded hypodermic syringe needles, have also been studied and they can be considerable (Philipp, 1993).

8.5 Guideline Values

No guideline values are presented for the well being associated with aesthetic enjoyment of recreational water environments, as currently there is no clear health basis for their derivation.

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CHAPTER 9

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 diffuse sources such as run-off from land. In most cases there will be significant dilution or attenuation of contaminants depending on the circumstances. The potential risks from chemical contamination of recreational waters, apart from toxins produced by marine and freshwater algae, marine animals or other exceptional circumstances, will be very much smaller than the potential risks from microbiological contaminants. It is, therefore, extremely unlikely that water users will come into contact with sufficiently high concentrations of most contaminants to cause acute effects or ill effects following a single exposure. Even repeated (chronic) exposure is unlikely to result in ill effects at the concentrations of contaminants found in water and with the exposure patterns of recreational users. However it remains important to ensure that chemical hazards and any potential human health risks associated with them are controlled and that users can be reassured as to their personal safety.

For recreational water and bathing beach users, the dangers of chemical contamination will depend on the particular circumstances of the water and beach(es) under consideration. For example, a fast flowing upland river, remote lakes, or drinking water reservoirs 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 a water body, used for recreational purposes, receives significant wastewater discharges consideration of its chemical constitution should be made and how recreational areas will be influenced taking into acount both the dilution and dispersion of the discharge.

In general, significant contamination by naturally occurring contaminants at significant concentrations is less likely, 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 which may give rise to aesthetic degradation of the water.

In all cases chemical and physical contamination must be assessed on a local basis. The aesthetic quality of recreational water is extremely important for the psychological well-being of users. Chemical and physical agents may lead to aesthetic degradation and are addressed in Chapter 8.

Toxins from cyanobacteria and algae, whilst chemical in nature are addressed in Chapter 6.

9.1 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 the surface, including skin, eyes and mucus membranes, inhalation and ingestion. In assessing the risk from a particular contaminant the frequency, extent and likelihood of exposure is a crucial part of the evaluation.

Generally skin and mucous membrane surface exposure is the most but for immersion or partial immersion activities then the probability that some water will be ingested will increase. Inhalation can be important in circumstances where there is a significant amount of spray, such as in water skiing. The skill of the participant in water recreation will also be important in increasing or decreasing the extent of involuntary exposure, particularly ingestion.

The use of wet suits, for example, implies that long periods will be spent in the water. In addition by trapping water against the skin, the wet suit will create a micro-environment which will enhance the absorption of chemicals through the skin or the development of skin irritation or allergy.

Very young children are likely to ingest proportionally greater amounts of water than adults when bathing, swimming or indulging in water play. However, actual data on the quantities of water ingested while indulging in water sports are difficult to obtain.

Many substances of 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 users are in intimate contact with sediment then the sediment 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 only make a minor contribution to overall exposure.

9.2 Hydrogen Ion Concentration (pH)

Both excessively alkaline and acid waters may cause irritation, but pH only has a direct impact on the recreational uses of water at very low or very high pH values. Under these circumstances it may have effects on taste and the skin. 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. The eye may also be affected and high or low pH may contribute to and exacerbate irritation of the eye by chemicals.

Basu *et al.* (1984) studied the capacity of water from two inland lakes in Ontario to cause eye irritation in rabbits and human volunteers. Clearwater lake had a pH of about 4.5 and an acid neutralizing capacity of 40 microequivalents per litre (μeq/l), and Red Chalk Lake had a pH of about 6.5 with an acid neutralizing capacity of 70 μeq/l. No adverse effects were noted.

Water of high pH could conceivably have an adverse effect on hair condition by causing the hair fibres to swell and by cleavage of the cystine bridges between adjacent polypeptide chains of hair protein. However the impact will also be dictated by the buffering capacity of the water. It is difficult to specify limits but in very soft and poorly buffered waters with an alkalinity of less than about 40mg/l of $CaCO_3$, pH will be much 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 much greater.

9.3 Dissolved Oxygen

Dissolved oxygen will not have a direct effect on users but it will influence microbiological 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 sulphide. A dissolved oxygen concentration of greater than 80% saturation should be adequate to provide a sufficiently well oxygenated water.

9.4 Chemical Contaminants

The chemical quality of bathing waters does not seem to represent a serious health risk for recreational users and in most cases the concentration of chemical contaminants will be below drinking water guidelines. There are no specific rules which 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 Guidelines for Drinking Water Quality (WHO, 1993) can provide a starting point for deriving values which could be used to make a risk assessment under specific circumstances. These guideline values relate, in most cases, to life-time exposure. However drinking water guidelines need to be related to recreational exposure. Mance *et al.* (1984*)* have suggested that environmental quality standards for chemicals in bathing waters should be based on the assumption that bathing water only makes a relatively minor contribution to intake. They assumed a contribution for bathing of an equivalent of 10% of drinking water consumption. Since most authorities assume 2 l consumption of drinking water per day, an intake of 200 ml per day from recreational contact with water seems reasonably conservative.

For the purposes of these guidelines it is, therefore, assumed that water users will ingest 100 ml per recreational session with two sessions per day. It must be stressed that this approach is difficult to substantiate with quantitative data but it will still provide a useful rule of thumb for determining the potential risks of many common contaminants found in recreational waters.

There is a great deal of anecdotal evidence for 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 6 and 7, there is little scientific evidence to support this.

9.5 Inorganic Contaminants

Based on the calculation given above, a guideline for inorganic contaminants in recreational waters can be calculated from the WHO Drinking Water Guidelines. It must be noted that the chemical form of metals may significantly affect solubility and absorption and this needs to be taken into account in assessing any potential risks from metals.

9.6 Organic Contaminants

There are many organic contaminants which 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 such substances which have a high degree of lipophilicity such as chlorinated biphenyls.

Unfortunately data on the possible absorption of such substances from sediment through skin are extremely limited. For most recreational purposes the extent of contact is likely to be small but consideration needs to 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 such as chloroform or tri and tetrachloroethene and hydrocarbons such as toluene have been shown to absorb through skin from water. A recent study by the USEPA (USEPA, 1992) concluded that the contribution from skin absorption and inhalation could contribute as much again as drinking. In view of the significant margins of safety incorporated in guidelines for drinking water and their derivation for long-term exposure, this would seem to be adequately covered in the derivation of bathing water guidelines.

Oils have been discussed above in relation to aesthetic effects such as films on the surface, but some oil derived substances such as xylenes and ethylbenzene, which are volatile may also give rise to odours or tastes even though they are of low toxicity. Detergents too can give rise to aesthetic problems if foaming occurs, particularly since this can be confused with foam caused by by-products of algal growth. If the detergents are associated with untreated sewage then there is a risk of parasites being carried in the foam.

As with inorganic contaminants, The Guidelines for Drinking Water Quality could be used as a basis for assessing the potential risk from specific organic chemicals or if necessary deriving appropriate guidelines. However in the case of many common contaminants the most important consideration will be odour, guidance on which may also be found in the Guidelines for Drinking Water Quality.

9.7 Approach to Assessing Chemical Hazards in Recreational Waters

1. An inspection of the immediate area will show if there are any immediate sources of chemical contamination such as outfalls. These are a problem if they are easily accessible or 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 may be present and 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 needs to be carefully considered to determine whether there will be extensive contact with the water and if there is a significant risk of ingestion.
3. If on consideration it seems 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 knowledge of currents. 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 and only if this give rise to concern is there a need for wider sampling.
4. The quantitative risk assessment must consider the anticipated exposure both in terms of dose, i.e. is there significant ingestion, and the frequency of exposure. It must be recognised that the Guidelines for Drinking Water Quality, with a few exceptions covered 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, should be made quite clear. Without this there is a danger that even occasional, trivial exceedances of guidelines could unnecessarily undermine users confidence.
6. It is important in evaluating chemical hazards that the risks are not overestimated, but they should be related to risks from other hazards such as drowning or microbiological contamination which will almost invariably be much greater.

9.8 References

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CHAPTER 10

DANGEROUS AQUATIC ORGANISMS

Dangerous aquatic organisms may be encountered during recreational use of freshwater and coastal recreational environments. Such organisms vary widely and are generally of local or regional importance. The likelihood and nature of human exposure to the often depends significantly on the type of recreational activity concerned. Because of the wide variety of organisms that may be encountered a summary of those know to have caused significant ill-health injury or death to recreational water users is included in this chapter. Space prohibits full coverage of their geographic distribution recognition or management. Readers are advised to turn to specialised texts for such information.

Perceived risks involving dangerous aquatic organisms may have important economic repercussions in areas that depend to a large extent on recreational tourism as a source of income. A recent example is the decline in South African tourists visiting Lake Malawi because of news reports about schistosomiasis (bilharzia) cases. Similarly, news about malaria outbreaks in East Africa or dengue outbreaks in the Caribbean have had a serious impact on local economies in the past. Incidents of a less immediate public health concern (such as repeated shark attacks) also have a less intense impact in this sense and it wears out more rapidly. Local authorities and the private sector are usually well-inclined towards investing in preventive measures addressing such public health problems once they have been identified and assessed.

Two types of risks can be distinguished in relation to dangerous aquatic species: injury or intoxication resulting from direct encounters with predator or venomous species, and infectious diseases transmitted by species whose life cycles is linked to the aquatic environment.

Injuries from encounters with dangerous aquatic organisms are generally sustained in one of the following ways:

- accidentally brushing past a venomous sessile or floating organism when bathing;
- inadvertently treading on a stingray, weeverfish, or sea urchin;
- unnecessary handling of venomous organisms during sea shore exploration;
- invading the territory of large animals when swimming or at the waterside;
- swimming in waters used as hunting grounds by large predators; or
- intentionally interfering with, or provoking, dangerous aquatic organisms.

Many serious incidents can be avoided through an increase in public education and awareness. It is therefore important to identify and assess the hazards various aquatic organisms pose in a given region and bring the results to public attention. Awareness-raising should be targeted upon groups at particular risk (such as those know to have suffered adverse health effects) which may include local or visiting populations.

10.1 Non-venomous organisms

Animals which carry diseases are typically small and in themselves relatively harmless with only a few individuals of a population carrying the disease. Large animals, such as whales, can be very intimidating and pose a threat to humans by their size alone. Others, such as hippopotami or crocodiles, present a real threat to human health by their presence.

10.1.1 Disease transmitters

Mosquitoes

Tropical fresh or brackish water environments are havens for mosquitoes. Female mosquitoes require a blood-meal (from humans or other animals) to develop their eggs. In the process of taking a blood-meal, mosquitoes may ingest disease-causing organisms (so-called pathogens, such as the parasite causing malaria) from an infected person or animal. At a next blood-meal (mosquitoes go through various cycles of egg production) they will then inject the pathogen into a next person and this will spread the disease. All mosquitoes go through an aquatic larval stage, but the exact ecological requirements vary for the different species in different regions.

Two groups of diseases are of real public health importance for those who visit areas where transmission takes place (so-called endemic areas): malaria and arboviral diseases.

Malaria is caused by one of four species of parasite belonging to the genus *Plasmodium*. Malaria parasites are transmitted by *Anopheles* mosquitoes. These mosquitoes bite between dusk and dawn. Their breeding places are generally in clean fresh water, standing or slowly running, with some species breeding in brackish water coastal lagoons. They never breed in polluted water. Unlike *Culex* mosquitoes (see below), *Anopheles* mosquitoes do not produce the typical high-pitched buzz that is part of the nuisance experienced in mosquito-infested areas. The position of the mosquito body with respect to the wall (at a 45° angle) when the insect is resting is probably the easiest way to distinguish anopheline mosquitoes from culicine ones.

Arboviral diseases (arbo = arthropod borne) are caused by infections that are exclusively transmitted by mosquitoes. They include yellow fever, dengue and various types of encephalitis, such as Japanese encephalitis when it is associated with flooded rice fields in South, South-East and East Asia. Many of these infections are preventable, notably YF and JE. For dengue fever (also known as break-bone fever in some parts of the world) and its more severe variant dengue haemorrhagic fever, there is, however, no vaccine available.

The *Aedes* mosquitoes which transmit the dengue virus breed in small water collections in a man-made environment – hence the urban/human settlement associated distribution of the disease. While DHF is an important cause of death among children during outbreaks of the disease, classic dengue is merely a very debilitating disease for 4-6 weeks. *Aedes* mosquito species have black and white banded legs and they (sometimes ferociously) bite during daytime.

Culex mosquitoes, which breed in organically polluted water, are mainly known for the transmission of filariasis (which can eventually develop into elephantiasis). This disease is only likely to develop in people who have been exposed to infectious bites for many years.

Important note: the AIDS virus is NOT transmitted by mosquitoes!

Freshwater snails

Certain species of small freshwater snails (*Bulinus* sp. and *Biomphalaria* sp.) live in tropical lakes (either natural or man-made), in slow flowing rivers and in the irrigation and drainage canals of agricultural production systems that are contaminated with human excreta. These snails are the essential intermediate hosts for the larval development of trematode parasites of the genus *Schistosoma*. Once the larvae have developed into their infectious stage inside the snail, they are released into the water. They adhere to and penetrate the human skin. Following a complex trajectory through the human body (and an associated metamorphosis) they grow into adult trematode worms living in the veins of the liver or the urine bladder. Humans infected by *Schistosoma* suffer from a slowly developing chronic, debilitating and potentially lethal tropical disease known as bilharziasis or schistosomiasis. Typical symptoms include fever, anaemia and tissue damage. Upon complete diagnosis complete cure is possible using Praziquantel®.

10.1.2 Preventative measures

- Always try to obtain information from health authorities on the spot about the local vector-borne disease situation and ask for their guidance in risk prevention.
- In malaria endemic areas take the recommended prophylactic medicine.
- Wear protective clothing (long-sleeved shirts, long trousers) at the indicated biting times.
- Protect exposed parts of your body with repellents (e.g. DEET).
- Screened windows and air-conditioning help keep mosquitoes out of houses.
- Avoid skin contact with potentially contaminated water in schistosomiasis endemic areas.
- On return from a malarial area consult your physician about the possible risk of your having contracted the disease should you have symptoms such as fever, headaches, chills and nausea.

10.1.3 "In-water" hazardous organisms

Piranhas (freshwater)

Piranhas are restricted to the fresh waters of northern south America, in the Amazon Basin. The largest species is *Pygocentrus piraya* which reaches a size of 60 cm. Piranhas have powerful jaws with very sharp teeth which they use to communally attack and kill large prey animals. They can be dangerous to man. Splashing of the surface water is sufficient to attract a school of piranhas.

Snakes (freshwater)

Some non-venomous but large freshwater snakes such as the semi-aquatic anaconda, *Eunectes murinus*, can present a danger to human life. The anaconda, which reaches lengths of up to 7.6 m, lives in tropical South America. Anacondas generally constrict and suffocate large prey, often viciously (non-venomous) biting the victim before coiling. Attacks on humans have occurred, but the snake is not generally aggressive towards people and will usually endeavour to escape if approached.

Electric fishes (freshwater and marine)

Approximately 250 species of fish have specialised organs for producing and discharging electricity and are capable of delivering powerful electric shocks. These specialised organs are used by the fish to locate and stun prey, as a means of defence, and for navigation. The electric shock is delivered to a person when contact is made with the animal's skin surface. The majority of electric fishes continuously emit a low voltage electric charge in a series of pulses, with only two groups of electric fishes posing a serious threat to humans. The most dangerous of these is the freshwater electric eel (*Electrophorus electricus*), capable of producing an electric field of more than 600 volts. It can grow up to 3.4 m and lives in shallow rivers in tropical and sub-tropical South America. The fish is probably the only electric fish capable of killing a full grown human.

The most powerful marine electric fishes are the torpedo rays (*Narcine* sp. and *Torpedo* sp.), which are bottom-dwellers in all shallow temperate and warm seas. Electric rays vary greatly in their electric potential, some generating electric potentials of up to 220 volts. Shocks are used in defence and although strong enough to be dangerous, no fatalities are known. Fishermen in European waters have been known to receive a shock from their line before seeing what was caught (Dipper, 1987).

Sharks (mainly marine)

Sharks are most abundant in tropical and subtropical waters, but live in all the oceans excluding the Southern Ocean around the Antarctic continent. The majority of shark species are marine and representatives are found at all depths. Some shark species migrate regularly from salt to freshwater, whilst a few inhabit freshwater lakes and rivers. Not all shark species are dangerous to man.

Sharks are attracted by brightly coloured and shiny metallic objects, by the scent of blood, *e.g*. radiating from speared fish, and also by low frequency vibrations and explosions. Sharks are furthermore attracted to inshore dumping grounds. In tropical waters, most shark attacks on humans occur during their habitual feeding times during late afternoons and at night.

- the great white shark (*Carcharodon carcharias*) lives mainly in the open ocean, but some swim into shallow water. Most of the attacks on people have happened in estuaries. The great white is responsible for the largest number of reported attacks on humans. It is thought that humans might be mistaken for its normal seal prey.
- the tiger shark (*Galeocerdo cuvier*). This species is extremely widespread in the tropics and sub-tropics. Following the great white shark, the second most reported attacks on humans are attributed to tiger sharks.
- the mako shark (*Isurus oxyrinchus*). This is mainly an open ocean shark and occurs in all temperate and tropical oceans. It is often aggressive and dangerous when close to shores.
- the smooth hammerhead shark (*Sphyrna zygaena*). This shark species with its very distinctive head shape lives in all warm water oceans.
- the silvertip shark (*Carcharhinus albimarginatus*). The silvertip shark is very abundant around reefs and islands in the Pacific and Indian Oceans.
- the bull shark (*Carcharhinus leucas*). Although bull sharks are mainly located in the warm oceans of the world, it can at times be found up the Amazon and rivers in Australia, Guatemala and south-eastern Africa (Halstead *et al* 1990).

Barracudas & Needlefish (marine)

The great barracuda (*Sphyraena barracuda*) is widely distributed throughout the sub-tropical and tropical regions of the open oceans. It is 1.8 to 2.4 m long and very rarely attacks humans. Barracudas, however, frequently intimidate divers and snorkelers by closely shadowing them. Like sharks, barracudas are attracted to shiny metallic objects and dead fish.

The various species of needlefish pose a more significant threat to humans. Needlefish are slender, possess very long, strong and pointed jaws and reach an average length of 1.8 m. They are most often found swimming in surface waters. At night they are strongly attracted by bright lights. Cases exist of fishermen or divers on night expeditions being severely wounded and even killed by jumping needlefish (Halstead *et al*, 1990). They occur in the Caribbean, around the equatorial western African coast, Japan and are widespread throughout the western Indian Ocean.

Groupers (marine)

Groupers live in the shallow waters of the Indo-Pacific on coral reefs and in sandy areas. Their size (the giant grouper, *Promicrops lanceolatus*, can reach 3 m) means these generally non-aggressive fish are potentially dangerous. They are territorial fishes. Divers should look out for groupers before entering underwater caves and ensure that an exit is always open should a grouper wish to escape.

Conger and moray eels (marine)

The majority of eels are harmless. When provoked they will attack and can inflict fairly deep puncture wounds. Moray eels live in tropical waters on coral reef platforms where they hide in crevices and holes amongst the dead coral. Conger eels (*Conger conger*) live in temperate waters of the Atlantic in rocky areas which offer them hiding places inside caves, holes and cracks.

10.1.4 "Water-edge" hazardous organisms

Hippopotami (freshwater)

The hippopotamus, *Hippopotamus amphibius*, is chiefly an aquatic mammal inhabiting freshwater rivers and lakes from the Upper Nile down to South Africa. Despite being a herbivore, the hippopotamus is responsible for a significant number of human deaths in Africa. Due to their sudden and violent nature, and being fast swimmers, they pose a serious threat to humans in the water. Hippos are generally peaceable creatures and most often a herd will scatter, or at least submerge at the approach of man, but attacks are not uncommon. The majority of incidences are due to ignorance of their habits, in particular moving between a group of hippopotami on shore and water.

Crocodiles (freshwater and marine)

Crocodiles are found in tropical areas of Africa, Asia, the western Pacific islands and the Americas, the majority of species live in freshwater. All crocodiles are capable of inflicting severe harm, or causing death to humans. The more dense their populations are, the more dangerous is the individual. The largest living crocodiles may exceed 7.5 m. The saltwater crocodile (*Crocodylus porosus*) of south-eastern Asia is probably the most dangerous of all the marine animals. It lives mainly in mangrove swamps, river mouths and brackish water inlets, but has been seen swimming far offshore (Halstead *et al,* 1990). Crocodiles normally hunt at night and bask during the day, but might also hunt during the day if food is short The Nile crocodile (*C. niloticus*) has been rated as second only to the saltwater crocodile in danger to man (Caras, 1976).

Seals and sea lions (marine)

Seals and sea lions are not aggressive towards humans under normal circumstances. During the mating season, however, or when with pups, bulls might turn aggressive and attack intruders. Of particular concern are the Californian sea lion (*Zalophus californianus*) found along the west coast of North America and the Galapagos; and the bearded seal (*Erignathus barbatus*) found on the edge of the ice along the coasts and islands of North America and northern Eurasia (Halstead *et al*, 1990).

10.1.5 Preventative measures

- treat all animals with respect, and keep at a distance whenever possible;
- avoid swimming at night or in the late afternoon in areas where large sharks are endemic;
- avoid swimming in shark waters where garbage is dumped;
- avoid wearing shiny jewellery in the water where large sharks and barracudas are common;

- avoid attaching speared fish to the body where sharks, barracudas or groupers live;
- avoid wearing a headlight when fishing or diving at night in needlefish waters
- avoid swimming in murky brackish water inlets, river mouths and mangrove swamps inhabited by saltwater crocodiles;
- look out for groupers and moray or conger eels before swimming into caves or putting hands into holes and cracks of rocks; and
- when embarking on a canoe safari in hippopotamus and crocodile infested waters, always go with a knowledgeable guide who can assess risks properly and can judge territorial behaviour of hippopotami in water.

10.2 Venomous invertebrates

The effects of invertebrate venoms on humans range from mild irritation to sudden death. The invertebrates that possess some kind of venomous apparatus belong to one of five large phyla: Porifera (sponges); Cnidarians (sea anemones, hydroids, corals and jellyfish); Mollusca (marine snails and octopuses); Annelida (bristleworms); and Echinodermata (sea urchins and sea stars).

10.2.1 Porifera (freshwater and marine)

Sponges are simple multicellular animals, living mainly in shallow coastal and fresh waters around the world. They either attach to some form of substrate (be it rock, seaweed or a hard-shelled animal), or burrow into calcareous shells or rock. Although most sponges are harmless to humans, examples of toxic sponges are found world-wide. Painful skin irritations, sometimes persisting for many hours, are the common syndrome. No fatalities are known.

10.2.2 Cnidarians (marine)

Cnidarians are relatively simple, radially symmetrical body structure. Their body cavity has a single opening surrounded commonly by tentacles equipped with special cells known as cnidocytes. These cnidocytes contain characteristic capsule-like structures called cnidae, which in turn contain a thread that is mechanically discharged upon touch. Cnidarians are separated into 4 groups: the Hydrozoa (plume-like hydroids, 'fire corals', medusae and Siphonophora), Scyphozoa (free swimming jellyfish), Cubozoa (tall, box-shaped medusae) and Anthozoa (hard corals, soft corals and anemones). Hydroids and jellyfish possess so-called nematocysts (stinging capsules) which, when the cnidae thread is discharged, penetrate the prey and inject a toxin. Sea anemones and true corals on the other hand have spirocysts or ptychocysts with adhesive cnidae threads.

Hydrozoa

Most of the 2700 species of hydrozoa are harmless, but some can inflict painful injuries on humans. Well known examples of these are the sea firs, fire corals and Portuguese man-of-war. Apart from severe stinging cases from the Portuguese man-of-war, hydrozoan stings are not generally life threatening, although the pain can last several days.

Stinging or fire corals (for example *Millepora alcicornis*) have nematocysts which vary in stinging intensity according to species. These hydroid corals can cause a painful skin rash. They are generally found together with true corals in warm waters of the Indo-Pacific, the Red Sea and the Caribbean.

The stinging hydroid or fire-weed (*Aglaophenia cupresina*) is a hydroid colony. They resemble seaweed and grow on rocks and seaweeds in the tropical Indo-Pacific. If touched they causes a nettle-like rash lasting several days.

The Portuguese man of war (*Physalia physalis*, the Atlantic form) is a free-swimming colony of open-water hydrozoans that lives at the sea-air interface. *Physalia* is easily recognised by the prominent floating blue or purple gas-filled bubble which supports the stinging cells on the tentacles and zooids hanging below. The tentacles may reach a length of up to 10 m. Different species of *Physalia* are widespread throughout all oceanic regions, except the Arctic and Antarctic, and may be blown onto beaches in swarms after strong onshore winds. The nematocysts remain active even when beached. Stings by the various *Physalia* species are the most common marine stings presently known (International Consortium for Jellyfish Stings, 1993). The Atlantic species (*Physalia physalis*) is the more dangerous and has been responsible for several deaths.

Scyphozoa and Cubozoa

The number and variety of potentially harmful Scyphozoa and Cubozoa are too numerous to mention here, but the subject has been widely reviewed by Burnett (1991) and Williamson *et al* (1996). Williamson *et al* (1996) give detailed accounts of the dangerous jellyfish species, the harm they can inflict on humans and the recommended treatment for stings from each of the individual species.

The Scyphozoa, or true jellyfish, are typically pelagic and exist for the greater part of their life as medusae. They move by gentle pulsations of the bell but are frequently driven ashore and stranded by wind and currents. All jellyfish are capable of stinging but not many are considered a significant hazard to human health. Species of some genera, such as *Cyanea*, *Catostylus* and *Pelagia* may occur in large groups or 'swarms'.

The Cubozoa are renowned as the most dangerous of all cnidarians. They are characterised by a roughly cube-shaped body or bell, with tentacles arising from fleshy extensions in each lower corner of the bell. Several species of box jellyfish have been implicated in human deaths, with the box jellyfish or sea wasp (*Chironex fleckeri*) found along the Northeast coast of Australia, being among the most venomous of all marine creatures (Baxter and Marr, 1969). Circulatory and respiratory failure occur within a few minutes of being stung by *Chironex fleckeri* (Beadnell *et al*, 1992).

Anthozoa

Hard corals can cause abrasion injuries if a bather simply brushes against their hard branches. Certain coral colonies furthermore possess stinging nematocysts (*Goniopora, Plerogyra, Physogyra*) which can leave a rash if touched.

The majority of sea anemones are harmless except when their tentacles come into contact with delicate parts of the body, such as the face, lips, and under arms, resulting in a painful sting. One example is the common intertidal beadlet anemone (*Actinia equina*) found in the eastern Atlantic. More hazardous sea anemones include the hell's fire sea anemone (*Actinodendron plumosum*) found on the shady side of rocks and under coral ledges in the tropical Pacific. A sting from this anemone can cause skin ulcerations lasting for several months. *Triactis producta*, found in the Red Sea, gives painful stings which may later ulcerate (Halstead *et al*, 1990).

10.2.3 Mollusca (marine)

Molluscs are found in marine, freshwater and terrestrial environments. They all possess a distinct and well-developed head, a muscular foot and a soft, variable shaped body. Of the aquatic representatives of this large group only some cephalopods and the cone shells (*Conus*) produce venoms harmful to man.

All octopuses possess two powerful horny jaws which they can use to bite humans. The bites from the non-venomous (the majority) octopuses result in small puncture wounds causing moderate pain. Certain species of octopus, such as the blue-ringed octopus (*Hapalochlaena* (=*Octopus*) *maculosa*) or the spotted octopus (*Octopus lunulatis*), are equipped with venom which aids in the capture of prey. Bites from these species can be deadly (neuromuscular blockade) and should be treated with urgency. Both species inhabit shallow coastal waters of the tropical Indo-Pacific and normally show no aggression towards humans. The majority of reported bites have resulted from handling or interfering with the octopuses (Flecker and Cotton, 1955; Sutherland and Lane, 1969; Sutherland, 1983).

There are between 400 and 500 species of cone shells, all of them possess a highly developed venom apparatus. The tropical and sub-tropical cone shells, *Conus* sp., are usually found in shallow waters along reefs and on, or in sandy bottoms. They use their hypoon-like darts carrying the venom supply to catch prey and to discourage predators (Hinegardner, 1958). They often cause intense, localised pain at the site of the injury accompanied by nausea, vomiting, dizziness, and weakness. In more severe cases victims experience respiratory distress with chest pain, difficulties in swallowing, marked dizziness, blurring of vision and an inability to focus. Fatalities are caused by respiratory paralysis (Kohn, 1958; Endean and Rudkin, 1963; Russell, 1965). Most reported cases are from those organisms being handled.

10.2.4 Annelids (marine)

Of the Annelids (segmented worms) it is only some bristleworms, named after two bristle-like setae attached to all their segments, that are venomous. Bristleworms live under rocks and boulders. In venomous species the setae sting which, in the Caribbean fire worm (*Hermodice carunculata*), is known to paralyse (Halstead *et al*, 1990).

10.2.5 Echinoderms (marine)

Very few of the radially symmetrical adult echinoderms are hazardous to man. Most common minor injuries are abrasions or punctures acquired from the contact with the spines or skin of echinoderms. Examples of venomous species are only found within the starfish and sea urchins.

The crown of thorns starfish (*Acanthaster planci*) is the only venomous starfish and lives on coral reefs in the Indo-Pacific. Their upper surface is covered with many long, sharp and venomous spines, these can inflict painful wounds if handled. No serious injuries from *Acanthaster* have been recorded.

Sea urchins are found in all oceans, normally located on rocky foreshores and reefs. Most sea urchins can be handled safely, but a few species possess venomous spines or jaw-like pedicellariae capable of delivering very painful injuries (Halstead, 1971). These venomous species tend to be confined to the tropical and sub-tropical marine regions. Fatal incidences have occurred from handling the cap sea urchin (*Toxopneustes pileolus*), the most venomous sea urchin known from the Indo-Pacific.

10.2.6 Preventative measures

- always wear suitable footwear when exploring the intertidal area or wading in shallow water
- avoid handling sponges, cnidarians, cone shells, blue-ringed octopus, bristleworms or the felt cap sea urchin
- avoid accidentally brushing against hydroids, true corals and anemones
- avoid bathing in waters where Portuguese men-of-war are concentrated (often indicated by beached specimens)
- if bathing where jellyfish are prevalent, wear a lycra suit or other forms of protective clothing

10.3 Venomous Vertebrates

Venomous vertebrates deliver their venom either via spines, as many fish species, or through fangs, as in sea snakes. Injuries caused by venomous marine vertebrates are common, especially among people who frequently come into contact with these marine animals. Potent vertebrate toxins generally cause great pain in the victims, who may also experience extensive tissue damage.

10.3.1 Groups of venomous vertebrates

Catfish (freshwater & marine)

Catfish are bottom dwellers living in marine, freshwater or estuarine environments. They possess venomous dorsal spines which can inflict painful wounds even when the fish is dead (Halstead, 1988). The majority of catfish stings result from handling catfish while sorting fish catches. Some species, such as *Heteropneustes fossilis* from India, have been known to actively attack humans leaving a painful sting (Williamson *et al*, 1996).

Stingray (freshwater & marine)

Stingrays are found in the Atlantic, Indian and Pacific Oceans. They are predominantly marine, but the South American river ray (Pontamotrygonidae) lives in freshwater. Stingrays tend to be partially buried on sandy or silky bottoms in shallow inshore waters. One, or two at most, venomous spines in their tails can stab unwary swimmers who happen to tread on, or unduly disturb them. All stingray wounds, no matter how minor, should receive medical attention to avoid the chance of secondary infection. Some injuries caused by venomous stingrays can be fatal for humans if the spine pierces the victim's trunk; deaths have been reported both for marine (Rathjen & Halstead, 1969 and Fenner *et al* 1989) and freshwater (Marinkelle 1966) species.

Scorpionfish (estuarine and marine)

All species of scorpionfish possess a highly developed venom apparatus and should therefore be treated with respect. The estuarine stonefish, *Synanceia horrida* (syn. *S. trachynis*), is the most venomous scorpionfish known and occurs throughout the Indo-Pacific. The reef stonefish (*Synanceia verrucosa*), resembles coral rubble and lies motionless in coral crevices, under rocks, in holes, or buried in sand or mud where divers often mistake them for rocks. The pain associated with stings by a stonefish is immediate and excruciating, can last for days (Williamson *et al*, 1996). The lionfish and true scorpionfish also possess venomous.

Weeverfish (marine)

Weeverfish are confined to the north-eastern Atlantic and Mediterranean coasts. All four species (*Trachinus* spp. and *Echiichthys* sp.) contain venomous dorsal and gill cover spines. They are small (less than 4.5 cm) and lie partly buried in sandy bays at extreme low water where swimmers and beach walkers frequently step on them. Weeverfish are regarded by some as the most venomous fish found in temperate European waters (Halstead & Modglin, 1958; Russell & Emery, 1960).

Surgeonfish (marine)

Surgeonfish are herbivorous reef dwellers equipped with a sharp, moveable spine on the side and base of the tail. When excited, the fish can direct the spine forward making a right-angle with the body, ready to attack. Large surgeonfish, such as the Achilles surgeonfish (*Acanthurus achilles*) and the blue tang (*Acanthurus coeruleus*) of the warm seas of the western Atlantic, use their spines in defence and cause deep and painful wounds with a quick lashing movement of the tail (Halstead *et al*, 1990).

Snakes (freshwater and marine)

Poisonous snakes are air-breathing, front-fanged venomous reptiles and many are associated with both the marine and freshwater environments.

Of the 50 species of sea snake, the majority live close inshore or around coral reefs. They appear similar to land snakes, but have a flattened tail to aid in swimming. They are curious, generally non-aggressive creatures, but can be easily provoked to attack. All sea snakes are venomous and can inflict considerable harm if disturbed. White (1995) estimated a world-wide sea snake fatality rate of at least 150 per year.

Of the freshwater aquatic snakes, possibly the water moccasin, or cottonmouth, is the most dangerous to humans, the venom attacking the nervous and blood circulatory systems of the victim. The water moccasin, *Agkistrodon piscivorus*, is a pit-viper found throughout the south-eastern part of the United States. The species is never far from water and swims with its head well above the surface. The snake normally feeds on aquatic. When threatened, the snake opens its mouth wide to reveal the almost white lining which gives it its common name. The species can be aggressive and is densely populated in some areas. Its bite can result in gross tissue damage, with amputations of the affected limb not uncommon (Caras, 1976). Other species of the genus *Agkistrodon* are found throughout North America and Southeast Europe and Asia.

10.3.2 Preventative measures

- always “shuffle” feet when walking along sandy lagoons, or shallower waters where stingrays frequent;
- in catfish waters fishermen should be extremely careful when handling and sorting their catch;
- suitable footwear should be worn to avoid accidentally treading on weeverfish or stonefish;
- wear boots in snake-infested areas; and
- always carry anti-venom in snake-infested areas.

Table 10.1 Relative risk to humans posed by several groups of organisms

ORGANISM	DISCOMFORT	REQUIRES FURTHER MEDICAL ATTENTION	MAY REQUIRE EMERGENCY MEDICAL ATTENTION
NON-VENOMOUS ORGANISMS			
Sharks		✓	✓✓
Barracudas		✓	
Needlefish		✓	✓
Groupers		✓	
Piranhas		✓	
Conger eels		✓	
Moray eels		✓	
Electric fish		✓	
Seals & sea lions		✓	
Hippopotami		✓	✓
Crocodiles		✓	✓✓
VENOMOUS INVERTEBRATES			
Sponges	✓	✓	
Hydroids	✓	✓	
Portuguese man of war	✓	✓	✓
Jellyfish	✓	✓	
Box-jellyfish		✓	✓✓
Hard corals	✓	✓	
Sea anemones	✓	✓	
Blue-ringed octopus			✓
Cone shells		✓	✓
Bristle-worms	✓	✓	
Crown of thorns	✓	✓	
Sea urchins (most)	✓		
Flower sea urchin		✓	✓
VENOMOUS VERTEBRATES			
Stingrays		✓	✓
Catfish	✓	✓	
Weeverfish	✓	✓	
Stonefish		✓	✓
Surgeonfish	✓	✓	
Snakes		✓	✓

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CHAPTER 11

Monitoring and Assessment

In order to provide practical guidance concerning the design and implementation of monitoring programmes for recreational water use areas, WHO is developing a manual on this theme. The structure of the manual is based upon a framework 'Code of Good Practice (COGP) for Recreational Water Monitoring'. The Code was developed through an extensive process of consultation and within the context of co-operation between WHO and the European Commission. The Code is presented below. It constitutes a series of statements of principle or objectives which, if adhered to, would lead to a design and implementation of a monitoring programme of scientific credibility. The application of the Code under specific circumstances will be described in greater detail in the forthcoming manual.

A properly formulated COGP for monitoring provides an invaluable management tool. It should delineate the framework within which a particular process should operate, indicating the likely resource implications associated with properly implementing its objectives. It is important that a COGP is specific and that none of its component parts are open to diverse interpretation. The individual components should be reasonably self-contained as far as possible and the manager should be able to use the integrated COGP as a guide to the successful implementation of a programme to ensure the quality of a recreational water and/or bathing beach. The key linkages are between this particular COGP and the various chapters in the Guidelines for Safe Recreational-water Environments. Cross-referencing between the two should ensure that a valid and replicable monitoring and assessment programme is established.

The following COGP provides a linkage to the various health effects associated with recreational waters and incrementally builds up the component parts of a successful programme - key health issues; monitoring and assessment strategies; principal management considerations. It also provides sufficient detail to allow a manager to undertake such a programme, integrating all the component parts in a consolidated whole.

Code of Good Practice for Recreational Water Monitoring

This Code of Good Practice constitutes a series of statements of principle or objectives which, if adhered to, would lead to the design and implementation of a monitoring programme of scientific credibility. It applies in principle to the monitoring of all waters used for recreational activities which involve repeated or continuous direct contact with a water body. In many circumstances there are different approaches or methods which can be applied to achieve the objective stated in the Code. Whilst equally valid in isolation of one another, adoption of diverse approaches within a single programme would not lead to the comparability of results which may be required of an inter-location study or enforcement programme. Where data is to be compared between laboratories or between sites all available measures to ensure comparability of results should be implemented:

A quality assurance programme based on internal controls and external controls (inter-laboratory comparisons) are essential.

- Criteria should be developed and stated prior to data collection for dealing with participating laboratories consistently failing to comply with minimum analytical quality.
- Procedures for data omissions, sampling handling and rejection should be agreed prior to data collection and adhered to.

In regulatory monitoring programmes factors such as frequency of sampling, analytical methods, data analysis, interpretation and reporting, sample site selection and criteria for recreational water-use areas will generally be defined by the regulatory agency and should take account of the principles outlined in the code of good practice.

Section 1 - Design and Implementation of all Monitoring Programmes

Design of monitoring programmes

1.1 The objective(s) of a monitoring programme or study should be identified formally before the design of the programme and stated prior to data gathering.

1.2 Objectives should be described in a manner which can be related to the scientific validity of the results obtained. The required quality of any data should be derived from the statement of objectives and stated at the outset.

1.3 In designing and implementing monitoring programmes all interested parties (legislators, NGOs, local communities, laboratories etc.) should be consulted. Every attempt should be made to address all relevant disciplines and involve relevant expertise.

1.4 The scope of any monitoring programme or study should be defined. This would normally take the form of definition of criteria for inclusion/exclusion of recreational water-use areas and preparation of an inventory of recreational water-use areas

1.5 The catalogue of basic characteristics of all recreational water-use areas should be prepared and updated periodically (generally annually) - and also in response to specific incidents - in a standardised format. It should include as a minimum the extent and nature of recreational activities that take place at the recreational water-use area and the types of hazards to human health which may be present or encountered. Unless specifically excluded, the list of potential hazards to human health would normally include microbiological quality of water, cyanobacteria or harmful algae, drowning and physical hazards. Monitoring programmes frequently also address aesthetic aspects and amenity parameters because of their importance to health and well being.

1.6 Programme or study design should take account of information derived from the inventory of recreational water-use areas and catalogue of basic characteristics, which may require refinement of programme objectives.

1.7 The logistical planning of any monitoring programme or study should take account of socio-economic, technical/scientific and institutional capacities, staffing, equipment availability, consumable demands, travel and safety requirements and sample numbers; without compromising achievement of the objectives or scientific validity of the programme or study.

1.8 The hierarchy of authority, responsibility and actions within a programme or study should be defined. All persons taking part in the programme or study should be aware of their roles and inter-relationships.

1.9 Staff should be adequately trained and qualified including with regard to health and safety aspects.

1.10 Monitoring programmes should include appropriate quality assurance (QA) which does not infringe on health and safety and which covers the integrity of all observation, interview, field sampling and water quality analyses as well as data input, analysis and reporting.

1.11 A QA Officer should be appointed who reports directly to senior management. They should regularly audit all aspects of the operation with special regard to procedures, traceability of the data and reporting.

1.12 Essential elements of Quality Assurance (QA) programmes include:

- the writing and implementation of a Quality Manual and Standard Operating Procedures (SOPs). All SOPs should be regularly overhauled and updated as necessary and any deficiencies reported and appropriate remedial action taken.
- SOPs should include maintenance and updating of inventories and catalogues; methodologies for all major equipment, all sampling and analytical procedures; sample receipt, screening and storage; reporting.

1.13 Samples should be registered on arrival at the laboratory. The applied laboratory procedures should conform to the standard operating procedures defined at the laboratory. Where possible, all analytical procedures should follow defined ISO or APHA protocols. All equipment should be calibrated regularly and the operational procedures submitted to quality control staff in order to guarantee traceability of the data.

1.14 The programme should be evaluated periodically, and whenever the general situation or any particular influence on the environment is changed.

Data collection

1.15 Collection of data and information should utilise the most effective combination of methods of investigation including observation; water quality sampling and analysis; interview of appropriate persons and review of published and unpublished literature.

1.16 Frequency and timing of sampling and selection of sampling sites, should reflect beach types, use types and density of use as well as temporal and spatial variations in the recreational water-use area which may arise from seasonality, tidal cycles, rainfall, discharge and abstraction patterns, beach types and usage.

1.17 Sampling should provide a data set amenable to statistical analysis.

Data Handling

1.18 Data handling and interpretation of results should be done objectively without personal or political interference.

1.19 The need for transformation of raw data, before analysis, to meet the conditions for statistical analysis, should be agreed with a statistical expert before commencing analysis.

1.20 Data handlers and collectors should agree on a common format for recording results of analyses and surveys and should be aware of the ultimate size of the data matrix. Forms and survey instruments should be compatible with this format. Likewise, data handlers should agree on a format for the output of results with those responsible for interpreting and presenting the data.

1.21 Procedures for dealing with inconsistencies such as omissions in records, indeterminate results (e.g. indecipherable characters, results outside the limits of the analytical methods) and obvious errors should be agreed in advance of data collection. On receipt from the data collectors, record forms should be examined and the agreed procedure followed. Discrepancies should be referred immediately to the data collector for correction or amendment. Where re-sampling is impossible, estimates are preferable to leaving gaps in the record, but they should always be recorded as such and they will reduce the statistical degrees of freedom.

1.22 Ideally arrangements should be made to store data in more than one location and format, to avoid the hazards of loss and obsolescence. Data should be transcribed accurately, handled appropriately and analysed to prevent errors and bias in the reporting.

1.23 The statistical routine should be selected by a statistical expert.

1.24 Data should be handled and stored in such a way to ensure that the results are available in the future for further study and for assessing temporal trends.

Data Interpretation

1.25 Data should be interpreted and assessed by experts with relevant recommendations for management actions prior to submission to decision makers. Interpretations should always refer to the objectives - and should also propose improvements, including simplifications, in the monitoring activities - stressing the needs for future research and guidelines for environmental planning.

1.26 Interpretation of results should take account of all available sources of information, including those derived from inventory, catalogue of basic characteristics, sanitary and hazard inspection, water quality sampling and analysis, and interview including historical records of these.

Reporting

1.27 The findings should be discussed with the appropriate local, regional and/or national authorities and others involved in management (including integrated water resource management), such as the industrial development and/or national planning boards.

1.28 Results should be reported to all concerned parties including the public, legislators and planners. Any information relating to quality of recreational water-use areas should be clear, concise and integrate microbiological, aesthetic and safety aspects.

1.29 In issuing information to concerned parties (the public, regulators, NGOs, legislators etc.) it is essential that their requirements are kept in mind.

1.30 Where specific events such as rain, or extreme events such as epidemics occur, the competent public health authority should be informed and recommendations should be made to the bathing population about the risks of poor water quality.

1.31 Reports addressing the quality of recreational water-use area should be accompanied with reference to local and visitor perceptions of the aesthetic quality and risks to human health.

1.32 The deleterious impacts of human health hazards and aesthetic pollution and of control measures to avoid or reduce such impacts should be introduced into environmental health education programmes in both formal and informal educational establishments.

1.33 The usefulness of the information obtained from monitoring is severely limited unless an administrative and legal framework (together with an institutional and financial commitment to appropriate follow-up action) exists at local, regional and international level.

Aspects Relevant to Specific Hazards

The following items apply in addition to the general guidance given above in relation to specific hazards.

2.1 Physical Hazards, Drowning and Injury

2.1.1 The catalogue of basic characteristics should include, wherever relevant, hazards such as beach slopes, tides, flows and currents, actual user groups, nearby hazardous areas such as cliffs, shallow waters dangerous for diving; and other such hazards as identified from local knowledge and records of health effects.

2.1.2 Information regarding measures to prevent or ameliorate hazard exposure or outcomes including for example: lifeguard provision; staff training; sign; emergency telephones; access to first aid; medical facilities; fencing; warning systems for adverse conditions and emergency routes should be included in the catalogue of basic characteristics.

2.1.3 Monitoring and assessment programmes should address those hazards and preventative measures, described in 2.1.1 and 2.2.2 which are subject to change.

2.1.4 When assessing the significance of hazards, account should be taken of the severity and likelihood of adverse health outcomes together with the extent of exposure.

2.2 Microbiological Water Quality and Sanitary Inspection

2.2.1 Sanitary inspection should be undertaken as a necessary adjunct to water microbiological analysis to identify all real and potential sources of microbiological contamination. It should assess their impact on the quality of the recreational water-use area and bather health. During the inspection the temporal and spatial influences of pollution on water quality should receive full consideration.

2.2.2 An exhaustive sanitary inspection should be carried out immediately prior to the principal bathing season. Inspections of specific conditions should be conducted in conjunction with routine sampling during the bathing season. Pertinent information should be recorded on standardised check lists and used to update the catalogue of basic characteristics. If a problem is identified, it may be necessary to collect supplementary samples or information to characterise the problem.

2.2.3 Visual faecal pollution or sewage odour should be considered a definite sign of elevated microbiological pollution and necessary steps should be taken to prevent health risks to bathers.

2.2.4 Standard operating procedures for sanitary inspections, water sampling (including depth) and analyses should be well described to ensure uniform assessments.

2.2.5 Sample point location and distance between each should reflect local conditions (overall water quality, bather usage, predicted sources of faecal pollution, temporal and spatial variations due to tidal cycles, rainfall, currents, on-shore winds and point or non-point discharges) and may vary widely between sites.

2.2.6 Sterile sample containers should be used for microbiological samples. Scrupulous care should be taken to avoid accidental contamination during handling and sampling collection. Every sample should be clearly identified with time of collection, date and location.

2.2.7 Sample depth appropriate to the analysis should be selected adhered to consistently.

2.2.8 The sample should be kept in the dark and maintained as cool as possible within a chilled insulated container and returned to the laboratory promptly after collection. Samples should be analysed as soon as possible and preferably within 8h of collection. Sample storage is recommended not to exceed 24 h at 5^0 C.

2.2.9 Additional information should be collected at the time of sampling including: water temperature; weather conditions; water transparency; presence of faecal material; abnormal discoloration of the water; floating debris; cyanobacterial or algal blooms; flocks of sea birds and any other unusual factors. All information should be recorded on standardised checklists.

2.2.10 The minimum microbiological parameters that should be investigated are faecal streptococci or enterococci and thermotolerant coliforms or *E. coli.* While the former is a recommended indicator for salt water both can be used for freshwater. Additional parameters should be investigated if considered relevant and resources allow.

2.2.11 The influence of specific events such as the influence of rain on the recreational water-use areas, especially in relation to the duration of the peak contamination period should be established and prior agreed procedures implemented.

2.2.12 Extreme events such as epidemics and natural disasters may require additional measures to ensure there is no additional risk associated with recreational water-use areas.

2.2.13 The procedures to be used for transformation of raw data, to meet the statistical requirements should be agreed with the statistical expert prior to analysis. The most usual need is to transform bacterial counts to logarithms and to convert their approximately log-normal frequency distribution to normality.

2.2.14 When unexpectedly high microbiological results are obtained resampling should be undertaken to determine whether this was due to sporadic events or persistent contamination. In the latter case the source of pollution should be established and appropriate action taken.

2.3 Cyanobacteria and Algae

2.3.1 Monitoring of recreational water-use areas should be sufficient to identify risk of blooms, taking into account actual or potential accumulation of toxic cyanobacteria and algae.

2.3.2 Sampling points should be located to represent different water masses (stratified waters, waters coming from river mouths, etc.) in the investigation area and the sources of nutrients (discharges, upwellings, etc.). Possible transport mechanisms of toxic phytoplankton should be considered, possible physical forcings should be identified and sampling schemes arranged accordingly.

2.3.3 In areas of high risk sampling for algae should be carried out at least weekly. During development of blooms, sampling should be intensified to daily.

2.3.4 Monitoring of toxicity (using bioassays, chemical or immunological procedures) is only justified where reason exists to suspect that hazards to human health may be significant. In such cases, long-term information on phytoplankton populations (toxic, harmful and others) should be collected where appropriate.

2.3.5 Analyses of toxins should only be undertaken where standard, replicable and reliable analyses can be performed.

2.3.6 Where conditions are such that monitoring is considered essential temperature, salinity (in marine coastal areas), dissolved oxygen, transparency, presence of surface water stratification, phytoplankton biomass (chlorophyll), surface current circulation (transport of algae) and meteorological patterns such as seasonal rainfall, storms and special wind regimes should be considered.

2.4 Other biological, physical and chemical hazards

2.4.1 Monitoring for other locally important hazards is justified only where reason exists to suspect that hazards to human health may be significant. Such occurrence may be highly localised.

2.4.2 Only where standard, replicable and reliable analyses may be undertaken for known parameters should such analyses be undertaken.

2.4.3 Approaches to the assessment of the significance of locally important hazards will depend on the type of hazard and should take account of their magnitude and frequency; severity and occurrence of health effects; and other local factors.

2.5 Aesthetic aspects

2.5.1 Monitoring for specific aesthetic pollution parameters should be undertaken where hazards to human health and well being are suspected.

2.5.2 Selection of aesthetic pollution parameters for monitoring should take into account local conditions and should consider parameters such as surface accumulation of tar, scums, odours, plastic, macroscopic algae or macrophytes (stranded on the beach and/or accumulated in the water) or cyanobacterial and algal scums, dead animals, sewage-related debris and medical waste.

2.5.3 Sampling of aesthetic pollution indicators should take into account the perception and requirements of the local and any visiting populations in reference to specific polluting items as well as the feasibility of their monitoring.

CHAPTER 12

MANAGEMENT OPTIONS FOR HEALTHY RECREATIONAL-WATER USE

12.1 Integrated Management Framework

Recreational water activities can bring about negative health effects upon users as well as positive ones. These negative effects take various forms as has been demonstrated in previous chapters, the causes of which can be ultimately traced back to the forcing functions characteristic of water based recreational areas: increased pressure for use of coastal/lacustrine/riverine zones and the immediate maritime zone; trans-boundary pollution movement; multiplicity of stakeholders competing for control and use of the area leading to conflicts and conflicting demands upon the environment.

It is necessary to address these issues and implement effective management options in order to minimise and reduce the health consequences of all anthropogenic activities in these areas. The first step usually is the establishment of an integrated management system for marine and freshwater recreational waters, based on the concept of integrated coastal management (ICM). The ICM framework *is "a continuous and dynamic process that unites government and the community, science and management, sectoral and public interests in preparing and implementing an integrated plan for the protection and development of coastal systems and resources*"(GESAMP, 1996). Currently (1998), the ICM concept is not only geared to coastal lands but has broadened so that it now encompasses river catchment areas as inevitably rivers debauch into estuaries, and/or seas. Events that take place inland can have very severe impacts on the open coast. For example, riverine litter inputs (including sewage-related debris) on coastal beaches in large areas of many countries, far outweigh the marine or beach user litter input.

Some 177 nations open to an ocean, sea, or gulf and *circa* another 30 coastal semi-sovereign states have the legal power to manage their own natural resources and lands. Interconnections abound between individual elements but central is the conflicting issues, e.g. pollution of recreational waters, and the opportunities that provide the motivating factors for creating a management program e.g. tourism (Fig. 12.1). The objective of an ICM programme is to evaluate and resolve these conflicts. When deciding on a particular intervention, cost and benefits should be taken into consideration: costs (in terms of health, mitigation activities and public awareness) and benefits (in terms of enjoyment, reduction of health bills, decreased cleaning costs, additional recreational activities etc. - these are basically non-quantifiable but could be accounted for by the number of people going to the recreational site) of the bathing activity at a particular site.

The literature is replete with acronyms associated with ICM. It should be borne in mind that an *ICM programme* can be directed to one or more types of coastal areas which can extend from coastal mountain watersheds to offshore coastal boundary, whereas a *coastal zone management plan* must include coastal waters, the coastline and the coastland area. The former definition covers recreational waters. ICM not only involves comprehensive assessment, the setting of objectives, the planning and management of coastal systems and resources, but also takes into account traditional, cultural and historical perspectives and conflicting interests and uses. It is an iterative and evolutionary process for achieving *sustainable development* and implementing a continuous management capability that can respond to changing conditions. As such, the framework permits *integration* of the various needs and requirements for the coastal area and co-ordination of the actions, whether preventive or remedial and epitomises the spirit of Agenda 21 (UNCED, 1992). It is ideally geared towards the management of recreational waters (see also Chapter 1).

Integration relates to both vertical (levels of government and non-governmental organisations) and horizontal (cross-sectoral) co-ordination of stakeholders whose actions influence the quality/quantity of water based resources reflected in the planning and management strategies (Fig. 12.1). The ecosystems, public access and service systems determine the quality, quantity and distribution of the resources of the water-based recreational areas. It is worthy of note that among the many acronyms for ICM, *planning* is never mentioned. It is tacitly assumed to be a sub set of *management*. Planning is a process of analysing systems, environments, resources and uses to produce a plan/framework which guides decision-makers. Plans are needed to escape cumulative impacts (small decisions), reduce the costs of permit letting and to provide a forum for the public. Land and water use plans *must* guide policy/decision making. In addition to planning, a programme should also have applied research together with education/public outreach.

Sustainable development is taken to meet the needs of the present without compromising the ability of future generations to meet their own needs. This concept has been sub-divided into *strong* sustainability, where the ecosystem is allowed to function in as natural manner as possible; and *weak* sustainability in which the overall stock of natural assets are preserved (Pearce and Warford, 1993). Turner (1997), regarded ICM as the steering mechanism for sustainable development policy formulation at the coast. He suggested that sustainability could only be achieved by balancing economic efficiency, equity and fairness together with adoption of the precautionary principle. Indicators - identified by a focus group of experts, for ICM are still bring refined and an ongoing European Union approach/framework, *The Pressure Indices Project* (EC, 1996), is attempting to deliver sustainable development by highlighting causal links via a pressure, state, response model (PSR). This was adopted by the World Resources Institute (Hammond *et al*., 1996).

Application of ICM requires a full understanding of the physical and social systems involved so that the various essential elements are effectively used to analyse accurately the main issues so as to prescribe appropriate solutions. Recreational water area planners must be skilful in applying appropriate management tools and methods in the design of an ICM program. As ICM is relatively new in most parts of the world resource managers will need to acquire the necessary skills via training schemes and experience before the system can be effectively adopted.

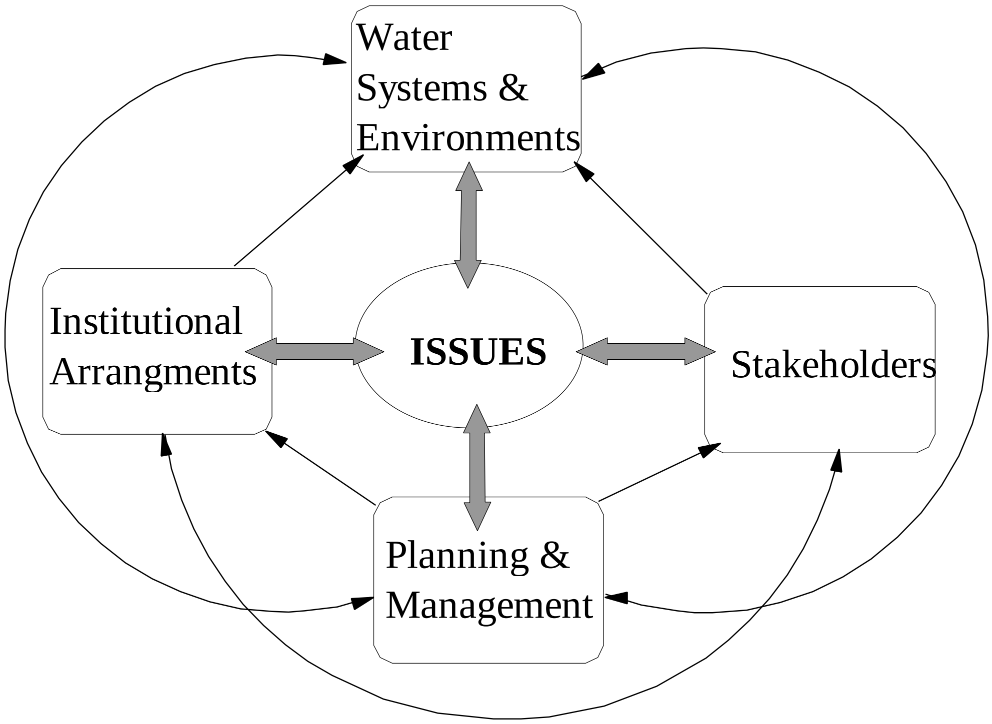

Figure 12.1. A schematic view of Integrated Management of recreational waters Arrows only show major pathways as many linkages occur.

Ideally the first step should be to develop national ICM programmes. If not then site-specific ICM programmes which could be more easily managed by local authorities. With experience and a deeper understanding of its concept, a systematic application of ICM could gradually cover the rest of the entire coastal zone (marine and freshwater). A national coastal policy could be established first with the provision to incorporate integrated planning and management into the development plans of national and local governments (Chua, 1993).

Current global capacity in coastal management is in a more formative stage of development than in other fields such as public health, which has a much longer history of international experience. The need for building human and institutional capacity has been identified in Agenda 21 of the UNCED conference as well as by a number of international environmental institutions, as essential for ICM and sustainable development in developing coastal states (UNCED, 1992; Crawford *et al.,* 1993). The positive results of integrated management cannot be discerned immediately as it takes time for the desired changes to occur. These require a shift in perception and stronger support on the part of the policy makers and sectors affected by the implementation of the ICM programmes (Crawford *et al.,* 1993).

12.2. Public awareness and support for informed personal choice

Information is increasingly reaching consumers on both the benefit of recreational use of coastal and freshwaters and the dangers associated with marine and beach activities. Benefits have been acknowledged since antiquity, thermal waters, sea and sand have been sought to cure illnesses, relax and energise the body.

Awareness raising and enhancing the capacity for informed personal choice is increasingly seen as an important factor in ensuring safe use of recreational water environments. It acts both directly (i.e. users are less likely to choose an area which is known to be less safe, or to practice unsafe behaviours so that overall exposure of the population will be reduced); and indirectly (the exercise of preference for safer environments will encourage investment in improvements). In order to operate effectively it is essential that the public is generally aware; that information is available and comprehensible; and that it allows meaningful comparison between alternative locations.

Increased awareness of the public regarding recreational water use and health is also likely to lead to a number of direct benefits where the principal factor leading to accident or disease is individual error of judgement. This may be the case regarding a number of accident hazards including for example diving into shallow water or over-estimation of swimming abilities (Chapter 2). Increased awareness may also lead to greater availability of rescue and life-saving skills amongst the general and water-user population.

12.2.1 Classification Schemes

A number of national and international classification schemes for water use areas (most commonly beaches) have been developed in recent years which include safety-related information, the products of which are intended to be used by users and potential users. International examples include the Blue Flag and Coastwatch programmes. Many countries have one or more national equivalents. In some of these programmes, human health concerns comprise a small component, or it is possible for areas that present a significant public health risk to receive high grading if other facilities are good or extensive. Such approaches may undermine the contribution of informed personal choice to the promotion of user safety. In general health-related aspects in such classification schemes should be able to assume a dominant character in classification if there is any likelihood that users will interpret them as indicating safety.

These schemes are common in many countries and range from use in large scale resorts to undeveloped recreational areas. They were designed to inform the public about assessment of an area's quality so that an informed choice could be made of recreational areas. Their continued development follows a recommendation of the Second International Conference on Tourist Health (WHO, 1990). The most popular in the European context is the Blue Flag but a number of other rating schemes are prevalent in countries like the UK, e.g. Seaside Awards; Good Beach Guide; Beachwatch. All these schemes look into parameters such as water quality, but none of them assess beach user preferences. Award schemes can have a large influence on tourism e.g. the beach award schemes in the USA (Leatherman, 1997). Nevertheless, it appears that confusion exists about the implications associated with these schemes (Williams and Morgan, 1995). They are used to:

- give consumers information about seawater quality so that they can make informed choices about holiday destinations and assess risks when bathing in coastal waters,
- advise businesses which operate on the coast and who want to reduce the risks caused by adverse publicity about poor seawater quality,

help resort managers and their local authorities who wish to ensure that there is a common standard and system of measuring those standards (Collins, 1994).

A specific problem that is commonly encountered in the development of classification schemes is that information is not comparable between locations. For example it is difficult to generate comparable information on microbiological quality because of problems with inter-laboratory comparability and, where such information is locally generated, it may be difficult to ensure the impartiality of laboratories and surveyors. At an international scale differing legislation, practice and interpretation between countries compound such problems.

The success of programmes of this type depends upon active information dissemination as well as the required technical interventions. Whilst comparison of different locations constitutes an important part of the information required for improved personal choice, active information dissemination at a local level and related to short-term changes is also necessary. For example, in some recreational water use areas, local water quality variation may be extreme or rapid such that areas are unsafe for physical or quality reason. Such areas require sign boarding and also information dissemination where a beach is unsafe at certain times for instance because of weather conditions or because local water quality changes. The requirement for and ability and commitment to undertake such information dissemination should constitute an important part of classification schemes.

Awareness raising is of particular importance amongst certain specialist user groups and should concern both the hazards that they may reasonably encounter together with the hazards they may present to other users. With the increasing use of recreational water areas by multiple user types (e.g. beaches used for swimming, jet skiing and sail boarding) this theme is of particular importance. Clubs and other user group associations have a special role to play in this regard.

The objective of awareness activities would be not only to raise the individual’s ability to correctly appraise the risk but also to raise the level of confidence of the public that the issue is being addressed and monitoring measures are being undertaken

12.3. Stakeholders

Figure 1.2 displays the variety of stakeholders and their role in the process of assessing and using recreational waters and taking remedial actions to limit health hazards. Central and local governments have a key responsibility, in establishing standards and regulation and ensuring their enforcement. UN bodies, such as the WHO, and international organisations, such as the Advisory Committee on the Protection of the Sea or Coastwatch Europe, provide further advice and guidance.

Research institutes and universities can contribute to the technical assessment of hazards and monitoring changes. Monitoring can also be undertaken by local NGOs, in particular when they wish to support their argument for increased precaution or to measure concentrations in a particular area which is not covered by government monitoring agencies. The tourism industry also is increasingly involved in monitoring effort. Resorts, sport clubs and beach hotels are undertaking activities such as monitoring seawater quality and bathing safety. Though their motivation may be a commercial one first - to “green” their activities and attract health-conscious and environmentally-sensitive tourists, this, at the same time, ensures the health of that environment on which the industry relies and the health of these customers who come back and bring more.

A number of stakeholders participate in raising the awareness of users to some of the dangers associated with recreational activities. Local NGOs, the tourism industry and local authorities contribute to the distribution of information brochures, the training of consumers in safe conduct and practice, the posting of warning notices and the zoning of dangerous areas. In so doing, they need to translate data gathered by scientists and technicians into understandable and user-friendly messages.

A powerful medium in awareness raising is the media - press, radio, internet and TV, which, increasingly, constitute the most effective means to reach individuals. The media have been instrumental in alerting citizens and tourists to the danger of exposure to UV sun rays in some countries. Though sometimes inexact or distorted, messages reach the greatest number of citizens. Raising awareness may bring about a change of behaviour. This is a long-term endeavour that may not translate into results immediately but greatly contributes to preventive efforts.

The tourism industry is a powerful stakeholder. Tourism has developed as a major and world-wide industry, creating a substantive demand for energy, raw materials, goods and services which in turn, also affects the quality of natural and cultural environments, including coastal waters, lakes and freshwater rivers. From its 100 million local inhabitants, the Mediterranean coast accommodates 230 million in the summer. Yet only 30 per cent of the sewage from the towns and cities receives any treatment before discharge into the sea. With degradation of the environment (local, national and global), to which the tourism industry is a contributor, some traditional tourism facilities and services are registering a decrease in both arrivals and satisfaction of consumers. In some areas that until quite recently were very popular, coastal tourism has declined because of problems linked to the quality of the waters. For example, algal blooms in the Adriatic Sea have made the water unattractive to swimmers ; beaches were closed in the Ukraine in the summer of 1995 because of cholera outbreaks. This same environment on which tourism draws its *raison d'être* is being valued by its customers so much so that deterioration leads to non-consumption, i.e. a cost to the tourism industry. The loss of economic revenue, more so than the concern for environmental degradation and direct health impacts, is prompting the industry to respond pro-actively and initiate good practice and, more importantly, to collaborate with government authorities on joint remedial actions.

12.4 Management Action

Figure 1.4 encapsulates a management framework with different levels of health risk and accordingly suggested relevant interventions, ordered in four major fields:

- regulatory compliance,
- public awareness and information,
- control and abatement technology, and
- public health advice and intervention.

ICM and integrated basin management (IBM) provide umbrellas for co-ordination among these areas of intervention covering the economic, abiotic/biotic and social systems. It should be noted that current ICM thinking encapsulates both coastal and river catchments. The scheme shown in Figure 1.4, has general applicability and can be applied to all hazards encountered in recreational water use areas and discussed in this publication.

12.4.1. Local authorities

Local authorities generally take the lead in bringing stakeholders together, identifying their needs and requirements and gaining their collaboration for easier acceptability of decision and participation in the implementation of the decisions. They are frequently the legal agency of government. In so doing, they should facilitate:

- the prioritisation of risks and hazards,
- the design of a checklist of possible intervention package,
- the identification of threshold indicators for extreme and dangerous situations.

Local authorities also contribute to the development of standards and regulations (either through contribution to national standard development or through development of local "by-laws"), and are also generally the lead agency in enforcing the standards as well as leading the monitoring process. The capacity of inspectors and regulatory agencies holding this responsibility is often inadequate and should be strengthened or at best maintained and better co-ordinated. Support may be obtained from industry itself, research institutes, universities or from NGOs and the public, which, when faced with knowledge environmental degradation, can effectively put pressure on the central government to re-deploy resources and ensure adequate monitoring and enforcement of standards and policies.

Local authorities ought to combine regulatory sanctions with positive incentives whereby direct users - whether industries or consumers - have a clear motivation and the means to act to reduce negative hazardous effects.

12.4.2. National Government

ICM is a powerful mechanism for allocation of natural resources based upon sound environmental and socio-economic planning and evaluation. It requires networking with all relevant national government activity, including international, national and economic development planning. It is a major objective of ICM to facilitate co-ordination among levels of government and their various bureaucracies in defining specific resource conservation goals.

Substantive international conventions have been drafted and endorsed with regard to protection of the marine and freshwater environment with associated clauses for preventing health hazards from use of recreational waters. The Bucharest Convention for the Protection of the Black Sea for example encompassed both sources of pollution and monitoring of data and status. The Convention also called for the establishment of Integrated Coastal Zone Management mechanisms to address these issues and bring about effective solutions in a collaborative way. The challenge is now to bring the principles and guidelines of these conventions down to regional planning and policy instruments and also down to standards that are feasible, relevant and effective to protect the environment, locals and tourists. Central governments are responsible for enabling proper policies, for facilitating networking, co-operation among sectors, access to information and guaranteeing recourse to litigation, but their effectiveness is frequently questioned.

One of the most important national government activities in many countries concerns the layout of a policy / management strategy for the accomplishment of ICM objectives. These are concerned with problems and opportunities regarding resources, economic development activities and societal needs in recreational water-use areas. Furthermore, national government general functions aim to direct, promote and co-ordinate all activities related to the application of laws concerning the coastal zone and in particular:

- To define the quality objectives and set criteria for their enforcement.
- To establish the general guidelines of programmes for the multi-purpose use of

recreational water areas and coastal environments in general.

- To set the general technical rules for enforcement of all laws and regulations concerning recreational water use zones and in particular to define general criteria and methodologies for the monitoring of recreational-water environments and activities, mode and frequency of sampling, sampling and analytical techniques, determination of values for recreational waters and effluent discharges, definition of procedures for the surveillance and control of discharges, the updating of values and technical criteria.

12.4.3 Citizens and customers

In the process of ICM, citizens and consumers have to be made more accountable. If the public demand higher environmental standards, then they have a corresponding responsibility to pay the price for conservation and consequent rehabilitation. Additionally, increased personal responsibility would go a long way in reducing the remedial cost burden. Economic costs of cleaning the coastline are extensive - for example, it costs more than £15million per annum to keep Kent, UK beaches litter free (Gilbert, 1996).

Finally, citizens are sometimes instrumental in contributing to remedial actions. Under the guidance of local authorities or NGOs, they often generously participate in beach cleaning exercises and riverine, fly tipping area clean-up campaigns. Locals may be more aware of the impacts of marine pollution upon human health and the health of the ecosystem as well. It becomes a “civic” action to clean the beach and, in many countries, large numbers follows this type of activity. For example, the citizen or citizens’ group operating on a voluntary basis, in the context of the UK’s Heritage Coasts, are responsible for litter picks in selected recreational areas. A much greater sense of responsibility by citizens would help improve the coastline as well as the quality of inland water recreational areas.

12.4.4 International NGOs and associations

Since 1987, the Foundation for Education and Environment in Europe (FEEE) attributes a green quality label, the “Blue Flags” to European beaches and recently also to marinas. The label takes into consideration not only good quality bathing water but also pollution from pleasure boats. It encourages coastal municipalities to improve the public awareness of visitors and resident. Spain, France, Italy, Greece and Turkey are part of this Foundation. The label is taken seriously and tourism operators in Bulgaria, Egypt and Tunisia are considering similar schemes. Government authorities are also showing good examples of effective incentive system. In Turkey, the Tourism Ministry has established a label system to encourage tourism managers to be more sensitive to environmental protection, and to limit environmental degradation in their activities. Though the schemes can clearly contribute to enhancing a good code of practice for the use of recreational waters, a lack of coherence and compatibility among award schemes somehow undermines their effectiveness and credibility. Issues related to such classification schemes are discussed in greater detail in Section 12.2.1.

12.4.5 Industry

Partly as a result of Government regulation but primarily to accommodate tourists changing preferences, the industry is adopting a more pro-active role in monitoring and controlling the environment. Respect for the environment is becoming a competitive issue for the industry and a precondition to its expansion and prosperity and it is becoming a matter of economics. Industry associations have recently come up with a series of codes of conduct addressed at individual travellers and tourists, tour operators and tourism services and facilities. Numerous examples are available. To cite but just a few, the most influential ones probably include the World Travel and Tourism Council (WTTC) Environmental Guidelines, the Pacific Asia Tourism Association (PATA) Code for Environmentally Responsible Tourism and the Travel Industry Association of Canada (TIAC) which developed an overriding framework of acceptable conduct principles for its affiliates. The Codes integrate care for the environment and prevention of health hazards.

12.5 Economic Aspects

It is up to the individual to balance enjoyment and risk - known or perceived. When health risks and/or lack of enjoyment are perceived to be greater than enjoyment, individuals walk away. This alone may be sufficient to make local and central authorities take measures. Particular attention should therefore be given to the socio-economic aspects of tourist health. Faced with a multi-billion dollar-revenue industry, costs of environmental degradation may be perceived to be negligible. They are not, if health costs, economic loss and valuation of ecological degradation are all taken into consideration. In terms of economic loss, dirty beaches and turbid bathing waters (as well as inadequate safe drinking water supply and sewerage systems) are clear deterrents for tourists. On the Black Sea coasts of the former Soviet Union, when national tourists massively went on deserting the traditional resorts in favour of nearby Turkey or further away Mediterranean places, governments took a serious review of the situation, analysed the cause and undertook to carry out bathing water monitoring studies, training of local inspectorates and development of preliminary rehabilitation plans. The GEF - Black Sea Environmental Programme concluded from a survey on the beaches of Romania, Turkey (Antalya) and Russia (Sochi) in summer 1995, that:

"*An estimated 21 million tourists visited the Black Sea in a recent year. If the environmental quality of the Black Sea continues to deteriorate, prospective and many actual visitors will choose to vacation elsewhere. Being forced to go elsewhere because of the poor quality of the Black Sea would cause a loss of economic welfare. The estimate of this annual loss for the Black Sea countries is $363 million for a further 10 percent decline in environmental quality. Those who continue to visit and bear the loss associated with poor quality is another source of economic loss, yet to be estimated*".

Improving the environmental quality of the Black Sea can create tourism benefits for those attracted to the Black Sea for this reason alone. One pilot study indicated that a 50 percent change in the Black Sea's environmental quality would induce 50 percent of one sampled group to choose the Black Sea in preference to the Mediterranean" (BSEP, 1996). However, Sorensen *et al.*, (1997), in an analysis for Integrated Coastal Management (ICM) of the Black Sea, have argued that despite the millions spent to 'save' the Sea, especially from eutrophication, current estimates suggests a benefit of some US$122 million in contrast to the $3,888 billion which is needed to be spent to control the nutrient problem, i.e. the cost and benefits of nutrient pollution control shows a disparity of US$3,766,000,000.

Though these numbers have to be taken with caution, the general trend and estimated range of economic loss can serve as a valuable indicator of the economic costs of beach and water quality deterioration. For a complete picture, health costs associated with treatment of injury and disease from use of recreational waters would need to be estimated, collecting data from local hospitals and medical practitioners. In addition, defensive expenditures to remedy the degradation problems of a beach should be assessed.

Using a similar valuation methodology, a recent report also concluded that problems connected with wastewater disposal from tourism related facilities (hotels, restaurants, commercial, etc.) in four areas of the Island of Rhodes, were costing the island US$8.1 million a year in lost tourist revenue as well as US$2.7 million in beach degradation and US$0.9 million in human health hazards in the early 1990s (UNEP, 1995). The Rhodes figures clearly point out the responsibility of the tourism industry in the degradation process. The study highlighted the merits for this industry to contribute to actions that generally improve the local coastal environment and more specifically address hazards associated with recreational waters. The principal hygiene services which are a base of effective policy to safeguard tourist health are represented by the water supply, solid and liquid waste disposal, hygiene in swimming pools, beaches and bathing waters (Pasini, 1989). Costs and benefits though frequently accrue to different sectors of the industry and population groups; economic costs fall mainly on small local tourism operators - as well as local authorities and residents, whereas economic benefits chiefly end up with large business entities. Balancing the various levels, priorities and requirements calls for an integrated approach, where all stakeholders can contribute to a common goal.

12.5.1 How to define management options?

Management interventions may vary for example, from educational projects to construction work, or from no-cost actions to heavy funded development but all are usually issue driven. The range of types of intervention available is introduced in Section 1.7 and the overall management framework described in Section 12.1.

The exact package of management options that would reduce and/or eliminate health hazards and risks related to recreational water uses will be a function of the nature (magnitude and frequency) and severity of the health impacts. Hazards are the physical capacity of a substance rendering it capable of causing harm; risk is the probability of that harmful event occurring. Additionally, they would also depend upon the priorities of government authorities, availability of support and funding, social awareness of the population, visitors and decision-makers and the degree of partnership and collaboration established among the various stakeholders.

12.5.2 Severity of the health hazard

The degree of severity of the health risk will be a function of the assessment of risk and health hazards (Chapter 1 and Figure 1.3) associated with recreational waters, in particular as these relate to items discussed in preceding chapters:

- accidents and physical hazards- chapter 2,
- water quality and microbiological hazards - chapter 4,
- exposure to heat and sunlight - chapter 3, and, to a lesser extent,
- contamination of beach sand - chapter 5 and
- exposure to algae - chapters 6 and 7.

Some further hazards may be locally – important depending upon specific circumstances as described in chapters 9 and 10.

Upon assessing the combined level of risk, three levels of response may be considered, each geared for a certain level of intervention (refer to Figs 1.3 and 1.4 in Chapter 1). which would provide essential services, additional actions for sensitive areas, or full intervention

The first level (essential services) should guarantee that a framework for intervention is established, essential services to prevent the occurrence of negative health effects are in place, and remedial actions can be mobilised. This could include the dissemination of minimum public awareness messages, the establishment of an integrated recreational water committee with participation of various stakeholders, and the development of a streamlined monitoring programme for water quality.

The second level (additional actions for sensitive areas) would provide an enhanced institutional setting with more sophisticated legislation and increased participation of stakeholders into the development and implementation of solutions, target intervention to areas prone to health hazards and rapid response when problems are evidenced, and a greater public awareness activity together with NGOs mobilisation to support the effort.

The third level ("full intervention") would ensure a full package of management options with a clear strategic plan for implementation of the various interventions, establish an Integrated Coastal/Recreational Waters Management system, which would, in turn develop appropriate tools (legislation, incentives, economic instruments, participation, etc.).

These three suggested levels correspond to the health risk severity of the bathing water area. A minimum level of intervention may suffice in an area little frequented by tourists and locals, with little or no record of health effects due to bathing activities and with no development plans to alter the shape and nature of the recreational water zone in the medium term. The first level of intervention should ensure that a response to a danger situation can be mobilised effectively and immediately. Levels 2 and 3 would need to be adapted to local conditions, taking into consideration past occurrences and likely trends for the medium term future. Preventive actions are effective in areas with good general environmental awareness levels, which have available resources and no imminent health danger and threats. Remedial actions would be required to minimise existing negative health effects. Usually a combination of the two would be selected, with respect to local conditions, availability of resources and valuation of the danger and impacts. The option is clearly also linked to the availability of funding, technical support and advice.

12.5.3 Institutional setting/socio-economic analysis

Upon assessing the combined level of risk and the institutional setting in place, various levels of response may be considered. The level and type of intervention can only be defined when nature and severity of hazards have been assessed and the institutional capacity of the stakeholders analysed. Chapter 1 provides schematic approaches to the various levels of intervention required related to the severity of hazards encountered (Figs 1.3 and 1.4).

There are important implications for management from the point of view of health. Tourism and leisure are two of the fastest growing industries and recreational water-users health must be protected for obvious reasons but also it is important to control the socio-economic expenditure involved.

The necessary management steps for the prevention and control of illness must be put into action and must also be accompanied by information and advice programmes to raise public awareness to the various risks that exist. These management actions will not only benefit the users of recreational water-use areas but also improve and develop the resort itself from an socio-economic point of view.

12.5.4 Participatory identification and design of the options

Enhancing the involvement and participation of the various stakeholders into the definition and discussion of the problems will help design acceptable recommendations. The ICM process introduces mechanisms to facilitate conflict resolution between competing recreational water sectors and helps reach agreeable solutions with respect to the environmental carrying capacity, while satisfying general area development needs. Within that integrated framework, the requirements and characteristics of, for example, the tourism industry in addition to that of other stakeholders, should be reviewed and considered.

Within an integrated planning process, tools such as zoning, Environmental Health Impact Assessment, environmental audits, and quality standards can be designed and enforced. Industrial representatives should be involved in discussion throughout the whole process to ensure that priority concerns are taken into consideration and that the proposed tools are generally acceptable to the industry which would facilitate compliance. A Development Plan would also include land use plans, overall legislation and regulation and could advocate the use of such tools as economic instruments to manage the recreational waters.

12.6 Development of responsibilities, standards, monitoring and compliance enforcement of management.

12.6.1 Responsibilities

Risk management is the making of decisions on whether or not risks to well-being are acceptable, ought to be controlled or reduced. The making of these judgements involves value judgements of some kind, whether a formal evaluation of costs of detriment from the hazard and the benefits of improvements, or a sub-conscious personal evaluation.

Responsibility for managing risks in water recreation takes place at two distinct levels:

- Participants in the activities, whether personally or collectively.
- Society regulators, through central and local government and the providers of recreational facilities.

There are well-defined strata within the regulatory and participatory roles through which control and advice flow. Both participators and regulators will in turn, need to rely on expert advice given either by professional institutions, other learned bodies and by individual experts and committees. Additionally, national sports organisations, central and local government may choose to carry out programmes of research on aspects of health and safety for their mutual use in gauging the benefits from improvements in quality of water and facilities.

The regulatory functions in risk management are very much the same as in other systems where public health and well-being are involved, such as drinking-water supply and food hygiene. They involve a devolvement of responsibilities downward and of reporting upwards. Governmental responsibilities for monitoring may be devolved to an environmental agency or to local authorities, with analysis being carried out by hospital, public health or university laboratories. Local authorities usually own or control access to public beaches and thus fall into the category of provider. This role should be independent of a local authority's responsibility for public health e.g. closing beaches and other recreational facilities, deemed hazardous to health and safety. This latter responsibility is a well-defined role of a local authority's Department of Environmental Health and of the local medical officer for environmental health or equivalent. Central government and local authorities have a responsibility for informing the public about health issues in water recreation.

Most participation in leisure activities is essentially voluntary, although committed participants in certain recognised sports may choose to belong to clubs e.g. canoeing, surfing, and sailing. In turn, clubs may be affiliated to regional and national organisations, which promote development of the sport at the highest national and international levels and issue rules and codes of practice to clubs and the wider membership. Clubs may own facilities and stretches of water. In general, the level of organisation shown in Table 10.1 below will ensure that club members enjoy the advantages of well-maintained facilities, training in proficiency and personal safety and knowledge and awareness of hazards. The degree of development of this structure is dependent upon economic factors and degree of commitment of participants to development of their sport.

Alternatively, the general public has to rely on such information about safety, hazards to health and well-being and facilities as it is able to gain from information provided by the news media, local authority notice boards, environmental groups and tourist publicity, as well as its own perceptions. Despite such information, the public is seldom well-informed and personal perceptions of pollution are most influenced visually and by smell. Choice of venue is strongly influenced by the availability of conditions of water and beach most suitable for the activity and the value decision is that of visiting one venue, rather than another, without travelling too far (Cutter *et al.*, 1979). The general public is therefore largely reliant on effective risk management by regulators.

No amount of action can eliminate risk entirely and the best that can be achieved practically is to reduce risk to a minimum health safety level. Furthermore, the difficulties outlined in Chapter 1 does not make it easy to implement policies for reducing risks in recreation to a defined level or to carry out cost-benefit analyses, in which the benefits of local improvements in reducing risk and increasing tourism are traded against the costs of carrying out the improvements (Barnard, 1996). Some of these difficulties in the management of marine water quality are described by Lacey and Pike, (1989). A manual (Foundation for Water Research, 1997) has attempted to give systematic procedures for calculating recreational, environmental and aesthetic benefits from improvements in water quality, by providing simplifying assumptions or alternatives to seemingly intangible benefits.

Participators can control risks *actively* only by acting on knowledge handed down to them in the form of guidance, codes of good practice, rules, training and information on the existence of local hazards, such as poor water quality, strong tidal currents, the existence of wrecks underwater, and so on. *Passively*, risks are controlled for by actions of the regulators (Section 12.2).

Participatory	**Expert advice**	**Regulatory**
National sports organisations Issue codes of practice and news letters for membership, regulate competitive sport promote high training. International liaison.	**Professional institutions, experts** Current awareness of health and safety issues, legislation, research. Liaison with, and exper representation on government committees and national sports organisations.	**Central government** Legislate standards, publish results of national monitoring, conduct national health surveillanc finance capital improvements.
Affiliated clubs Informing members of codes of practice, setting rules of conduct members, supervising organised events, promoting high standards of performance, providing training.		**Local authorities and government agencies** Monitoring, reporting results to central government, displaying results to public. Giving information on health. Enforcing public healt measures, closing facilities if conditions are for hazardous to health. Giving consent to improvements in facilities.
Individuals: **club members** - responsible to club for conduct and act on club's advice.		**Providers of facilities** May be local authorities (public facilities) or owners, including clubs with their own facilitie Adopting and implementing local codes of operational practice, providing safety facilities, carrying out improvements. Publicising facilitie and results of monitoring.
General public - Make own value judgements from personal awareness and knowledge.		

Table 10.1 Roles of participators, regulators and sources

12.6.2 Regulatory compliance

A number of problems affect the application of regulatory compliance and restrict the usefulness of this approach. For example, a marginal failure in water quality may be due to one of a number of contributing pollution sources. In the case of microbiological quality it is frequently the case that a number of sources - which may include riverine discharge, sewage, storm outflows, solid waste and agriculture - may all contribute and may be the responsibility of different authorities. A further problem concerns the issue of temporal variation. Whilst most regulatory regimes require compliance on a proportion of the time, periods of high risk may be brief and either be undetected by such regimes which exposes the public to increased risk, or be over-estimated, thereby condemning an otherwise safe location. Finally it should be recalled that legislation generally applies to specifically designated areas e.g. government defined bathing beaches, rather than to *all* potential recreational water use areas. Special interest groups and users of less-frequented locations may not be properly protected under such regimes.

The role of regulatory compliance is not however restricted to pollution control and may successfully be extended to the implementation of policy regarding areas suitable for development and provision of minimum facilities and supervision by local operators - for instance in terms of lifeguards and first aid facilities.

Regulatory action is of two kinds. *Local action* consists of improvements to facilities to eliminate hazards and thereby to reduce risks. Examples are the construction of sewage treatment works and long sea outfalls to reduce contamination of the sea with sewage, or designating areas of the sea to be used for water skiing, which do not conflict with bathing. *Global policy* (regional, national or international) usually takes the form of creating standards or guidelines to control risk. Inherently, standards provide a means of judging whether conditions are acceptable or not and, therefore, whether improvements are needed. Purpose-designed programmes of monitoring and analysis must accompany them, which provide information on quality.

12.6.3 Enforcement

Strong enforcement of a regulatory approach may also focus attention on the high cost of pollution control intervention and in some cases it has been argued that this is disproportionate to the public health benefit obtained. Enforcement is an essential step of the management system. Pollution control measures are most effectively deployed within a wider context of ICM. In order to be effective, standards, Guidelines and codes of practice must address the root causes of hazards. For example, medical waste found on a beach should be cleared but *sourcing* it is the *prime* consideration. Considerable attention has been focused of late upon the role of legislation, standards and enforcement of compliance, especially with regard to pollution control and microbiological pollutants.

12.6.4 Monitoring and standards

Monitoring and enforcing standards should not only translate into sanctions. Proper information and providing encouragement and positive incentives are more effective ways to achieve results. Results of monitoring programmes must be made readily available to participators - so that they can make informed decisions on using the facilities - and to the regulators, so that they can take decisions with owners of facilities to carry out needed improvements. The public is also entitled to receive the results of monitoring- perhaps in a simplified form- so that individuals can choose whether or not to visit a particular beach or water.

12.7 References

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Annex I

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