Guidelines for safe recreational water environments

VOLUME 1
COASTAL AND FRESH WATERS

WORLD HEALTH ORGANIZATION
GENEVA

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List of acronyms and abbreviations

AFRI	acute febrile respiratory illness
AIDS	acquired immune deficiency syndrome
ASP	amnesic shellfish poisoning
BCC	basal cell carcinoma
CBO	community-based organization
CDC	Centers for Disease Control and Prevention (USA)
cfu	colony-forming unit
COGP	Code of Good Practice
CPR	cardiopulmonary resuscitation
DALY	disability adjusted life year
DSP	diarrhetic shellfish poisoning
EAP	emergency action plan or procedure
EC	European Commission
GAE	granulomatous amoebic encephalitis
GI	gastrointestinal
HACCP	hazard analysis and critical control point
HAV	hepatitis A virus
HEV	hepatitis E virus
HIA	health impact assessment
HIV	human immunodeficiency virus
IARC	International Agency for Research on Cancer
IBM	integrated basin management
ICAM	integrated coastal area management
ID_{50}	dose of microorganisms required to infect 50% of individuals exposed
ILS	International Life Saving Federation
i.p.	intraperitoneal
LOAEL	lowest-observed-adverse-effect level
MM	malignant melanoma
MOE	Ministry of Environment
MOH	Ministry of Health
MOT	Ministry of Tourism
NGO	nongovernmental organization
NMSC	non-melanoma skin cancer
NOAEL	no-observed-adverse-effect level
NSP	neurotoxic shellfish poisoning

PAM	primary amoebic meningoencephalitis
PDF	probability density function
PFD	personal flotation device
pfu	plaque-forming unit
PSP	paralytic shellfish poisoning
QA	quality assurance
QMRA	quantitative microbial risk assessment
SCC	squamous cell carcinoma
SLRA	screening-level risk assessment
SOP	standard operating procedure
SPF	sun protection factor
TCBS	thiosulfate–citrate–bile salts–sucrose
TDI	tolerable daily intake
USLA	United States Lifesaving Association
UV	ultraviolet
UVR	ultraviolet radiation
WHO	World Health Organization
WTO	World Tourism Organization

Preface

The World Health Organization (WHO) has been concerned with health aspects of the management of water resources for many years and publishes various documents concerning the safety of the water environment and its importance for health. These include a number of normative "guidelines" documents, such as the *Guidelines for Drinking-water Quality* and the *Guidelines for Safe Use of Wastewater and Excreta in Agriculture and Aquaculture*. Documents of this type are intended to provide a basis for standard setting. They represent a consensus view among experts on the risk to health represented by various media and activities and on the effectiveness of control measures in protecting health. They are based on critical review of the available evidence. Wherever possible and appropriate, such guidelines documents also describe the principal characteristics of the monitoring and assessment of the safety of the medium under consideration as well as the principal factors affecting decisions to be made in developing strategies for the control of the health hazards concerned.

The *Guidelines for Safe Recreational Water Environments* are published in two volumes:

- *Volume 1: Coastal and Fresh Waters* provides a review and assessment of the health hazards encountered during recreational use of coastal and freshwater environments. It includes the derivation of guideline values and explains the basis for the decision to derive or not to derive them. It addresses a wide range of types of hazard, including hazards leading to drowning and injury, water quality, exposure to heat, cold and sunlight, and dangerous aquatic organisms; and provides background information on the different types of recreational water activity (swimming, surfing, etc.) to enable informed readers to interpret the Guidelines in light of local and regional circumstances. With regard to water quality, separate chapters address faecal pollution, free-living microorganisms, freshwater algae, marine algae and chemical aspects. It describes prevention and management options for responding to identified hazards.

- *Volume 2: Swimming Pools, Spas and Similar Recreational Water Environments* provides a review and assessment of the health hazards associated with recreational waters of this type; their monitoring and assessment; and activities available for their control through education of users, good design and construction, and good operation and management. It includes the derivation of guidelines including guideline values and explains the basis for the decision to derive or not to derive them. It addresses a wide range of types of hazard, including water quality, hazards leading to drowning and injury, contamination of associated facilities and air quality.

In addition to the above volumes of the *Guidelines for Safe Recreational Water Environments*, a practical guide entitled *Monitoring Bathing Waters*,[1] has been produced. It describes the principal characteristics of and approaches to the monitoring and assessment of coastal and freshwater recreational water environments. It emphasizes the need to utilize information of diverse types and from diverse sources in order to develop a valid assessment; and the need to establish effective links between the information generated and interventions to control risk in both the short and long term. It includes comprehensive practical guidance for the design, planning and implementation of monitoring programmes and assessments; and a Code of Good Practice for the monitoring and assessment of recreational water environments, to assist countries in developing such codes for national use and to promote international harmonization. Material relating to toxic cyanobacteria, including that in chapters 7 and 8 is based upon *Toxic Cyanobacteria in Water*,[2] which was prepared by an international group of experts.

The development of WHO activity on 'recreational' or 'bathing' water can be traced back to two expert consultations in the 1970s.[3] These meetings highlighted the breadth of possible hazards associated with recreational water use and noted that prospective volunteer studies offered the "best hope of progress" in terms of establishing links between water quality and bather health. They also suggested the grading of beaches according to bands of indicator counts and the use of sanitary assessments for beaches. These initial meetings were followed by a series of expert consultations. The meeting in Valetta, Malta held during 1989, reviewed the status of microbial guidelines for bathing waters and examined the potential protocols for epidemiological investigations. The importance of protocol design was clear at the Valetta meeting, and two principal approaches were reviewed—namely, the prospective case–control and the randomized trial. Two years later in Athens, Greece the early results of epidemiological investigations that employed both protocols were reviewed. It was decided at this meeting that both approaches were appropriate and could yield useful data for Guidelines derivation. The results of a series of major epidemiological studies in the United Kingdom were presented and critically reviewed at a meeting held in Athens, Greece in 1993.

The preparation of the *Guidelines for Safe Recreational Water Environments* Volume 1 covered a period of almost a decade and involved the participation of numerous institutions, more than 130 experts from 33 countries worldwide, and further reviewers and meetings. The work of the individuals concerned (see Acknowledgements) was central to the completion of the work and is much appreciated.

[1] Edited by J. Bartram and G. Rees, published in 2000 by E & FN Spon on behalf of WHO.

[2] Edited by I. Chorus and J. Bartram, published in 1999 by E & FN Spon on behalf of WHO

[3] Meetings: Ostend, 1972; Bilthoven, 1974; Valetta 1989; Athens 1991; Athens 1993; Bad Elster 1996; Jersey 1997; Farnham 1998; Annapolis 1999; Farnham 2001.

In 1994, following discussions between the WHO Regional Office for Europe and WHO Headquarters, it was agreed to initiate development of guidelines concerning recreational use of the water environment, examining all possible health outcomes from both natural waters and swimming pools, including those related to water quality. This was undertaken as a collaborative initiative between WHO Headquarters and the WHO European Centre for Environment and Health, Rome, Italy. A comprehensive review of the scientific literature on sewage pollution of recreational water and health, eventually published as Prüss (1998), provided the focus for an expert consultation in Bad Elster in 1996. This meeting concluded that the epidemiological basis had been laid for evidence-based normative guidelines on faecal pollution of recreational water. The consultation also received information on new research findings quantifying the impacts of non-sewage sources of faecal bacteria on recreational water compliance with microbial water quality criteria. The implications of these findings were that many bathing waters might fail current water quality norms because of the influence of diffuse source pollution, which would not be reduced by sewage treatment alone.

At a further expert consultation hosted and co-sponsored by the States of Jersey in 1997 drafts of all chapters of the two volumes of Guidelines were reviewed, these were revised and further reviewed at a meeting the following year in Farnham, UK 1998. The Draft Guidelines for coastal and fresh waters were then submitted for international expert appraisal and received intensive review.

In 1999, an expert consultation co-sponsored by the US EPA and held in Annapolis, USA, resulted in the "Annapolis Protocol" (WHO, 1999), which suggested a new approach towards evaluation and regulation of faecal pollution of bathing waters. The Annapolis Protocol outlines a combined sanitary inspection and microbial measurement approach that is used to classify recreational waters. In addition, the protocol suggests the use of relevant information to facilitate real-time public health protection. Thus, the principal focus of regulation is expanded from retrospective numerical compliance assessment to include real-time management and public health protection. A further expert consultation to take account of the Annapolis protocol and other newly available information in the draft guidelines was held in Farnham, UK, in 2001. The Guidelines were finalized through a series of chapter-by-chapter conference calls with selected experts, in November 2002.

During the development of the Guidelines, careful consideration was given to previous assessments, in particular the work of the Mediterranean Action Plan, the Black Sea Environmental Programme, the activities undertaken by and for the European Commission, the activities undertaken by the US Environmental Protection Agency, including its "BEACH" programme and others.

In light of the importance of the subject area for health and the degree of attention it receives from the political and scientific communities and the general public, it is envisaged that new information will become available rapidly during future years. WHO would be pleased to learn of major related developments and will endeavour to ensure the continuing validity of the Guidelines through issuing addenda or further editions as appropriate.

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Executive summary

This volume of the *Guidelines for Safe Recreational Water Environments* describes the present state of knowledge regarding the impact of recreational use of coastal and freshwater environments upon the health of users—specifically drowning and injury, exposure to cold, heat and sunlight, water quality (especially exposure to water contaminated by sewage, but also exposure to free-living pathogenic microorganisms in recreational water), contamination of beach sand, exposure to algae and their products, exposure to chemical and physical agents, and dangerous aquatic organisms. As well, control and monitoring of the hazards associated with these environments are discussed.

The primary aim of the Guidelines is the protection of public health. The purpose of the Guidelines is not to deter the use of recreational water environments but instead to ensure that they are operated as safely as possible in order that the largest possible population gets the maximum possible benefit. The adverse impacts of recreational use of coastal and freshwater environments upon the health of users must be weighed against the enormous benefits to health and well-being—rest, relaxation and exercise—associated with the use of these environments.

The Guidelines are intended to be used as the basis for the development of international and national approaches (including standards and regulations) to controlling the health risks from hazards that may be encountered in recreational water environments, as well as providing a framework for local decision-making. The Guidelines may also be used as reference material for industries and operators preparing development projects in recreational water areas, as a checklist for understanding and assessing potential health impacts of recreational projects, and in the conduct of environmental impact and environmental health impact assessments in particular.

The information provided is generally applicable to any coastal or freshwater area where recreational water use occurs. The preferred approaches adopted by national or local authorities towards implementation of the Guidelines, including guideline values, may vary depending on social, cultural, environmental and economic characteristics, as well as knowledge of routes of exposure, the nature and severity of hazards, and the effectiveness of control measures.

A guideline can be:

- a level of management;
- a concentration of a constituent that does not represent a significant risk to the health of members of significant user groups;

- a condition under which such exposures are unlikely to occur; or
- a combination of the last two.

When a guideline is not achieved, this should be a signal to investigate the cause of the failure and identify the likelihood of future failure, to liaise with the authority responsible for public health to determine whether immediate action should be taken to reduce exposure to the hazard, and to determine whether measures should be put in place to prevent or reduce exposure under similar conditions in the future.

Drowning and injury prevention

Drowning, which has been defined as death arising from impairment of respiratory function as a result of immersion in liquid, is a major cause of death worldwide, particularly for male children. Near drowning is also a serious problem as it may have life-long effects. The recovery rate from near drowning may be lower among young children than among teenagers and adults. Studies show that the prognosis for survival depends more on the effectiveness of the initial rescue and resuscitation than on the quality of subsequent hospital care.

Drowning may be associated with swimming as well as with recreational water uses involving minimal water contact, such as recreational use of watercraft (yachts, boats, canoes) and fishing. Alcohol consumption is one of the most frequently reported contributory factors associated with drownings for adults, whereas lapses in parental supervision are most frequently cited for children. In cold weather, immersion cooling may be a significant contributory factor.

Of sports-related spinal cord injuries, the majority appear to be associated with diving. Injuries in diving incidents are almost exclusively located in the cervical vertebrae, resulting in quadriplegia or paraplegia. Data suggest that body surfing and striking the bottom is the most common cause of spinal injury. Alcohol consumption may contribute significantly to the frequency of injury. Other injuries associated with recreational water use activities include brain and head injuries, fractures, dislocations and other minor impact injuries, and cuts, lesions and punctures.

Prevention is the best way to reduce the incidence of injury and death related to the aquatic environment, and the majority of injuries can be prevented by appropriate measures at a local level. Physical hazards should first be removed or reduced if possible, or measures should be taken to prevent or reduce human exposure. Physical hazards that cannot be completely dealt with in this way should be the subject of additional preventive or remedial measures. These include drowning prevention programmes, public information and warnings (such as signs, flags and general education and awareness raising), the provision of effective lifeguard supervision and rescue services, and the establishment of different recreation zones for different recreational activities using lines, buoys and markers.

Monitoring of a site for existing and new hazards should be undertaken on a regular basis. The frequency and timing of inspections will vary with the location.

Sun, heat and cold

The recreational use of water environments sometimes leads to exposure of individuals to extreme solar radiation and to extreme conditions of heat or cold.

Ultraviolet radiation (UVR) from sunlight can be divided into three bands: UVA, UVB and UVC. As the ozone layer becomes depleted, the protective filter provided by the atmosphere is progressively reduced, and human beings are exposed to higher UV levels, in particular higher UVB levels.

Overexposure to UVR may result in acute and chronic damage to the skin, the eyes and the immune system. The most noticeable acute effect of excessive UV exposure is erythema, the familiar inflammation of the skin commonly termed sunburn. Photokeratitis and photoconjunctivitis are other acute effects of UV exposure. Chronic effects include two major public health problems: skin cancers (both non-melanoma skin cancers and malignant melanoma) and cataracts. Chronic exposure to UVR also causes a number of degenerative changes in the skin (e.g., freckles) and accelerates skin aging. There is also increasing evidence for an immunosuppressive effect of both acute high-dose and chronic low-dose UV exposure on the human immune system.

Not all effects of UV radiation are adverse. The best known beneficial effect is the stimulation of the production of vitamin D in the skin. UVR from artificial sources is also used to treat several diseases and dermatological conditions, including rickets, psoriasis, eczema and jaundice.

Simple protective measures are available and should be adopted to avoid adverse health effects on the skin, eyes and immune system. These include minimizing the amount of time spent in the sun, including complete avoidance of midday sun exposure; seeking shade; and wearing loose-fitting and tightly woven clothing, a broad-brimmed hat and wrap-around sunglasses. Furthermore, a broad-spectrum sunscreen with sun protection factor of 15 or more should be applied liberally on all areas of the body not covered by clothing and should be reapplied often. Sun protection programmes to raise awareness and achieve changes in lifestyle are urgently needed to slow down and eventually reverse the trend towards more skin cancers. The global solar UV index is an important vehicle to raise public awareness of UVR and the risks of excessive UV exposure and to alert people to the need to adopt protective measures.

Exposure to cold water may cause considerable problems for users of recreational waters. The immediate effect of sudden immersion in cold water can be a debilitating reflex response called cold shock, which includes life-threatening respiratory and cardiovascular effects and may lead to drowning. Sudden immersion in cold water often results in impaired swimming ability, which is believed to be responsible for the majority of sudden cold-water immersion deaths. Safety precautions include wearing suitable protective garments when swimming in cold water and using a life-jacket when boating to keep airways clear of water even when unconscious.

In a hot environment, people can suffer serious physical ailments, such as heat cramps, heat exhaustion and heat stroke. The very young, the elderly, patients using drugs that interfere with temperature regulation, people suffering from pre-existing chronic diseases and frequent consumers of alcohol appear to be particularly susceptible. Avoidance measures include consumption of non-alcoholic, non-caffeinated beverages, replacement of salt lost through sweating and retreat to shaded areas. Disorders due to heat occur most frequently when there are rapid changes in thermal conditions, such as during heat waves.

Faecal pollution and water quality

The most frequent adverse health outcome associated with exposure to faecally contaminated recreational water is enteric illness. A cause–effect relationship between faecal or bather-derived pollution and acute febrile respiratory illness (AFRI), which is a more severe health outcome than gastroenteritis, has also been shown.

There is consistency in the overall body of evidence concerning health effects from faecally polluted recreational waters, and a series of randomized controlled trials performed in the United Kingdom form the key studies for derivation of guideline values for the microbiological quality of recreational waters. For marine waters, only intestinal enterococci (faecal streptococci) showed a dose–response relationship for both gastrointestinal illness and AFRI. The guideline values are expressed in terms of the 95th percentile of numbers of intestinal enterococci per 100 ml and represent readily understood levels of risk based on the exposure conditions of the key studies.

There is inadequate evidence with which to directly derive a water quality guideline value for fresh water. Application of the guideline values derived for seawaters to fresh waters would be likely to result in a lower illness rate in freshwater swimmers, providing a conservative guideline in the absence of suitable epidemiological data for fresh waters. Studies under way may provide a more adequate basis on which to develop freshwater guideline values.

The guideline values should be interpreted or modified in light of regional and/or local factors. Such factors include the nature and seriousness of local endemic illness, population behaviour, exposure patterns, and sociocultural, economic, environmental and technical aspects, as well as competing health risk from other diseases that are not associated with recreational water.

The initial classification of a recreational water environment is based upon the combination of evidence for the degree of influence of (human) faecal material (by sanitary inspection of beach and water catchment) alongside counts of suitable faecal index bacteria (a microbial quality assessment). Information to be collected during sanitary inspections should cover at least the three most important sources of human faecal contamination of recreational water environments for public health purposes: sewage; riverine discharges (where the river is a receiving water for sewage discharges and either is used directly for recreation or discharges near a coastal or lake area used for recreation); and bather contamination, including excreta. Where human inputs are minimal, investigation of animal faecal inputs should be explored.

In the microbial water quality assessment, the sampling programme should be representative of the range of conditions in the recreational water environment while it is being used. An important issue is that of collecting sufficient numbers of samples so as to make an appropriate estimation of the likely densities to which recreational water users are exposed. The precision of the estimate of the 95th percentile is higher when sample numbers are increased. The number of results available can be increased significantly by pooling data from multiple years, unless there is reason to believe that local (pollution) conditions have changed. For practical purposes, data on at least 100 samples from a 5-year period and a rolling 5-year data set can be used for microbial water quality assessment purposes.

The outputs from the sanitary inspection and the microbial water quality assessment can be combined to give a five-level classification for recreational water environments—very good, good, fair, poor and very poor. Following initial classification, it is proposed that all categories of recreational water environment would be subject to an annual sanitary inspection (to determine whether pollution sources have changed) and continued water quality monitoring.

Another component of the assessment of a recreational water environment is the possible "upgrading" of a recreational water environment if a significant change in management reduces human exposure to microbial risk.

Follow-up analyses are recommended when the intestinal enterococci counts are high but the sanitary inspection suggests low sanitary impact, or vice versa. A primary role of the follow-up is to help identify the source of the faecal pollution, thereby assisting in the assessment and management of faecal contamination in recreational water environments.

In certain circumstances, there may be a risk of transmission of pathogens associated with more severe health effects (such as infectious hepatitis or typhoid fever) through recreational water use. Public health authorities should be alert to such hazards where exposure may occur and should take appropriate action to protect public health.

Population groups that may be at higher risk of disease include the young, the elderly and the immunocompromised, as well as visiting populations susceptible to locally endemic disease. If such groups are significant water users, then this should be taken into account in risk assessment and management.

Management action in response to a recreational water environment classification indicating unacceptable faecal contamination can be both immediate, such as public health advisories, and long term, such as pollution abatement.

Free-living microorganisms

In addition to microorganisms introduced to recreational waters through human or animal faecal contamination, a number of pathogenic microorganisms are free-living in such areas or, once introduced, are capable of colonizing the environment.

Vibrio species are natural inhabitants of marine aquatic environments in both temperate and tropical regions. The occurrence of vibrios does not correlate with the occurrence of the traditionally used bacterial faecal index organisms, except perhaps in waters receiving human wastes from disease outbreaks (mainly cholera). Due to the ubiquitous nature of *Vibrio* species in the aquatic environment, their presence in bathing water cannot be controlled by water quality control measures such as wastewater treatment and disinfection. Human carriers and shedding appear to be of only limited importance in the epidemiology of *Vibrio* infections associated with recreational water use. For *V. cholerae*, 10^6 organisms or more are typically needed to cause cholera, so that it is unlikely that persons bathing or involved in other recreational water activities would ingest vibrios in numbers high enough to cause gastrointestinal disease. However, the risk of extraintestinal infections associated with human pathogenic *Vibrio* species, especially wound and ear infections, during recreational activities in water is of health importance, although the infectious doses for such infections are unknown.

Aeromonas spp. are considered autochthonous inhabitants of aquatic environments and are ubiquitous in surface fresh and marine waters, with high numbers occurring during the warmer months of the year. Clinical isolation of these microbes presents the same seasonal distribution. Numbers may be high in both polluted and unpolluted habitats with densities ranging from <1 to 1000 cells per ml. Sewage can also contain elevated numbers (10^6–10^8 cells per ml) of aeromonads. *Aeromonas* has been found to have a role in a number of human illnesses including gastroenteritis. Cases of wound infections in healthy people associated with recreational water have been described, as have cases of pneumonia following aspiration of contaminated recreational water.

Free-living amoebae are unicellular protozoa common to most soil and aquatic environments. Of the many hundreds of species of free-living amoebae, only members of the genus *Acanthamoeba*, *Naegleria fowleri* and *Balamuthia mandrillaris* are known to infect humans, often with fatal consequences. *Acanthamoeba* have been isolated from natural and artificial waters. Certain species are pathogenic to humans and cause two clinically distinct diseases affecting the central nervous system: granulomatous amoebic encephalitis (GAE) and inflammation of the cornea (keratitis). *Naegleria fowleri*, which is found in thermal freshwater habitats worldwide, causes primary amoebic meningoencephalitis (PAM) in humans. PAM is usually fatal, with death occurring in 3–10 days after exposure. Infection usually results from swimming in contaminated water, although the infectious dose for humans is not known. *B. mandrillaris* encephalitis is largely a disease of the immunocompromised host, and certain cases of GAE attributed to *Acanthamoeba* have in fact been shown to have been caused by *B. mandrillaris*.

Leptospires are excreted in the urine of infected animals, which can then contaminate soil, mud, groundwater, streams and rivers. Humans become infected either directly through contact with infected urine or indirectly via contaminated fresh water or soil. Virulent leptospires gain entry to the body through cuts and abrasions of the skin and through the mucosal surfaces of the mouth, nose and conjunctiva. In cases due to exposure to recreational water, the incubation period seems to vary between 2 and 30 days, but generally is between 7 and 14 days. The clinical manifestations of leptospirosis vary considerably in form and intensity, ranging from a mild flu-like illness to a severe and potentially fatal form of the disease, characterized by liver and kidney failure.

Evidence suggests that although infection with free-living microorganisms or pathogenic leptospires via recreational water use may be life-threatening, the incidence of such infection is very low and, in many cases, is limited to specific areas. As such, no specific guideline values have been recommended, although authorities should be aware of the potential hazards posed by these organisms and act accordingly. Assessment of the likely hazard (e.g., the likelihood of thermal warming of fresh waters) and education of water users and health professionals are important control measures.

Microbial aspects of beach sand quality

Bacteria, fungi, parasites and viruses have all been isolated from beach sand. A number of them are potential pathogens. Factors promoting the survival and dispersion of pathogens include the nature of the beach, tidal phenomena, the presence of sewage outlets, the season, the presence of animals and the number of swimmers. Transmission may occur through direct person-to-person contact or by other means, although no route of transmission has been positively demonstrated.

Concern has been expressed that beach sand or similar materials may act as reservoirs or vectors of infection. However, the capacity of microorganisms that have been isolated from beach sand to infect bathers and beach users remains undemonstrated, and the real extent of their threat to public health is unknown. There is therefore no evidence to support establishment of a guideline value for index organisms or pathogenic microorganisms on beach sand.

The principal microbial risk to human health encountered upon beaches and similar areas is that arising from contact with animal excreta, particularly from dogs. Regulations that restrict access seasonally on frequently used beaches or place an obligation upon the owner to remove animal excreta, increased public awareness and beach cleaning are preventive management actions.

Algae and cyanobacteria in coastal and estuarine waters

Several human diseases have been reported in association with many toxic species of dinoflagellates, diatoms, nanoflagellates and cyanobacteria (blue-green algae) that occur in the marine environment. The toxicity of these algae to humans is due to the presence of algal toxins. Marine algal toxins become a problem primarily because they concentrate in shellfish and fish that are subsequently eaten by humans, causing shellfish poisoning (not dealt with in this volume).

Marine cyanobacterial dermatitis ("swimmers' itch" or "seaweed dermatitis") is a severe contact dermatitis that may occur after swimming in seas containing blooms of certain species of marine cyanobacteria. The symptoms are itching and burning within a few minutes to a few hours after swimming in the sea where the cyanobacteria are suspended. Some toxic components, such as aplysiatoxin, debromoaplysiatoxin and lyngbyatoxin A, have been isolated from marine cyanobacteria. These toxins are highly inflammatory and are potent skin tumour promoting compounds.

Nodularia spumigena was the first cyanobacterium recognized to cause animal death. The toxin produced by *N. spumigena*, called nodularin, acts as a hepatotoxin, in that it induces massive haemorrhages in the liver of mammals and causes disruption of the liver structure. To date, there have been no reports of human poisoning by *N. spumigena*, but humans may be as susceptible to the toxins as other mammals. Therefore, it is possible that small children may accidentally ingest toxic material in an amount that may have serious consequences.

Inhalation of a sea spray aerosol containing fragments of marine dinoflagellate cells and/or toxins (brevetoxins) released into the surf by lysed algae can be harmful to humans. The signs and symptoms are severe irritation of conjunctivae and mucous membranes (particularly of the nose) followed by persistent coughing and sneezing and tingling of the lips.

Available data indicate that the risk for human health associated with the occurrence of marine toxic algae or cyanobacteria during recreational activities is limited to a few species and geographical areas. As a result, it is inappropriate to recommend specific guideline values.

Within areas subject to the occurrence of marine toxic algae or cyanobacteria, it is important to carry out adequate monitoring activities and surveillance programmes. In affected areas, it is appropriate to provide health information to general practitioners and the general public, in particular recreational water users. Precautionary measures include avoiding areas with visible algal concentrations and/or algal scums in the sea as well as on the shore, avoiding sitting downwind of any algal material drying on the shore and showering to remove any algal material.

Algae and cyanobacteria in fresh water

Many species of freshwater algae may proliferate quite intensively in eutrophic (i.e., nutrient-rich) waters. However, they do not form dense surface scums or "blooms," as do some cyanobacteria. Toxins they may contain therefore are not accumulated to potentially hazardous concentrations. For this reason, most adverse health impacts from recreational use of fresh waters have been associated with cyanobacteria rather than with freshwater algae.

Progress in analytical chemistry has enabled the isolation and structural identification from toxic cyanobacteria of three neurotoxins (anatoxin-a, anatoxin-a(s) and saxitoxins), one general cytotoxin, which inhibits protein synthesis (cylindrospermopsin), and a group of toxins termed microcystins (or nodularins, found in brackish waters), which inhibit protein phosphatases. Most of them have been found in a wide array of genera, and some species contain more than one toxin.

Allergic or irritative dermal reactions of varying severity have been reported from a number of freshwater cyanobacterial genera (*Anabaena*, *Aphanizomenon*, *Nodularia*, *Oscillatoria*, *Gloeotrichia*) after recreational exposure. Bathing suits and particularly wet suits tend to aggravate such effects by accumulating cyanobacterial material and enhancing disruption of cells and liberation of cell content. It is probable that these symptoms are not due to recognized cyanotoxins but rather to currently largely unidentified substances.

In contrast to dermal contact, uptake of cyanobacteria though ingestion or aspiration involves a risk of intoxication by cyanotoxins. Most documented cases of human injury through cyanotoxins involved exposure through drinking-water, and they demonstrate that humans have become ill—in some cases seriously—through ingestion or aspiration of toxic cyanobacteria. 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, as well as hay fever symptoms, dizziness, fatigue, and skin and eye irritations.

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.

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/ml (corresponding to 10 µg chlorophyll-a/litre under conditions of cyanobacterial dominance) can be derived. A level of 100 000 cyanobacterial cells/ml (equivalent to approximately 50 µg chlorophyll-a/litre if cyanobacteria dominate) represents a guideline value for a moderate health alert in recreational waters. The presence of cyanobacterial scum in swimming areas represents the highest risk of adverse health effects, due to abundant evidence for potentially severe health outcomes associated with these scums.

Because adequate surveillance is difficult and few immediate management options are available (other than precluding or discouraging use or cancelling water sports activities such as competitions), provision of adequate public information is a key short-term measure. Medium- to long-term measures are identification of the sources of nutrient (in many ecosystems phosphorus, sometimes nitrogen) pollution and significant reduction of nutrient input in order to effectively reduce proliferation not only of cyanobacteria, but of potentially harmful algae as well.

Aesthetic issues

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 that produce undesirable aquatic life. Clean beaches are one of the prime parameters that are desired by recreational users. Local economies may depend on the aesthetic quality of recreational water areas, and the environmental degradation of beaches is known to lead to loss of income from tourism.

Water at swimming areas should ideally 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. Aside from the safety factor, clear water fosters enjoyment of the aquatic environment. 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 and dense mats of floating and suspended debris.

Visitor enjoyment of any beach is generally marred by litter. The variety of litter found in recreational water or washed up on the beach is considerable and includes, for example, discarded food/wrapping, bottles/cans, cigarette butts, dead fish, discarded condoms, discarded sanitary towels, and syringes, needles and other medical wastes. Unlike most litter, medical waste and broken glass also represent hazards to health.

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. Odour thresholds and their association with the concentrations of different pollutants of the recreational water environment have not, however, been determined.

Marine debris monitoring can be used to provide information on the types, quantities and distribution of marine debris, to identify sources of marine debris, to explore public health issues relating to marine debris and to increase public awareness of the condition of the coastline. Management options include manual or mechanical beach cleaning.

Chemical and physical agents

Chemical contaminants can enter surface waters or be deposited on beaches from both natural and anthropogenic sources. Exposure is one of the key issues in determining the risk of toxic effects from chemicals in recreational waters. The form of recreational activity will therefore play a significant role. Routes of exposure will be direct surface contact, including skin, eyes and mucous membranes, inhalation and ingestion. In assessing the risk from a particular contaminant, the frequency, extent and likelihood of exposure are crucial parts of the evaluation.

pH has a direct impact on the recreational uses of water only at very low or very high pH values. Under these circumstances, it may contribute to irritation of the skin and eyes.

The potential risks from chemical contamination of coastal and freshwater recreational waters, apart from toxins produced by marine and freshwater cyanobacteria and algae, marine animals or other exceptional circumstances, will be very much smaller than the potential risks from microbial contaminants. It is extremely unlikely that water users will come into contact with sufficiently high concentrations of most contaminants to cause 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.

In most cases, the concentration of chemical contaminants will be below drinking-water guidelines. As long as care is taken in their application, the WHO *Guide-*

lines for Drinking-water Quality can provide a starting point for deriving values that could be used to make a preliminary risk assessment under specific circumstances. These guideline values relate, in most cases, to lifetime exposure following consumption of 2 litres of drinking-water per day. For recreational water contact, an intake of 200 ml per day—100 ml per recreational session with two sessions per day—may often be reasonably assumed.

An assessment of the chemical hazards in recreational water may involve inspecting the immediate area to determine if there are any immediate sources of chemical contamination, such as outfalls; considering the pattern and type of recreational use of the water to determine whether there will be extensive contact with the water and/or a significant risk of ingestion; and chemically analysing the water to support a quantitative risk assessment.

It is important that the basis of any guidelines or standards that are considered to be necessary for chemical constituents of recreational waters be made clear. Without this, there is a danger that even occasional, trivial exceedances of guidelines could unnecessarily undermine users' confidence. It is also important in evaluating chemical hazards that the risks are not overestimated. The risks should be related to risks from other hazards such as drowning or microbial contamination, which will almost invariably be much greater.

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 often depend significantly on the type of recreational activity concerned.

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

Injuries from encounters with dangerous aquatic organisms are generally sustained by 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 seashore 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.

Disease vectors include mosquitoes, which transmit malaria parasites and the viruses responsible for dengue fever, yellow fever and various types of encephalitis; and certain species of freshwater snails, which host the larval development of trematode parasites of the genus *Schistosoma*, which can cause a chronic, debilitating and potentially lethal tropical disease known as bilharzia or schistosomiasis in humans. Preventive measures include asking local health authorities for guidance on the local vector-borne disease situation and risk prevention, wearing protective clothing, using repellents and avoiding skin contact with water in schistosomiasis endemic areas.

"In-water" hazardous organisms include piranhas, snakes, electric fish, sharks, barracudas, needlefish, groupers, and moray and conger eels. Many have been known to attack and wound humans. Preventive measures include avoiding swimming in areas where large sharks are endemic; avoiding wearing shiny jewellery in the water where large sharks and barracudas are common; avoiding attaching speared fish to the body where sharks, barracudas or groupers live; avoiding wearing a headlight when fishing or diving at night in needlefish waters; and looking out for groupers and moray or conger eels before swimming into caves or putting hands into holes and cracks of rocks.

"Water's-edge" hazardous organisms include hippopotami, crocodiles and alligators. Preventive measures include keeping the animals at a distance whenever possible, avoiding swimming in areas inhabited by crocodiles or alligators, and embarking on safaris in hippopotamus- and crocodile-infested waters with a knowledgeable guide who can assess risks properly and judge the territorial behaviour of hippopotami in water.

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 octopi), Annelida (bristleworms) and Echinodermata (sea urchins and sea stars). Preventive measures include wearing suitable footwear when exploring the intertidal area or wading in shallow water, avoiding handling sponges, cnidarians, cone shells, blue-ringed octopus, bristleworms or the flower sea urchin, avoiding brushing against hydroids, true corals and anemones, and avoiding bathing in waters where Portuguese man-of-war are concentrated.

Venomous vertebrates deliver their venom either via spines, as with many fish species (e.g., catfish, stingray, scorpionfish, weeverfish, surgeonfish), 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. Preventive measures include shuffling feet when walking along sandy lagoons or shallower waters where stingrays frequent, exercising caution when handling and sorting a fishing catch, wearing suitable footwear in shallow water and snake-infested areas, and carrying anti-venom in snake-infested areas.

Monitoring and assessment

WHO has developed a book based upon a framework "Code of Good Practice for Recreational Water Monitoring". This Code comprises a series of statements of principle or objectives that, 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 that involve repeated or continuous direct contact with a water body.

The Code is published in *Monitoring Bathing Waters*. It 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, and 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. Cross-referencing between the Code and the various chapters of these Guidelines should ensure that a valid and replicable monitoring and assessment programme is established.

The Code and *Monitoring Bathing Waters* provide guidance on the design and implementation of a monitoring programme, including the design of a monitoring programme that includes appropriate quality assurance, data collection, data handling, data interpretation and reporting. In addition to this general guidance, guidance is given in relation to specific hazards that may be encountered in recreational water use areas.

Application of guidelines and management options for healthy recreational water use

The possible negative health outcomes associated with the use of recreational water environments result in the need for guidelines that can be converted into locally (i.e., nationally or regionally) appropriate and applicable standards and associated management of sites to ensure a safe, healthy and aesthetically pleasing environment.

A number of points need to be considered in converting guidelines into regulations adapted to local circumstances. Using the recreational water quality classification system for faecal pollution as an example, the principal requirements that would need to be incorporated into provisions would normally include:

- the establishment of a water quality classification system;
- the obligation upon the national or appropriate regulatory authorities to maintain a listing of all recognized recreational water areas in a publicly accessible location;
- the definition of responsibility for establishing a plan for recreational water safety management and its implementation;
- independent surveillance and provision of information to the public;
- the obligation to act, including the requirement to immediately consult with the public health body and inform the public as appropriate on detection of conditions potentially hazardous to health; and
- a general requirement to strive to ensure the safest achievable recreational water use conditions;

Several management interventions can be identified:

- Regulatory compliance, which includes risk management, is the making of decisions on whether or not risks to well-being are acceptable or ought to be controlled or reduced and for which responsibility lies in the hands of society regulators and participants in the activities; regulatory action at both the local level (i.e., improvements to facilities to eliminate hazards and thereby to reduce risks) and the policy level (usually taking the form of creating standards or guidelines to control risk); enforcement of regulatory compliance; and monitoring and standards, whose aim is to promote improvement.

- Control and abatement technology (e.g., the control and abatement of pollution discharges with respect to the various levels of sewage treatment). When planning for the development of new recreational water projects or for the upgrading of existing ones, a health impact assessment (HIA), which considers changes in environmental and social determinants of health resulting from development, should be incorporated. HIA results in a package of recommended measures to safeguard health or mitigate health risks, as well as health promotional activities.
- Public awareness raising and enhancing the capacity for informed personal choice are increasingly seen as important factors in ensuring the safe use of recreational water environments and an important management intervention. One important tool used by associations and governments to enhance the public's capacity for informed personal choice is beach grading or award schemes.
- The provision of public health advice, is a key input to public awareness and informed personal choice, since it is vital that the public receive the correct information. One aspect of this management intervention is response to short-term incidents and breaches of standards. Prevention and rescue services can also be considered to fall within this intervention.

Multiple stakeholders are involved in the process of adapting and applying guidelines and standards. One way in which all the relevant stakeholders can be brought together is through the establishment of an integrated management system for marine and freshwater recreational areas based on the concept of integrated coastal area management (ICAM). This involves comprehensive assessment, the setting of objectives, and the planning and management of coastal systems and resources. It also takes into account traditional, cultural and historical perspectives and conflicting interests and uses. In an ICAM programme, the exact package of management options to reduce or eliminate health hazards and risks related to recreational water uses will be driven by the nature (including frequency and severity) of the health impacts. Upon assessing the combined level of risk, three levels of response may be considered (basic, expanded and full), each geared for a certain level of intervention.