

**GUIDELINES FOR SAFE  
RECREATIONAL-WATER  
ENVIRONMENTS**

**VOLUME 2: SWIMMING POOLS, SPAS AND  
SIMILAR RECREATIONAL-WATER  
ENVIRONMENTS**

*FINAL DRAFT*

*FOR CONSULTATION  
AUGUST 2000*

**WORLD HEALTH ORGANIZATION**

# CONTENTS

Page

LIST OF ACRONYMS AND ABBREVIATIONS

PREFACE

ACKNOWLEDGEMENTS

EXECUTIVE SUMMARY

## CHAPTER 1. INTRODUCTION

---

1.1 GENERAL CONSIDERATIONS

1.2 TYPES OF POOLS AND SPAS

1.3 TYPES OF USERS

1.4 HAZARD AND RISK

1.4.1 *Types of hazard encountered*

1.4.2 *Assessment of hazard and risk*

1.4.3 *The use of epidemiology in assessing risk*

1.4.4 *The use of quantitative microbiological risk assessment in assessing risk*

1.4.5 *Degree of water contact*

1.5 NATURE OF THE GUIDELINE VALUES

1.6 MEASURES TO REDUCE RISKS

1.7 REFERENCES

## CHAPTER 2. DROWNING, INJURIES AND POOL SAFETY MANAGEMENT

---

2.1 DROWNING AND NEAR-DROWNING

2.1.1 *Drowning*

2.1.2 *Near-drowning*

2.1.3 *Contributory factors*

2.1.4 *Preventive actions*

2.2 SPINAL INJURY

2.2.1 *Contributory factors*

2.2.2 *Preventive actions*

2.3 BRAIN AND HEAD INJURY

2.4 RETINAL DISLOCATION

2.5 FRACTURES, DISLOCATIONS AND ABRASIONS

2.6 DISEMBOWELMENT

2.7 HAZARDS ASSOCIATED WITH TEMPERATURE EXTREMES

2.8 HAZARDS ASSOCIATED WITH "FEATURE POOLS"

2.9 REFERENCES

## CHAPTER 3. MICROBIOLOGICAL HAZARDS

---

- 3.1 FAECALLY DERIVED VIRUSES
  - 3.1.1 *Hazard identification*
  - 3.1.2 *Outbreaks of viral illness associated with swimming pools*
  - 3.1.3 *Risk assessment*
  - 3.1.4 *Risk management*
- 3.2 FAECALLY DERIVED BACTERIA
  - 3.2.1 *Hazard identification*
  - 3.2.2 *Outbreaks of bacterial illness associated with swimming pools*
  - 3.2.3 *Risk assessment*
  - 3.2.4 *Risk management*
- 3.3 FAECALLY DERIVED PATHOGENIC PROTOZOA
  - 3.3.1 *Hazard identification*
  - 3.3.2 *Outbreaks of protozoan illness associated with swimming pools*
  - 3.3.3 *Risk assessment*
  - 3.3.4 *Risk management*
- 3.4 NON-FAECALLY DERIVED BACTERIA
  - 3.4.1 *Legionella spp.*
  - 3.4.2 *Pseudomonas aeruginosa*
  - 3.4.3 *Mycobacterium spp.*
  - 3.4.4 *Staphylococcus aureus*
  - 3.4.5 *Leptospira interrogans*
- 3.5 NON-FAECALLY DERIVED VIRUSES
  - 3.5.1 *Molluscipoxvirus*
  - 3.5.2 *Human papilloma virus*
- 3.6 NON-FAECALLY DERIVED AMOEBAS
  - 3.6.1 *Naegleria fowleri*
  - 3.6.2 *Acanthamoeba spp.*
- 3.7 NON-FAECALLY DERIVED FUNGI
  - 3.7.1 *Trichophyton spp. and Epidermophyton floccosum*
- 3.8 REFERENCES

## CHAPTER 4. CHEMICAL HAZARDS

---

- 4.1 CONCENTRATIONS OF CHEMICALS IN SWIMMING POOL ENVIRONMENTS
  - 4.1.1 *Disinfectants*
  - 4.1.2 *Disinfectant by-products*
  - 4.1.3 *Chemicals contributed by swimmers*
- 4.2 EXPOSURE TO CHEMICALS IN SWIMMING POOLS, SPAS AND SIMILAR RECREATIONAL-WATER ENVIRONMENTS
  - 4.2.1 *Ingestion*
  - 4.2.2 *Inhalation*
  - 4.2.3 *Dermal contact*
  - 4.2.4 *Measured and estimated exposures by all routes*
- 4.3 HEALTH HAZARDS ASSOCIATED WITH CHEMICALS IN SWIMMING POOL ENVIRONMENTS
  - 4.3.1 *Disinfectants*
  - 4.3.2 *Disinfectant by-products*
  - 4.3.3 *Chemicals that interfere with disinfectant efficiency*
  - 4.3.4 *Other water quality parameters*
- 4.4 RISK ASSESSMENT
  - 4.4.1 *Chlorine disinfection*

- 4.4.2 *Ozone disinfection*
- 4.4.3 *Other disinfection systems*
- 4.5 RISK MANAGEMENT
- 4.6 REFERENCES

## **CHAPTER 5. MANAGING WATER AND AIR QUALITY**

---

- 5.1 PRE-SWIM HYGIENE
- 5.2 DISINFECTION
  - 5.2.1 *Choosing a disinfectant*
  - 5.2.2 *Characteristics of various disinfectants*
  - 5.2.3 *Disinfectant by-products*
  - 5.2.4 *Disinfectant dosing*
- 5.3 FILTRATION
- 5.4 COAGULATION
- 5.5 DILUTION
- 5.6 CIRCULATION AND HYDRAULICS
- 5.7 BATHING LOAD
- 5.8 ACCIDENTAL RELEASE OF FAECES OR VOMITUS INTO POOLS
- 5.9 SPECIAL CASE OF SPA POOLS
- 5.10 SPECIAL CASE OF VESSEL POOLS
- 5.11 AIR QUALITY
- 5.12 MONITORING
  - 5.12.1 *Turbidity*
  - 5.12.2 *Disinfectant residual*
  - 5.12.3 *pH*
  - 5.12.4 *Oxidation–reduction potential*
  - 5.12.5 *Microbiological quality*
  - 5.12.6 *Miscellaneous*
- 5.13 REFERENCES

## **CHAPTER 6. GUIDELINE IMPLEMENTATION**

---

- 6.1 GOOD DESIGN AND CONSTRUCTION
- 6.2 GOOD OPERATION AND MANAGEMENT
  - 6.2.1 *Lifeguards*
  - 6.2.2 *Pool safety operating procedures*
- 6.3 PUBLIC EDUCATION AND INFORMATION
  - 6.3.1 *Signage*
  - 6.3.2 *Education*
- 6.4 REGULATIONS AND GOOD PRACTICE
  - 6.4.1 *Regulatory requirements and enforcement*
  - 6.4.2 *Certification schemes*
- 6.5 REFERENCES

## List of Acronyms and Abbreviations

AFR	accidental faecal release
AIDS	acquired immune deficiency syndrome
BCDMH	bromochlorodimethylhydantoin
BDCM	bromodichloromethane
cfu	colony-forming unit
CPR	cardiopulmonary resuscitation
CPSC	Consumer Product Safety Commission (USA)
DBAA	dibromoacetic acid
DBAN	dibromoacetonitrile
DBCM	dibromochloromethane
DCAA	dichloroacetic acid
DCAN	dichloroacetonitrile
DMH	dimethylhydantoin
GAE	granulomatous amoebic encephalitis
HIV	human immunodeficiency virus
HPV	human papilloma virus
HUS	haemolytic uraemic syndrome
HVAC	heating, ventilation and air conditioning
ID <sub>50</sub>	infective dose for 50% of the population
ILS	International Life Saving Federation
ISO	International Organization for Standardization
LOAEL	lowest-observed-adverse-effect level
MBAA	monobromoacetic acid
MCAA	monochloroacetic acid
NOAEL	no-observed-adverse-effect level
NOEL	no-observed-effect level
NTU	nephelometric turbidity unit
ORP	oxidation–reduction potential
PAM	primary amoebic meningoencephalitis
pfu	plaque-forming unit
QMRA	quantitative microbiological risk assessment
TCAA	trichloroacetic acid
TCAN	trichloroacetonitrile
TDI	tolerable daily intake
TDS	total dissolved solids
THM	trihalomethane
UV	ultraviolet
WHO	World Health 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 “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 represent a consensus view among experts on the risk to health represented by various media and activities and are based upon a 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.

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. This has been undertaken as a collaborative initiative between WHO Headquarters and the WHO European Centre for Environment and Health, Rome.

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

- *Volume 1: Coastal and Fresh Waters* provides an authoritative referenced review and assessment of the various health hazards encountered during recreational use of coastal and freshwater environments. It includes the derivation of guideline values or conditions 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, physical hazards (leading to drowning and injury) and exposure to heat, cold and sunlight; 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 microbiological hazards, freshwater algae, marine algae and chemical aspects.
- *Volume 2: Swimming Pools, Spas and Similar Recreational-water Environments* provides an authoritative referenced 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 guideline values or conditions 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, physical hazards (leading to drowning and injury), contamination of associated facilities and air quality.

Following a series of consultations and expert contributions, these volumes are now being made available in draft form. Final publication of the Guidelines will be undertaken once both volumes are available in draft form and following final review. Until that time, comments upon this draft are welcome and should be addressed to:

Dr Jamie Bartram  
Water, Sanitation and Health Programme  
Department of Protection of the Human Environment  
WHO Headquarters  
20 Avenue Appia  
CH-1211 Geneva 27  
Switzerland

Telephone: +41.22.791 35 37  
Telefax: +41.22.791 41 59  
E-mail: bartramj@who.int

In addition to the above volumes of the *Guidelines for Safe Recreational-water Environments*, a manual entitled *Monitoring Bathing Waters*, edited by J. Bartram and G. Rees and published in 2000 by E & FN Spon on behalf of WHO, 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 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.

The preparation of the *Guidelines for Safe Recreational-water Environments* has covered a period of six years and has involved the participation of numerous institutions, more than 50 experts from 20 countries worldwide, and six meetings of experts and for coordination. The work of the individuals concerned (see Acknowledgements) was central to the completion of the work and is much appreciated.

Each principal area of work in the development of the Guidelines was the responsibility of a coordinator or coordinators. Each section or chapter was prepared by one or more experts or developed from contributions received; reviewed at a meeting of experts; and revised by selected experts in light of the recommendations of that meeting. The draft text is now being subjected to wider review.

During the development of the draft materials, careful consideration was given to previous assessments, in particular the work of the International Programme on Chemical Safety and also of the Health and Safety Executive, United Kingdom; Sport England; and the Centers for Disease Control and Prevention, USA.

## **Acknowledgements**

The assistance of the following persons in the development of this draft for consultation of the *Guidelines for Safe Recreational-water Environments. Volume 2: Swimming Pools, Spas and Similar Recreational-water Environments*, either in contribution of text or through provision of comments and constructive criticism, is appreciated:

G. Aggazzotti, University of Modena, Modena, Italy  
J. Bartram, WHO, Geneva, Switzerland [formerly of WHO European Centre for Environment and Health, Rome, Italy]  
C. Branche, National Center for Injury Prevention and Centers for Disease Control and Prevention, Atlanta, GA, USA  
M. Cavaliere, Azienda Comunale Energia e Ambiente (ACEA), Rome, Italy  
J. Cotruvo, NSF International, Washington, DC, USA  
A.P. Dufour, Environmental Protection Agency, Cincinnati, OH, USA  
G. Fantuzzi, University of Modena, Modena, Italy  
L. Fewtrell, Centre for Research into Environment and Health, Leeds, United Kingdom  
B. Guthrie, Pool Water Treatment Advisory Group, Norfolk, United Kingdom  
M. Kadar, National Institute of Hygiene, Budapest, Hungary  
A. Mittelstaedt, Recreational Safety Institute, New York, NY, USA  
E. Mood, Yale University, New Haven, CT, USA  
K. Pond, WHO, Rome, Italy  
M. Rayer, NSF International, Ann Arbor, MI, USA  
R.G. Rice, RICE International Consulting Enterprises, Ashton, MD, USA  
W. Robertson, Environmental Health Directorate, Health Canada, Ottawa, Canada  
E. Stottmeister, Federal Environment Agency, Bad Elster, Germany  
A. Wooler, International Life Saving Federation, Leuven, Belgium



## **Executive Summary**

This volume of the *Guidelines for Safe Recreational-water Environments* describes the present state of knowledge regarding the hazards associated with the recreational use of swimming pools, spas and similar recreational-water environments — specifically, injuries and physical hazards, microbiological contamination and exposure to chemicals. Monitoring of health-related physical, chemical and microbiological parameters is also discussed, as are measures that can be taken to reduce the risks associated with the hazards encountered in recreational-water environments.

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 swimming pools, spas and similar recreational-water facilities are operated as safely as possible in order that the largest possible population gets the maximum possible benefit.

The Guidelines are intended to be used as the basis for the development of national approaches to controlling the hazards that may be encountered in recreational-water environments. The information provided is generally applicable to indoor and outdoor public pools and spas, semi-public pools and spas (as encountered in clubs, hotels and schools, for example) and private (domestic) pools and spas. A “spa” for the purposes of these Guidelines is defined to include hot tubs (domestic), whirlpools (commercial/facility) and natural mineral baths. The preferred approaches adopted by national or local authorities towards implementation of guideline values and conditions may vary between these types of environment.

A guideline can be either a concentration of a constituent that does not represent a significant risk to the health of members of significant user groups or a condition under which such exposures are unlikely to occur. When a guideline is exceeded, 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, injuries and pool safety management**

Drowning, which can generally be defined as death by suffocation due to immersion in water, typically accounts for a small but significant percentage of accidental deaths. Most studies of accidental drowning have focused on children, and in some countries drowning is the leading cause of injury deaths among younger age groups. It has been suggested that most drownings occur in backyard pools and hot tubs, the majority while the child’s supervisor assumed the child was safely indoors.

Near-drowning, in which rescue was successful and death was prevented, can result in considerable disability if submersion was long enough. The possible outcomes of near-drowning, including brain injury, paralysis, respiratory conditions and nervous system trauma, can generate considerable medical costs in maintenance care. It has been estimated that for every child who drowns, four children are hospitalized for near-drowning.

Alcohol consumption is one of the most frequently reported contributory factors associated with drownings and near-drownings for adults, whereas lapses in parental supervision are most frequently cited among children. Also of large concern is the danger of drownings and near-drownings in spas and pools due to inlets and outlets where the suction is strong enough to cause

entrapment of body parts or hair, causing the victim's head to be held under water.

Few preventive measures for drowning and near-drowning have been evaluated. Warnings displayed in clear and concise signage as well as water safety instruction and adult supervision all may have value as preventive actions. Installation of isolation fencing around outdoor pools has been shown by some studies to decrease the number of pool immersion injuries by more than 50%. Preventive measures for hair and body entrapment in spas and pools include the use of grills on drain gates that preclude hair entrapment, dual drains, an accessible emergency shut-off for the pump, and the wearing of bathing caps.

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 diving into the upslope of a pool bottom or into the shallow portion of the pool is the most common cause of spinal injuries in pools. Alcohol consumption may contribute significantly to the frequency of injury. Education and raising awareness appear to offer the most potential for diving injury prevention.

Other injuries associated with swimming-related activities include brain and head injuries, retinal dislocation, and arm, hand, leg and foot/toe injuries. Expert opinion suggests that the latter are common and generally go unreported. Causes include slippery decks, uncovered drains, reckless water entry, running on decks, and tripping on swimming aids left on the poolside. Maintenance of surfaces, supervision of pool users, providing appropriate warnings, improved pool design and construction, ensuring good underwater visibility and pool safety education are among the actions that can reduce these incidents.

High temperatures in spas can cause drowsiness, which may lead to loss of consciousness or to heat stroke and death. Exposure to low temperatures in plunge pools, which are used in conjunction with saunas or steam baths, may result in slowed heart beat, hypothermia, impaired coordination, loss of control of breathing, muscle cramps and loss of consciousness. Temperature extremes should be avoided by users with medical problems, pregnant women and young children. Educational signage and displays, warnings from pool staff and regulations on time limits for exposure and medical preconditions can reduce these adverse outcomes.

### **Microbiological hazards**

The risk of illness or infection associated with swimming pools, spas and similar recreational-water environments has been linked to faecal contamination of the water due to faeces released by bathers or contaminated source water. Many of the outbreaks related to swimming pools have occurred because disinfection was poorly or not at all applied. The majority of reported swimming pool-related outbreaks have been caused by viruses; recently, however, reported outbreaks have been more frequently associated with bacteria and protozoa.

Viruses that have been linked to swimming pool outbreaks include adenoviruses, hepatitis A virus, Norwalk virus and echovirus. Adenoviruses have been reported most frequently. Symptoms associated with exposure to adenoviruses include pharyngo-conjunctival fever, an infection of the eyelids or throat. Symptoms of infection by the other viruses include nausea, vomiting, headache, diarrhoea and fever.

*Shigella* and *Escherichia coli* O157 are two closely related bacteria that have recently been linked to outbreaks of illness associated with swimming in pools. Symptoms of *E. coli* O157 infection include bloody diarrhoea (haemorrhagic colitis) and haemolytic uraemic syndrome

(HUS), as well as vomiting and fever in more severe cases. HUS, characterized by haemolytic anaemia and acute renal failure, occurs most frequently in infants, young children and elderly people. Symptoms associated with shigellosis include diarrhoea, fever and nausea.

Risk of illness in swimming pools that has been linked to pathogenic protozoa mainly involves two parasites: *Giardia* and *Cryptosporidium*. These two organisms have a cyst or oocyst form that is highly resistant to environmental stress and highly resistant to disinfectants. As well, they both have a low infective dose and are shed in high densities by individuals who have giardiasis or cryptosporidiosis. Giardiasis is characterized by diarrhoea, cramps, foul-smelling stools, loss of appetite, fatigue and vomiting, whereas symptoms of cryptosporidiosis include diarrhoea, vomiting, fever and abdominal cramps.

The control of viruses and bacteria in swimming pool water is usually accomplished by the proper application of chlorine and other disinfectants. *Giardia* cysts and *Cryptosporidium* oocysts are very resistant to chlorine, however, and must be inactivated by ozone or eliminated through the use of filtration.

Episodes of gross contamination of a swimming pool due to an accidental faecal release (AFR) cannot be effectively controlled by normal disinfectant levels. Where pools or spas are not disinfected, AFRs present an even greater problem. The only approach to maintaining health safety under conditions of an AFR is to prohibit the use of the pool until the contaminants are inactivated. This involves immediately clearing the pool of people, maintaining disinfectant levels at the top of the recommended range, vacuuming and cleaning the pool, filtering the water for several turnover cycles and backwashing the filter.

Pool operators can help prevent faecal contamination of pools by encouraging pre-swim showering and toilet use and confining young children to pools small enough to drain in the event of such an incident. The education of parents of small children and other recreationists with regard to good hygienic behaviour at swimming pools is another approach that may prove to be useful for improving health safety at swimming pools and the reduction of AFRs.

As well as pathogenic enteric organisms, a number of infectious non-enteric organisms may be transferred in recreational-water environments, via human shedding (e.g., from saliva or mucus discharges). Infected users can directly contaminate pool or spa waters and the surfaces of objects or materials at a facility with primary pathogens (notably viruses or fungi) in sufficient numbers to consequently lead to skin and other infections in patrons who come in contact with the contaminated water or surfaces. Opportunistic pathogens (notably bacteria) can also be shed from users and transmitted via contaminated water in pools or spas. In addition, certain free-living aquatic bacteria and amoebas can grow in pool or spa waters, in pool or spa components or facilities (including heating, ventilation and air conditioning [HVAC] systems) or on other wet surfaces within the facility to a point at which they may cause a variety of respiratory, dermal or central nervous system infections or diseases.

Most of the fraction of legionellosis, a lung infection caused by *Legionella* species, associated with recreational-water use appears to be associated with spas, as spa waters and associated equipment create an ideal habitat (warm, nutrient-containing, aerobic water) for the selection and proliferation of the bacteria. *Pseudomonas aeruginosa* is also frequently present in whirlpools, as it is able to withstand high temperatures and disinfectants and to grow rapidly in waters supplied with nutrients from bathers. In spas, the primary health effect associated with the presence of *P. aeruginosa* is folliculitis, an infection of the hair follicles that produces a

pustular rash under surfaces covered with swimwear. Otitis externa and infections of the urinary tract, respiratory tract, wounds and cornea have also been linked to spas.

It is extremely difficult to control the growth of *Legionella* and *P. aeruginosa* in spas, as the design and operation of spas make it difficult to achieve adequate residuals in these facilities. Frequent monitoring and adjustment of pH and disinfectant levels are essential. The adequacy of disinfection should be verified routinely using heterotrophic plate counts (in disinfected pools and spas) and faecal coliform (or *E. coli*) tests (in all pools and spas), as well as tests for specific organisms such as *P. aeruginosa* (Crandall & Mackenzie, 1984). Faecal coliform and *E. coli* concentrations of less than 1 per 100 ml should be readily achievable through good management practices. *P. aeruginosa* concentrations of less than 1 per 100 ml should be readily achievable in continuously disinfected pools or spas, whereas a guideline concentration of less than 10 per 100 ml is more realistic for pools and spas without residual disinfectant. In addition, swimming pool and spa operators should require users to shower before entering the water and control the number of bathers and their duration of exposure. As the warm, moist environment on decks, drains, benches and floors provided by spas and pools provides an ideal environment for the growth of *Pseudomonas*, thorough cleaning of surfaces and materials around spas and pools where the organism may persist is also necessary. For *Legionella* control, filters should be backwashed frequently, HVAC systems serving the room in which the spa is located should be cleaned and disinfected regularly, and rooms housing spas should be well ventilated to avoid an accumulation of *Legionella* in the indoor air. Spas and ancillary equipment should be drained regularly and thoroughly cleaned.

Molluscipoxvirus, which causes molluscum contagiosum, an innocuous cutaneous disease, human papilloma virus, which causes benign cutaneous tumours, and *Epidermophyton floccosum* and various species of fungi in the genera *Trichophyton*, which cause superficial fungal infections of the hair, fingernails or skin (in particular tinea pedis, or “athlete’s foot”), are spread by direct person-to-person contact or indirectly through physical contact with contaminated surfaces. As the primary source of these viruses and fungi in swimming pool and spa facilities is infected bathers, the most important means of controlling the spread of the infections is educating the public about the diseases, the importance of limiting contact between infected and non-infected people and medical treatment. Thorough regular cleaning and sanitation of surfaces in facilities that are prone to contamination can also reduce the spread of the diseases.

### **Chemical hazards**

Chemicals found in pool water include those that are related to water treatment — both the disinfectants themselves and the by-products that are produced from chemical reactions between the disinfectants and organic and inorganic material in the raw water — and those that are contributed by the swimmers, which include soap residues, cosmetics, suntan oil, sweat and urine.

A variety of disinfectants are used for pool water treatment. Those used most frequently in large, heavily used pools include chlorine, ozone and chlorine in combination and chlorine dioxide; less frequently used disinfectants include bromine and iodine. The formation of by-product chemicals associated with disinfection of pool waters varies with the chemical. Trihalomethanes (THMs), haloacetic acids, haloacetonitriles, halo ketones, chloropicrin, chloral hydrate and bromal hydrate have all been detected in pool water. Concentrations of THMs, which are significant chlorine and bromine disinfectant by-products, have been measured the most

frequently. The main constituent among THMs in freshwater pools is chloroform, whereas bromoform predominates in saltwater pools.

THMs have also been measured in air because they are volatile and vaporize from the pool water. The higher their vapour pressure and concentration in water, the more readily they escape into the air above the pools. Other factors enhancing the transport of THMs into the air are a low water solubility, high water temperatures, a large contact area between the pool water and the air above it, and water turbulence caused by bather movements. Indoor pools allow a build-up of airborne THMs that would not occur at outdoor pools. The measured air concentrations generally decrease with increasing height above the pool surface.

There are three main routes of exposure to chemicals in swimming pools or spa waters — inhalation of volatile or aerosolized solutes, dermal contact and direct ingestion of the water. Inhalation exposures are controlled by the water concentrations, turbulence, mass transfer properties, air concentrations, length of time in the vicinity of the pool and physical activity, which will affect breathing rate and other factors. Air concentrations will be higher in indoor pools than in outdoor pools. Dermal exposure will be a function of body surface area, time in water, water concentrations and skin permeability, which is a function of the octanol/water partition coefficient of the chemical and other factors. Direct ingestion is probably the least of the exposure sources for volatile, non-polar chemicals, since it is limited to the amount of water that would be swallowed and the chemical concentration. Body burdens contributed from ingestion, dermal contact and inhalation are difficult to distinguish experimentally.

Although the adverse health effects associated with the ingestion of many disinfectants and disinfectant by-products in drinking-water have been well documented, much less has been written on the health hazards specifically associated with exposure, particularly by inhalation and dermal contact, to these chemicals in swimming pools, spas and similar recreational-water environments.

The principal databases on exposure to pool volatiles have focused on chloroform and other THMs, due to their ease of analysis, high concentrations, frequency of occurrence and possible toxicity. They are the only disinfectant by-products for which information is available on concentrations in both pool water and ambient pool air. Exposure calculations using chloroform as a representative of chlorination systems and bromoform as a representative of ozonation systems are useful for drawing general conclusions about the hazards associated with exposure to chemicals in pool environments.

Dermal contact is the dominant exposure route for chloroform in swimming pools. Where chloroform levels are moderate to high, swimmers — in particular competitive swimmers and children — may exceed the tolerable daily intake for chloroform in chlorine-disinfected pools. High dilution rates, pre-swim showering, good ventilation and use of alternative disinfectants are all actions that can be taken to minimize risk of exposure to chloroform. For swimmers and pool attendants or lifeguards in indoor or outdoor pools where ozone is the primary disinfectant, the presence of disinfectant by-products is generally minimal, and guideline values are not required.

### **Managing water and air quality**

Management of microbiological and chemical hazards associated with swimming pool environments can minimize their effects.

Pre-swim showering will remove traces of sweat, urine, faecal matter, cosmetics, suntan oil and other potential water contaminants. The result will be cleaner pool water, easier disinfection using smaller amounts of chemicals, and water that is more pleasant to swim in. Pre-swim showers should be en route from changing rooms to pool, can be continuous to encourage use and must run to waste. Water supplied for the showers must be of drinking water quality. All users should be encouraged to use the toilets before bathing to minimize urination in the pool and AFRs.

Swimming and bathing pool water must be hygienically safe — free of pathogens and exhibiting no properties or constituents that may cause human health to be impaired. These water quality requirements can be met only through optimal matching of the following factors: disinfection (to destroy or remove infectious microorganisms so that the water cannot transmit disease-producing biological agents); pool hydraulics (to ensure optimal distribution of disinfectant throughout the pool); appropriate treatment (to remove pollutants and microorganisms); and addition of fresh water at frequent intervals (to dilute substances that cannot be removed from the water by treatment).

The choice of disinfectant depends on a variety of factors, including compatibility with the source water supply (hardness and alkalinity), bathing load, oxidation capacity, and margin between disinfectant action and adverse effects on human health. Chlorination is the most widely used pool water disinfection method, usually in the form of chlorine gas or sodium or calcium hypochlorite. Ozone in combination with chlorine or bromine is a very effective disinfection system, as the use of ozone alone cannot ensure a residual disinfectant capacity throughout the swimming pool.

The production of disinfectant by-products can be controlled to a significant extent by minimizing the introduction of precursors through good hygienic practices, maximizing their removal by treatment and dilution, and rigorous attention to the monitoring of chemical parameters. It is inevitable, however, that some volatile disinfectant by-products will be produced in the pool water and escape into the air. This hazard can be managed to some extent through good ventilation.

Filtration is crucial to good water quality. If filtration is poor, water clarity — a key factor in ensuring underwater visibility and hence the safety of swimmers — will be affected. Disinfection will also be compromised by reduced clarity, as particles associated with turbidity can surround microorganisms and shield them from the action of disinfectants. In addition, filtration (following coagulation) is important for removing *Cryptosporidium* oocysts and *Giardia* cysts and some other protozoa that are resistant to chlorine disinfection.

Disinfection and treatment will not remove all pollutants. The design of a swimming pool should recognize the need to dilute the pool water with fresh water. Dilution limits the build-up of pollutants from bathers (e.g., constituents of sweat and urine) and elsewhere, the by-products of disinfection and various other dissolved chemicals. Pool operators should replace pool water as a regular part of their water treatment regime.

It is important to manage air quality as well as water quality in swimming pool, spa and similar recreational-water environments. Rooms housing spas should be well ventilated to avoid an accumulation of *Legionella* in the indoor air. In addition, ventilation will help reduce exposure to disinfectant by-products in air.

Parameters that are easy and inexpensive to measure and of immediate health relevance — that is, turbidity, disinfectant residual and pH — should be monitored most frequently and in all pool types. For turbidity, the ability to see either a small child at the bottom of the pool or lane markings or other features on the pool bottom from the lifeguard position while the water surface is in movement, as in normal use, can be converted to turbidity equivalents and monitored routinely. These turbidity equivalents can be compared with 0.5 nephelometric turbidity units, which is a useful upper limit guideline for optimized water treatment, and the more stringent guideline chosen.

For chlorine-based disinfectants, adequate routine disinfection should be achieved with a free chlorine residual level of at least 1 mg/litre throughout the pool. In a well operated pool, experience suggests that it is possible to achieve such a residual with maximum levels in any single point always below 2 mg/litre for public pools and 3 mg/litre for semi-public pools. Lower residuals (0.5 mg/litre or less) will be required with the additional use of ozone, whereas higher levels (2–3 mg/litre) may be required for spa and hydrotherapy pools.

Disinfectant residuals should be checked by sampling the pool before it opens and after closing. The frequency of testing during swimming pool use depends upon the nature and use of the swimming pool. Samples should be taken at various parts of the pool, including the area of the pool where the disinfectant residual is lowest. If the routine test results are outside the recommended ranges, the situation should be assessed and action taken.

The pH value of swimming pool water must be maintained within the recommended range to ensure optimal disinfection and coagulation. In order to do so, regular pH measurements are essential, and either continuous or intermittent adjustment is usually necessary. For heavily used pools, the pH value should be measured continuously and adjusted automatically; for other pools, it is sufficient to measure the pH value regularly and adjust it intermittently.

Whether any other parameters — physical, chemical and microbiological — need to be monitored is in practice determined by management capacity and intensity of use. However, microbiological monitoring at varying frequencies is generally needed in public and semi-public pools. Microbiological quality should be checked before a pool is used for the first time, before it is put back into use after it has been shut down for repairs or cleaning, if there are difficulties with the treatment system or when contamination is suspected (e.g., after an AFR). Routine testing for *P. aeruginosa* in spa pools is also recommended.

### **Guideline implementation**

The use of recreational-water environments is associated with enormous health benefits arising from exercise and relaxation. At the same time, it is recognized that effective management options need to be implemented in order to minimize and reduce the detrimental health consequences associated with the use of recreational-water environments.

Management interventions vary, and a wide range of preventive and corrective actions are available for the development and management of public, semi-public and private pools, spas and other recreational water-related facilities. Such actions may be grouped in four major categories: design and construction of facilities, operation and supervision — including lifeguard training and the development of pool safety operating procedures — public education and information, and regulatory requirements and enforcement. All of these can remediate differing health outcomes. Successful implementation of the Guidelines will require development of suitable skills and expertise, as well as the elaboration of a coherent policy and legislative framework.