

Guidelines for Safe Recreational-water Environments:

Coastal and Fresh-waters

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for Consultation

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WORLD HEALTH ORGANIZATION

CHAPTER 1

INTRODUCTION

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. The hazards concerned fall into a number of groups: accidents and physical hazards (leading for example to drowning or injury); water quality (especially contamination by sewage); exposure to heat and sunlight; contamination of beach sand; exposure to algae and their products; dangerous aquatic organisms and chemical contamination.

The hazards that are encountered in recreational water environments vary from site to site and so does the nature and extent of exposure. Most available information relates to health outcomes arising from exposure through swimming and ingestion. In the development of these Guidelines, all available information was taken into consideration, accounting for the different routes of exposure.

In order to properly interpret and apply the Guidelines in a manner appropriate to local conditions, it will be necessary to take into account the social, cultural, environmental and economic factors of the site, alongside knowledge of both routes of exposure and the nature and severity of hazards. In doing so, local, national and international standard-setting bodies may develop standards that differ between regions and within regions according to differences in these factors.

In seeking to control health hazards associated with the recreational use of the water environment, responsible and concerned bodies dispose of a range of diverse potential means of intervention. Enhancing the capacity for informed individual choice is often seen as an important component, which can be achieved through both general awareness-raising activities and availability and comparability of information. Properly planning the development of the area will contribute to a more harmonious management of recreational waters, avoiding conflicts and competition which are often root causes for health risks to the users. Defining standards of quality, monitoring its indicators and enforcing them will directly contribute to the prevention of hazards. Finally, technical solutions to remediate the problem or to prevent exposure to hazardous areas or conditions can be adopted.

National and local public agencies working in the area of recreational water use have a responsibility to promote and to ensure a safe environment, for example in managing hazards which may lead to drowning or injury or poor microbiological quality. Water recreational areas may be under some form of ownership or associated with a provider of facilities or services. Owners or service providers and their personnel are key players in the control of hazards to human health and in some jurisdictions may have a legal obligation to execute continued “due diligence” relative to the safety of water or beaches. Rural or undeveloped water recreational areas often have different management arrangements and priorities. In all cases considerable capacity to limit health risks is in the hands of the user who should assume a degree of responsibility when engaged in recreational activities. NGOs and special interest groups also have an important role to play.

In light of the diversity in exposure, hazard and nature of interventions, these guidelines are structured as shown in Fig.1.1

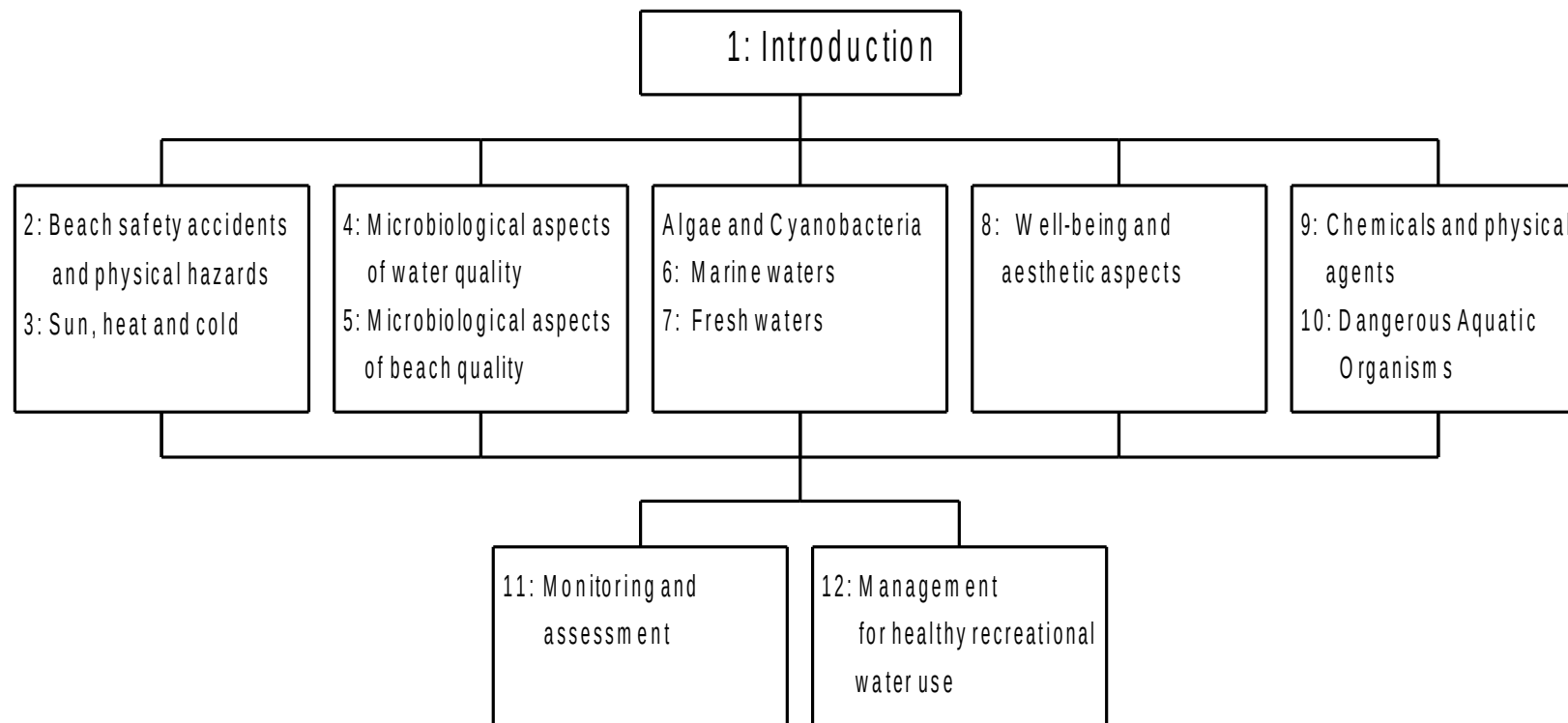


Figure 1.1 Guideline Structure

1.1 General Considerations

The primary aim of the *Guidelines for Safe Recreational-water Environments* is the protection of public health.

The Guidelines are intended to be used as the basis for the development of international and national approaches to control of the 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 well as a checklist for understanding and assessing potential health impacts of recreational projects and in the conduct of Environmental Impact Assessment and of Environmental Health Impact Assessment in particular.

Where Guideline Values are presented, these are not mandatory limits, but measures of the safety of a recreational water environment. In developing strategies for the protection of public health, competent government authorities would take into account the general education of both adults and children and also the efforts and initiatives of NGOs and industry operators in this area.

The main reason for not promoting the adoption of international standards for recreational-water environments is the advantage provided by adoption of a risk-benefit approach. In the specific case of recreational water use, development of such approaches concerns not only health risks and benefits, but inter-relates with other risks and benefits especially those concerning environmental pollution / conservation, as well as local and national economic development and the health benefits and well-being derived from recreational use of the water environment.

This approach can often lead to the adoption of standards that are measurable, and can be implemented and enforced. These would deal with, for example, water quality, beach quality and dissemination of information. Other standards may relate to the education of children and adults or to the obligation to prepare and disseminate comparative studies of the quality of alternative recreational water use locations. Clearly a broad-based policy approach will be required which will include legislation as well as positive and negative incentives to alter behaviour and monitor situations.

Such a broad base will require significant efforts in inter-sectoral co-ordination and co-operation at national and local levels; and successful implementation will require development of suitable skills and expertise as well as the elaboration of a coherent policy and legislative framework.

1.2 Types of Hazard Encountered in the Recreational-water Environment

The importance of hazards to human health should be weighed against the benefits for human health and well-being derived from recreational water use. Hazards to human health exist in even unpolluted environments, e.g. eye irritation and some additional eye infections occur in bathers, probably as a result of reduction in the eye's natural defences through limited contact with water and do not relate to water quality or pollution *per se*.

The existence of a diverse range of hazards in the recreational-water environment indicates the need for an understanding of their relative importance for health and of the costs and resources required for their control. Hazards include factors associated with accidents (including drowning, near drowning and spinal injury); microbiological pollution; exposure to heat, cold and sunlight; exposure to toxic algal products; and occasional chemical pollution.

Drowning, near drowning and spinal injury arising from accidents are severe health

outcomes of great concern to public health. Other accidents, such as cuts from glass and other wastes, whilst less severe, cause distress and decrease the benefits to well-being arising from recreation. Human behaviour - especially alcohol consumption- is a prime factor that increases the likelihood of accidents, as up to 50 percent of drowning deaths are associated with alcohol in some countries.

Notwithstanding the above, much attention has focused in recent years upon microbiological hazards. In particular, health risks associated with contamination of water by sewage and excreta and associated gastro-enteric outcomes, have been the topics of both scientific and general public interest. It should be noted that the hazards concerned are not restricted to this group and potentially include skin, eye and ear infections arising from pollution of water by excreta and bathers; and other infectious agents with more severe potential health outcomes such as leptospirae. However, in general terms, it appears that contamination of recreational water with excreta and sewage is widespread and common, affects large numbers of recreational water users, the majority of which result in mild gastro-enteric symptoms.

Because hazards may give rise to health effects after short-term exposures it is important that standards, monitoring and implementation enable preventive and remedial actions within real time frames. For this reason, emphasis in the Guidelines is placed upon identifying circumstances and procedures that are likely to lead to a continuously safe environment for recreation. This approach emphasises monitoring of both conditions and practices and the use of threshold values for key indicators assessed through programmes of monitoring and assessment.

1.3 Types of Use

There are many different types of recreational usage of water environments, for example:

- No contact, where enjoyment is of aesthetic beauty of the water environment.
- Limited contact, e.g. boating, rowing, fishing.
- Meaningful direct contact that involves a negligible risk of swallowing water e.g. wading.
- Extensive direct contact with full body immersion and a meaningful risk of swallowing water e.g. swimming. Children frequently appear in this group as they play longer in recreational waters, are more susceptible to infections than adults and are also more likely to swallow (or even intentionally drink) recreational water.

Within the socio-economic context of recreational water use, the importance of tourism is considerable - in terms of its size, impacts on socio-economic and environmental spheres and the responsibility and means to intervene that it has at its disposal. Each year, millions of tourists flock to the sea, coast and tourism is the world's third largest industry and the prime economic sector in some states and regions, such as the Caribbean. Tourism receipts have increased at some 11 per cent / year over the past 10 years (WTO, 1995). In addition, behaviour and practice have changed and tourism is a versatile industry. This is creating increased competition for use of coastal waters and beach areas, making the need for clearer regulations and codes of conduct more necessary. A characteristic of recreational waters is the transboundary nature of the problems of pollution. This requires an international approach with management and conservation measures taken at the commons level. For example, the Black Sea and other UNEP Regional Seas Programmes

address pollution issues at the regional level, encouraging governments to carry out coherent monitoring and regulatory activities, collectively and collaboratively.

Mutually supportive actions must take place, coherently, at the local, national and international level. On the other side of the matrix, a *multiplicity of stakeholders* intervenes in the assessment, use and protection of recreational waters. Their role and responsibilities have to be defined and their efforts harnessed through an integrated planning framework. Figure 1.2 displays the variety of stakeholders and their role in the process of assessing and using recreational waters and taking remedial actions to limit health hazards. Chapter 12 discusses further the roles of stakeholders.

1.3.1 Conflicts between different water activities

Competition for suitable, available waters and the popularity of recreation often create conflicts between activities, as indicated in Table 1.1. These conflicts can be resolved by regulation, codes of good practice and voluntary agreements, recognising that all legitimate activities can thereby be accommodated - the essence of Integrated Coastal Management. High activity sports often present an internal conflict between enjoyment of the excitement and hazard, resolvable by proper attention to safety, training and supervision. The process of Integrated Coastal Management (chapter 12) introduces mechanisms to facilitate the resolution of conflicts between such competing sectors of the coastal zone and to help to reach agreeable solutions, with respect to the carrying capacity of the environment, whilst satisfying the general needs of the area. In coming to agreement, management will usually have to adopt pragmatic solutions.

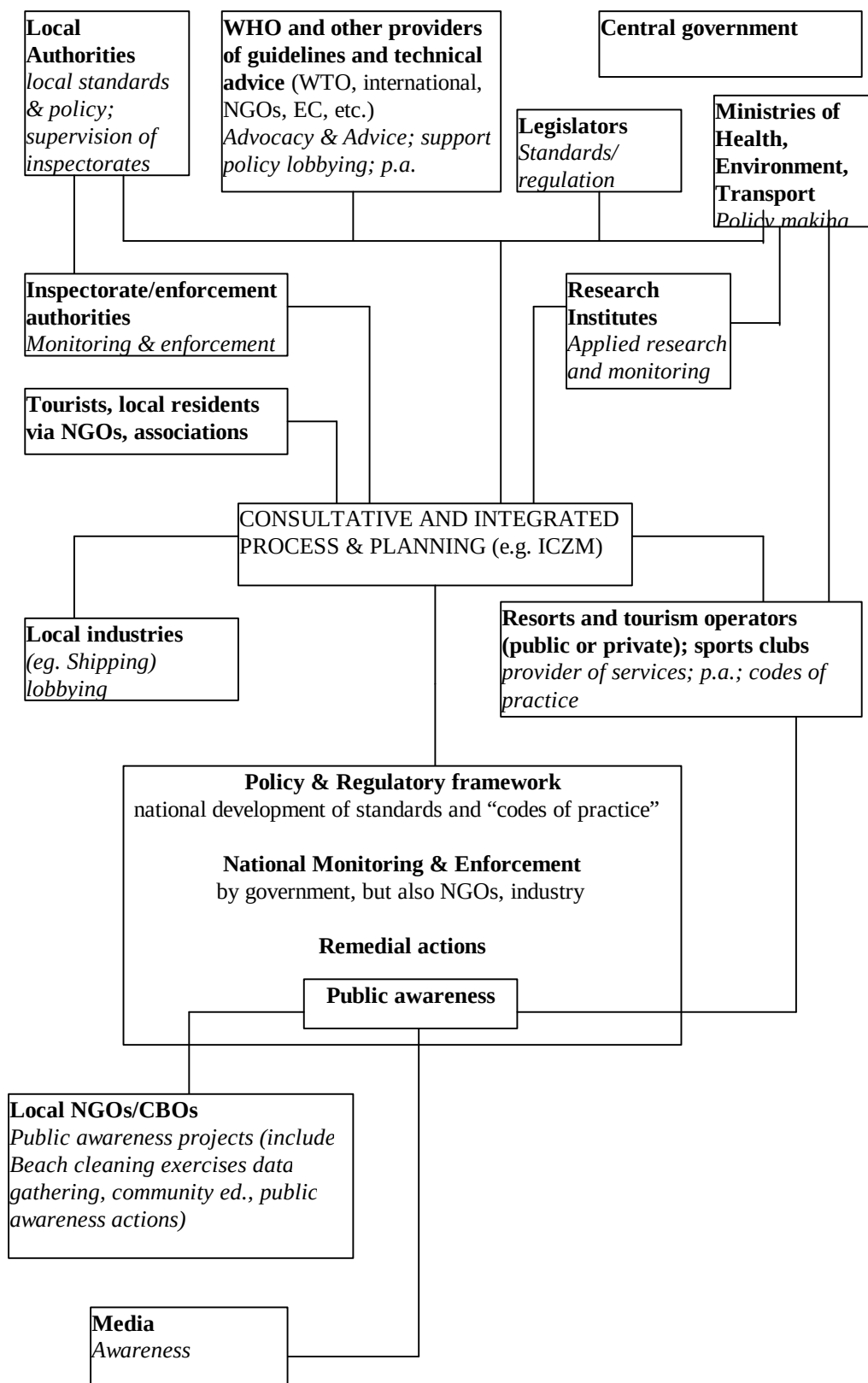


Figure 1.2. Stakeholders in recreational waters

Table 1.1 Examples of conflicting interactions between and within different water recreations and possible control measures

Recreation	Conflicting interactions	Possible control measures
White-water rafting and canoeing, canoe slalom.	Challenge and excitement enhances enjoyment, but presents hazard of injury and drowning.	Wearing of buoyancy aids, safety helmets, organised training in life-saving, local and national codes of practice, classification of courses by difficulty, supervision and rescue cover at organised events
Water skiing, jet skiing, windsurfing.	Hazard of injury to bathers, conflict with movements of commercial shipping, fishing and yachting. Powered craft create noise and oil pollution, affecting enjoyment by other users.	Creating local restriction zones to avoid conflict. Engine designs and oils formulations to avoid visible emission of oil.
Use of inland waterways for boating under power, canoe touring, and angling.	Injury to bathers.	Prohibit bathing where water quality and conditions are unsuitable, otherwise create or designate bathing areas.
Recreational use of drinking-water reservoirs.	Contamination of drinking-water supplies by faeces, litter, oil and fuel.	Restrict uses to angling from shore or row-boat, dinghy sailing, bird watching and walking, with local codes of practice, supervised by wardens and clubs; no dogs, provision of litter collection and toilets.
Dog-walking and horse-riding on beaches.	Fouling of beaches, potential transmission of toxocariasis from dog faeces, particularly to children. Horses colliding with people on the beach.	Banning dogs and horses from recognised bathing beaches during the bathing season.

1.4 Hazard and risk

Popularly, these terms are used interchangeably, although correctly, a *hazard* is a set of circumstances that could lead to harm - harm being injury, illness, or loss of life. Some examples of hazards in water recreation are given in Table 1.2. The *risk* of such an event is defined (Lacey and Pike, 1989), as the probability that it will occur as a result of exposure to a defined quantum of hazard. The *rate of incidence*, or *attack rate* is the expected number of events that occur for this defined quantum of hazard. Strictly speaking, probabilities and rates obey different laws, but if the probabilities are small and events are independent, the two values will be approximately equal. Risks can vary from negligible - an adverse event occurring at a frequency of below one per million, to high -

fairly regular events that would occur at a rate of greater than one in a hundred (Calman, 1996).

1.4.1 Assessment of hazard and risk

Assessments of hazard and risk are essential preliminaries to the development of policies for controlling and managing risks to health and well-being in water recreation. Both draw upon experience and the application of common sense, as well as the interpretation of data. Isolated measurements of risk are not very helpful when decisions have to be made for managing risks or developing policies for controlling them. Figure 1.3 provides a schematic approaches to comparing health hazards encountered during recreational water use. A severe health outcome such as diving into shallow water resulting in permanent paralysis or death may only affect a small number of bathers annually but warrant a high management priority. Minor skin irritations encountered at the other end of the scale, may affect a higher number of bathers per year but does not result in any incapacity and such hazards require lower management priority. This figure can be applied throughout the Guidelines to each of the hazards discussed.

Data on risk takes three main forms:

- National and regional statistics of illness and deaths.
- Clinical surveillance of incidence of illness and outbreaks.
- Epidemiological studies and surveys.

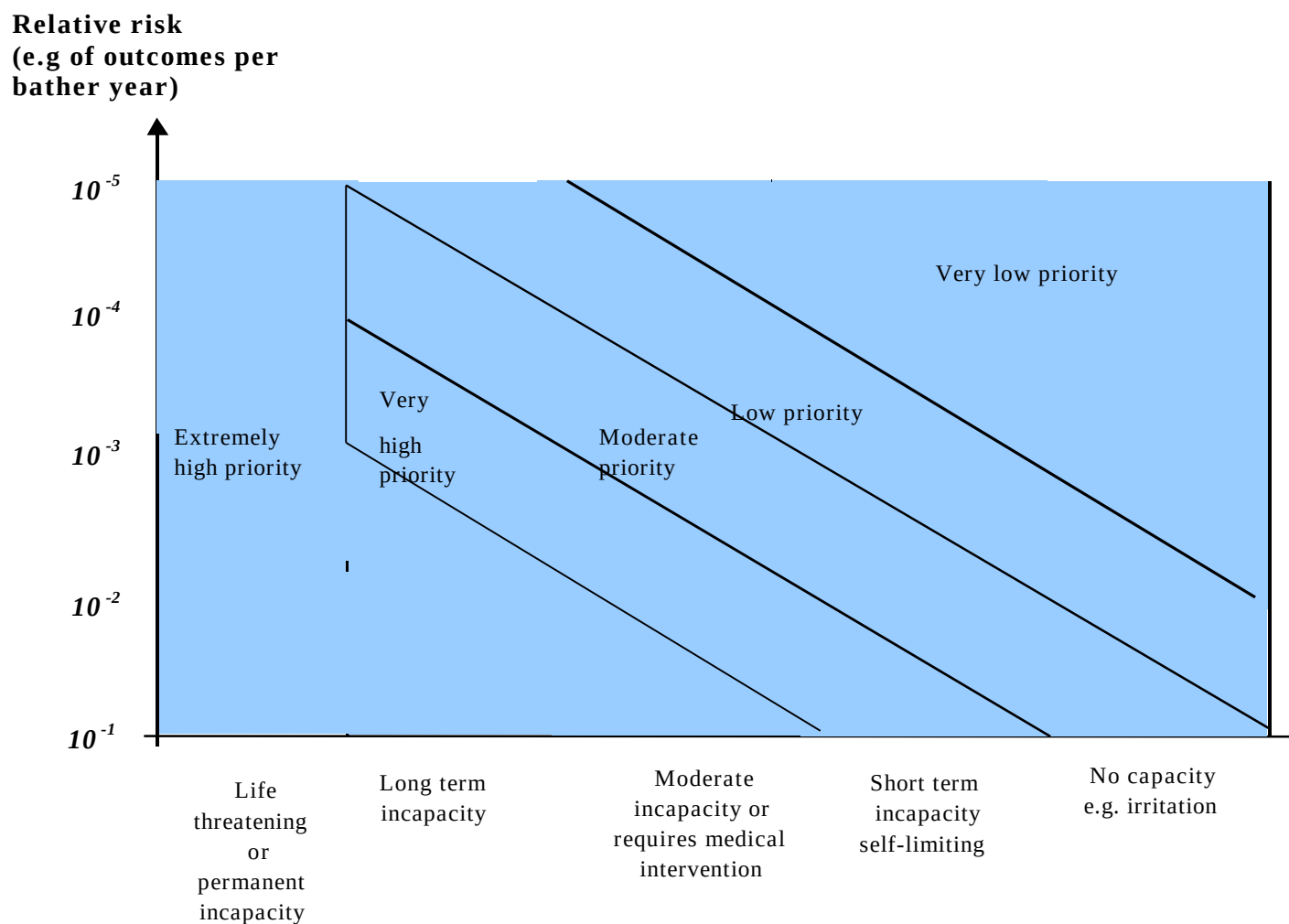
Published statistics are seldom sufficiently detailed for risk assessment. Surveillance is the process of continuous and vigilant assessment of the state of public health and of safety and acceptability. Processes of surveillance for drinking-water supplies have been recommended by WHO (1976; 1997), and involve a dual responsibility of a national, governmental regulator and the supplier or provider of the service. Systems for surveillance of public health operate in most countries. They serve the broad purpose of alerting either regulator or supplier to changes in incidence of disease and to the need for initiating immediate investigation of the causes and remedial action. Such investigation will involve epidemiology, which is the study of the occurrence and causes of disease in populations. Galbraith and Palmer (1990), give details of the use of epidemiology in surveillance. Epidemiology may also be used as a research tool to investigate hypotheses concerning the causes of illness.

Table 1.2 Examples of different types of hazard encountered in water recreation

Type of hazard	Examples (with chapter references in parentheses)
Drowning	Caught in tidal and rip currents, cut-off by rising tides, falling overboard, caught by submerged obstacles, falling asleep on inflatables and drifting into deep water far from shore (2).
Injury	• Impact against hard surfaces or sharp objects (2). The impact may be driven by the participant (diving, collision, treading on broken glass and jagged metal), or by the force of wind and water. • Attack by aquatic animals (shark, conger and Moray eels, piranhas, seals).
Physiological	• Chilling, leading to coma and death (3). • Thermal shock, leading to cramps and cardiac arrest (3). • Acute exposure to heat and ultraviolet radiation in sunlight - heat exhaustion, sunburn, sunstroke (3). • Cumulative exposure to sun - skin cancers (basal and squamous cell carcinoma, melanoma (3).
Infection	• Ingestion or inhalation of, or contact with pathogenic bacteria, viruses, fungi and parasites, which may be present in water and sand as a result of faecal contamination, or carried by participants or animals using the water, or naturally present (4, 5). • Bites by mosquitoes and other insect vectors of parasitic diseases (10).
Poisoning and toxicoses	• Ingestion or inhalation of, or contact with chemically contaminated water, including oil slicks (9). • Stings of poisonous and venomous animals (jellyfish, weaver fish (<i>Trachinus</i> spp.), sting rays (10). • Ingestion or inhalation of, or contact with blooms of toxigenic Cyanobacteria in freshwater (7) or of dinoflagellates in marine water (6).
Aesthetic	Revulsion from visible pollution, turbidity, scums or odour (8)

Note: The numbers in parenthesis refer to the corresponding chapters.

Figure 1.3 Schematic approach to comparing health hazards encountered during recreational water use



1.4.2 The use of epidemiology in assessing risk

There is a considerable body of epidemiological information concerning the effects of faecal contamination of bathing waters on the incidence of gastro -enteritis and other transmissible diseases to bathers and other participants in water recreation. This has been critically reviewed (Cartwright, 1992; Fewtrell and Jones, 1992; Pike, 1989, 1994; Prüss, 1996) and is re-examined later in this volume. The epidemiological data concerning some other types of hazards is considerably weaker and this is especially the case with regards to drowning and accident hazards.

Epidemiological information is more reliable than published statistics for assessing risks, since its rigorous disciplines are designed to eliminate sources of bias and errors in interpretation. On the other hand, this rigour limits epidemiological studies to single, or a few closely related hazards and carefully defined populations. Hence, epidemiological approaches do not always measure the full range of variation in population responses (Grassman, 1996). Their results can therefore only be applied to activities and subjects similar to those studied.

There are other reasons why it is difficult to estimate risk directly, such as:

- In most active water sports, enjoyment arises from the use of skill to avoid and overcome perceived hazards. The degree of competence of participants and the use of properly designed equipment and protective clothing, accompanied by supervision and training, will considerably modify the risk.
- Risks of acquiring infectious disease will be considerably influenced by innate and acquired immunity (for examples, see Gerba *et al.*, 1996). The former comprises a wide range of biological and environmental factors (age, sex, nutrition, socio -economic and geographic), as well as body defences (impregnability of the skin, lysozyme secretion in tears, mucus and sweat, the digestive tract and phagocytosis). Previous challenge by pathogens often results in transient or long -lasting immunity.
- Assessment of harm itself and the degree of harm suffered depend upon judgement at the time. Medical certification of injury and of physiological illness and infection, accompanied by clinical diagnosis, is the most reliable information. Information obtained by survey, or questionnaire will contain a variable degree of uncertainty caused by the subjects' understanding of the questions, their memory of the events and any personal bias of the subject and interviewer. Survey information is only as good as the care that has gone into its design and conduct. Data for aesthetic insult is entirely subjective, but frequencies of particular types of waste objects on stretches of beaches can be quantified.
- The causes of harm must be ascertained as far as possible at the time. There are considerable difficulties in the cases of low -level exposures to chemical and physical agents which have a cumulative or threshold effect, and of infectious diseases caused by those pathogens which have more than one route of infection or have a long period of incubation. For example, gastro -enteric infections at seaside resorts may result from person-to-person contact and faulty food hygiene in catering, as well as from ingesting sewage-contaminated water.
- Where data is in the form of published regional or national statistics giving attack rates, the exact basis on which the data are collected and classified must be ascertained. For example, national statistics on deaths by drowning, will usually include suicides, occupational accidents (fishermen, mariners, construction workers) and misadventure in recreation.

- It cannot be assumed that risk is directly proportional to exposure, or that risks from multiple exposures, or a combination of different factors will combine additively.

Definitions of relative risk and odds ratio

Controlled epidemiological studies involve comparison of attack rates between the experimental group exposed to the hazard and an unexposed control group, carefully selected to be otherwise as identical as possible. The objects of such studies take the form of statistical examination to disprove the null hypothesis that there is no significant difference in the outcome between the two groups. The results are therefore usually presented in the form of *relative risk* (risk of outcome in the exposed group / risk of outcome in the control group), or the *odds ratio* (odds of outcome in the exposed group / odds of outcome in the control group), together with a statement of the level of statistical significance (the probability that the stated result could have occurred by chance).

If the baseline rate of illness unrelated to exposure is r , (the fraction of the control group who become ill) and exposure to the hazard studied increases it by a factor, b , the rate observed in the exposed group is obviously br and the relative risk is $br/r = b$. The odds ratio is defined as $[br/(1 - br)]/[r/(1 - r)]$, or the ratio of ill to well exposed subjects divided by the ratio of ill to well control subjects. The odds ratio is larger than the relative risk, but the differences are small, when the direct risks are 1 per cent or less. Odds ratios are readily calculated in the analytical procedure known as logistic regression analysis, which is commonly used to analyse the effects of different factors on illness in large, multivariate epidemiological studies. Relative risk has no real meaning in retrospective case-control studies of outbreaks, where the number of well, but exposed subjects is an unknown fraction of the total population who were exposed to the hazard and the odds ratio is therefore given instead.

1.5 Nature of the Guideline Values

1. A guideline represents a concentration of a constituent that does not represent a significant risk to the health of individual members of significant user groups or a condition under which such concentrations are unlikely to occur. In deriving Guideline Values account is taken of both the severity and frequency of associated health outcomes.
2. Water conforming to the Guidelines may present a health risk to especially susceptible individuals or to certain user groups.
3. 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.
4. For most parameters there is no clear cut off value at which health effects are excluded and the derivation of Guideline Values and their conversion to standards therefore includes an element of valuation addressing the frequency and nature of associated health effects. This valuation process is one in which societal values play an important role and the conversion of Guidelines into national policy, legislation and standards should therefore take account of environmental, social and economic factors.

5. Also because of the above, the existence of a Guideline Value or national standard does not imply that environmental quality should be degraded to this level. Indeed a continuous effort should be made to ensure that recreational water environments are of the highest attainable quality.
6. Many of the hazards associated with recreational use of the water environment are of an instantaneous nature: accidents and exposures to microbiological infectious doses may occur in very short periods of time. Short-term deviations above Guideline Values or conditions are therefore of importance to health and measures should be in place to ensure and demonstrate that recreational water environments are continuously safe during periods of actual or potential use.

The *Guidelines for Safe Recreational-water Environments* do not address:

- exposures associated with foodstuffs and in particular water products such as shellfish;
- protection of aquatic life or the environment;
- occupational exposures by individuals working in recreational-water environments;
- waters afforded special significance for religious purposes and which are therefore subject to special cultural factors;
- risks associated with ancillary facilities which are not part of the recreational water environment, e.g. beach sand is addressed, while toilet facilities in adjacent areas are not considered beyond assertion of the need for them in order to minimise soiling of the recreational environment;
- the importance of aesthetic factors in ensuring maximum benefit for well-being from recreational use of the water environment is discussed, but no Guideline Values for aesthetic aspects are derived since their valuation is one of societal and cultural values which cannot be expressed solely in quantitative terms and their control will not reduce adverse health effects;
- seasickness;
- the 'bends' decompression sickness and other phenomena restricted to sub-aqua and deep sea diving; and
- therapeutic uses of waters (thalassotherapy, spas).

Swimming pools, spas and similar recreational water environments are addressed in the companion Volume: *Guidelines for Safe Recreational-water Environments: Swimming pools, spas and similar Environments*.

1.6 Measures to Reduce Risks in Water Recreation

Table 1.2 has listed and classified the main types of hazard encountered in water recreation. Study of the examples given, indicates that reduction of most, if not all, of their associated risks can be obtained by avoiding the circumstances giving rise to the hazard or mitigating their effect. Table 1.2 also suggests particular types of recreation that may be prone to certain hazards and actions that may be taken to reduce the risk. For example, glass left on a beach will cause the hazard of cuts to walkers with bare feet, which may be overcome by regular cleansing of the beach, provision of litter bins and educational awareness campaigns. This suggests that each type of recreational activity should be subject to a hazard assessment to determine what type of control measures will be most effective. Figure 1.4 provides a schematic example of the use of Guideline Values in risk management and in relation to specific measures. Assessment should include modifying

factors, such as local features, seasonal effects and competence of the participants. Management plays a key role here and this is expanded upon in Chapter 12.

A general strategy is presented in Tables 1.3 - 1.5, for deducing the most appropriate control measures and bases for developing Guidelines and for reducing risks in water recreation. Different forms of recreation involve standards of different degrees of water contact and exposure to the various hazard forms. For each recreation, more than one hazard will be encountered, but the list of hazards for each sport will differ. Measures for risk reduction will therefore be tailor -made to each form of recreation and to particular circumstances. Because of this complexity, detailed examples of hazards and their associations with particular forms of recreation will be considered in later chapters.

1.6.1 Presentation of risk reduction strategies

The overall basis for such a risk reduction strategy depends on broad classifications of recreational activities, according to the degree of contact with water (Tables 1.3 - 1.5). This is because water contact is the prime factor influencing the hazard types likely to be encountered excepting drowning. The degree of water contact directly influences the degree of contact with infectious disease some physical hazards and toxic agents found in contaminated water and therefore the likelihood of contracting illness and the symptom severity. Definitions of water contact classes (NTAC, 1968) and of illnesses are given in these tables, which are based upon recommendations used elsewhere (e.g. Pike and Gale, 1992).

These tables are largely self-explanatory. It may be noted in Table 1.5 that the participants in the whole -body contact sports of sub-aqua diving, surfing, water skiing, white-water canoeing, rafting and windsurfing, normally wear wet suits or other appropriate protective clothing, which limit skin exposure to the agents of leptospirosis, and to venomous animal stings, as well as to chilling and ultraviolet radiation, but may aggravate symptoms caused by contact with toxic cyanobacteria under some circumstances. The wearing of hard hats and buoyancy jackets in sailing and canoe touring (Table 1.5) as protection against head injuries and drowning, respectively.

Table 1.3 Strategies for reducing risks from hazards in non-contact recreation

Definition of non-contact recreation, With examples (and main hazards ¹)	Hazards	Appropriate risk-reduction measures
Those in which there is normally no contact with water, but where water is incidental enjoyment of the activity		Guidelines and standards for ecological and biological quality to protect fish, other aquatic life and vegetation. Regular environmental assessments of stretches of water, improving facilities, publicity. Personal awareness and action.
Angling (1,2,4,6) Boating under power (1,2,4) Picnics (1,2,4) Walking (1,4) Sun-bathing (3) Bird-watching (2,4)	1. Falling-in, drowning 2. Leptospirosis (freshwater) 3. Sunburn, erythema, sunstroke, skin cancer 4. Aesthetic revulsion from fish deaths, anaerobic conditions, oil and other visible pollution 5. Bites from mosquitoes and other vectors 6. Infection following skin injury and repeated exposure to water	1. Where appropriate: safety rails, lifebelts, warning notices, broadcast gale warnings, education. Personal care. 2. Bankside management to control rodents, litter collection. Treat and cover cuts and abrasions. Seek medical advice if influenza -like symptoms are noticed a few days after recreation 3. Local publicity. Apply sunscreen or sunblock, limit exposure. 4. Control and licensing of discharges from sewage works, industry, storm-sewer outfalls, agriculture, landfills and from craft 5 Health warnings to travellers, anti -malarial therapy, avoidance of infested regions. 6. Exercising care; covering all injuries with waterproof dressings

KEY ¹ Numbers in brackets refer to numbered hazards (column 2) and appropriate risk-reduction measures (column 3)

Table 1.4 Strategies for reducing risks from hazards in incidental-contact recreation

Definition of incidental-contact recreation, With examples (and main hazards¹)	Hazards	Appropriate risk-reduction measures
Those in which only the limbs are regularly wetted and in which greater contact is unusual		Guidelines and standards for ecological and biological quality. Regular environmental assessments. Advice to sports clubs and public. Personal awareness
Rowing, sailing, canoe touring (1,2,3,5) Paddling, adults (1-8) for young children, see Table 2.5	1. Falling-in, drowning . 2. Leptospirosis (fresh-water) 3. Cyanobacterial toxicoses (fresh-water) 4. Injury; treading on broken glass or jagged metal waste 5. Sunburn, sunstroke, skin cancer 6. Stings of weaver fish (seashore) 7. Swimmer's itch (schistosomiasis, fresh-water ponds) 8. Infection from beach sand through skin abrasion	1. See Table 1.3 2. See Table 1.3 3. Control of eutrophication, monitoring of cyanobacterial populations, curtailing recreation during blooms. Local publicity. Personal awareness: reporting blooms, avoiding contact, washing -down body and equipment after exercise 4. Litter control, cleansing beach. Putting rubbish in bins or taking it away 5. See Table 1.3 6. Local awareness of a rare problem 7. Control weeds and aquatic snails. Avoid warm, snail-infested ponds 8. Exercising care, covering all injuries with waterproof dressing

Key. ¹.Numbers in brackets refer to numbered hazards (column 2) and appropriate risk-reduction measures (column 3)

Table 1.5 Strategies for reducing risks from hazards in whole-body contact recreation

Definition of whole-body contact recreation, with examples (and main hazards ¹)	Hazards	Appropriate risk-reduction measures
Those in which the whole body, or the face and trunk are frequently immersed, or the face frequently wetted by spray and where it is likely that water will be swallowed		Guidelines and standards for microbiological, biological and ecological quality. Regular environmental assessments. Improvements to facilities. Advice to sports clubs and public, publishing results of microbiological monitoring. Personal awareness, competence and use of protective gear where appropriate
Sub-aqua diving (1 - 8, 10) Long-distance swimming (1 - 7, 9, 10, 12) Surfing (1 - 3, 6, 7, 10, 12) Water skiing (1 - 10, 12) White-water canoeing (1 - 3, 6 - 8) Rafting (1 - 3, 6 - 8)) Bathing (1 - 12) Windsurfing (sailboarding)(1 - 8, 10, 12) Children's exploratory and predatory Activities (1 - 9, 11, 12) Paddling by young children (1 - 5, 7, 9,11, 12)	1. Drowning 2. Waterborne infections ² 3. Water-washed infections ³ 4. Leptospirosis (fresh-water) 5. Cyanobacterial toxicoses (fresh- water)	1. See Table 1.4 2. Microbiological standards. Licensing, control and treatment of discharges of sewage, effluents, storm sewage and slurries. Improvements where indicated by unsatisfactory microbiological quality. Personal awareness of local conditions 3. Only measures which reduce water contact, although these may reduce enjoyment 4. See Table 1.4 5. See Table 1.4

Table 1.5 (continued) Strategies for reducing risks from hazards in whole-body contact recreation

Definition of whole-body contact recreation, with examples (and main hazards ¹)	Hazards	Appropriate risk-reduction measures
For examples, see previous page	6. Impact injury 7. Injury; treading on broken glass or jagged metal waste 8. Collision with, entrapment by wrecks, piers, weirs, sluices and underwater obstructions 9. Stings of weaver fish (sea-shore), jellyfish, sting rays 10. Attack by marine animals (sharks, conger and Moray eels, seals) 11. Swimmers' itch (schistosomiasis, fresh-water) 12. Sunburn, sunstroke, skin cancer	6. Notices indicating hazards. Personal awareness and avoidance, wearing head and body protection, where appropriate 7. Litter control, cleansing beach. Putting rubbish in bins or taking it away 8. Notices to mariners, marker buoys, posting warnings. Personal awareness 9. Local awareness of a rare problem 10. Posting warnings. Personal awareness and avoidance 11. See Table 1.3 12. See Table 1.3

Key. ¹ Numbers in brackets refer to numbered hazards (column 2) and appropriate risk-reduction measures (column 3)

² Infections caused by pathogens derived from faecal pollution (typhoid and paratyphoid fevers, shigellosis, infectious hepatitis, pharyngo-conjunctival fever, gastro-enteritis, cryptosporidiosis).

³ Infections caused by water interfering with the body's natural defences and washing opportunist pathogens from the skin and other body surfaces on to sensitive sites. Examples are outer ear canal infection (*otitis externa*), conjunctivitis, some fungal and other skin infections

1.7 Management Action

1.7.1 Integrated coastal management

Integrated coastal management (ICM) and integrated basin management (IBM) are usually initiated in any country that has problems with one or more of the following: fisheries, recreation / tourism, hazards, and mangrove depletion. Therefore coastal hazards are but one of a wide range of issues, interests and constraints that affect planning and management of coastal areas. Decisions relating to management of coastal hazards should be made with reference to all relevant Government policies and other factors that affect coastal amenity and use. Social, economic, aesthetic, recreational and ecological factors all need to be considered. Successful ICM also requires *“integration over time, with immediate day-to-day management objectives being co-ordinated and consistent with long-term national and international policy goals”* (OECD, 1993, p.16). It focuses on the interaction between various activities/resource demands carried out within the coastal zone as distinct from other regions.

Management should be co-ordinated to reconcile different, sometimes conflicting outputs:

- management of land resources for urban, industrial, mining, tourism and conservation activities
- management of coastal waters for recreation, aquaculture, conservation, transport and mining
- management of living marine resources
- provision of coastal defences.

ICM and IBM provide umbrellas for co-ordination among these areas of intervention covering the economic, abiotic/biotic and social systems. The term ICM is used rather than Integrated Coastal Zone Management as this was one of the key recommendations of the 1996 Xiamen workshop on this topic (Sorensen, 1997). It should be noted that current ICM thinking encapsulates both coastal and river catchments.

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

- Regulatory compliance
- Public awareness and information
- Control and abatement technology and
- Public health advice and intervention

The scheme shown in Figure 1.4 has general applicability and can be applied to all areas covered by the various chapters and can be applied throughout the Guidelines to the various different types of hazards discussed.

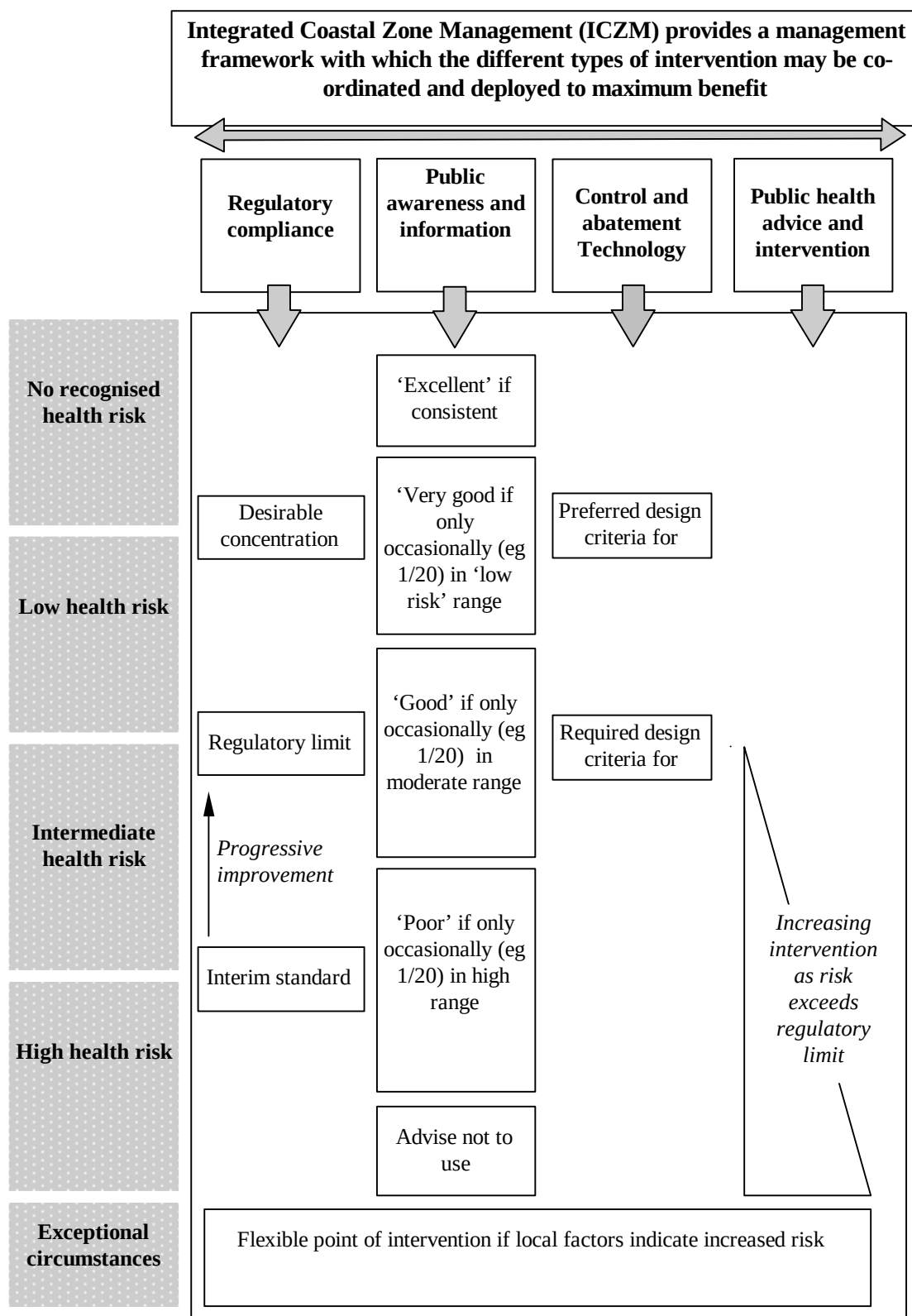


Figure 1.4 Management framework and types of intervention in relation to different types and degrees of hazard

1.7.2 Regulatory compliance

‘Watchdog’ Institutions responsible for the programmed process of sampling, measurement and subsequent recording of various characteristics (e.g. Governmental Environmental Agencies/ Local Authorities, with analysis being carried out by hospitals, public health or university laboratories) should assess conformity of recreational waters and use areas to local or national standards. In those countries where it is difficult to achieve the guideline objectives, central and local governments may set interim standards to ensure a progressive improvement toward the regulatory limits and possibly the desirable conditions.

Standard setting, monitoring and enforcement are discussed in further detail in section 12.6.

1.7.3 Public awareness and support for informed personal choice

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

This theme is discussed in more detail in section 12.2.

1.7.4 Control and abatement technology

As the increase in health risks in certain environments is recorded, institutions responsible (e.g. water companies) should identify the causes and put in place measures to combat the risks. At this stage remedial technologies should be identified. For example, the control and abatement of pollution discharges with respect to the various levels of sewage treatment that may be carried out; fencing of dangerous areas, provision of lifeguards, etc.

1.7.5 Public health advice and intervention

When a guideline value is exceeded, the authority responsible for public health should determine if immediate action should be taken to reduce exposure to the hazard and also determine whether measures should be put in place to prevent or reduce exposures under similar conditions in the future.

Available evidence suggests that many hazards associated with recreational use of the water environment are of an instantaneous or short-term nature. In the case of accidents, drowning has been associated with offshore winds carrying inflated toys and buoyancy aids away from the coast. In the case of water quality, certain beaches or areas are known to register increased pollution under certain conditions - chapters 4 - 8. Such conditions may relate to tide, wind direction or rainfall for example. In eutrophic freshwater, wind may be associated with the accumulation of cyanobacterial ‘scums’ in some areas, present a special hazard to children who may be tempted to play in the scum material. Whenever such conditions occur and constitute a risk to public health, short-term advisory notices may be considered necessary and the decision to place such notices should be based upon public health considerations.

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Preface

WHO has been concerned with health aspects of the management of water resources for many years and publishes various documents concerning the safety and importance for health of the water environment. These include a number of 'Guidelines' 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 amongst experts on the risk to health represented by various media and activities and are based upon a critical view of the available evidence. Wherever possible and appropriate such Guidelines also describe the principal characteristics of the monitoring and assessment of the safety of the medium concerned and describe 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.

It is proposed to publish the *Guidelines for Safe Recreational-water Environments* 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 the 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 water recreational 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 through 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 being progressively made available in the form of drafts for consultation. 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:

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In preparation of the contents of individual chapters, there was found to be limited information to support critical health risk assessment in certain areas. Most conspicuously, very limited literature concerning accidents and accident causation was recovered and this significantly constrained the development of the corresponding chapter (Chapter 2: Beach Safety, Accidents and Physical Hazards). Two chapters concern aspects which are typically of locally-specific character (Chapter 9: Chemical and Physical Aspects of Water Quality) and Chapter 10 (Dangerous Aquatic Organisms) and these are addressed in less detail than other chapters.

The scale and nature of health effects arising from aquatic activities as well as other sports and recreation is uncertain mainly because of the lack of a co-ordinated approach to data collection.

In addition to the above volumes of the *Guidelines for Safe Recreational-water Environments* a manual on monitoring and assessment of coastal and fresh-waters “Monitoring Bathing Waters” (Bartram and Rees, 1999), published 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 emphasises the need to utilise 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. It includes a code of good practice for monitoring and assessment of recreational water environments to assist countries in developing such codes for national use and to promote international harmonisation.

In developing the health risk assessments for coastal and freshwater and for swimming pools, spas and similar recreational-water environments it was found necessary to prepare reviews of the significance of the presence of various specific micro-organisms. These reviews represent a valuable reference source for those concerned with the control of risks to public health and in particular in the interpretation of the hazards presented by the occurrence of specific agents. For these reasons these review documents will be published separately.

The preparation of these Guidelines would not have been possible without the generous support of the following which is gratefully acknowledged: The European Commission; The States of Jersey, United Kingdom; The Ministry of Health of Germany;

The Ministry of Environment of Germany; and The Ministry of Health of Italy.

The preparation of the *Guidelines for Safe Recreational-water Environments* covered a period of five years and involved the participation of numerous institutions, more than 45 experts from 16 countries world-wide, further reviewers and six meetings of experts and for co-ordination. The work of the individuals concerned, whose names appear in Annex 1, was central to the completion of the work and is much appreciated.

Each principal area of work in the development of the Draft for Consultation was the responsibility of a co-ordinator or co-ordinators. Each section or chapter was prepared by one or more experts or developed from contributions received, subject to peer review, reviewed by an expert meeting and revised in light of the recommendations of that meeting by selected experts.

During the development of the draft materials careful consideration was given to previous assessments and in particular the work of the Mediterranean Action Plan; the Black Sea Environmental Programme; the activities undertaken by and for the European Commission; and the Environmental Health Criteria Documents of the International Programme on Chemical Safety.

Chapter 7: 'Freshwater Algae and Cyanobacteria' is based upon the "Toxic Cyanobacteria in Water" (Chorus and Bartram, 1999), published by E & FN Spon on behalf of WHO. Toxic Cyanobacteria in Water was prepared by an international group of experts whose contributions are gratefully acknowledged.

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. The Organization would be pleased to learn of major related developments and will endeavour to ensure the continued validity of the Guidelines through issuing of addenda or further editions as appropriate.

Other activities concerned with the relationship of recreational water use and health are also in development. A newsletter 'current waves' on the theme is published twice yearly in English in co-operation with the Robens Centre for Public and Environmental Health, WHO Collaborating Centre for the Protection of Water Quality and Human Health. A sister publication in Italian is also in development. In order to subscribe to either of these please contact the addresses below.

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CHAPTER 2

BEACH SAFETY, ACCIDENTS AND PHYSICAL HAZARDS

The assessment of hazards should take into account the severity and likelihood of health outcomes and the extent and density of use of the recreational area. Health risks that might be acceptable for an infrequently used and undeveloped recreational area may result in immediate remedial measures at other areas that are widely used or highly developed.

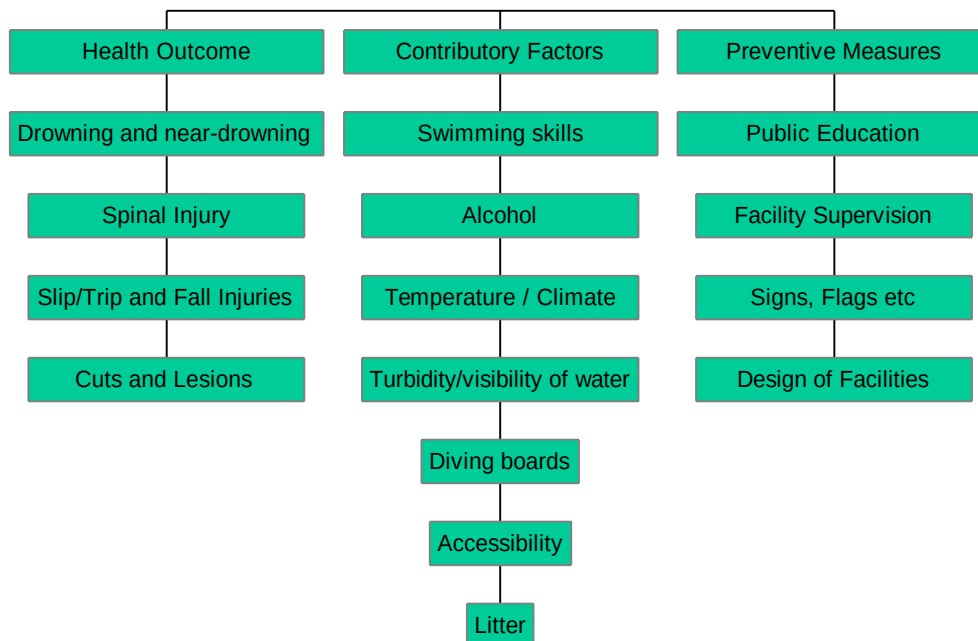
2.1 Health Outcomes

A variety of health risks and adverse outcomes may arise from the interrelationship of different contributory factors and preventive measures (figure 2.1). The most prominent health outcomes resulting from recreational use of water are:

- Drowning and near-drowning.
- Major impact injuries (including spinal injuries resulting in various degrees of para and quadriplegia; head injuries resulting in concussion, brain injury and loss of memory and motor skills; and back injuries resulting in limited mobility).
- Slip/trip/fall injuries (including bone fracture/breaks resulting in temporary or permanent disability; facial injuries resulting in nose and jaw dislocations and scarring; abrasions).
- Cuts, lesions and punctures.
- Retinal dislocation resulting in near blindness or blindness.

Information concerning adverse health outcomes; their association with causal and contributory factors; concerning the occurrence of these risk factors and concerning the efficiency and deployment of preventive measures provides a basis for the protection of public health and of recreational water user populations.

Figure 2.1 Examples of health outcomes, contributory factors and preventative measures associated with the use of recreational water use environments



2.1.1 Drowning and near drowning

Drowning and near drowning are important health issues and merit special consideration in the development and management of water recreational facilities.

Information concerning drowning and other accidents is not systematically collected in all countries. Data concerning deaths through drowning are available from the WHO mortality database but in general accidents related to bathing waters and recreational activities are not separately recorded (WHO, 1996). Drowning typically accounts for a small but significant percentage of accidental deaths (eg 2 per cent in Denmark, Steensberg, 1998) and overall incidence rates for death by drowning (all causes) have been estimated around 6 per 100,000 by several authors (eg Plueckhahn, 1979; Quan *et al*, 1989). In terms of all accidental deaths in the WHO European Region, drowning accounts for less than 10 per cent of the 280,000 deaths due to accidents (WHO, 1996). Drowning statistics typically include suicides; domestic drownings (eg in bath tubs by both adults and children and accidental drownings of infants); as well as drowning following immersion during occupational and recreational activity (the latter in both swimming pools and natural waters).

Most studies of accidental drowning have concentrated on children and in some countries drowning is the leading cause of injury deaths amongst lower age groups (see for example Smith, 1995).

In cooler climates especially, the cause of death may be either drowning or immersion cooling, although the two may be poorly differentiated and the difference is of limited significance for preventive measures. The importance of cooling is discussed in chapter 3.

Contributory factors

Data suggest that males are more likely to drown than females and this is generally associated with higher exposure to the aquatic environment (through both occupational and recreational uses) and consumption of alcohol (leading to decrease ability to cope, impaired judgment and greater bravado) (Mackie 1978; Plueckhahn, 1979; Plueckhahn, 1984; Quan *et al* 1989; Nichter and Everett, 1989; Detz and Baker, 1994 Howland *et al* 1996). In many countries drownings are significantly associated with alcohol consumption and this is one of the most frequently reported contributory factors associated with the greatest proportion of drownings.

Amongst children, lapses in parental supervision are the most frequently cited contributory factor in drownings and near drownings (see for example Quan *et al* 1989).

Drowning and near drowning may be associated with recreational water uses with low water contact. Recreational use of water craft (yachts, boats, canoes) and fishing (both from water craft and waters edge or solid structures) have been associated with drownings (Plueckahn, 1972; Nichter and Everett, 1989; Steensberg 1998). Such recreational water uses may occur during cold weather and immersion cooling may therefore be a significant contributory factor (see chapter 3). Non-use of life jackets even when readily available is frequently cited as a significant contributory factor in these cases (Plueckhahn, 1979; Patetta and Biddinger, 1988; Steensberg 1998)

Several commentators have noted disproportionate numbers of recreation-associated drownings in either fresh (Plueckhahn 1979; Spyker, 1985; Quan *et al*, 1989) or coastal/marine (Nichter and Everett, 1989) waters. In the absence of information on relative frequency of use, data on association are difficult to evaluate and the findings specific to locality. Informal peer supervision in more densely used areas and the desire for

greater seclusion may be significant factors. Private pools (including ornamental, swimming and paddling pools), contribute significantly to drowning statistics, especially in children but are not addressed in this volume.

The availability of cardio-pulmonary resuscitation (CPR) (including infant and child CPR) skills (Patetta and Biddinger, 1988; Orłowski, 1989; Liller *et al*, 1993) and of rescue skills amongst witnesses (Patetta and Biddinger, 1988) have been reported to be important in determining the outcome of accidental immersions.

Whilst a high proportion of persons drowning are non-swimmers, (eg two thirds - Spyker, 1985), the role of swimming skills in preventing drowning and near drowning is unclear (Patetta and Biddinger 1988, Asher *et al* 1995). In one study in North Carolina, USA, the activities most frequently associated with drownings were (in descending order) swimming, wading and fishing (Patetta and Biddinger, 1988).

Attempted rescue represents a significant risk to the rescuer. For example one study in North Carolina, USA reported the death by drowning of the would-be rescuer in a significant number of cases (Patetta and Biddinger, 1988).

'Breath-hold diving' has been associated with a number of drownings amongst individuals with excellent swimming skills and has an explicable biological causation (Craig, 1976; Spyker 1985).

For both drowning and near-drowning pre-existing diseases are associated risk factors and higher rates of drowning are reported amongst those with seizure disorders (Greensher, 1984; CDC, 1986; Patetta and Biddinger, 1988) as are pediatric seizures (Quan *et al* 1989).

Further documented contributory factors in drownings include water depth and poor water clarity (Quan *et al* 1989).

Preventive and management actions

Most drownings occur in non-swimmers and the value of swimming lessons as a preventive measure appears easy to support. There is significant debate regarding the age at which swimming skills may be safely acquired. Whilst evidence does not suggest that water safety instruction increases young children's risk of drowning, their increased skills do not decrease the need for adult supervision and the impact of training on decreasing parental vigilance has not been assessed (Asher *et al* 1995).

Both drowning and near drowning have been associated with many contributory factors (see for example Poyning, 1979 and above discussion). The principal contributory factors and preventive and management actions for drowning and near drowning are similar and are summarised in Table 2.1.

Table 2.1 Drowning and near-drowning contributory factors and principal preventive and management actions

Contributory factors	Principal preventive and management actions
Alcohol consumption	Continual adult supervision (infants)
Cold	Provision of lifeguards
Sea current (including tides, undertow and rate of flow)	Provision of rescue services (lifeboats)
Offshore winds (especially with flotation devices)	Access to emergency response (eg telephones with emergency numbers)
Ice cover	Local hazard warning notices
Pre-existing disease	Availability of resuscitation skills/facilities
Underwater entanglement	Development of general public (user) awareness of hazards and safe behaviours
Bottom surface gradient and stability	Development of rescue and resuscitation skills amongst general public and user groups
Waves (coastal, boat, chop)	Coordination with user group associations concerning hazard awareness and safe behaviours
Water transparency	
Impeded visibility (including coastal configuration, structures and overcrowding)	Wearing of lifejackets when boating
(In most countries males and infants constitute a disproportionate number of drownings)	

Near drowning

The availability of information concerning near-drowning is weaker than that for drowning and it is likely that there is a significant under-reporting. Several studies indicate that near drownings and immersion accidents requiring hospitalisation or emergency treatment outnumber drownings *per se* by a significant factor (see for example Spyker, 1985; Liller *et al*, 1993).

The possibility of surviving submersion injuries in cold water (eg less than 21C) is significant and children and adults have been submerged for significant periods (eg up to 40 minutes) with normal neurologic recovery (Spyker, 1985).

The recovery rate from near drowning may be lower amongst young children than amongst teenagers and adults and a proportion of survivors suffer subsequent anoxic encephalopathy (Pearn *et al*, 1976; Petersen, 1977; Pearn, 1977; Patrick *et al* 1979) leading to long-term neurologic deficits (Quan *et al* 1989).

Clinical studies of 'near drowning' show that the prognosis depends more on the effectiveness of the initial rescue and resuscitation than on the quality of subsequent hospital care, particularly when immersion occurs in freshwater (Plueckahn, 1979).

2.1.2 Spinal injury

Data concerning the number of spinal injuries sustained as a result of swimming or water recreation accidents is not widely available or systematically collected. Few estimates of incidence and prevalence are available. Stover and Fine (1987) estimated the total prevalence of spinal cord injury in the USA to be around 906 per million with an annual rate of incidence of around 30 new spinal cord injuries per million persons at risk.

Blanksby *et al* (1997) have tabulated data from a series of studies regarding diving accidents as the cause of acute spinal injury in various regions of the world. In one study (Steinbruck and Paeslack, 1980) 212 of 2587 spinal cord injuries were caused by sports or diving accidents, amongst which 139 were associated with water sports, the majority (62 per cent) with diving. Diving accidents were found to be responsible for 3.8 to 14 per cent of traumatic spinal cord injuries in a comparison of French, Australian, English and American studies (Minaire *et al*, 1979); and for from 2.3 per cent (in a South African study) to 21 per cent (in Poland) in the review article of Blanksby *et al* (1997).

It has been suggested that the number of recreation related spinal cord injuries is likely to increase as increased recreational use is made of the water environment because of population growth, greater affluence and potentially global climate change.

In diving accidents of all types, injuries are almost exclusively located in the cervical vertebrae (Minaire *et al*, 1979; Blanksby *et al*, 1997). Statistics such as those cited above therefore underestimate the importance of these injuries which typically cause quadriplegia or (less commonly) paraplegia. Thus in Australia for example diving accidents account for approximately 20 per cent of all cases of quadriplegia (Hill, 1984). The financial cost of these injuries to society is high because of those affected are frequently healthy younger persons - principally males under 25 years (data on sex and age of diving related spinal injuries in various parts of the world are reviewed in Blanksby *et al* 1997).

Contributory factors

Data from the USA suggest that diving into a wave at a beach and striking the bottom was the most common cause of spinal injury, whilst 10 per cent occurred when the injured person dived into water of known or unknown depth, particularly from high platforms, including trees, balconies and other structures.

Alcohol consumption may contribute significantly to the frequency of injury through diminished awareness and information processing (Blanksby *et al* 1997) and is frequently cited in studies.

Special dives such as the swan or swallow dive are particularly dangerous because the arms are not outstretched above the head but to the side. Entering the water with arms by the sides is also especially hazardous for the same reason (Steinbruck and Paeslack, 1980).

Minimum depths for safe diving are greater than frequently perceived but the role played by water depth has not been conclusively ascertained. Technique and education appear to be important in injury prevention (Perrine *et al*, 1994; Blanksby *et al* 1997) and inexperienced or unskilled swimmers require greater depths for safe diving. The velocities reached from ordinary dives are such that sight of the bottom even in clear water may provide an inadequate time for deceleration response (Yanai and Hay, 1995). Most diving injuries occur in relatively shallow water (1.5m or less) and few in very shallow water (eg less than 0.6m) where the hazard may be more obvious (Gabrielsen, 1988; Branche *et al*, 1991).

Familiarity with the water body is not necessarily protective and in a study from South Africa (Mennen, 1981) it was noted that the typical injurious dive is into a water body known to the individual.

Data from the Czech Republic suggest that spinal injuries are more frequently sustained in open freshwater bathing areas than in supervised swimming areas; although the number of injuries sustained in freshwater areas in this country appears to be declining (EEA/WHO, 1999).

There is no evidence that impact upon the water surface gives rise to serious (spinal) injury (Steinbruck and Paeslack, 1980; and Schneider regarding cliff diving in Acapulco, cited in *op cit*).

A proportion of spinal injuries will lead to death by drowning. Whilst data on this are scarce it does not appear to be common (see for example EEA/WHO 1999 regarding Portugal). In other cases the act of rescue from drowning may give rise to spinal cord trauma after the initial impact (Mennen, 1981; Bankesby *et al*, 1997).

Preventive and management actions

The principal contributory factors and preventive and management actions for spinal cord injury are summarised in Table 2.2. Evidence suggests that preventive programmes can be effective. In Ontario for example, water related injuries were found to be the leading cause of serious injuries in 1989 and preventive programmes established by Sportsmart Canada and widespread education the incidence decreased to 27.5 per cent in 1991 - 1992 (Tabor *et al*, 1993). Because of the young age of many injured persons awareness raising and education regarding safe behaviours is required early in life. Many countries have school age swimming instruction which may inadequately stress safe diving and which may provide a forum for increased public safety (Damjan and Turk, 1995). Education and awareness-raising appear to offer most potential for diving injury prevention, in part because people have been found to take little notice of signs and regulations (Hill, 1984).

Table 2.2 Major impact injuries: contributory factors and principal management actions

Contributory factors	Principal preventive and management actions
Diving	Local hazard warnings
• into a wave	General public (user) awareness of hazards and safe behaviours
• into water on unknown depth	Early education in diving hazards and safe behaviours
Bottom surface type	Use separation/segregation
Water depth	Lifeguard supervision
Conflicting uses in one area	Emergency services, access
Jumping into water from trees/balconies/structures	
Underwater visibility	

2.1.3 Impact, slip trip and fall injuries

Concussions, brain injury and skull scalp abrasions have occurred through beach and aquatic recreational activities such as diving into shallow water.

Injuries to the nose and jaw areas have occurred when underwater swimming, shallow diving and hitting objects such as walls and piers. These and other injuries have been reported as a result of slipping, tripping or falling whilst entering or leaving the water.

Accidents involving limb fractures or breaks of different types have many causes and may occur in a variety of settings in or around water.

Table 2.3: Slip/trip/fall and minor impact injuries contributory factors and principal management actions

Contributory factors	Principal preventive and management actions
Diving into shallow water	General user awareness of hazards and safe behaviours
Underwater objects (walls, piers)	Appropriate surface type selection
Underwater visibility	Adjacent fencing (eg of docks and piers)
Adjacent surface type (eg of water fronts and jetties)	

2.1.4 Cuts lesions and punctures

There are many reports of injuries sustained as a result of stepping on glass, broken bottles and cans. Discarded syringes and hypodermic needles may present more serious risks (Philipp *et al.*, 1995). The use of footwear on beaches should be encouraged as well as adequate litter bins and cleaning operations. Education policies to encourage users to take their litter home are a key remedial measure.

Table 2.4 Cuts lesions and punctures – contributory factors and principal management actions

Contributory factors	Principal preventive and management actions
Presence of broken glass, bottles, cans, medical wastes	Beach cleaning
Walking and entering water barefoot	Solid waste management
	Provision of litter bins
	General public awareness and safe behaviours
	General public awareness regarding litter control
	Local first aid availability

2.1.5 Retinal dislocation

Sidewall impact by the head, diving and jumping into the water from height have been known to cause retina detachment.

Table 2.5 Retinal dislocation - contributory factors and principal management actions

Contributory factors	Principal preventive and management actions
Jumping into water from height	General public awareness of safe behaviours
‘Bombing’ (jumping onto other water users)	
Diving into water	

2.2 Interventions and Control Measures

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 taken to

prevent or reduce human exposure. Physical hazards that cannot be completely dealt with in this way should be the subject of additional preventative or remedial measures. For example, open or rough water, rough wave, riptides, and bottom debris could all be the subject of general education, general warning notices or special warnings at times of increased risk.

The term hazard is generally used in relation to the capacity of a substance or event to adversely affect human health. In this context, the absence of appropriate control measures may be treated as a component of the chain of causation. For example, the lack of guards, rescue equipment, signs and other remedial actions can contribute to a variety of health outcomes.

Very limited evidence is available regarding the effectiveness of control measures in preventing injury. Furthermore, the effectiveness of many interventions inter-relates to others and with socio-cultural factors. In addition, the most appropriate interventions will be influenced significantly by factors such as cost and extent of use of the area concerned. Measures may be significantly influenced by whether users are principally from the local community or are generally unfamiliar with the location.

2.2.1 Public information and warnings

Signs

Signs are a method of warning the public as to those activities and other concerns that are hazardous or dangerous. Signs may be inexpensive and easy to install and are generally applicable to all water recreation areas and levels. Signs are best deployed to reinforce previous awareness-raising and education. Limited evidence suggests that signs alone may be un-noticed or have very limited impacts upon behaviour (Hill, 1984; Goldhaber and de Turck, 1988).

If swimming or bathing is prohibited or advised against, then signs should be placed at the key access points and along the area with the harmful conditions and resultant harm noted. Signs other hazards and information:

- “Hours of guard operation” posted at the beachfront indicates the hours within which lifeguard duty operates.
- Different prohibitions with descriptive words or statements.
- Water temperature, tide times, wave action, current, riptides, or other water actions, displayed to alert the water user to specific local hazards.
- Potentially hazardous organisms - sharks, sting-rays, jellyfish, seaweed if of local concern.
- Examples of various rescue methods and the code for emergency signals posted so that the public can be alerted along with emergency procedures.

On rural beaches it has been suggested that safety boards be displayed at all principal access points to beaches, in car parks (if present) along perimeter roads and at particular hazard spots. Information provided may include the hazards of the particular location, the times of high and low water, the distance of the nearest telephone and the more useful numbers, the location of the nearest first aid facilities.

Flags

Flags provide an alternative or supplement to signs to give information. It is essential that the meaning of the different coloured flags is clear and this is preserved on

signboards erected at the beach access and the base of the flagpoles themselves. However, care must be taken with flag as there is little international agreement.

Flags can be used for other information and for separation of activity. Flags may be customised to indicate, for example, “patrolled bathing area”, “surfing only areas”, etc..

Education

Information for the public should be distributed to encourage recreational activities on beaches, healthy behaviour while there, efforts to protect children against physical hazards such as broken bottles and metal objects by the wearing of footwear on suspect beaches, and advice about improving services such as the provision of more litter bins and their frequent emptying, and requests for the public to use the litter bins or take their litter home (Philipp *et al.*, 1997).

Swimming clubs, voluntary lifesaving groups, can play an important part in this process. Education policies to raise awareness of physical hazards are also an essential element of management of recreational water use areas. The provision of information becomes more important where less can be done to reduce the risk through other measures. Water safety strategies should be aware of the vulnerability of groups suffering from medical problems and these groups should be given special attention.

2.2.2 Lifeguarding

Data regarding the effectiveness of lifeguard supervision in preventing drownings are equivocal. In Australia in the 1970s for example less than 10 per cent of fatal immersions occurred at marine beaches and virtually none when lifeguard supervision was operating (Plueckhahn, 1979; Mackie 1979). However in other environments the effectiveness of lifeguarding supervision in preventing drowning and near drowning has been questioned for swimming pools (see for example Quan *et al.*, 1989) and limited data concerning freshwater or marine sites are available. The logical conclusion is that much depends on the quality of lifeguarding and attention needs to be paid to ensuring effectiveness. The low frequency of submersion injury hampers the study of prevention activities. In one study based upon voluntary reporting by lifeguards, 42 ‘assists’ were reported, only four of which required medical assistance and transport, suggesting a ratio of roughly ten interventions for each submersion injury. In contrast to the high proportion of males in actual submersion injuries, males and females were similarly represented in ‘assists’ (Spyker, 1985).

Provision of lifeguards is a highly-visible measure which may contribute to safety in various ways – by directly assisting in prevention of drowning (rescue, resuscitation); injury prevention (e.g., advising users not to enter dangerous areas); and a more general educational role (which may include water quality hazards and heat/cold/sunlight for example). As with other areas of control measures and interventions, very limited information is available regarding the effectiveness of lifeguard provision in practice.

Lifeguarding Tower or Post

Lifeguard towers should be placed to allow observation of the area or span of control. Where resources allow, it has been suggested that lifeguards should only be deployed singly when radio contact can provide back up.

Lifeguard chairs should be located at a point where their vision is not impaired. The beach frontage line and, therefore, the direction of the chair should be oriented to insure

minimum solar glare as the lifeguards view the water. Wind, wave action and other factors should be considered.

At ocean recreation areas, the towers should be placed as close to the water edge as practical at high tide and may be moved at intervals with the changing tide, so that they will be a minimum distance away from the water edge at all tidal stages. Where a beach is divided by a jetty or other obstacle to clear observation, each part should ideally be independently observed.

A floating Guard Station, consisting of a platform or flat bottom boat moored is sometimes used as incidents may occur offshore.

Various equipment can help lifeguards in their duties. According to local priorities these may include, for example: rescue equipment box (with such items as: "Shepherds crook", ring buoy and lifeline, dragline, torpedo); first aid equipment (such as: resuscitation kit, sting kits, abrasion and cut kit, oxygen, hot pack, cold pack, splint, sand bags, stretcher); telephone or radio for communication; miscellaneous equipment box (containing items such as binoculars, lifeguard manual, beach operations manual, incident reports, accident reports, water quality test kit); maintenance box (containing barrier booms and barrier nets for debris and protection, floating protective lines, buoys and symbols); rescue craft.

All equipment should be inspected throughout the year and replaced or repaired as necessary.

Lifeguard Qualification

Lifeguards should generally have special and general training and suitable qualification. They are generally responsible for observation of the beach to anticipate problems and identify an emergency quickly, carry out rescues and give immediate first aid, communicate with swimmers and beach users, enforce bylaws where appropriate, promote awareness of specific and general hazards and for incident reporting.

Lifeguards should hold a current qualification from an appropriate and recognised training and assessment agent (e.g. competent in lifesaving methods, capable in swimming, competent in methods of artificial resuscitation). Re-qualification should be undertaken at intervals such as every two years, although practical rescue and resuscitation skills should be practised frequently. Both fitness and technical knowledge tests should be required. Physical competence should be stipulated as part of the contract of employment. Good practice would generally require that records be kept of all training and qualifications and be available for inspection.

Lifeguards should have locally-specific knowledge concerning the presence of natural and man-made features, the topography of the beach area, tides and currents, the distance to qualified medical assistance, hazards and risks, public relations and crowd management and the implementation of "Normal Operational Policy" (NOP) and Emergency Action Plans (EAP) where these exist.

Lifeguard Policies

It has been suggested that a normal operation procedure (NOP) addressing accident prevention strategy should be established and made available. NOP should clearly state how operation works in terms of safety provisions. It should contain details on the risk assessment, a plan of beach outlining hazards, access points, vantage points and blind spots, information points, zones, positioning of public rescue equipment and protective features, supervision requirements e.g. lifeguard provision, rotating systems, qualification,

surveillance levels and daily routines, the duties of other beach staff, emergency provision, and on NOP effectiveness.

In addition, it has been suggested that an emergency action procedure (EAP) be formulated. The EAP should provide step-by-step procedures for each member of the team in the following areas: rescue management, continuity of supervising during rescue, communication procedure during incident, both within the team and with external agencies, after care, the expected level of performance. Lifeguard levels of performance should be established and incorporated within the NOP/EAP and training programme.

Lifeguard Duty Period

Lifeguards on duty should be easily identified (such as by special uniform, which may be a particular colour - Ideally, lifeguards should be on duty during all bathing hours and sufficient regular breaks should be incorporated. When on duty, lifeguards should not perform other tasks which might detract from supervision.

It has been suggested that if lifeguard service is interrupted then warning signs should be posted and the beginning and end of this period should be communicated with megaphones and signs.

Rescue craft have proven important in offshore rescue of swimmers in difficulty and other recreational uses. Whilst costly they receive a high degree of public support and where available contribute to preventing loss of life and injury. For reasons of cost they are most frequently deployed in areas of dense use or particular hazard. For effective use of rescue craft effective communication linked to rapid deployment is important.

2.2.3 Use separation

The waterfront and bathing area may be use for diverse purposes such as transit (pedestrian, vehicular), sunning, swimming, paddling, watercraft (yachts, powerboats canoes, jetskis) and as a route of access; and the water itself may be used by both swimmers and non- swimmers. As a result of multiple and often dense use, conflicts may emerge and in many cases zoning or other restrictions on certain uses may become necessary.

Use separation is a measure for minimising risk where different user groups coexist within a confined area. Different zones for different activities may include for example swimming, diving, sailboarding, or powerboating, conservation zones and naturalist zones.

Zoning

Zoning limits users to specific areas, i.e. the least hazardous, facilities supervision and separates incompatible activities. In general, non-swimming activities such as boating, water skiing, jet skiing, surfing should not take place in the swimming/bathing area.

Diving is a factor in many cases of spinal injury associated with recreational water use. It is unclear whether the provision of diving areas such as floating diving piers and fixed platforms increases or reduces the health risk.

Lines

Lines, buoys and markers may be useful in limiting the water recreation area and separating different activities. At ocean beaches where tide current and wave action might prohibit such buoys limits, guards may patrol the limits or establish a reference line in the water that should signal alert.

Lines can also be used to prevent swimmers from entering dangerous areas or to warn of changing conditions. At oceanfront recreation areas, when jetties subdivide oceanfront area, a surf line could be set for example at a distance of 30 feet from the jetties. No bathing should be permitted between the jetty and the surf line. Lines could also be set to indicate separation of shallow to deep areas, underwater obstructions, radical changes in slope etc.

The anchoring rope for buoys and markers should not create any risk of entanglement. The buoys are not intended as rest areas.

Designation of Boating areas

Special lanes for boat launching are important to minimise collisions and rough water and waves causing panic. They are generally perpendicular to the shoreline and delimited by floating lines. At the beach side, close to slipways, warning signs and/or buoys should be provided. Boats should launch through this lane at a specific low speed; for example not more than 3 knots. If boating areas are not delimited, all kind of boats (sailcrafts, powercrafts, and jet skis included) an exclusion zone may be defined, for example in the 200m zone. Specific regulations may be identified for the use of surfboards or similar apparatus; for example, these may be banned with a distance of 200 feet of any fishing pier or within 100 feet of any bather.

2.2.4 Infrastructure and planning

Waterfront areas are accessed for a variety of purposes some of which affect safety. Routes used for emergency access for instance during launching of rescue craft or to provide access to ambulances should be suitably maintained and continuous accessibility assured.

Ready access to telephones or other means of communication with emergency services may contribute to speed of rescue or resuscitation. Most telephones are located to be readily accessible and clearly visible, are marked on local maps and numbers of key emergency services posted at them.

In many recreational water use areas certain locations or subareas may present significant continuous hazards to human health, for example due to currents and rocks. Access to such areas may be discouraged or prevented by a combination of one or more of signing, fencing and lifeguard supervision. In some instances caution lines are used to discourage access, intentional or otherwise, by swimmers.

In areas with or without lifeguards, rescue equipment may be provided which is accessible for public use. All such safety equipment should be easily recognisable and kept in good repair. They could for example be placed on stands, so that they are clearly visible from a distance, at a maximum height of 1.7 m above the ground. Public rescue equipment may include ring buoys, life buoys, throw bags/lines, ring buoys/lines; torpedo buoys which should be available with at least 30m of line. Location intervals from 25 to 200 m have been proposed, but should be evaluated according to the response required for a given water recreation area. It is recommended that public rescue equipment be placed throughout the winter.

2.2.5 Beach capacity

It has been suggested that it is desirable for water recreation area to have an estimated load (number of bathers/visitors) that it may carry to prevent overcrowding. Whilst overcrowding may impede effective lifeguarding and therefore contribute to

causation of drowning, in practice this is difficult to enforce and users needs and perceptions vary considerably between areas. Of more importance is the adequate management of the recreational water use area in order to minimise risk.

2.3 Management

2.3.1 Assessing Hazards and Health

The assessment of hazards in a beach or water is critical to ensuring safety. The assessment should take into account several key considerations, which include:

- The presence and nature of natural or artificial hazards.
- The severity of the hazard characteristic as related to health outcomes.
- The availability and applicability of remedial actions.
- The frequency and density of use.
- The level of development.

The potential health outcomes associated with various hazards are summarised in Tables 2.1 - 2.5 and the “severity” of the hazard can be related to the relative risk in Figure 1.3. The severity of the hazard can serve as a tool to initiate further research or investigation into the resolution of the hazard as well as to highlight or emphasise priority protective or remedial management measures.

2.3.2 Inspection Programmes and Protocols

The investigation of hazards in or near present or potential recreation areas, including land and water, natural and man-made, results from a visual inspection procedure. The investigation of physical hazards involves an understanding of the process of causation leading to injury.

The assessment of hazards should take into account the severity and likelihood of health outcomes and the extent and density of use of the recreational area. Health risks that might be acceptable for an infrequently used and undeveloped recreational area may result in immediate remedial measures at other areas that are widely used or highly developed.

Physical hazards vary greatly between sites. Monitoring of a site for existing and new hazards should be undertaken on a regular basis. The inspection and further investigation of hazard require an understanding of the elements involved in such a programme.

The identification of physical hazards and the subsequent monitoring of any changes to the hazard depend upon potential and present water recreation areas and the hazards encountered. The purposes of inspection and investigation are to provide a routine, systematic, periodic and relevant verification of events, structures, conditions or other situations that represent hazards, whether “theoretical” or “actual” and under “real” conditions.

The following steps have been identified to evaluate an inspection process of recreational areas for hazards.

1. Determine what is to be inspected and how frequently.
2. Monitor changing conditions and use patterns with regularity.
3. Establish a regular pattern of inspection.
4. Develop a series of checklists suitable for easy application throughout the system. Checklists should reflect national and local standards where they exist.
5. Establish a method for reporting faulty equipment and maintenance problems.

6. Develop a reporting and monitoring system that will allow easy access to statistics regarding 'when, where, why and how' questions needing answers.
7. Investigate the frequency of positive and negative results of inspections.
8. Motivate and inform employees of the inspection process through in-service training.
9. Use outside experts to critically review the scope, adequacy and methods of the inspection programme.

The frequency of inspection will vary according to density of use and the speed of change in both the hazards encountered and the remedial actions in place at a specific location.

Timing of inspections should take account of periods of maximum use (e.g. inspection in time to take remedial action before major holiday periods) and periods of increased risk.

The frequency of inspection therefore has to be predicted on size of the facility, number of features in the facilities, extent of past incidents or accidents.

The criteria for inspections and investigations may vary from country to country. In some countries there might be legal requirements and/or voluntary standard setting organisations.

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CHAPTER 3

SUN, HEAT AND COLD

Patterns of recreational use of water environment sometimes lead to exposure of individuals to extreme conditions of heat, or cold and prolonged and extreme solar radiation, which may have significant human health effects.

Ultraviolet radiation may damage the skin, the eyes and the immune system. Specific individual and public responses are essential to avoid major damage by the sun, which generates UV radiation. It is expected that the stratospheric ozone depletion will lead to an increased exposure to UV radiation. Although, international policy measures taken to protect the ozone layer have reduced global annual production of ozone-depleting substances by 80-90 per cent of its maximum value (Anon, 1991), time delays in atmospheric processes are such that no international measure effects can yet be seen in ozone concentrations in the stratosphere or in the amount of ultraviolet-B (UV-B) radiation reaching the earth's surface. The ozone-depleting potential of all chlorine and bromine species (CFCs, halons, etc.) in the stratosphere is expected to reach its maximum between 2000 and 2010. Therefore stratospheric ozone depletion will continue (EEA, 1998) and have subsequent effects on human health (Amron and Moy, 1991).

The Intergovernmental Panel on Climate Change (Watson *et al.*, 1997), has predicted that the global mean temperature will increase between 1-3.5°C by the year 2100. For some regions and countries the effects might be positive, meanwhile for other regions and countries the impact will be negative. In healthy individuals, an efficient heat regulatory system normally enables the human body to cope effectively with a moderate rise in ambient temperature. Under normal conditions, recreational water bodies may influence people's perception of ambient temperature conditions. A person perceives high temperature in a town at midday much higher than the same day on the beach under an umbrella. Heat illness may occur under more extreme conditions and is influenced by human behaviour.

Exposure to cold water may cause considerable problems for users of recreational waters. Cold water may cause hypothermia and consequently facilitate drowning, but considerable variation exists from one individual to another in the rate of body cooling and the incidence of survival in cold water. The variability is a function of body size, fat content, prior acclimatisation, and overall physical fitness. Children are the most vulnerable group due to their reduced body index and fat content.

3.1 Exposure to Ultraviolet Radiation and Health Effects

Sunshine consists of electromagnetic radiation of different wavelengths: electric waves, radio waves, infrared waves, visible light, UV radiation, roentgen rays, gamma rays and cosmic rays. Part of this radiation (6 per cent) is ultraviolet radiation (UV radiation). For the consideration of human health effects, this is divided into three bands, known as: UVA, UVB and UVC whose wavelengths are measured in nanometers (nm). The UV part of the solar spectrum is invisible to humans.

- UVA (315 - 400 nm) accounts for most of the sun's UV radiation that reaches Earth. UVA causes a light temporary tan but does not protect the skin. It can do damage at a deeper level within the skin and is associated with premature skin ageing.
- UVB (280 - 315 nm) accounts for a smaller proportion of the UV radiation to reach Earth. UVB can cause redness, burning, blistering and even second degree burns. UVB wavelengths are most effective in producing sunburn in the short-term together with premature skin ageing in the long term, waves around

the 300 nm peak being particularly active. Wavelengths below 315 nm, do not pass through window glass, if the glass is thicker than 3 mm. (Frain-Bell, 1977).

- UVC (200 - 280 nm) is almost all absorbed by the ozone layer in the atmosphere and does not reach the Earth's surface. UVC penetrates very little into the skin, but damages the eyes (WHO, 1994). The maximum measure of photokeratitis has been observed around 270 nm.

The amount and type of solar radiation, especially UV radiation that may reach a given part of the earth at any given time is determined by a great variety of factors, including latitude, the seasons of the year, the time of the day, altitude, local atmospheric conditions (smog, cloudiness, haze, smoke, dust, fog, humidity, aerosol particles), variations in the ozone layer thickness, and height of the sun above the horizon. Although clouds containing smoke and other forms of contamination prevent much of the UV reaching the skin, this is not the case for ordinary rain clouds since UV is transmitted to a certain extent through water. Also clouds tend to screen off the heat-producing infra-red ray thus leading to a deceptive amount of UV-B radiation, exposure times being prolonged as a result of the cooler temperature (Frain-Bell, 1977;). Direct UV exposure has both harmful and beneficial effects on humans (Table 3.1) .

3.1.1. The effects of UV radiation on skin

The transmission of radiant energy varies (0-70 per cent) with wavelength and different areas of human skin (WHO, 1990). The dead cell layer of the stratum corneum mostly absorbs shorter wavelengths; wavelengths that produce sunburn (290-315 nm) are also mostly absorbed in the epidermis. About five to fifteen per cent of the UVB radiation penetrates into the papillary dermis and the depth of UVB penetration depends on the degree of melanin pigmentation of the skin. Longer wavelengths penetrate more deeply into the dermis.

Transmission into the skin of different wavelengths depends upon:

- the thickness of the epidermis;
- the degree of hydration;
- the concentration of visible light absorbing elements such as melanin, proteins (keratin, elastin, collagen); and
- the number of spatial arrangements of melanosomes and of blood vessels. In fair skinned people from 10 to 15 per cent of 290-315 nm waves penetrate into the dermis, meanwhile in dark skinned persons only 5-10 per cent.

The human skin consists of three layers (Fig. 3.1) - the epidermis (outermost part), the dermis and the subcutaneous tissue. In the epidermis two major cell types are found: the keratinocytes and the melanocytes. Keratinocytes produce keratin, which form the outermost part, the stratum corneum. It is a 'waterproof' wall and the major barrier that protects the skin from the loss of body fluids and entrance of toxic agents. Melanocytes are the cells that produce melanin and are stimulated when skin is exposed to sunlight. Human skin colour depends on how much melanin pigment is present in the epidermis. Melanin, which is formed as melanosomes in the melanocytes of the epidermis basal layer is secreted amongst the keratinocytes, taken up and transported towards the stratum corneum during which time it absorbs UV radiation and in this way provides protection. As these pigment granules move towards the surface, ultimately to be lost in normal skin shedding, the pigment needs to be topped up by continuing UV exposure (Frain-Bell, 1977). Melanin is not a definite chemical entity, but a collection of different polymers at various stages of

oxidation. The glutathione system (GSH) is a major factor of controlling skin pigmentation; GSH levels are controlled by the environment and not by heredity and in the white population, GSH levels are low (WHO, 1994b).

Table 3.1 Summary of the main effects of solar UV radiation on the health of human beings

Nature of effects	Direction of effect	Strength of evidence
Effects on immunity and infection		
Suppression of cell mediated immunity	Harmful	Sufficient
Increased susceptibility to infection	Harmful	Inadequate
Impairment of prophylactic immunisation	Harmful	Inadequate
Activation of latent virus infection	Harmful	Inadequate
Effects on the eye		
Acute photokeratitis and photoconjunctivitis	Harmful	Sufficient
Climatic droplet keratopathy	Harmful	Limited
Pterygium	Harmful	Limited
Cancer of the conjunctiva	Harmful	Inadequate
Lens opacity	Harmful	Limited
Uveal melanoma	Harmful	Limited
Acute solar retinopathy	Harmful	Sufficient(?)
Macular degeneration	Harmful	Inadequate
Effects on the skin		
Malignant melanoma	Harmful	Sufficient
Non-melanotic skin-cancer	Harmful	Sufficient
Sunburn	Harmful	Sufficient
Chronic sun damage	Harmful	Sufficient
Photodermatitis	Harmful	Sufficient
Other direct effects		
Vitamin D production	Beneficial	Sufficient
Other cancers	Beneficial	Inadequate
General well-being	Beneficial	Inadequate
Indirect effects		
Effects on climate, food supply, disease vectors, air pollution, etc.	Probably harmful	Inadequate

Limited = suggestive but not conclusive evidence; ?=some uncertainty about assigned classification

Inadequate=no evidence

Source: WHO, 1996 based on Armstrong, 1994

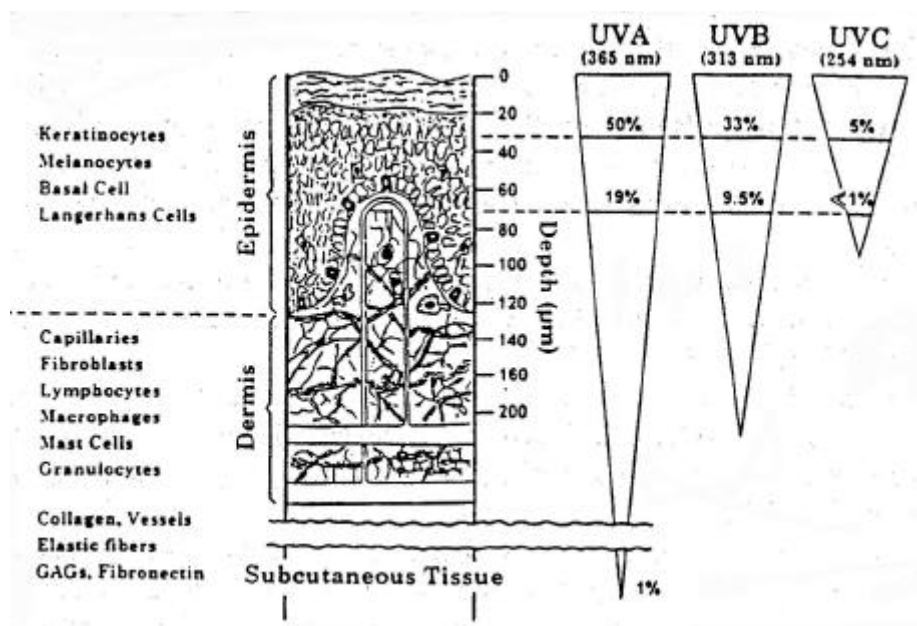


Figure 3.1 Schematic of human skin depicting the layers, cell types, structural components and percent transmittance of UVA, UVB and UVC radiation at different depths (Bruls *et al*, 1984)

The effects of UV radiation on the skin can be acute or chronic. The acute effects are erythema and sunburn meanwhile the chronic effects can be freckles and solar lentigines, melanocytic nevae, solar keratosis, photoageing and cancer.

The short-term effect of solar radiation is the production of erythema, and is due to UV action on both epidermis and dermis. In a mild reaction, some epidermal cells are killed, with associated vascular dilatation present as redness with some swelling, followed by a certain amount of exfoliation and subsequent pigmentation. A more severe blister response in which the whole epidermis dies, is usually followed by a de-pigmented area which may well fail to re-pigment until the following summer season. The sunburn reaction of the body is a complex inflammatory process.

The sensitivity of skin to UV has been defined by six phototypes (WHO, 1994):

- Skin type 1: White skin, never tans and always burns. Often with fair or red hair, blue eyes, pale skin and freckles.
- Skin type 2: White skin, burns easily but may tan eventually. May have fair hair, blue eyes and freckles.
- Skin type 3: White skin, tans easily and burns rarely. Often with dark hair and eyes, with slightly darker skin.
- Skin type 4: White skin, never burns, always tans. With darker hair, skin and eyes.
- Skin type 5: Brown skin (e.g. mongoloids Middle Eastern Population)
- Skin type 6: Black skin (e.g. Afro-Caribbean).

When skin is exposed to UV, two distinct tanning reactions ensue (WHO, 1994b). Immediate pigment darkening (IPD) begins immediately on exposure to UV and is caused

by the darkening of the pigment melanin that is already present in the skin; it is normally seen only in people who have at least moderate constitutive tan. Such pigmentation begins to fade within a few hours after cessation of exposure. UVA is regarded as being most effective for IPD. Delayed tanning takes about three days to develop and is more effectively produced by UVB than by UVA. Delayed tanning is more persistent than IPD and results from an increase in the number, size and pigmentation of melanin granules. Exposure to UVB results also in an increase in the thickness and scattering properties of the epidermis.

Changes in the dermis, affect particularly the collagen and elastic tissue framework and walls of the small blood vessels in the skin, leading to dry, lax, wrinkled skin and dilated blood vessels.

At smaller doses, the acute inflammatory process induced by UV radiation is quickly repaired with residual microscopical damage. However, cumulative damage appears after chronic sub-erythematous doses of UV radiation and is visible (Lavker *et al.*, 1995; Fisher *et al.*, 1997).

Much of the research on sunburn has been undertaken in Australia. There, a single 15 to 20 minute exposure of light-coloured skin to the sun in the middle terrestrial latitudes during summer can produce sunburn. In the majority of the human population with light-coloured skin, perhaps two thirds or more, careful repeated exposures will result in a protective tan. However, the immediate pigment darkening induced by UVA is not protection against UV damages (Cesarini, 1995). The remainder receive little or no protective tanning, and sensitivity continues, leading to repeated sunburn on exposure to solar UV radiation particularly in the UV-B range (Commonwealth of Australia, 1988).

The acute skin sensitivity is expressed as 'Minimal Erythema Dose' (MED)". The MED is defined as the lowest UV radiation dose that produces perceptible redness up to 24h following exposure to a defined spectral band (either UVB or UVA). In fair-skinned people the MED is equivalent to approximately 12 to 25 minutes of sun exposure in northern latitudes during June and July.

One of the effects of chronic UV radiation exposure is photoageing. Photoageing is characterised by dryness, roughness, irregular pigmentation such as freckling/lentigines, actinic keratosis, wrinkles, elastosis, loss of elasticity and sebaceous hyperplasia (Gilchrest, 1996).

Freckles are light brown spots found most commonly in skin types 1 and 2, particularly after exposure to the sun and are a sign that the skin cannot tan evenly. People with a tendency to develop freckles should take special care in the sun. An increased risk of melanoma has been observed in relation to freckling in childhood and an increased risk of non-melanocytic skin cancer in relation to both freckling and prevalence of solar lentigines (WHO, 1994b).

Solar keratosis are benign proliferation's of epidermal keratinocytes. They are very common on exposed body sites in older people living in areas with high ambient solar irradiance.

Many epidemiological studies have implicated solar radiation as a cause of skin cancer in fair-skinned humans (IARC, 1992; WHO, 1994b). In recent years, UV specific mutations of prominent cancer associated genes, such as ras, the p53 gene and the MTS-1melanoma associated gene, have been identified in several types of skin cancer; particularly in skin cancer occurring in UV sensitive patients with the DNA repair deficient disease Xeroderma pigmentosum (IARC, 1992; Dumaz, 1993; Sage, 1993; Ziegler, 1993; Dumaz, 1994). While such mutations may directly cause malignant cells, other forms of

UV-induced DNA damage and failure of the repair mechanisms occur indirectly via modification of cellular activities including those that contribute to the body's immune system. (Chapman *et al.*, 1995). However, recent molecular biology technologies applied to investigate the sequence of pre cancerous (solar keratosis) and cancerous lesions, have revealed that p53 mutations are present in most lesions. Moreover, the mutations are not haphazardly distributed but occur in specific locations (UV signature) on the p 53 gene.

There are two main types of skin cancer: non-melanotic skin cancer (NMSCs) and malignant melanoma (MM). The NMSC are divided into two types: Basal cell (rodent ulcer) and squamous cell cancer, BCC and SCC respectively (Glass and Hoover, 1989). The ratio of BCC to SCC in fair skinned population is 4:1. The risk of these cancers was thought to correlate with cumulative life time exposure to solar radiation, but recent evidence suggests that the relation is more complex - at least for BCC in which it appears that childhood exposure may be important (Vitasa, 1990; Krickler 1995; Moan and Dahlback, 1992). These cancers usually develop on parts of the body most often exposed to sunlight (e.g. face, neck, scalp, hands and arms).

Basal cell cancer is considered benign as it almost never causes secondary effects, but can be very damaging to the flesh around it, meanwhile squamous cell cancer can develop secondary effects.

BCC and SCC are seldom life threatening although treatment is sometimes lengthy and unpleasant occasionally producing disfiguring results. After treatment, patients have to be particularly careful to avoid UV exposure, and to regularly check their skin. It is thought that people are born with a set limit for the sunshine amount of sunshine that one can be exposed to before becoming prone to these problems. Therefore outdoor workers, or white-skinned people who have moved to hot countries are more likely to exceed their limit with time and are most at risk.

There is considerable epidemiological evidence supporting the role of UV radiation with regards to the risk of developing NMSC and the following findings have contributed to the listing of UV radiation as human carcinogen (IARC, 1992):

- The incidence of NMSC is greater in the areas of high insulation (Scotto *et al.*, 1983; IARC, 1992)
- outdoor workers have more NMSC compared to indoor workers
- people who sunburn easily and tan poorly are more likely to develop NMSC than those who can tolerate substantial sun exposure without burning and who tan well (Stern, 1986)
- NMSC appear on areas of the body receiving the most UVR, usually the head, neck and hands (Czarnecki, 1991; Krickler, 1994).

Malignant Melanoma (MM); a cancer of the pigment producing cells of the skin, the melanocytes) usually develops on an already pigmented patch such as a mole, and will always cause secondaries if left untreated (Philipp *et al.*, 1983, 1984, 1987). It grows downward into the skin so there is a need to be vigilant and notice even small skin changes.

The case for the role of sunlight exposure as risk for the development of MM is very complex. Nonetheless, there is epidemiological evidence supportive of the role of sunlight exposure as a risk factor for MM, particularly severe sunburn in childhood (Katsambas and Nicolaidou, 1996; Weinstock, 1996). MM does not seem to depend on cumulative exposure to UV, so can occur in young and old age groups. Intermittent periods of intense exposure (e.g. indoor workers who sunbathe on holiday or enjoy outdoor sports), are frequently noted in patients with MM. Childhood sunburn seems of special significance in some but is difficult to prove conclusively, although children of white

skinned people who move to warmer countries have a higher incidence of MM than their parents.

MM is typically found on the legs of young women, the face of older women and the backs of men, but can occur anywhere. Many melanomas occur on the less irradiated sites of the body, suggesting that mechanisms - mediated by hormonal or immunological factors and that are not damaging to DNA - may be involved. People with a large number of moles or larger than average moles have a higher chance of developing MM.

It is not clear which UV wavebands contributes the most in causing cutaneous melanoma. Although UVB is believed to be the main carcinogen in sunlight, there are suggestions that the broad spectrum component ultraviolet A (315-400 nm) may also contribute to some extent (Marks, 1994), leading to the recommendation to include broad spectrum cover in sunscreens (Cole *et al.*, 1986). The incidence of melanoma in white populations has risen by 3-7 per cent every year since at least the 1960s, and probably reflects a progressive increase in average levels of personal exposure to solar radiation, due to changes in patterns of recreation, clothing and occupation that are unrelated to stratospheric ozone depletion (Armstrong and Kricker, 1994). Increases in melanoma incidence in West- Europe and America have occurred in all age-groups although some recent evidence indicates a down turn- probably related to behaviour- among younger people (Armstrong and Kricker, 1994)

3.1.2 Effects of ultraviolet radiation on the eyes

The external epithelial layer of the eye, the cornea and conjunctiva, absorbs virtually all UVR with a wavelength of less than 290nm. Excessive exposure may damage the outer tissue. Acute exposure may cause photokeratitis ('snow blindness') and chronic exposure, may cause pterygium and climatic droplet keratopathy. Staying on a beach may mean prolonged exposure to UV radiation. This is exacerbated by the reflection of the sun's rays on the water. Children may be particularly exposed as they normally do not use sunglasses.

UVA is thought to cause cataracts of the lens by generating free radicals in ocular tissue and therefore damaging protein molecules (Hollows and Moran, 1981; Taylor *et al.*, 1988; Dahlback *et al.*, 1989; Dolin, 1994; WHO, 1994c; Tyrell, 1994). Cataract is opacity of the lens and may be congenital or acquired. Cataracts are a leading cause of blindness in many parts of the world (WHO, 1990). WHO (1993) reported that half of the world's 35 million blind people lost their eyesight because of cataract. It is believed that the disease may be triggered by wavelength over 290 nm in as many as 3.5 million people, or 20 per cent of the global figure of cataract sufferers. In the so-called 'cataract belt', geographical areas near the equator, the condition strikes individuals between 35 and 45 years of age. In Europe and North America it is a disease of the elderly. In tropical regions, which lack the sharp seasonal variations of northern latitudes, UV radiation is much more intense (WHO, 1993). However, the southern half of the globe receives more UV radiation than the northern.

Scientific debate persists over the role of UV-B in cataract formation (Dolin, 1994; WHO, 1994c). Some epidemiological studies have found positive relationships, others have not (see for example, Taylor *et al.*, 1988; Rosmini., 1994). However, more quantitative epidemiological studies are needed. Attention should also be paid to the fact that certain drugs used in photochemical therapy can cause photosensitising reactions and may therefore exacerbate ocular damage resulting from UV exposure (Lermann, 1988). These drugs include retinoic acid compounds (used to treat acne) and psoralens, thiazides, phenothiazines, barebiturates and allopurinol (Lermann, 1986).

3.1.3. Beneficial effects of exposure to solar radiation

UV radiation is known to have systemic effects, the best known being the conversion of 7-dehydrocholesterol to vitamin D₃ in the skin. Deficiency of vitamin D leads to rickets, a disease still frequent in children living north of latitude 60 °N. There are other systemic effects, such as improvement of the body's tolerance to toxic agents, lowering of blood pressure, etc. Therefore, an increase in ambient UV radiation could have some beneficial effects, particularly on circumpolar populations (WHO, 1990). Nevertheless, the beneficial conversion in the skin of 7-dehydrocholesterol to vitamin D₃ for the prevention of rickets, does not require large doses of UV-B radiation (Commonwealth of Australia, 1988). However, no excess of vitamin D production is to be feared since overexposure to UVB transforms the provitamin D₃ into inefficient lumeferol.

3.1.4 Measures to protect from ultraviolet radiation

To avoid any adverse health effects from exposure to UV radiation special protective behaviours and measures should be undertaken. Mid-day sun exposure should be completely avoided, wearing of sun protecting textiles with high sun protection, hats, and glasses will provide significant protection. For two hours on either side of midday, 60 per cent of daily solar radiation is received at the earth's surface (Marks, 1990). Wearing a hat with a 10cm brim reduces solar radiation to the head and neck by 70 per cent (Marks, 1990). Furthermore, modern chemical sunscreens have become very effective, if used properly. It seems reasonable that these modifications of behaviour, would mitigate the risks of skin cancer from increases in UVR exposure for races with light-coloured skin (WHO, 1990).

Management with respect to the above is principally through continuing educational/personal experience. Sign boards etc. on beaches are very relevant (Fig 3.2. and Table 3.2) and can and sometimes are, displayed on beaches. It is much more a personal choice and the cognitive dissonance of the individual plays a large part in determining whether appropriate measures are taken.

Table 3.2 Choosing a Sun Screen Cream:

- ◆ Use high Sun Protection Factor (SPF) which protects against UVB. Children and people with fair or red hair and fair skin need SPF of at least 30.
- ◆ Preferably use a cream which also protects against UVA (SPF>8);
- ◆ Apply at least every 2 hours and after swimming.
- ◆ Sweat, wind and towel friction will wear the cream away.
- ◆ False tanning creams do not necessarily provide any protection against burning.

What does SPF mean?

- ◆ SPF stands for Sun Protection Factor, and is a measure of how much a sunscreen protects your skin from the sun. The higher the SPF, the greater the protection.
- ◆ Sunscreens usually carry an SPF rating, usually found on the front of the bottle. This rating may range from 2 to 60.
- ◆ A sunscreen's SPF is measured by timing how long skin covered with sunscreen takes to burn when compared with unprotected skin.
- ◆ So if your unprotected skin would burn in 10 minutes in the midday sun, by using a sunscreen of SPF 2 this would double the time spent before burning, to 20 minutes.

When using a sunscreen, remember:

- ◆ apply thickly and evenly over all exposed areas;
- ◆ those parts of the body which are not usually exposed to the sun will often burn more easily (those parts more usually exposed tend to be thicker);
- ◆ pay particular attention to ears, lips, bald patches, and even the soles of your feet;
- ◆ apply your sunscreen before you go in the sun;
- ◆ and re-apply regularly, especially after swimming.

Which SPF?

- ◆ An SPF factor greater or equal to 15, provides good protection generally. A substantial photoprotection will be provided by SPF 30 and high photoprotection will be provided by SPF 40+.
- ◆ If your skin is type 1 or 2 - that is, if you burn easily and tan with difficulty or not at all - you should avoid strong sunshine or cover up with tightly-woven clothing, a hat and sunglasses, and use SPF 30.
- ◆ If you usually tan before you burn, you should still take care in strong sunshine at home and abroad, and use SPF 15 or more in temperate climates, and a higher SPF in strong sunshine at home or if abroad in areas with high sunshine.
- ◆ If your skin is naturally brown or black, you're a skin type 5 or 6. Sunscreens are useful in any case and are useful to protect from photoageing, Moisturising creams are useful - the sun dries out all types of skin.
- ◆ After-sun creams may help to counteract the drying-out of the skin caused by the sun. But they cannot help repair more serious skin damage.

Sunscreens

Sunscreens may protect against erythema assuming they filter primarily in the correct spectral region, i.e. UVB. Many sunscreens also contain physical screens (micronized pigment particles) which scatter UVA and UVB radiation. The efficacy of sunscreens is expressed as the 'Sun Protection Factor' (SPF): $SPF = MED \text{ with sunscreen} / MED \text{ without sunscreen}$.

Traditionally, the SPF is primarily a measure of the anti-erythema UV protection but this does include a UVA component if SPF is greater than 8. World-wide accepted regulations established 2 mg/cm^2 as the standard dose for test application of sunscreens. The SPF may be misleading as SPF 2 absorbs 50 per cent of UV radiation, SPF 15 - 93.33 per cent and SPF 40 - 97.75 per cent, i.e. apparently, there is a very little difference between SPF 15 and 40. However, several studies have shown that sunscreen users apply

between 0.5 and 1.0 mg/cm² (Bech-Thomsen and Wulf, 1993), and the SPF 15 will become a 4 and will absorb 75 per cent of erythema UV; whereas SPF 40 will become 10 and absorb 90 per cent of erythema UV.

A sunscreen of a given SPF may be primarily a UVB absorber or it may have a flat spectral profile absorbing UVA as well as UVB. The use of a flat spectral profile (i.e. neutral density filter) indicates that the sunscreen changes only the quantity rather than the quality of the solar UV radiation (WHO, 1994 b). The general accepted methods to determine the SPF of a sunscreen have been described by the US Food and Drug Administration (FDA) and Colipa (1994). Harvey, (1995) reviewed evidence for the effectiveness of sunscreens. He commented that all sunscreens contained substances that reduced UVB levels and some contained UVA reducing substances. The sun protection factor (SPF) of a sunscreen represents the factor by which erythema UV (mainly UVB) is reduced. There is currently no international agreement as to the way in which the reduction of UVA should be represented, and some sunscreens for which UVA reduction is claimed, actually achieve relatively little reduction (Diffey and Farr, 1991). Currently sunscreen formula can be evaluated for protection against UVA as established by an Australian-New Zealand in vitro method. To meet the Australian requirement of UVA protection, the average transmittance from 320 to 360 nm must be less than or equal to 10 per cent (PF 10), when measured through a sample prepared following the Australian and New Zealand method (Australian Plate Procedure given under Appendix C of AS/NZ 2064).

Sunscreens that filter out both UVB and UVA (broad spectrum) are currently recommended on the basis of the likely carcinogenic potential of UVA (Hawk, 1991). Titanium dioxide is most effective at reducing UVA levels, although cosmetically it is less acceptable since it produces obvious skin whitening (Diffey and Farr, 1991). Microfine titanium dioxide produces less skin coloration (Galley *et al.*, 1992) but mixed with Zinc Oxide, it has a favourable human safety profile and is photostable. Regular re-applications of sunscreen are necessary when subjects swim or sweat profusely.

Cloud cover reduces infra red radiation levels much more than UV radiation which are generally reduced by only between 20 and 40 per cent (Truhan, 1991). UV levels even on a cloudy summer day can be substantial, especially around midday (Marks, 1990) so similar precautions are advisable on cloudy summer days as on sunny days. Water droplets act as a 'scatterer', so that the diffused component of solar radiation is higher. Incorrectly, people associate heat with only a 'strong sun'. As UV light does not produce a feeling of heat, anything that cools the skin in the sun is inappropriately interpreted as decreased UV exposure, e.g. wind flow whilst sailing.

Since it is estimated that between 50 per cent and 80 per cent of lifetime UV exposure occurs during childhood, (Wakefield and Bonett, 1990; Marks *et al.*, 1990), UV reduction strategies should probably be concentrated upon children and their parents (Holman and Armstrong, 1984). This suggests school briefings/lessons as well as parental education. Nevertheless, there has been, and continues to be, debate about the effectiveness of sunscreens - (see section 4.2.6) despite evidence of their effectiveness in animals (Gurish *et al.*, 1981; Kligman *et al.*, 1980). Some workers have suggested that the false sense of security engendered by sunscreens may even have led to a net increase in total UV exposure, perhaps contributing to the current observed increase in skin cancer incidence (Skolnick, 1991; Dobak and Fu-Tong, 1992). Others have mathematically modelled the likely impact of regular sunscreen (SPF 15) use during the first 18 years of life and

estimated that the lifetime incidence of NMSCs would be reduced by 78 per cent. Choosing a correct sun screen could be very important (Table 3.2).

No experimental study has yet documented a preventive effect of sunscreens against skin cancer, but one randomised controlled trial examined the effect on precursor lesions of NMSC - solar/actinic keratoses (Thompson *et al.*, 1993). These are believed to be pre-malignant lesions although the rate of transformation into squamous cell cancer was found to be low. In this Australian study of 588 adults (aged 40 years and over) randomly allocated to daily use of either a broad spectrum (UVB and UVA reducing) sunscreen or a placebo cream during one summer, there was a significant difference in the number of keratoses per subject after eight months (mean difference 1.53 keratoses, 95 per cent confidence intervals: 0.81, 2.25). This was attributable to fewer new lesions and more spontaneous remissions. All subjects were advised to avoid the sun in addition to sunscreen use. Although results are indicative of benefit, the authors acknowledged that the participants were highly motivated and compliant, having taken part in previous skin cancer research, with 25 per cent of them having previously had skin cancer. Extrapolation of these results to a low risk population is therefore not straightforward. Indeed observational work in the UK in an elderly population has shown no protective effect of sunscreens against solar keratoses (Harvey *et al.*, 1994).

Reduction in exposure to solar UVR has been advocated by NIOSH (1989) and by the American Academy of Dermatology and CDC (Goldsmith *et al.*, 1996). There is currently an agreement that reduction in solar UVR exposure will reduce the risk of skin damage. The daily use of a broad spectrum sunscreen with a minimum SPF 15 is part of the strategy to reduce chronic skin damage produced by sunlight.

3.1.5 UV-Index

The global solar UV-index is a joint recommendation of World Health Organisation, World Meteorological Organisation, United Nations Environmental Programme and the International Commission on Non-ionising radiation Protection (ICNIRP). It is the result of international consensus from a panel of health experts and scientists assembled at the request of WHO in its INTERSUN program. The UV-Index can be considered a tool in addition to news and weather reports, to bring to the attention of people the problem of sun overexposure, and to encourage photoprotection implementation. The global UV-Index is based on a unit expressed in the number obtained by multiplication of the solar efficient erythral strength (averaged on one hour) expressed in Watt/m² by 40. This value is obtained by combining the solar spectrum and erythral action spectrum of human skin (CIE) normalised at 297 nm. It estimates the maximum skin damaging UV measured over a period of 10-30 minutes at solar noon on a given day. The UV-Index is not limited in its maximum and extends from 1 up to about 15 on earth surface, according to the time, month, and geographical location. The UV-Index can be predicted since clear sky values can be modified by cloud cover. It is already available to several media in North America, in Europe, Australia, and public access to the information is increasing in all parts of the world. A simple table can be used to adapt photo-protection measures to the UV-Index (Table 3.3).

3.1.6 Health education campaigns

Primary prevention programmes are widely used in many countries. In the UK, for example, 89 per cent of health authorities were found to be implementing such programmes in an attempt to meet the Government's Health of the Nation target of stabilising skin

cancer incidence by the year 2005 (Sabri and Harvey, 1996), but relatively few have been evaluated (Melia *et al.*, 1994). In the short term, many education campaigns have been evaluated by measuring changes in knowledge, attitudes and behaviour but as Melia *et al.*, (1994) have pointed out, the value of this type of intervention depends on the extent to which intentions lead to behaviour modification, and whether this is sustained. Results in terms of impact on skin cancer incidence or mortality may not be apparent for some time. However, Australian data shows that changing people's attitudes to suntans and sun protection is possible and can lead to less sunburn (Hill *et al.*, 1993). Anecdotal studies have also suggested a reduced frequency and severity of skin tumours when a sunlight reduction programme has been studiously followed by people with xeroderma pigmentosum (Marks, 1994).

Harvey (1995) reported that the Australian 'Slip! Slop! Slap!' campaign which started in 1980, and its high-profile follow-up 'SunSmart' in 1988, were effective in increasing both awareness and self-reported sun-protection behaviour. An evaluation of the earlier campaign found some evidence of increased hat and sunscreen use over one year (Rassaby *et al.*, 1983). Evaluations of other health education campaigns in various countries have reported improved public knowledge about the dangers of exposure to sunshine but no significant change in sun-protection behaviour (Cameron and McGuire, 1990; Bourke *et al.*, 1995). Where a corresponding change in behaviour was reported this was in the use of sunscreens (Bourke *et al.*, 1995; Hughes *et al.*, 1993). To date there is *no* direct experimental evidence that sunscreens are effective in reducing skin cancer incidence (Sabri and Harvey, 1996). It has also been reported that amounts and methods of application of sunscreen are less than adequate (Harth *et al.*, 1995). An evaluation of the UK Health Education Authority's (1989) prevention campaign 'Are you dying to get a sun tan?' found a significant increase in the proportion of people aware that high SPF sunscreens reduced sun exposure, but unfortunately both before and after the campaign the majority of people were unaware that high meant an SPF greater than six (Cameron and McGurie, 1990). Similarly, in spite of the intensive publicity for Australia's preventive campaign, which resulted in a high overall level of knowledge and awareness of skin cancer, important areas of ignorance concerning risk factors were still found to exist (Martin, 1995).

Table 3.3 UV-Index, solar exposures and photo-protection

Solar strength	UV-Index	Burning time for sensitive skin (types 1 and 2)	Recommended Photoprotection for children and types 1 and 2	Recommended sunscreen SPF	Recommended sunscreen SPF for types 3 and 4 or acclimated
Low	1	3 hours			
Low	2	1,5 hour			
Average	3	1 hour	Hat + Shirt	15	8
Average	4	40 minutes	Hat + Shirt	15	8
High	5	30 minutes	Hat + Shirt	30	15
High	6	25 minutes	Hat + Shirt	30	15
Very high	7	20 minutes	Shade	40	30
Very high	8	18 minutes	Shade	40	30
Extreme	9	16 minutes	Shade	40	30
Extreme	10	14 minutes	Shade	40+	40
Extreme	11	12 minutes	Shade	40+	40

One point of UV-Index is roughly equal to 1 SED (Standard Erythema Dose = 100 J.m⁻²)

Changes in knowledge and attitude about sun exposure have also been evaluated following health education programmes for school children of all ages (Johnson and Lookingbill, 1984; Goldstein and Leshner, 1991; Hughes *et al.*, 1993; Hughes 1994; Reding *et al.*, 1995; Thornton and Piacquadio, 1996). One American study evaluated a programme for children as young as 4 or 5 years of age (Loescher *et al.*, 1995) and found it to be successful in increasing knowledge and comprehension of sun safety. Again, there is no evidence from these studies that improved knowledge has led to safe practice, although Reding *et al.*, (1995), reported a 'possible' self-reported behaviour change. In contrast, marked increases in self-reported protective behaviour have been reported after distribution of an information comic book (Putnam and Yanagisako, 1982).

An Australian review of the psychological literature on sun tanning suggests that although many people show high levels of knowledge of the dangers of tanning this does not translate into behaviour because a sun tan remains desirable, particularly amongst adolescent groups (Arthey and Clark, 1995). Harvey (1995), has also reported that two cross sectional studies - one from Australia the other from the United States - have analysed factors associated with sunscreen use among adolescents (Cockburn *et al.*, 1989; Banks *et al.*, 1992). Both studies indicated that a majority of teenagers in these countries took inadequate sun protection measures - 70 per cent in the larger of the studies (Cockburn *et al.*, 1989). Some findings were consistent across the two studies - for example that subjects who burn easily were more likely to use sunscreens - although the proportion of these using adequate amounts remained below 50 per cent. One study found females more likely to use sunscreen, (Banks *et al.*, 1992), the other that they were less likely to do so, (Cockburn *et al.*, 1989). Cockburn *et al.*, (1989) also found that smokers were less likely to use sunscreen.

The most striking findings of these studies concern the role of knowledge, attitudes and beliefs in determining behaviour. It was clear that beliefs about such matters as the cost and messiness of sunscreens, and the social acceptability of wearing hats were powerful predictors of sun protection behaviour, as was peer and parental behaviour. The cost of

sunscreens was reported to be a significant perceived barrier to their greater use and any systematic effort to reduce their cost to the public would clearly need to be the subject of general policy (Harvey, 1995). Knowledge, on the other hand, was not significantly associated with actual behaviour. The implication of this work was that simple fact sheets about skin cancer aiming to enhance knowledge are unlikely to be effective in changing primary protective behaviour in this age group. The intervention studies described already tend to confirm this observational finding. Cockburn *et al.*, (1989) suggested that primary prevention should use a multifaceted approach that attempts to modify beliefs among both teenagers and their parents, for example by the use of public figures - such as sporting personalities - to provide role models was proposed.

With secondary prevention, various ways of promoting early detection, especially of melanoma, have been tried through organised population screening by health professionals, opportunistic screening and health education, but there has been little evaluation of these interventions (Melia *et al.*, 1994)

Action that can be taken in the prevention of malignant melanoma has been summarised by Melia *et al.*, (1994) as:

- The benefits of education about sun protection are as yet unproven but if organised effectively, education is likely in the long term to reduce the risk of most skin cancers as well as photo-ageing.
- The benefit of campaigns promoting early detection must be assessed in terms of reducing the incidence of late-stage melanomas and mortality across all sections of the community.
- Local initiatives require a multi-disciplinary approach to ensure co-operation between general practitioners, dermatologists, pathologists and health promotion officers.
- Local initiatives should be supported by a national programme promoting sun protection and awareness of melanoma risk and national monitoring of changes in knowledge and behaviour.

Health authorities should ensure adequate provision of health services in advance of primary prevention, and early detection campaigns, as both are likely to increase the number of people seeking advice about suspicious skin lesions. Despite the lack of evidence for the effectiveness of education campaigns, public information is justified (Melia *et al.*, 1994). Information for the public should include advice on ultraviolet radiation, the adverse and beneficial effects of exposure to sunshine, awareness about what is skin cancer, how it can be recognised and what prevention measures can be taken (Fig.3.2). This is where ICM could help with such information prominently displayed in recreational areas, tourist offices etc. as well as campaigns carried out at recreational areas. ICM at the local level has a large role to play in information dissemination. Table 3.4 suggests general advice for the public based on a consensus statement of a British working party on cancer prevention and others (Marks, 1994; Editorial, 1992a and b; HEA, 1994; Avon Skin Cancer Prevention Working Group, England, 1993).

Figure 3.2 Public information regarding sunlight

Sunlight is linked to: ⇒ <i>thickening of the skin;</i> ⇒ <i>loss of elasticity (sagging);</i> ⇒ <i>burns of the skin;</i> ⇒ <i>temporary retardation of the immune system;</i> ⇒ <i>cataracts of the eyes;</i> ⇒ <i>skin blemishes;</i> ⇒ <i>skin cancer.</i>	Australian education campaign: ✓ SLIP on a <i>-shirt</i> ✓ SLOP on the <i>suncream</i> ✓ SLAP on a <i>hat</i>
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Table 3.4 Suggested advice for the public

Do's and don'ts • Loose UV protecting textiles with long sleeves, and broad-brimmed hats to protect the head, face and neck, should be worn as they are effective sunscreens. • Stay in the shade, use an umbrella or sunshade if there is no natural shade, particularly between the hours of 11.00 and 15.00 when the sun is highest in the sky and temperatures usually hottest. • Wear good quality sunglasses with an ultra violet filter and side shields to reduce reflected UVR. In their purchase, comfort, price, design, protection and strength all play a part. Remember too, that they should be kept clean as vision problems are aggravated by dirt, scratches or smears on their lenses. • The sun's rays are reflected from many surfaces e.g. sand, water, snow, rocks, therefore skin should be protected even in the shade. • Tan slowly, gradually increasing the time you spend in the sun each day. • Be aware of your skin type, the fairer the skin and the more easily you burn the greater the protection needed. • Avoid burning. • Babies under six months should be kept out of direct sun. • Parents and carers should be made aware of the importance of not allowing a baby's or child's skin to burn as this puts them at greater risk of malignant melanoma later in life. • The best protection for children is to cover up with sun protecting clothes and a hat. • A high SPF (over 30) should always be used for babies and children. A high SPF should be used particularly for babies and children and those with especially sensitive skin.
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3.2 Heat

3.2.1 Warm ambient temperature

Human body temperature is maintained within a narrow range despite extremes in environmental conditions and physical activity. This is also true for most birds and mammals, and such animals are termed homeothermic, or warm-blooded). In healthy individuals, an efficient heat regulatory system will normally enable the human body to cope effectively with a moderate rise in ambient temperature. Within certain limits of mild heat stress and physical activity, thermal comfort can be maintained, and physical and mental work can be pursued without detriment. In cases of extreme temperatures, the human body is able to react with a series of adaptation mechanisms. The most significant are sweating, dilatation of the peripheral blood vessels, an increase in some hormones (antidiuretic hormone and aldosterone) and an increase in respiratory rate and pulse. In the mean time the body tries to loose as few salts as possible and decreases the renal blood flow.

Heat acclimatisation, ordinarily takes from 7 to 14 days, but complete acclimatisation to an unfamiliar thermal environment may take several years (Babayev, 1986; Frisancho, 1991). Acclimatisation lowers the threshold for sweating which is the most effective natural means of combating heat stress and can occur with little or no changes in the body core temperature. As long as sweating is continuous, people can withstand remarkable high temperatures, provided water and sodium chloride, the most important physiological constituents of sweat, are replaced. Disorders due to heat most frequently occur with rapid changes in thermal conditions, especially in low latitudes and in densely populated urban areas (WHO, 1990; Weiner *et al.*, 1984). This was well illustrated by the 1980, 1983, 1988 and 1995 heat waves in the USA (CDC, 1995). In Europe in the 1987 Athens, Greece, heat wave, deaths exceeded the expected death rate by 2000 (Katsouyanni *et al.*, 1988, 1993). The elderly, the very young (0-4 years), persons with impaired mobility, persons suffering from pre-existing chronic diseases, such as arteriosclerosis, previous heart failures, diabetes, congenital absence of sweat glands, and also frequent consumers of alcohol (Schuman *et al.*, 1964; Kilbourne, 1982), appeared to be dis-proportionally affected by such weather extremes, probably because they have a lesser physiological coping ability (CDC, 1995).

A comfortable temperature for most people, is around 20-28 °C. Factors influencing thermal comfort include air temperature, humidity, wind speed and fluxes in short wave and long wave radiation. A 'state of the art complete heat budget' model has recently been developed and takes into account all mechanisms of heat exchange between the human body and its environment (Jendritzky, 1996). This model considers optimal to be the condition where humans need to exert minimal thermoregulation and they were able to take both, metabolic rates and clothing into account. This heat budget model showed also that a middle age person walking on the beach at midday copes better with heat exposure than the same person walking on an urban road at midday.

3.2.2 High water temperature

The safe upper limit of water temperature for recreational immersion varies from individual to individual and seems to depend on psychological rather than physiological considerations. Unlike cold water, the mass to surface area ratio in warm water favours the child. Physiologically, neither adult nor child would experience thermal stress under modest metabolic heat production as long as the water temperature was lower than the normal skin temperature of 33°C (Newburgh, 1949). The rate at which heat is conducted from an immersed human body is so rapid that thermal balance for a body at rest in water can be

attained only if the water temperature is about 34 °C (Beckman, 1963). The survival of an individual submerged in water at a temperature above 34 to 35 °C depends on the tolerance to an elevation of the internal temperature, and there is a real risk of injury with prolonged exposure. Water ranging in temperature from 26 to 30 °C is comfortable for most swimmers throughout prolonged periods of moderate physical exertion (Ministry of National Health and Welfare, Canada, 1992). The degree of hazard varies with water temperature, immersion time, and metabolic rate of the swimmer.

Deaths have been reported from extremely hot water (approximately 43.3 °C) in a natural spa. High water temperatures can cause drowsiness, which may lead to drowning. Also raised body temperatures may lead to heat stroke and death.

3.3. Low Water Temperature (Cold)

Keatinge (1979), has reviewed the importance of keeping warm as cold rather than simple drowning is the main killer after open sea accidents. This has been further emphasised by a study which showed that most people lost at sea were good or very good swimmers, so inability to swim was not a large factor in their deaths (Home Office, 1977). When body temperature falls, there is first confusion and later loss of consciousness, so that the head often goes under water and drowning is the immediate cause of death. With a life-jacket capable of keeping the head out of water drowning is avoided, but only a limited respite is gained since death due directly to hypothermic cardiac arrest will soon follow. However, this is by no means inevitable. The rate of body cooling can be slowed, and in some cases halted entirely, in many different ways. Wearing warm clothing as well as a life-jacket can greatly prolong survival in cold water; floating and remaining still rather than exercising also aids survival in these conditions. However, children, particularly boys, have less fat than adults and cool very rapidly in any but the warmest water.

Swimming is difficult in very cold water (around 0 °C), and good swimmers often drown suddenly if they attempt to swim even short distances in water at these temperatures without a life-jacket. A careful study of reported drowning cases carried out by Press (1969), showed that 299 out of 874 (34 per cent), occurred in waters listed as very cold (assumed to be below 20°C), which bears out much of the above as regards survival in cold waters. In addition, a much higher percentage of those succumbing in cold water were considered good swimmers.

Exercise in the water increases the loss of body heat and correspondingly decreases survival time. This is reflected in frequent reports of drowning of expert swimmers who tried to reach shore after a sinking, whereas those who remained in the water near the lost ship survived until rescued.

It has been suggested that the thermal characteristics of waters used for bathing and swimming should not cause an appreciable increase or decrease in the deep body temperature of bathers and swimmers (Ministry of National Health and Welfare, Canada, 1992). At least in Canada, it has been reported that the natural water temperature is an important factor governing the character and extent of recreational activities, primarily in the summer months. Numerous children have been inexplicably drowned on winter weekends when fine weather brings them out on to cold water in small craft. Children generally assume that if they have passed swimming tests in a warm pool they can rely on swimming to reach a nearby shore. In practice they may find that they are unable to swim even a few yards when the water temperature is very low. The practical message is simple: life-jackets or some other form of flotation aid should always be worn by those, particularly children and young men, in small craft when the water is cold (Keatinge, 1979). This is a

dictum that coastal managers can pass on to the general public via notice boards, leaflets, etc. at all recreational sites especially resort areas.

Even small amounts of alcohol can cause hypoglycaemia if taken without food by someone who has exercised for an hour or two. It causes not only confusion and disorientation but also, in cold surroundings, a rapid fall in body temperature. Unless sufficient food is eaten at the same time, small amounts of alcohol can be exceedingly dangerous on long distance swims, as well as after rowing or other strenuous and prolonged water sports exercise. The number of deaths produced in this way is not known, but there are reasons to believe that it is substantial (Keatinge, 1979) and a recent UK estimate was 25-50 per cent (Rouse, 1991).

Immediate treatment is much more important than any later action in reviving victims of immersion hypothermia. A hot bath - no hotter than you can stand putting your hand in - is the most effective method of achieving this. If a hot bath is not readily available, time should not be wasted in searching for one. Cardiac massage should not be given unless the heart has definitely stopped. In drowning, cardiac arrest and cessation of breathing should be treated by tipping water out of the stomach and giving immediate external cardiac massage and artificial ventilation. People who have inhaled water should always subsequently be sent on to hospital in case of late pulmonary complications, but in both hypothermia and drowning, it is immediate treatment that largely determines the outcome (Keatinge, 1979).

Persons engaging in winter water recreation such as ice skating and fishing, should have the knowledge that whole body immersion must be avoided. Accidental immersion in water at or near freezing temperatures is dangerous, because the median lethal immersion time is less than 30 minutes for children and most adults (Molnar, 1946; NAS, 1973). Considerable variation exists from one individual to another in body cooling rates and survival incidence in cold water. The variability is a function of body size, fat content, prior acclimatisation, and overall physical fitness. The ratio of body mass to surface area is greater in large, heavy individuals and their temperatures change more slowly than those of small children (Kreider, 1964).

3.5 References

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CHAPTER 4

MICROBIOLOGICAL ASPECTS OF WATER QUALITY

4.1 Public Health Basis

Recreational waters generally contain a mixture of pathogenic and non-pathogenic microbes derived from: sewage effluents; the recreational population using the water (from defecation and/or shedding); industrial processes; farming activities; and wild-life; in addition to any truly indigenous micro-organisms. This mixture can present a hazard to the bather where an infective dose of pathogen colonises a suitable growth site in the body and leads to disease. In the case of diseases transmitted by the faecal-oral route this site is the alimentary canal, but it could also include other potential sites of infection such as the ears, eyes, nasal cavity and upper respiratory tract.

What constitutes a minimal infective dose depends upon the specific pathogen, the form in which it is encountered, the conditions of exposure and on the host's susceptibility and immune status. For viral illness, this dose might be very few viable infectious units (Fewtrell *et al.*, 1993). In reality, the body rarely experiences a single isolated encounter with a pathogen and the effects of multiple and simultaneous pathogenic exposures are poorly understood (Esrey *et al.*, 1985).

A generalised dose response has been proposed to illustrate the response to exposure to a mixed array of enteric pathogens (Esrey *et al.*, 1985; Fig. 4.1.). Important theoretical implications of this model are:

- At high levels of pathogen dose (E-F) an intervention which results in only moderate reduction in pathogen load may have little impact on the incidence of either severe or mild diarrhoea.
- At moderate/high levels of pathogen dose (D-E) only the incidence of severe diarrhoea may be reduced
- At moderate/ low levels of pathogen dose (B-D) both severe and mild diarrhoea incidence may be reduced, but at different rates.

Available information is consistent with such a pattern of response to exposure by recreational water users to enteric pathogens by ingestion. Thus, studies world wide have demonstrated that:

- pathogenic microbes are found in recreational waters;
- bathers, and other recreational water users, experience an elevated level of symptom of some diseases reporting; and
- the rate of symptom acquisition for some diseases, correlates with the concentration of microbiological indicator species which derive from the same sources as many of the pathogens.

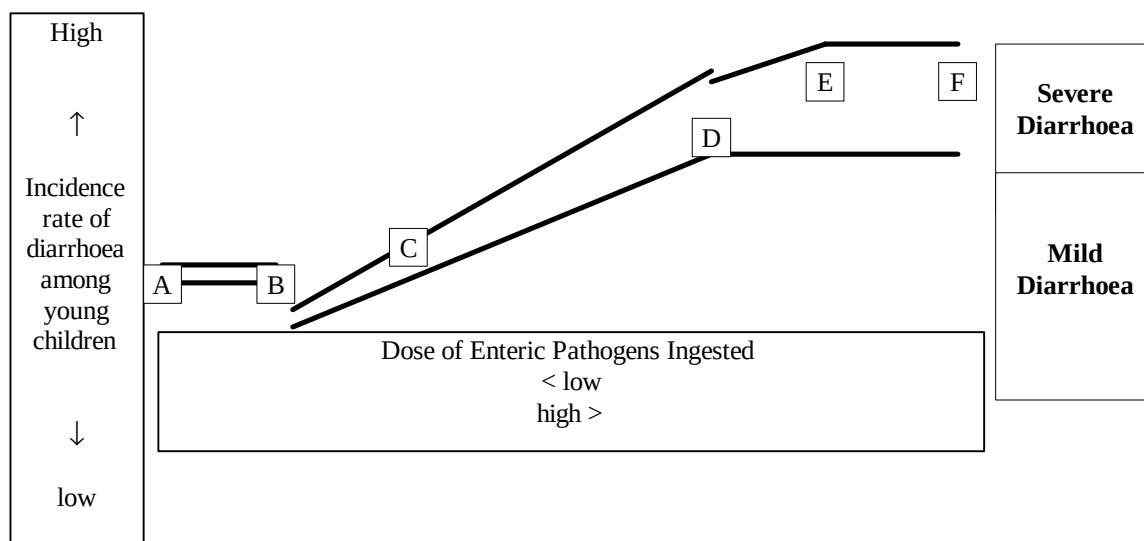


Figure 4.1 Dose response relationship for young children at various levels of response to an array of enteric pathogens. Adapted from Esrey *et al*, (1985).

At a practical level this work implies that the greatest public health gains are to be found by focusing activity in areas of greatest water related disease prevalence and where environmental health conditions are worst. Various intervention types on water-related disease incidence can also be assigned weighting values.

In addition to the general risk associated with exposure to a mixed array of enteric pathogens a number of additional microbiological hazards may be encountered by recreational users of the water environment. These include, for example, leptospirosis (Weils disease), caused by leptospires.

4.2 Health Effects from Exposure to Recreational Water

This section examines evidence of adverse health outcomes associated with recreational water exposure from published epidemiologic studies on surface waters, such as seas, lakes and rivers. It constitutes a review of all identified and accessible papers published on the subject.

4.2.1. Selection of studies

Outbreaks and cases of illness related to swimming in recreational waters have long been reported. Outbreak reports have associated cases of diverse health outcomes (e.g. gastroenteric symptoms, typhoid fever, meningo-encephalitis (Prüss, 1998) with exposure to recreational water and in some instances identified the specific etiological agents. However, in general, they have not sufficiently described water quality nor provided information on any dose-response relationship. Such information is needed for estimating the health risks from exposure to recreational water and for taking appropriate health protection measures. Relevant studies, mainly epidemiological studies investigating dose-response relationships, or health consequences at differing water quality levels, were selected from the literature with a view to evaluating the following relationships:

- the dose-response relationship between health outcomes and bathing water quality;
- the existence of threshold values of indicator-bacteria counts for health outcomes; and

- a possible variation in the severity of outcomes as a function of microbiological water quality.

Epidemiological studies have investigated mainly gastrointestinal symptoms, eye infections, skin complaints, ear, nose and throat infections and respiratory illness. Several types of epidemiological study may be used for estimating health risks related to recreational water quality, including case-control studies, cohort studies and randomized controlled trials.

Case-control studies

In this retrospective study design type, people with the disease of interest (case group) and people unaffected by the disease (control group) are selected. Cases and controls are matched on a small number of variables, e.g. age and sex. Exposure to bathing water is compared between cases and controls. Case-control studies may have some limitations: bias in selection and bias in finding appropriate controls; differential recall of bathing water exposure between cases and controls; absence of adequate water quality information. This type of study has difficulty in defining a precise dose-response relationship between outcome and water quality.

Cohort studies

Disease-free populations (i.e. cohorts) of bathers and non-bathers are identified and classified into subgroups according to exposure to recreational water quality. In prospective studies, the whole cohort is followed up to see how the subsequent development of new cases of the disease differs between the groups of different exposures. Follow-up is a crucial element in identifying the outcome of the study population. This, however, may be difficult for some populations such as tourists. The variation of the composition in different exposure groups may also be difficult to control.

In retrospective studies, exposure and outcome have already taken place when the study begins. Data are not collected with the passage of time as in prospective studies. As in case-control studies, retrospective estimation of exposure to water quality may be inaccurate. Potential bias may arise from divergences in the groups of different exposure.

Randomized controlled trials

This approach is essentially an experiment, which involves allocation of exposure to water. A randomized design would optimize the chance of similarity between the groups of exposure, in particular in respect to susceptibility to disease. Also, water quality could be more accurately assessed in case of controlled exposure. A more accurate assignment of exposure to water can be achieved. Major practical problems (e.g. costs, recruitment of sufficient number of participants) and ethical problems (e.g. inclusion of children, exposing subjects to water of low quality) may be associated with such a study.

In the study types mentioned above, several factors may impact upon the validity of health impact evaluations of water quality.

Control for confounders

Control for non-water-related risk factors (e.g. food and drink intake, age, sex, history of certain diseases, drug use, spread by personal contact, additional bathing, sun, socio-economic factors) is important for discarding a confounded relationship between water quality and outcome of interest.

Study population size

For detecting associations with a sufficient level of significance, adequate sample sizes must be determined on the basis of expected attack rates in exposed groups. The choice of a narrow range of bathing water quality increases the needed population size.

Selection of study population

Recruitment method may introduce a bias (e.g. in cohort studies by approaching persons on the beach and in randomized controlled trials by publicity). A low response rate in follow-ups is also a potential source of bias due to differential reporting, e.g. higher response among participants experiencing symptoms would lead to overestimating the effect. Results will only be transferable to populations with immunity status comparable to the study population.

Illness definition and reporting

For assessing the mainly minor complaints, reliance can be made on reporting of symptoms, in particular as etiologic agents are usually not identifiable or isolatable. However, validation of symptoms may usually be obtained by examination by a medical doctor. External factors such as media or publicity may influence on self-reporting. When collecting data by interviews, differences among interviewers should be avoided by adequate training. This will optimize interviewer uniformity. Furthermore, exposure status should not be known to the interviewer prior to the interview on health outcome and will avoid interviewer bias.

Exposure definition and assessment

Exposure definition should take potential infection pathways into account. Ingestion of water, degree and duration of water contact should therefore be assessed accurately. Place and time of exposure should be assessed by adequate measurement of suitable indicators or pathogens. Control for the substantial amount of temporal and spatial indicator variation and the relation to individual bathers (Fleisher, 1993) presents a major difficulty in observational study designs. Furthermore, the indicator organisms used do not relate well to viruses, which may represent an important part of the aetiological agent. The limited precision of current methods of counting indicator organisms adds substantial measurement error (Fleisher, 1990). These factors lead to misclassification bias, and hence underestimation of the effect.

Exposure of the reference group should equally be well defined and appropriately chosen. It has been suggested that non-swimmers may also, to a certain extent, be exposed to poor water quality, as viruses may be transferred from the water to the air (Feachem, 1982). Therefore, swimming-associated illness estimation with beach non-swimmers chosen as the unexposed may underestimate the effect.

Adequate data analysis

Data analysis should permit control for confounders or effect modifiers for which adequate techniques exist such as stratification and multivariate analysis. The latter method usually needs smaller numbers of data and permits clearer understanding of exposure and disease interrelationship.

Analysis for congruity

Collected data should be analyzed whether they are in line with reported results and whether there are other non-reported findings. Concomitant outcomes should be measured, analysed and reported.

Bather and non-bather groups may differ (e.g. in their health status), which may be the cause of the choice of different activities (i.e. bathing or not bathing). Swimming-associated illness estimation using non-swimmers on the beach as the unexposed groups may underestimate the true effect.

Recent studies have suggested that certain symptoms may result from exposure to water itself rather than from microbiological water quality, e.g. WHO/UNEP, (1994), by irritation or disturbance of the body defences or by naturally occurring micro-organisms not specific to randomised control studies. To estimate each risk factor independently, the following associations between swimming and health consequences were reviewed to assess the risk:

- of contact with water itself, the incidence rates for swimming in relatively unpolluted water compared with the incidence rates of non-swimmers; and
- due to microbiological water quality, the incidence rates for swimming in polluted water compared with the incidence rates of swimmers in relatively unpolluted water.

All the following selection criteria had to be met by the studies for selection:

- The health outcomes were clearly related to water quality.
- The study was sufficiently documented to determine the associations of interest; in particular, study design and reported data had to allow comparison of attack rates of swimmers in differing water qualities.
- The exposure or outcome assessment did not differ significantly among the exposure or outcome groups. An example of exposure to water is white-water canoeing which is similar to swimming as water intake is likely, through turn-over/ ingestion or droplet inhalation.
- The study population was large enough (four or more diseased per exposure group).
- The response rate was higher than 50 percent and the water was not artificially chlorinated.

In this review, 22 of 37 identified studies were selected (Table 4.1 and 4.2). None of the selected studies addressed the more severe health outcomes resulting from exposure to recreational water. This is probably due to their low occurrence in the temperate regions where most of the studies were conducted, and also because investigations of more rare outcomes require larger study populations. However, two identified, but non-selected studies (El Sharkawi & Hassan, 1979; Public Health Laboratory Service, 1959) investigated poliomyelitis, typhoid and paratyphoid fever in relation to bathing water quality. Although these studies provided little information regarding the relation of cases of illness to water quality, and are of weak study design, they are nevertheless discussed in this review.

Eighteen of the 22 studies were prospective cohort studies, two were retrospective cohort studies (Ferley *et al.*, 1989; Mujeriego *et al.*, 1982) and only two (Fleisher *et al.*, 1996; Kay *et al.*, 1994) were randomized controlled trials. All studies assessed water quality by measuring indicator micro-organisms, usually bacteria of faecal origin. The studies used different indicators, the most commonly used being enterococci, *Escherichia coli* and faecal coliforms. Only a few studies measured also pathogenic micro-organisms.

In eleven of the selected studies (Table 4.1, group 1), water quality data were measured daily (or even at time of exposure (Fleisher *et al.*, 1996; Kay *et al.*, 1994) and analysed according to the individual exposure day. In most of the other studies, only the seasonal water quality means of beaches were analysed for association with outcomes.

Table 4.1 List of selected studies

Group	Reference	Year	Country	Study design	Water	Comments
1, 4, 5, 10	Fleisher <i>et al</i> , 1996	1996	UK	randomized controlled trial	marine	d
1, 4, 5	Haile <i>et al</i> , 1996	1996	US	prospective cohort	marine	
4, 9	Van Dijk <i>et al</i> , 1996	1996	UK	prospective cohort	marine	c
1, 3, 5, 10	Bandaranayake <i>et al</i> , 1995	1995	New Zealand	prospective cohort	marine	d
1, 2, 5	Kueh <i>et al</i> , 1995	1995	Hong Kong	prospective cohort	marine	b
4, 5, 9	CSIR 1995	1995	South Africa	prospective cohort	marine	a, c
1, 4, 5, 7, 8, 10	Kay <i>et al</i> , 1994	1994	UK	randomized controlled trial	marine	d
2, 5, 6, 7, 9	Pike, 1994	1994	UK	prospective cohort/cs	marine	a, b, c
3, 10	Corbett <i>et al</i> , 1993	1993	Australia	prospective cohort	marine	a, d
1, 3, 5, 7, 10	Fewtrell <i>et al</i> , 1992	1992	UK	prospective cohort	fresh	d
1, 2, 5, 6, 10	UNEP/WHO no 46, 1991	1991	Israel	prospective cohort	marine	b, d
2, 5, 10	UNEP/WHO no 53, 1991	1991	Spain	prospective cohort	marine	a, b, d
2, 5	Cheung <i>et al</i> , 1989	1989	Hong Kong	prospective cohort	marine	a, b
2, 5, 7, 8, 9	Ferley <i>et al</i> , 1989	1989	France	retrospective cohort	fresh	a, b, c
1, 4	Lightfoot 1989	1989	Canada	prospective cohort	fresh	
1, 2, 5, 6, 10	UNEP/WHO no 20, Fattal <i>et al</i> , 1988	1987	Israel	prospective cohort	marine	b, d
1, 3, 5, 8	Seyfried <i>et al</i> , 1985	1985	Canada	prospective cohort	fresh	
2, 5, 7, 8	Dufour, 1984	1984	US	prospective cohort	fresh	a, b
2, 5, 6, 9	Cabelli, 1983	1983	Egypt	prospective cohort	marine	a, b, c
2, 5, 7, 8	Cabelli <i>et al</i> , 1982	1982	US	prospective cohort	fresh & marine	a, b
2, 5, 8	Mujeriego <i>et al</i> , 1982	1982	Spain	retrospective cohort/cs	marine	b, a
1, 2, 5, 9, 10	Stevenson, 1953, 3-day study	1953	US	prospective cohort	fresh	B, c, d

Key: Group - see text; cs: cross-sectional study; a: only use of the seasonal mean for analysis of association with outcome was reported; b: control for less than three confounders reported, or no reporting at all; c: exposure not defined as head immersion/head splashing/water ingestion; d: less than 1700 bathers and 1700 non-bathers participated in the study. Note: Two studies analysed the same data sets (van Dijk *et al*, 1996; Pike, 1994), but came to different conclusions:

Table 4.2 Non-selected studies

First author	Date
Alexander <i>et al.</i> ,	1992
Brown <i>et al.</i> ,	1987
Calderon <i>et al.</i> ,	1982
Dewailly <i>et al.</i> ,	1986
El Sharkawi <i>et al.</i> ,	1986
Fewtrell <i>et al.</i> ,	1994
Foulon <i>et al.</i>	1983
Hoadley <i>et al.</i> ,	1975
McBride <i>et al.</i> ,	1993
New Jersey Department of Health	1989
Philipp <i>et al.</i> ,	1985
Public Health Laboratory Service	1959
Seyfried <i>et al.</i> ,	1984

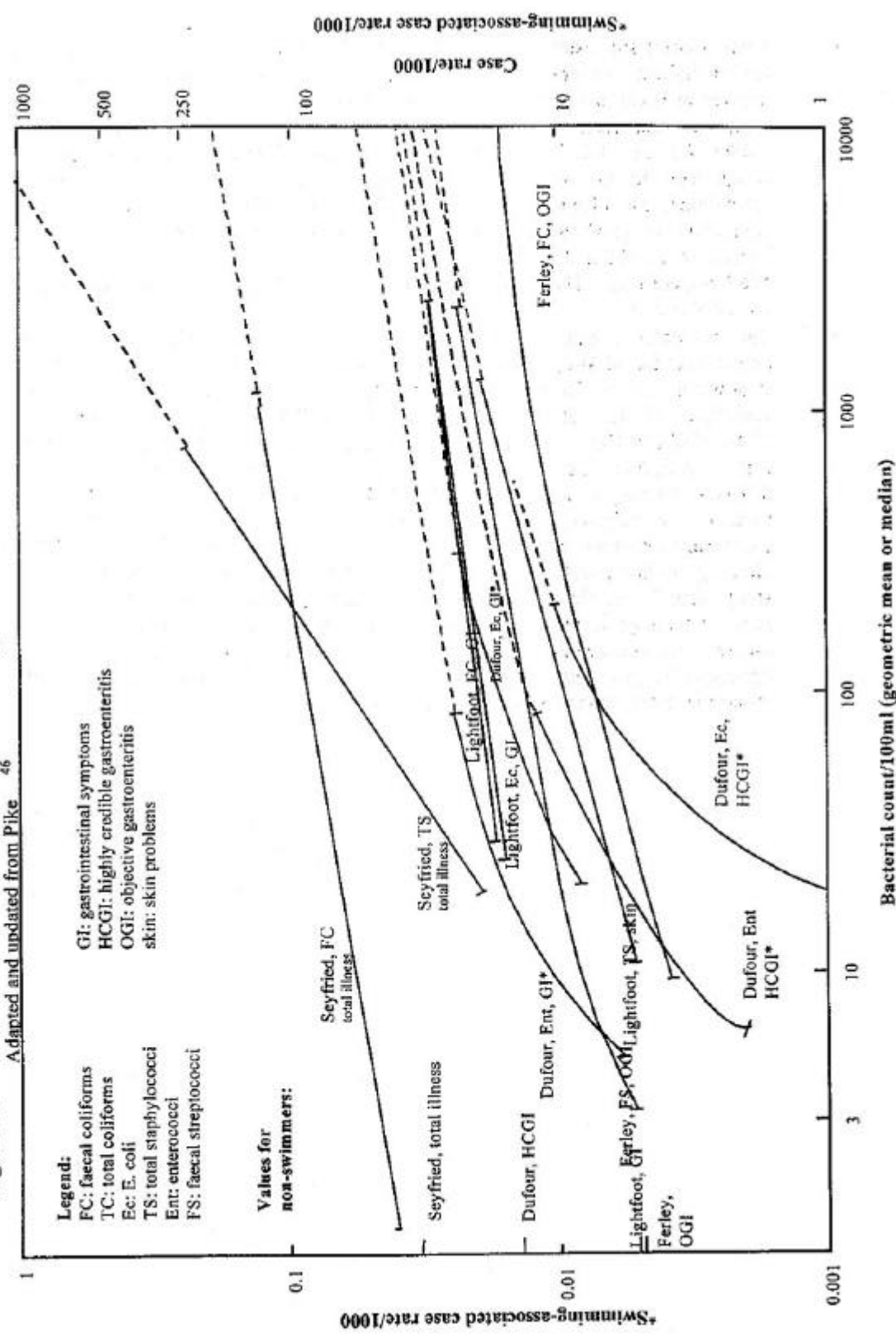
Twelve studies reported controlling for less than three non-water-related risk factors (Table 4.1, group 2), four studies for three to four of such potential confounding factors (Table 4.1, group 3) and six studies reported controlling for seven or more of them (Table 4.1, group 4). Confounding factors included food and drink intake, age, sex, history of certain diseases, drug use, personal contact, additional bathing, sun, socio-economic factors etc.

4.2.2 Study results

- The rate of certain symptoms or symptom groups was significantly related to the count of faecal indicator bacteria or bacterial pathogen. An increase in outcome rate with increasing indicator count, was reported by 19 of the 22 selected studies (Table 4.1, group 5). In one study (Mujeriego *et al.*, 1982) mycosis and eye and ear infections were inversely related to the count of indicator bacteria. In three studies, (van Dijk *et al.*, 1996; Corbett *et al.*, 1993; Lightfoot 1989) no significant relationships were found with faecal indicators.
- Increased symptom rates in the lower age groups were reported by several studies (Table 4.2a, group 6).
- Mainly gastrointestinal symptoms (including 'highly credible' or 'objective' gastrointestinal symptoms) were associated with faecal indicator bacteria such as enterococci, faecal streptococci, thermotolerant coliforms and *E. coli*.
- Overall relative risks of exposure to relatively clean water were compared to non-swimmers for evaluating the risk of contact with water itself. For gastroenteric symptoms, these relative risks all lie between 1.0 and 2.5 (Table 4.1, group 7), with only one value being significantly different from 1.0 (Cabelli *et al.*, 1982).
- Overall relative risks of swimming in relatively polluted water versus swimming in clean water are compiled in Tables 4.3 and 4.4. All overall relative risks ranged between 0.4 and 3.

- Many studies suggested continuously increasing risk models with thresholds for various indicator organisms and health outcomes. The suggested models of illness rate versus bacterial counts are compiled in Figs. 4.1 and 4.2. The numerical values suggested numerical values of illness rate versus bacterial count are given in Tables 4.3 and 4.4. The bulk of the suggested threshold values are low in comparison to the water qualities often encountered in coastal waters of recreational use (Table 4.1, group 8). They range from only a few indicator counts/100 ml to about 30 counts/100 ml, and were higher for Egypt and Hong Kong (around 100 to 200 indicator counts/100 ml; Cabelli, 1983 and Cheung *et al.*, 1989 respectively). These two studies also described lower case rates for similar bacterial counts.
- The indicator organisms which correlate best with health outcome were enterococci/faecal streptococci for both marine and freshwater, and, *E. coli* for freshwater. Other indicators showing correlation are faecal coliforms and staphylococci. The latter might be correlated to bather density (Cheung *et al.*, 1991; UNEP/WHO, 1988) and were reported to be significantly associated with certain symptoms, i.e. those affecting ear and skin and respiratory and enteric diseases (Cheung *et al.*, 1991; UNEP/WHO, 1988; Seyfried *et al.*, 1985). The variation in staphylococci density could not be explained by sources of contamination other than shedding by bathers (El Sharkawi and Hassan, 1979) although further investigations would be necessary to confirm this hypothesis. One study found significant correlation's between gastrointestinal symptoms and specific pathogenic bacteria (Kueh *et al.*, 1995). A stronger relationship (i.e. a greater increase health outcome versus water quality) between exposure and gastroenteric symptoms than found in other studies has been reported by the randomized controlled study investigating that outcome.

Figure 4.2 Predicted risks of illness in swimmers against bacterial count in freshwater



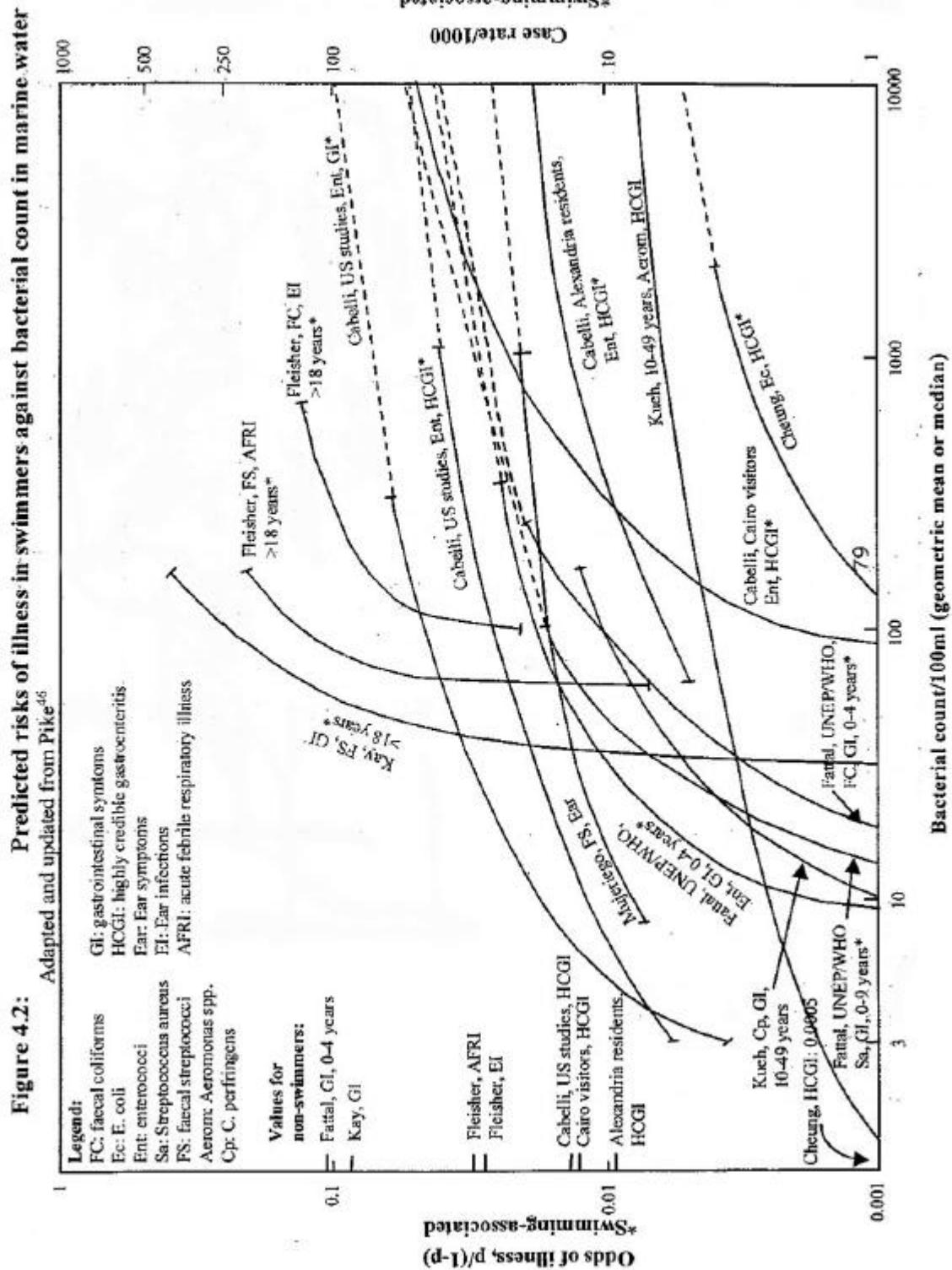


Table 4.3 Freshwater - Relative Risk (RR), swimming versus non-swimming in differing water quality

Author Year	Health outcome ^s	Indicator	Mean indicator count (per 100 ml)	RR (95%Confidence Interval)	Incidence rate IR (*1000)	Exposure
Dufour 1984	GI	Enterococ ci	13 vs 5 20 vs 5 25 vs 5 71 vs 5 20 vs 7 23 vs 7 39 vs 7	1.03 (0.82-1.30) 1.51 (1.25-1.83)** 1.01 (0.82-1.24) 1.38 (1.13-1.69)** 0.67 (0.53-0.84)** 1.64 (0.52-1.80)** 1.07 (0.87-1.33)	56 vs 55 58 vs 55 55 vs 55 75 vs 55 38 vs 57 37 vs 57 61 vs 57	Head immersion
Fewtrell 1992	Flu R Ear/Eye GI S All	Faecal coliforms	285 vs 22	1.76 (1.31-2.37)** 1.51 (1.06-2.14)* 3.53 (1.13-11.03)* 2.97 (2.01-4.37)** 2.02 (1.05-3.86)* 1.59 (1.31-1.93)**	445 vs 252 322 vs 214 68 vs 19 418 vs 141 137 vs 68 671 vs 422	White water canoeing
Ferley 1989	Objective AGID	Faecal streptoco cci	50 vs 20 100 vs 20 500 vs 20 1000 vs 20 2000 vs 20	1.24 (?) 1.42 (?) 1.84 (?) 2.02 (?) 2.20 (?)	12 vs 10 14 vs 10 18 vs 10 20 vs 10 22 vs 10	Bathing
Stevenson (3-day study) 1953	All	Total coliforms	2300 vs 37 730 vs 37	1.42 (1.09-1.86)* 1.14 (0.82-1.59)	122 vs 86 99 vs 86	Swimming

Key

*p<0.05; ** p<0.01

^sEar/Eye= ear or eye infections; S= skin complaints; GI= gastrointestinal symptoms; R= respiratory illness;

AGID= acute gastrointestinal disease

HCGI= highly credible gastro-enteritis

Flu=influenza

All=any symptom

Note: Not all non-significant results are listed.

Table 4.4 Sea water - Relative Risk (RR), swimming versus non-swimming in water of differing quality

Author Year	Health outcome ^s	Indicator	Mean indicator count (per 100 ml)	RR (95%Confidence Interval)	Incidence rate IR (*1000)	Exposure
Bandarana -yake 1995	R HCGI	Entero- cocci	(1.5-4) vs (0-1.5) (4-13) vs (0-1.5) (13-232) vs (0-1.5) (13-232) vs (0-1.5)	1.55 (0.66-3.63) 1.76 (0.76-4.07) 3.02 (1.31-6.93)** 0.84 (0.27-2.63)	37 vs 24 42 vs 24 71 vs 24 22 vs 26	Head immersion
Cabelli 1982	GI	Entero- cocci	154 vs 3.5 91 vs 3.5 31 vs 3.5 22 vs 3.5 20 vs 3.5 14 vs 3.5 7 vs 3.5 5.7 vs 3.5	2.21 (1.41-3.47)** 2.63 (1.67-4.12)** 1.59 (1.01-2.48)* 2.95 (1.91-4.56)** 2.16 (1.51-3.10)** 1.52 (0.93-2.49) 1.39 (0.89-2.17) 2.31 (1.63-3.29)**	60 vs 27 72 vs 27 43 vs 27 81 vs 27 59 vs 27 42 vs 27 38 vs 27 63 vs 27	Head immersion
Cabelli Egypt 1983	vomiting, diarrhoea	Entero- cocci	residents 5760 vs 103 286 vs 103 6780 vs 73 211 vs 73 9160 vs 214 954 vs 214 visitors 6780 vs 73 211 vs 73 9160 vs 214 954 vs 214	1.95 (0.91-4.16) 0.97 (0.38-2.51) 2.44 (1.18-5.05)* 1.33 (0.57-3.11) 1.87 (0.94-3.71) 2.05 (1.05-4.04)* 2.39 (1.47-3.87)** 1.21 (0.67-2.16) 2.57 (1.15-5.70)* 2.76 (1.17-6.51)*	31 vs 16 16 vs 16 30 vs 12 16 vs 12 19 vs 10 21 vs 10 51 vs 22 26 vs 22 45 vs 18 48 vs 18	Head immersion
Cheung 1989	HCGI	E. coli	119 vs 69 142 vs 69 254 vs 69 266 vs 69 269 vs 69 414 vs 69	1.42 (0.42-5.27) 0.62 (0.11-3.39) 0.47 (0.09-2.55) 0.49 (0.11-2.18) 1.75 (0.54-5.69) 2.47 (0.76-8.01)	3.1 vs 2.1 1.3 vs 2.1 1.0 vs 2.1 1.1 vs 2.1 6.5 vs 2.1 7.4 vs 2.1	Head immersion
Fattal 1983 and UNEP/WH O MAP N°20 1987	GI age 0-4 all ages HCGI age 0-4 all ages other symptom	Entero- cocci	49(25-410) vs 7(0-14) " " "	1.88 (1.01-3.50)* 1.50 (1.01-2.23)* 2.07 (1.17-3.65)** 1.36 (0.95-1.94) NS	209 vs 111 104 vs 69 221 vs 107 104 vs 76	Head immersion +splashing +swallow.

Author Year	Health outcome ^s	Indicator	Mean indicator count (per 100 ml)	RR (95%Confidence Interval)	Incidence rate IR (*1000)	Exposure
Haile 1996	S	faecal coliforms	642 vs 5 130 vs 5 51 vs 5	2.02 (1.07-3.81)* 0.83 (0.39-1.76) 1.94 (1.04-3.63)*	14 vs 6 6 vs 6 14 vs 6	face immersion
Kay 1994	GI	faecal strepto- cocci	80+ vs 0-19 70(60-79) vs 0-19 50(40-59) vs 0-19 30(20-39) vs 0-19	2.80 (1.33-5.89)** 2.58 (1.44-4.64)** 1.68 (0.91-3.12) 0.97 (0.53-1.73)	304 vs 109 281 vs 109 183 vs 109 106 vs 109	head immersion
CSIR 1995	GI	faecal strepto- cocci. faecal coliforms	10.4(0-163) vs 0.8(0-28) 21.9(0-436) vs 3.8(0-324)	1.68* (1.09-2.60)	61 vs 36	entering water up to or beyond waist
UNEP/WHO MAP N°46 1991	GI R	Enterococ ci	40(31-51) vs 9(2- 30) “	1.95 (1.08-3.52)* 2.55 (1.27-5.05)**	131 vs 65 124 vs 47	head immersion +splashing +swallow
UNEP/WHO MAP N°53 1991	enteric dermatitis	faecal streptococ ci	2835 (130-11500) vs 407 (40-1800)	1.51 (0.65-3.54) 2.02 (1.25-3.27)*	21 vs 14 78 vs 38	head immersion +splashing +swallow.

Key

* p<0.05; ** p<0.01

^sS= skin complaints; GI= gastrointestinal symptoms; HCGI= highly credible gastro-enteritis;

R= respiratory illness

Note: Not all non-significant results are listed.

4.2.3 Limitations

Relatively few studies reported associations for other than gastroenteric symptoms.

The studies did not yield any findings on the relationship of severity of symptoms to differences in water quality.

Very little information was available on the association of more severe health outcomes and water quality. The non-selected study investigating typhoid and paratyphoid fever in Egypt (El Sharkawi and Hassan, 1979) reported significantly higher incidence rates of these outcomes for bathing at “polluted beaches” than for bathing at “non-polluted” beaches. The cut-off point for classification of beaches into the “non-polluted” and “polluted” categories was a mean summer concentration of 3,000 faecal coliforms/100 ml of the bathing water. Sewage outlets were located at all polluted beaches, and at none of the “non-polluted” beaches. The non-selected study investigating typhoid and paratyphoid fever, and poliomyelitis in the UK (Public Health Laboratory, 1959) reported several cases of paratyphoid fever associated with sewage polluted bathing in waters of mean total coliform concentrations of about 10,000 per 100ml.

4.2.4 Bias and validity of study results

The most important types of bias in this context are likely to be introduced by the use of indicators assessing water quality and the individual exposure assessment (Table 4.5). These factors lead to non-differential misclassification bias, which signifies error in assessment of certain parameters (here water quality) leading to classifying individuals into the wrong category (here exposure). It is non-differential when misclassification occurs randomly. Non-differential bias leads to underestimation of the relationship between health effects and water quality.

Selection of study populations which are more immune (e.g. adults) leads to underestimation of the effect for the population of interest. Non-control for confounders may either under- or overestimate the effect. All other types of bias probably introduce only minor bias.

Since several of these causes of bias may occur in one and the same study, errors introduced are multiplied which could be very important, probably leading to underestimation of the health effect of water quality. Non-differential misclassification bias, the most important bias in the reviewed studies, should be smaller in the randomized controlled studies (Fleisher *et al.*, 1996; Kay *et al.*, 1994) than in the observational studies, as their assessment of individual exposure (water quality and degree of water contact assessment) is more accurate. This probably explains the higher risk estimates for gastroenteric symptoms, and the stronger relationship with indicator counts, compared to findings of the other studies. The same probably applies to the relationships reported by the randomized controlled trial investigating nonenteric illnesses (Fleisher *et al.*, 1996). Since this was the first study to investigate recognized classifications of non-enteric illnesses, and due to the lack of other reported relationships, comparison with other studies is not possible at this time.

The population size is another factor that may influence the study results. According to power calculations (CDC, 1994) the *study population size* should reach a minimum of 1700 swimmers and 1700 non-swimmers under the hypothesis of a 5 percent background illness rate and an excess rate of 50 percent for a significant result (90 percent power). Not all studies reached this number of participants (Table 4.2a, group 10), but excess rates were sometimes reported to be higher and so some studies could still yield significant results.

Special attention should be given to the low threshold values reported. Misclassification of exposure may produce artificially low thresholds for increased risk. The one randomized controlled trial reviewed here analysing gastrointestinal symptoms (Kay *et al.*, 1994), which should yield the most accurate relationship, suggested a threshold of 33 faecal streptococci/100 ml for increased risk of gastroenteric symptoms, which is higher than suggested in other studies. In addition to misclassification bias in observational studies, the difference in thresholds could be due to a study population limited to adults in the randomized controlled trial, their immune status for diarrhoeal diseases being probably higher than for the average population (Martines *et al.*, 1993). Furthermore, study populations from Hong Kong (Cheung *et al.*, 1991) and Egypt (Cabelli, 1983), showed higher thresholds (and case rates). Also, within the Egyptian study, the visiting population (from another inland town) showed higher attack rates for gastroenteric symptoms than the local population. These results could not be explained by bias only and suggest the influence of immune status on susceptibility to water-related disease, or a lower pathogen-to-indicator ratio in the natural waters. The thresholds may also be influenced by the sample size, i.e. they may decrease when sample size increases. However, the Hong Kong and Egypt studies were among those with the largest sample

size among the reviewed studies; whereas the sample size of the randomized controlled trial studying gastroenteric symptoms was relatively small.

Table 4.5 Some types of bias in epidemiological studies of recreational water

Type of bias	Description
Use of indicator micro-organisms for assessing water quality of exposure	Temporal and spatial indicator variation is substantial, and difficult to relate to individual bathers (Fleisher <i>et al</i> , 1990), unless the study design is experimental (Fleisher <i>et al</i> , 1996; Kay <i>et al</i> , 1994). Also, the limited precision of methods for counting indicator organisms added substantial measurement error (Fleisher, 1990). Furthermore, the indicator organisms used do not relate well to viruses, which may represent an important part of the aetiological agents.
Use of seasonal means for assessing water quality	Several studies use seasonal means of indicator organisms rather than daily measurements for characterizing individual exposure that adds substantial inaccuracy.
Assessment of pathway of exposure	Certain studies do not take into account the potential infection pathway for defining <i>exposure</i> , e.g. mainly head immersion or the ingestion of water (Table 4.2a, group 9) for gastroenteric symptoms. Difficulties in exposure recall further increase inaccuracy of individual exposure.
Non-control for confounders	The non-control for confounders, such as food and drink intake, age, sex, history of certain diseases, drug use, personal contact, additional bathing, sun, socio-economic factors etc., may influence the observed association.
Selection of unrepresentative study population	Results reported for certain study populations (e.g. limited age groups or from regions with certain endemicities) are a priori not directly transferable to populations with other characteristics.
Self-reporting of symptoms	Most observational studies relied on self-reporting of symptoms by the study population. Validation of symptoms by medical examination (Fleisher <i>et al</i> , 1996; Kay <i>et al</i> , 1994) would have reduced potential bias. External factors, such as media or publicity may have influenced on self-reporting.
Response rate	The response rate was more than 70% in all, and more than 80% in most studies. Differential reporting, e.g. higher response among participants experiencing symptoms, would probably not have major consequences.
Recruitment method	The recruitment method consisted in approaching persons on the beach in almost all observational studies and was operated by advertisement for the randomized controlled studies.
Interviewer effect	Differences in the methodology of data collection among interviewers may influence the study results.

4.2.5 Quality of Evidence

Bradford Hill (1965) proposed a set of criteria for evidence in environmental disease causation. Their fulfilment for the associations described here, are shown in Table 4.6.

Table 4.6 Criteria for causation in environmental studies (according to Bradford Hill,1965). Application to bathing water quality and gastrointestinal symptoms.

Criterion	Explanation	Fulfilment
1. Strength of association	Difference in illness rate between exposed and non-exposed groups, measured as a ratio	Yes significant associations have been found; the ratios are relatively low (usually <3)
2. Consistency	Has it been observed by different people at different places?	Yes in several countries and by various authors
3. Specificity of association	A particular type of exposure is linked with a particular site of infection or a particular disease	No
4. Temporality	Does the exposure precede the disease rather than following it?	Yes most studies permit to show temporal relationship
5. Biological gradient	A dose-response curve can be detected	Yes most of the selected studies show significant dose-response relationships
6. Plausibility	Does the present relationship seem likely in terms of present knowledge?	Yes e.g. the results are in line with findings on ingestions of infective doses of pathogens
7. Coherence	Cause-and-effect interpretation of the data should not conflict with knowledge of natural history and biology of the disease	Yes
8. Experiment	Did preventive actions change the disease frequency?	preventive actions have not yet been described in the studies
9. Analogy	Are similar agents known to cause similar diseases in similar circumstances?	Yes similar to ingestion of recreational water, gastrointestinal symptoms are known to be caused by faecally polluted drinking-water

4.2.6 In reviewing the 22 studies, seven of Hill's nine criteria were fulfilled. The criterion on the specificity of the association is not applicable because etiologic agents are suspected to be numerous and relatively outcome unspecific. Results of experiments on the impact of preventive actions on health outcome frequency have not yet been reported.

The degree of criteria fulfilment suggests that the most likely interpretation of the association is causation. The frequency of gastrointestinal symptoms in exposed groups is influenced by a change in indicator concentration in recreational water. Exposure to

bathing water of poor quality is probably an important component cause (i.e. a causal factor within the causal process) for gastrointestinal symptoms .

4.2.7 Conclusions and consequences for health protection

This review of published studies suggests that:

- A causal relationship does exist between gastrointestinal symptoms and recreational water quality as measured by indicator-bacteria concentration. A strong and consistent association was reported with temporality and dose-response relationships, as well as biological plausibility and analogy to clinical cases in drinking water pollution.
- In 19 out of 22 studies, the rate of certain symptoms or symptom groups was significantly related to the count of faecal indicator bacteria in recreational water. Gastrointestinal symptoms were the most frequent health outcome for which significant dose-related associations were reported. Symptom rates were usually higher in the lower age groups.
- Several indicators were used for describing water quality. Most probably, the indicators showing correlation with health outcome varied according to faecal contamination of the water or contamination by other bathers. Consequently, despite different indicators, the trend in reported associations was similar.
- For marine and freshwater, low threshold values for increased risk compared to water qualities are frequently encountered in coastal recreational waters and this suggests the existence of a dose-response relationship between bacterial counts and symptoms. Results of the randomized controlled trials (Fleisher *et al.*, 1996; Kay *et al.*, 1994) were probably the most accurate, as exposure, water quality and illness are much more accurately assessed than in observational studies where an artificially low threshold (due to the misclassification bias) is achieved. These results are however primarily indicative for adult populations in temperate climates. Studies which reported higher thresholds and case rate values (for adult populations or populations of countries with higher endemicities) may suggest increased immunity, which is a plausible hypothesis but requires further studies to confirm.
- There were indications that more severe health outcomes may occur when bathing in grossly sewage polluted water in endemic regions. This suggests that special measures may be considered at these very high levels of faecal pollution.
- The most frequent health outcome associated with exposure to recreational water is gastrointestinal symptoms. These are most often correlated with faecal streptococci/enterococci for marine or freshwater, and *E. coli* for freshwater.
- The associations between recreational water and gastrointestinal symptoms have been investigated by a great number of epidemiological studies. Only a few associations have been reported for other health outcomes, such as ear infections, respiratory symptoms or more severe health outcomes.

4.3 Specific types of health outcome

A sound public health basis for a causal relationship between faecal contamination and adverse health outcomes amongst user groups ingesting contaminated water exists (section 4.1). The overall body of evidence from epidemiological studies indicates that

mild to moderate self-limiting symptoms are reported amongst user groups ingesting faecally-contaminated water; at frequencies that increase with exposure (section 4.2). In this section the state of knowledge regarding types of health outcome is summarised.

4.3.1 Gastrointestinal illness

Enteric illness, such as self-limiting gastro-enteritis, is the most frequently reported adverse health outcome investigated and reported in the published literature.

There is an association between gastrointestinal symptoms and indicator-bacteria concentrations in recreational water. The studies reported a strong and consistent association with temporality and dose-response relationships, as well as biological plausibility and analogy to clinical cases in drinking water pollution.

In 19 out of the 22 studies selected in this review, the rate of certain symptoms, or symptom groups, was significantly related to the count of faecal indicator bacteria in recreational water. Gastrointestinal symptoms are the most frequent health outcome for which significant dose-related associations were reported. Symptom rates were usually higher in the lower age groups.

The body of evidence suggests a causal relationship between increasing recreational exposure to faecal contamination and frequency of gastro-enteritis. Most causes of bias affecting the selected studies are likely to lead to under estimation of the health effect of water quality and consequently most reported a shallow dose-response curve. The one randomised trial - which should yield the most accurate relationship - suggests a considerably steeper curve. The limited information concerning the nature of the dose-response relationship limits ability to undertake a cost-benefit approach to control of these hazards. The existence of dose-response relationships between bacteria counts and symptoms is evident. Results from the randomised trial (Kay *et al.*, 1994) are probably the most accurate, as exposure, water quality and illness were much more accurately assessed than in observational studies.

Misclassification of exposure may produce artificially-low threshold values for increased risk. Threshold values varied between studies but were generally low in comparison with water qualities prevailing in natural waters world-wide. The one randomised trial - which should yield the most accurate relationship - suggested a threshold of 33 faecal streptococci/100 ml for increased risk of gastro-enteritis, which is higher than the other studies.

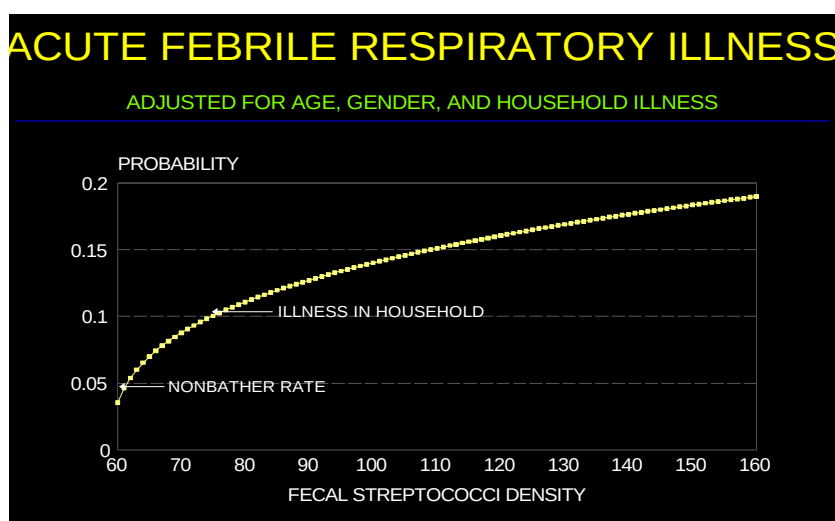
Several indicators were used for describing water quality in the reviewed studies. Most probably, the indicators showing correlation with health outcome varied according to faecal contamination of the water or contamination by other bathers. Consequently, despite different indicators, the trend in reported associations was similar. Limited evidence suggested that local populations bathing in sewage-contaminated waters may suffer less ill-health than visiting populations, presumably due to the influence of immune status.

4.3.2 Acute febrile respiratory illness

A cause-effect relationship between faecal pollution or bather-derived pollution and acute febrile respiratory illness is biologically plausible. Associations occurred between acute febrile respiratory illness (AFRI) and microbiological indicators of both faecal pollution and of bather load. A significant dose-response relationship (with faecal streptococci) has been reported in one study with a threshold of 59 faecal streptococci per 100 ml (Fleisher *et al.*, 1996; Fig. 4.2).

AFRI was the first illness associated with recreational-water exposures that has an international disease classification (IDC) number and thus the most objectively derived illness found to be associated with bathing waters. It is also a more severe health outcome than the more frequently assessed self-limiting gastrointestinal symptoms. When compared to gastro-enteritis, probabilities of contacting AFRI are generally lower and are associated with similar faecal streptococci concentrations.

Figure 4.4 Dose-response relationship between faecal streptococci and acute febrile respiratory illness (Fleisher *et al.*, 1996)



4.3.3 Ear infection

Associations between ear infections and microbiological indicators of faecal pollution and bather load have been reported. A significant dose-response relationship (with faecal coliforms) has been reported in one study (Fleisher *et al.*, 1996). When compared to gastro-enteritis, the statistical probabilities are generally lower and are associated with higher faecal coliform concentrations than those for gastrointestinal symptoms and for acute febrile respiratory illness. A cause effect relationship between pollution or bather-derived pollution and ear infection is biologically plausible.

4.3.4 Eye Ailments

Increased rates of eye symptoms have been reported amongst bathers e.g. Fleisher *et al.*, 1996) and evidence suggests that bathing, regardless of water quality, compromises the eye's immune defences leading to increased symptom reporting in marine waters. Despite biological plausibility, no credible evidence for increased rates of eye ailments associated with water pollution is available.

4.3.5 Skin diseases

No credible evidence for an association of skin disease with either water exposure or microbiological water quality is available.

4.3.6 Hepatitis, enteric fever and poliomyelitis

Most epidemiological investigation has either not addressed severe health outcomes (such as hepatitis, enteric fever or poliomyelitis) or has been undertaken in areas of low endemicity or zero reported occurrence of these diseases. By inference from the very strong evidence for transmission of self-limiting gastro-enteritis, much of which may be of viral aetiology, transmission of infectious hepatitis (HAV, HEV) and of poliomyelitis should exposure of susceptible persons occur is possible and biologically plausible.

One of the studies, reported in 1959 from the United Kingdom, concerned the risk associated with two serious illnesses, namely poliomyelitis and enteric fever (PHLS, 1959). Notified cases were retrospectively matched with controls living in the same street. Questionnaires were administered to identify any difference in the history of exposure to sea water in the cases and the controls. This five year investigation in maritime district councils, failed to identify any association between poliomyelitis and a history of sea bathing. Polluted sea water was implicated in four cases of enteric fever. Using this retrospective design it was clearly not possible to relate disease to any index of water quality, though a conclusion was drawn that enteric fever may occur with exposure to coliform organism concentrations (i.e. total coliform) greater than 10,000 colony forming units (cfu) per 100 ml.

Sero-prevalence studies for Hepatitis A and leptospiral antibodies amongst windsurfers and water skiers exposed to contaminated waters have not identified any increased health risks (Philipp *et al.*, 1989).

4.3.7 Leptospirosis

Leptospire are shed in the urine of infected animals. Unlike other infections reviewed in this chapter, the principle source of infection is animal urine rather than human excreta. Rodents are considered to be the main reservoir of *L. icterohaemorrhagiae*, cattle and sheep of *L. hardjo*, dogs of *L. canicola* and so on, although this is only a general rule, and no serovar is confined entirely to one animal species. From water contact *L. icterohaemorrhagiae* and *L. hardjo* are likely to be the most important. Most *L. hardjo* infections are farming related, but infected cattle grazing by a watercourse, or spillages of infected slurry reaching water, may present a risk of human infection to users.

Sero-prevalence studies for Hepatitis A and leptospiral antibodies amongst windsurfers and water skiers exposed to contaminated waters have not identified any increased health risks (Philipp *et al.*, 1989).

It is impractical to eradicate potential sources of leptospiral infection. Since the incidence of disease is relatively low, sensible precautionary measures for high risk groups are the best means of achieving the greatest protection. Many local authorities, and specific water user groups now produce information leaflets on leptospirosis, with the aim of raising public awareness and highlighting sensible precautions. These include covering cuts and scratches with water proof plasters, showering after water immersion, and the provision of litter control to minimise the rodent population (Fewtrell *et al.*, 1993)

4.4 Health Risk and Management

Exposure to faecal pollution through contaminated recreational water leads to detectable health effects of varying nature and severity and there is clear and growing evidence of a dose-response relationship linking faecal pollution with both enteric and non-enteric illness. Available evidence also indicates that pollution-related health effects occur at levels of faecal indicator bacteria which are encountered in recreational waters

world-wide and which may be substantially below the prevailing legal standards in many parts of the world. In deriving approaches to the control of health risks associated with recreational water quality, national authorities have to take account of a number of interacting and sometimes opposing factors with the objective of ensuring that waters used for recreation are “safe”. In addition to the assessment of health risk, social and economic factors should be considered. These factors are important and should be considered when developing national and local public health policies and strategies.

- *Social factors* include, for example, customary bathing practice (control of risks associated with ritual bathing may, for example, require special treatment); and the concept of “acceptable” or “tolerable” risk.
- *Economic factors* include the cost of control measures; the cost of ill-health; the economic aspects of tourism and other recreational and competing uses on the national and local economy; and the cost of controlling more serious endemic illnesses on a regional basis.

For example, in some countries or localities it may be considered that investments necessary to reduce diarrhoeal disease arising from recreational water exposure, might be more effectively employed in controlling other routes of exposure, such as improving drinking water supply and quality. Elsewhere, the weight of social pressure might be found to favour considerable intervention in the control of risks attributable to recreational water exposure. Finally, where recreational water use, whether by local or tourist populations, is of economic importance, greater emphasis may be given to ensuring international comparability in quality objectives. Competent (generally health) authorities have the responsibility of ensuring that risks to health are recognised by all concerned parties and that all reasonable measures are taken to ensure their control. It should be recalled that most studies to date have been undertaken in areas with low endemicity of more severe pathogens (such as *Salmonella typhi*, the cause of typhoid fever) and, where endemic, due attention should be given to these.

4.4.1 Assessing the safety of recreational waters

Most approaches, to date, have involved defining an individual beach or area of recreational water as passing or failing a defined microbiological standard. Since a single beach or recreational area may vary widely in relation to microbiological measures of health risk within relatively short periods of time, such an approach has inherent limitations and may condemn beaches which are in fact safe for much of the time; or contrariwise imply the safety of a beach which is, in reality unsafe on many occasions. This variability is both temporal and spatial and may be due to a number of factors. It may mean that different orders of magnitude in the degree of faecal pollution may be encountered within a few metres on a single beach, or within a few hours at the same sampling point. In such circumstances, the value of classifying a beach as intrinsically safe or unsafe based on a limited number of determinations of indicator bacteria density from a number of locations at one time, or group of samples taken at a specific point in time is questionable.

Water quality assessments, to date, have relied heavily upon the use of microbiological enumeration. This has a series of associated limitations:

- such data are considered expensive to collect in many countries;
- they are of questionable value given the local spatial and temporal variability in recreational water quality noted above (i.e. there are fundamental sampling protocol problems);

- recent studies have indicated that comparability of monitoring data generated even by well-run laboratories may be extremely poor (i.e. there are problems of analytical reproducibility and inter-laboratory comparability).
- data so produced may not be suitable for the purposes of inter-beach comparison for which it is often used (i.e. there are fundamental problems in interpretation and presentation).

Because of the time delay before microbiological analytical results are available and the frequency of analysis undertaken, approaches which rely primarily upon microbiological water quality analysis are always retrospective in nature. It is, in part, for this reason that beach “safety” has often been assessed in terms of issuing compliance with a standard across a retrospective period (usually the previous years bathing season). Such approaches may therefore fail to provide information useful for public advisories prior to risk onset. They do, however, permit decisions to be made about long-term improvement and remedial engineering works.

Difficulties may be encountered in enforcing legislation for water quality where the cause(s) of failure may be unclear or multiple. For example, a beach failing a standard may be known to be influenced by both a river discharge and a sewage discharge. Who is responsible for failure? Upstream polluters, or the authority discharging sewage? Both? How should the cost for remediation be proportioned?

4.4.2 Derivation of microbiological Guideline Values

In this document the term “Guideline Value” is used. The nature of guideline values is described in Section 1.5.

The adopted approach taken to the derivation of a Guideline Values for Microbiological water quality is described below and includes discussion of factors which should be taken into account when adapting such values specific to local conditions and priorities.

There is no universally-applicable risk management formula. “Acceptable” or “tolerable” excess disease rates are especially controversial because of the voluntary nature of recreational water and the generally self-limiting nature of the most studied health outcomes. Guideline Values for recreational water quality should be interpreted or modified in light of regional and/or local factors including the nature and seriousness of local endemic illness, population behaviour, exposure patterns, social, economic, cultural, environmental and technical aspects as well as competing health risk from other non-recreational water associated diseases. It is up to society to define “acceptable” or tolerable excess disease and for national authorities to apply these principles for risk management under their specific conditions.

The approach adopted below to the definition of Guideline Values for microbiological quality seeks to define a series of values known to be associated with increasing frequency and range of types of disease. It is likely that the scale of values would be further associated with increasing severity within health outcomes. Information that contributes to the definition of values derives from:

- published ‘threshold values’ and ‘adverse effect levels’ in individual epidemiological studies for gastro-enteritis and other human health outcomes.
- rates of disease incidence derived from assumed typical disease distribution curves and probability density functions for indicator organisms.

In light of the limited available evidence for all types of natural recreational waters, a tentative and sufficiently solid scientific basis for relating a health outcome to recreational water quality can thus only be proposed for gastrointestinal symptoms and

streptococci/ enterococci. Guideline Values are defined only for coastal waters and are expressed in terms of faecal streptococci/100 ml. Most studies have identified faecal streptococci and enterococci as the indicator organisms which correlate most closely with health outcomes in coastal waters (for an explanation of these groups see Godfree *et al.*, 1997). For freshwaters, better correlations have been obtained with faecal coliforms/*Escherichia coli* but insufficient information is available for derivation of Guideline Values at present. The balance of evidence suggests that, under many circumstances, the same level of faecal indicator bacteria in a freshwater environments may correspond to a greater health risk than in a marine environment.

Bacteriophages are being considered as potentially suitable indicators but currently this is a matter for research rather than regulation.

This scientific and epidemiological base may not cover all global climatic regions or recreational water types. Therefore, Guideline values may change in future years as additional information becomes available. These risk estimates have been calculated for temperate marine waters in countries with low rates of endemicity of more severe potentially recreation-associated illness. However, inland waters receiving sewage effluents, and areas where sewage effluent is disinfected prior to disposal, may have more pathogens at equivalent indicator concentrations and, therefore be associated with higher risks than suggested in this section.

Water quality monitoring should take into account and quantify uncertainties resulting from the imprecision of current techniques of indicator organism enumeration. Quantification of such uncertainty is necessary to ensure valid linkage to the results of the epidemiologic relationships from the Guideline Values are derived. In particular, approaches which take full account of information concerning sources of pollution and concerning the level and variability of resulting contamination are required.

The Guideline Values are summarised in Table 4.7. Principal considerations in their derivation are explained in the following sections under the titles:

- expression in terms of a 'typical bather'
- criteria for compliance
- indicator level/burden of disease relationship
- threshold values and adverse effect levels
- severe health outcomes.

The specific values should be adapted to take account the variations in social, economic, environment and technical factors in translation into national or local standards and legislation.

Table 4.7 Guideline Values for microbiological quality of marine recreational waters (faecal streptococci/100 ml)

95 percentile value of faecal streptococci per 100 ml	Basis of derivation	Estimated disease burden
10	This value is below the no-observed adverse effect level (NOAEL) in most epidemiological studies that have attempted to define a NOAEL.	Using the indicator level/burden of disease relationship it corresponds to the 95 percentile value which is associated with less than a single excess incidence of enteric symptoms for a family of four healthy adult bathers having 80 exposures per bathing season (rounded value), over a 5 years period. Making a total of 400 exposures.
50	This value is above the threshold and lowest-observed-adverse-effect level (LOAEL) for gastro-enteritis in most epidemiological studies that have attempted to define a LOAEL.	Using the indicator level/burden of disease relationship it corresponds to the 95 percentile value that is associated with a single excess incidence of enteric symptoms for a family of four healthy adult bathers having 80 exposures per bathing season (rounded value).
200	This value is above the threshold and lowest -observed-adverse-effect level for all adverse health outcomes in most epidemiological studies.	Using the indicator level/burden of disease relationship it corresponds to the 95 percentile value that is associated with a single excess incidence of enteric symptoms for a healthy adult bather having 20 exposures per bathing season (rounded value).
1000	Derived from limited evidence regarding transmission of typhoid fever in areas of low-level typhoid endemicity and of paratyphoid. These are used in this context as indicators of severe health outcome.	The exceedence of this level should be considered a public health risk leading to immediate investigation by the competent authorities. Such an interpretation should generally be supported by evidence of human faecal contamination (e.g. a sewage outfall).

Footnotes

1. This table would produce protection of 'healthy adult bathers' exposed to marine waters intemperate north European waters.
2. It does not relate to children, the elderly or immuno-compromised who would have lower immunity and might require a greater degree of protection. There are no available data with which to quantify this and no correction factors therefore applied.
3. Epidemiological data on fresh waters or exposures other than bathing (e.g. high exposure activities such as surfing or white water canoeing) are currently inadequate to present a parallel analysis for defined reference risks. Thus a single guideline value is proposed, *at this time*, for all recreational uses of water because insufficient evidence exists at present to do otherwise. However, it is recommended that the severity and frequency of exposure encountered by special interest groups (such as body, board and windsurfers, sub-aqua divers, canoeists and dinghy sailors) are taken into account (chapter 1).
4. Where disinfection is used to reduce the density of indicator bacteria in effluents and discharges the presumed relationship between faecal streptococci (as indicators of faecal contamination) and pathogen presence may be altered. This alteration is, at present, poorly understood. In water receiving such effluents and discharges faecal streptococci counts may not provide an accurate estimate of the risk of suffering from mild gastrointestinal symptoms.
5. The values calculated here assume that the probability on each exposure is additive.

Expression in terms of a typical bather

Health professionals often define an “acceptable” disease risk at low “negligible” levels such as 1 case per 100,000 population over a lifetime of exposure. This is not appropriate in the case of faecal contamination of recreational waters where the most likely health effect is thought to be self-limiting gastro-enteritis or non-enteric illness. Under such circumstances, application of lifetime probabilities of illness of 1/100,00 are inappropriate and overly stringent. However, health effects of bathing in recreational waters contaminated with domestic sewage when taken in the aggregate, can have substantial adverse public health consequences. It is therefore more appropriate to express the health risk in terms of excess risk of illness to the exposed relative to the unexposed. One method of accomplishing this is to express health risk in terms of the rate of illness affecting a “typical” bather over a fixed period of time. For this purpose, a typical bather is considered here as a person receiving 20 exposures throughout a bathing season each of which might involve three instances of head immersion and approximately ten minutes in the water. This could, for instance, be during a 10 day holiday in which the bather entered the water twice per day, or through a person visiting a local beach one day every two weeks during a 20 week bathing season and entering the water twice per visit. Guideline Values can be constructed such that this “typical” bathers risk of illness over the specified number of exposures is below a pre-defined risk or probability of illness.

Criteria for compliance

Many agencies have chosen to base criteria for recreational water compliance upon either 95 percent compliance levels or geometric mean values of water quality data collected adjacent to the beach. Both are subject to the effects of extreme values, however, the 95 percent compliance system has the merit of being more easily understood and makes better use of the overall data set. The most appropriate method of calculating the 95 percentile would be to first generate a probability density function (pdf) based on the distribution of indicator organisms over a defined bathing area and then use the properties of this pdf to define the 95 percentile value of this distribution. Since currently used indices of water quality are microbiological, they have been shown to be log₁₀ normally distributed therefore the log₁₀ normal distribution becomes a valuable tool in either risk assessment or compliance assessment.

The indicator level/burden of disease relationship

This approach makes maximum use of all available information and is not overly susceptible to variability in single sample concentrations that can cause non-compliance with a numerical limit value. Published or site specific dose – response curves of the probability of illness over increasing indicator organism exposure, can then be used in conjunction with the pdf (as described above) to yield both prospective Guideline Values or actual expected disease burden at a particular recreational water location. An example is shown in Box 4.1.

Box 4.1

Assume a regulator wishes to set a standard or guideline at a level of a specific indicator organism such that the probability of becoming ill does not exceed 0.05. (1 case/20 exposures).

Explanation of this process requires the introduction of a disease burden model illustrated graphically by Figure 4.3A, the dose response relationship, Figure 4.3B the pdf and Figure 4.3C the disease burden calculation. Here 1,000 persons are assumed to be exposed, of these, 621 experience water quality unlikely to produce any health effect. Of the 321 who experience water quality that might make them ill, 71 become ill with symptoms of gastro-enteritis. Thus, the disease burden (or risk of illness) can be calculated for any beach if a suitable dose-response curve is available and the bacterial pdf can be drawn. Clearly if the mean value of the pdf in Figure 4.3C moves to the right, i.e. the beach is more polluted, then the number of individuals exposed to water that might make them ill is increased.

Reference values can be defined by adjusting the mean point of the pdf (i.e. the log₁₀ normal distribution of faecal indicator concentrations) until the excess disease burden is one case in 20 exposures. This can be repeated using the other desired probabilities of illness (i.e. 1 in 80 = 0.0125 and 1 in 400 = 0.0025). Figure 4.3D illustrates this process. The 95%ile point of the pdf is then reported as the 'standard or guideline value' associated with the accepted level of illness.

This method requires the regulator to assume constant variance (or spread) in the beach pdf. This is required if a single regulatory compliance value is required.

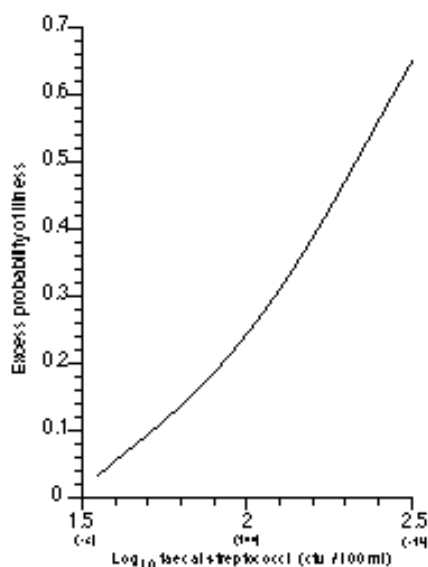


Figure A

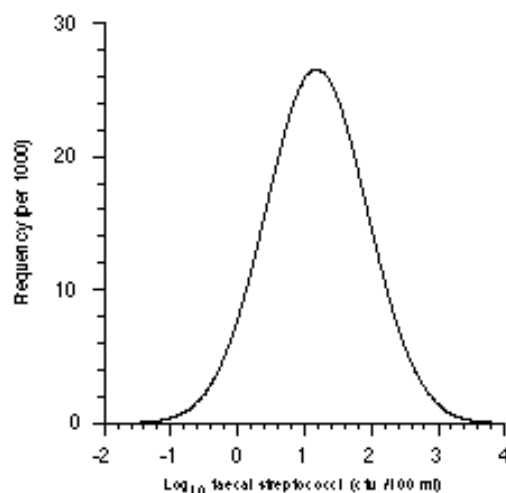


Figure B

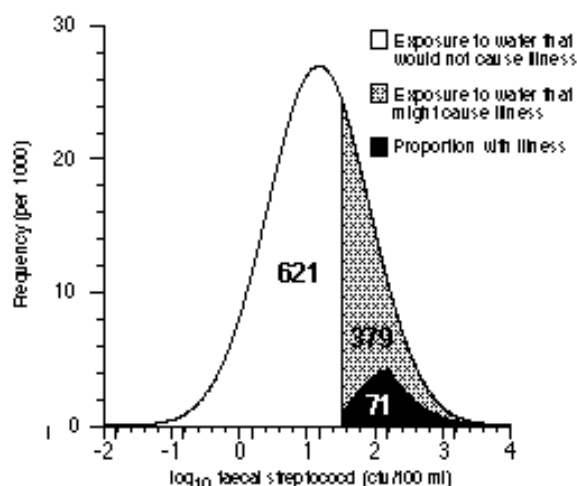


Figure C

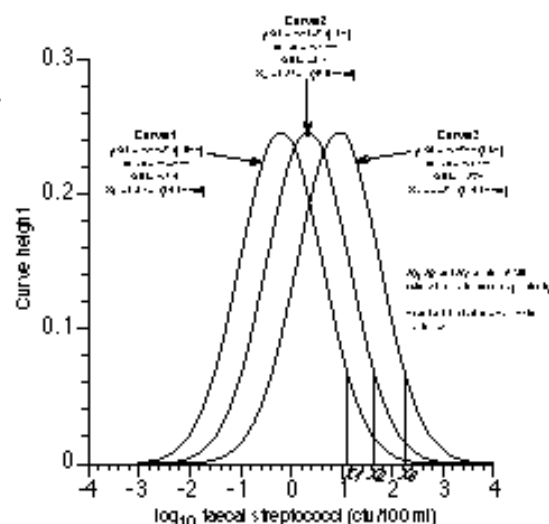


Figure D

Figure 4.5 A-D. Calculation of the Guideline Values or actual expected disease burden at a particular recreational water location.

It is important to note that in the Guidelines reported here:

- the statistical distribution of faecal streptococci, or other faecal indicator concentration in the bathing water, measured during the bathing season, is represented by a $\log_{10}$ normal distribution, or pdf characterised by fig 4.3A and Box 4.1
- the standard deviation in the $\log_{10}$ faecal streptococci concentration i.e. equal to 0.8103 which is believed to be typical and is derived from a recent study of over 11,000 EU bathing waters (Kay *et al.*, 1996)
- illness attack rates in the bather population are equal to those experienced by adult bathers in UK sea waters. The Guideline Values therefore predict a lesser degree of protection to children or other categories of user who experience

greater risk because of their duration or location of exposure than is implied in Fig. 4.3 and Table 4.7;

- the attack rate of illness does not increase outside the calibration range of the model (i.e. beyond about 150 faecal streptococci per 100ml). This assumption, again, will lead to some underestimate in the total disease burden but is appropriate given the lack of data to support the high attack rates which would be suggested if the mathematical form of the dose-response curve were to be extrapolated beyond the upper limit of faecal streptococci exposure from which it was derived.

The values are supported both by precise risk estimates facilitated by the randomised cohort investigations trials (Kay *et al.*, 1994; Fleisher *et al.*, 1996) and by the other current investigations. (Prüss, 1998). This approach was chosen in recognition of the fact that other studies did not provide the precision required to complete this type of risk quantification. However, other studies, have exhibited significant elevation in gastrointestinal symptoms following exposure to waters at or around this concentration.

Severe health outcomes

As described in section 4.3 there is reason to believe that severe infectious diseases - such as infectious hepatitis or typhoid fever may be transmitted to susceptible bathers making recreational use of water polluted with the causative agents. Very limited evidence exists regarding safety, and public health authorities should be alert to such hazards where exposure may occur.

Very few studies have associated 'serious' illness with recreational water exposures. One retrospective study suggested that, where the median of total coliform concentration exceeded 10,000/100ml, then risk of paratyphoid transmission might be expected (PHLS, 1959). Fig. 4.4 therefore outlines an urgent action level for faecal streptococci of 1,000. This figure is derived from the PHLS (1959), 10,000/100ml figure using the following conversion factors: total coliform to faecal coliform 0.2 (i.e. $10,000 \times 0.2 = 2,000$) and faecal coliform to faecal streptococci 0.5 (i.e. $2,000 \times 0.5 = 1,000$). An observed value of over 1,000 faecal streptococci in recreational water, should lead to immediate investigation and where appropriate intervention by the competent authorities (Fig. 4.4).

Application of this numeric value may not be appropriate in regions where endemic disease in the population is not adequately characterised by the levels observed in the early UK investigation. Local agencies should consider appropriate advisory action levels in the light of local circumstances and/or different endemic illnesses.

4.4.3 Practical assessment and control measures

In addition to information derived from measurements of water quality, much information which may assist in assessing the safety of recreational waters and in controlling associated risks is often readily available. Such information may concern, for example:

- sources of faecal pollution including point sources such as rivers and direct sewage discharges and non-point sources;
- degree and type of treatment applied to sewage;
- rainfall;
- wind;
- tides and currents; and
- coastal physiography.

At present, no field tested approach is available which has succeeded in quantitatively defining a single index of “safety” relating to these factors. These factors are discussed below in the context of commonly-encountered circumstances and recognised conditions under which risk may be elevated. Emphasis is given to defining periods of times of high risk on the basis of recognisable environmental factors which may be used to provide advice to users and public health authorities and thereby directly assist in the management of risk. These factors are described briefly below with regard to their relevance for recreational water quality.

4.4.4 Coastal areas

Rivers discharging in coastal areas may carry a heavy load of micro-organisms from diverse sources including municipal sewage (treated or otherwise) and from animal husbandry. Following rainfall, microbial loads may be significantly increased due to surface runoff, urban storm-water overflows and re-suspension of sediments. Coastal pollution levels may therefore be elevated following rainfall and periods of high risk in some coastal areas may be found to correlate with such climatological data. Once recognised and characterised, simple advisory measures may be taken prospectively to alert water users of such risks and/or prevent recreational use during such periods

4.4.5 Riverine recreational areas

Riverine recreational areas will be subject to similar influences to those indicated above. In addition, where water flow is managed, either for recreation (such as where water is impounded before discharge) or for other purposes, the act of impoundment and discharge may itself lead to elevated microbial levels through re-suspension of sediment. Rivers are commonly receiving environments for sewage effluents following secondary or biological treatment in some countries. Much lower levels of effluent dilution may occur in riverine environments than in their coastal equivalents and differential pathogen – indicator organism relationships may exist between saline and non-saline waters. The balance of evidence suggests that, under many circumstances, the same level of faecal indicator bacteria in a freshwater environments may correspond to a greater health risk than in a marine environment.

4.4.6 Coastal sewage outfalls

Sewage discharges to (marine or freshwater) coastal areas may be managed in diverse ways. These include:

- direct discharge onto the beach or equivalent;
- short or long sea outfalls (where the sewage is carried a variable distance to sea or lake by pipe and then discharged);
- holding through the day and discharge at night; and
- holding throughout the recreational season and subsequent discharge (in winter).

Direct discharge of crude, untreated sewage (for instance through short outfalls) into recreational areas presents a serious risk to public health. Public health authorities should take measures to protect public health where this occurs and co-operate with appropriate authorities to encourage cessation of this practice. Recreational water users, other than swimmers, may venture into areas adjacent to effluent discharges where water quality has not, traditionally, been monitored but where health risks may be significantly elevated. These exposures also present a potentially significant risk for the population concerned and should be managed through appropriate measures.

In public health terms, it is generally assumed that the processes of dispersion, dilution, sedimentation and inactivation (through isolation, predation, natural die-off etc.) following discharge into the marine (or freshwater) environment from a piped outfall will lead to a certain degree of safety regarding public health. A number of confounding factors reduce the efficiency of this in practice. Most important among these are those which lead to the rapid movement of sewage into recreational areas. For example, where sewage is relatively warm and of low salinity when compared to the receiving water, it may mix poorly and form a floating “slick”. Such slicks should not form where properly designed and operated diffusers are in place on the outfall. Where they form they will be readily influenced by wind and may therefore pollute bathing beaches severely. While not providing long-term security for public health, periods of high risk (such as of on-shore wind) may be recognised on such beaches and action (advisory notices, zoning or banning of bathing) taken as appropriate. Coastal currents and tides may also give rise to similar problems and may also be recognised and dealt with in a similar manner.

Control of sewage pollution of beaches by holding sewage in storage for varying periods of time is practised in some countries. Where sewage is retained throughout the bathing season, water users are effectively isolated from the source of pollution. Such an approach is of limited applicability for practical reasons and will only be fully effective where there is a strict cut-off of recreational activity at the end of the bathing season. The efficacy of shorter-term detention - such as detention during the day and discharge at night - is less certain and is strongly influenced by the nature of the discharge and environmental factors as discussed above. The health risks associated with sediments remains poorly understood.

4.4.7 Sewage treatment

The degree of treatment applied to sewage varies widely and includes:

- discharge of raw, untreated sewage;
- combination and screening (to break up solids and remove large particles);
- lagooning;
- screening to remove large solids ("preliminary" treatment);
- conventional primary treatment (simple settling);
- conventional secondary treatment (biological treatment);
- conventional tertiary treatment (e.g. UV and microfiltration).

Of these, lagooning, conventional primary plus secondary treatment; tertiary treatment and disinfection will effect a significant reduction in indicator and/or pathogen contamination. It should however be recalled that some treatments and notably disinfection may affect the validity of the assessment of risk due to possible differential die off rates between indicator and pathogenic organisms leading to underestimates of risk. However, to date there is no clear data that estimate the magnitude of this effect, if any.

4.4.8 Coastal configuration

Sheltered coastal areas such as closed bays often attract recreational water users and may present special problems. Small volume, low circulation, and low water exchange rates often occur in such bodies of water. When such waters are intensively used for recreational purposes, the microbial density in the water may be strongly influenced by slow exchange rates, thus “trapping” sewage effluents for relatively long periods of time. Bathers themselves can influence water quality directly. This is most commonly seen as microbial build-up during the day such that peak levels are reached during the afternoon.

However, in recreational waters where this is found to occur, presently available evidence does not clearly identify whether such contamination by bathers represents an increased risk to health.

Sheltered coastal areas and shallow lakes may also be subject to accumulation of sediments which may be associated with high microbial loads and which may be re-suspended by water users. The health risks associated with resuspended sediments remains poorly understood.

4.5 Relating Guideline Values to preventive and remedial actions

It is important that Guidelines serve to promote progressive improvements in environmental quality for health and are not a simple censure for failure. Systems of categorising water quality and award schemes for clean and healthy environments are two approaches to this problem. It must be noted that the Guideline Values in this document represent higher, and thus safer, water quality than is presently encountered at many beaches world-wide.

4.5.1 Informed personal choice

A flexible approach to regulation and public involvement in setting “acceptable risk” at local or regional level, moves the principal risk management strategy towards the concept of informed individual choice. In some regions such a strategy may induce competition between resorts/destinations based upon relative safety. Eventually, economic competition may prove effective in facilitating improvement in recreational water quality.

Classification of beaches into various categories of health thereby provides users with the ability to make informed choices in selecting between potentially competing recreational locations. Informed consumer choice can, reduce overall exposure and adverse health outcome and produce an economic incentive for water quality improvement. Guideline Values may facilitate informed choice through a system of beach classification (such as Classes A to E in Fig. 4.4). These classes provide the incentive to improve poor locations through public awareness of both beach class and risk to health.

4.5.2 Public Health Advisories and Warnings

Some locations will consistently have very poor water quality due to the proximity of effluent discharges, others will have intermittently poor water quality due to accidental pollution that may be rare, and/or impossible to predict. Still more sites will have episodic, but possibly predictable, deterioration in water quality such as that driven by meteorological conditions, particularly heavy rainfall. In any of these circumstances, local public health agencies may wish to consider action to prevent risk to the recreator population through the issue of an advisory notice or other form of public notification. The level at which an advisory might be issued depends on local circumstances which includes levels and type of endemic illness prevalent in the population and the existence of any 'outbreaks' or endemic occurrence of potentially serious illness which may be spread by bathing water exposure.

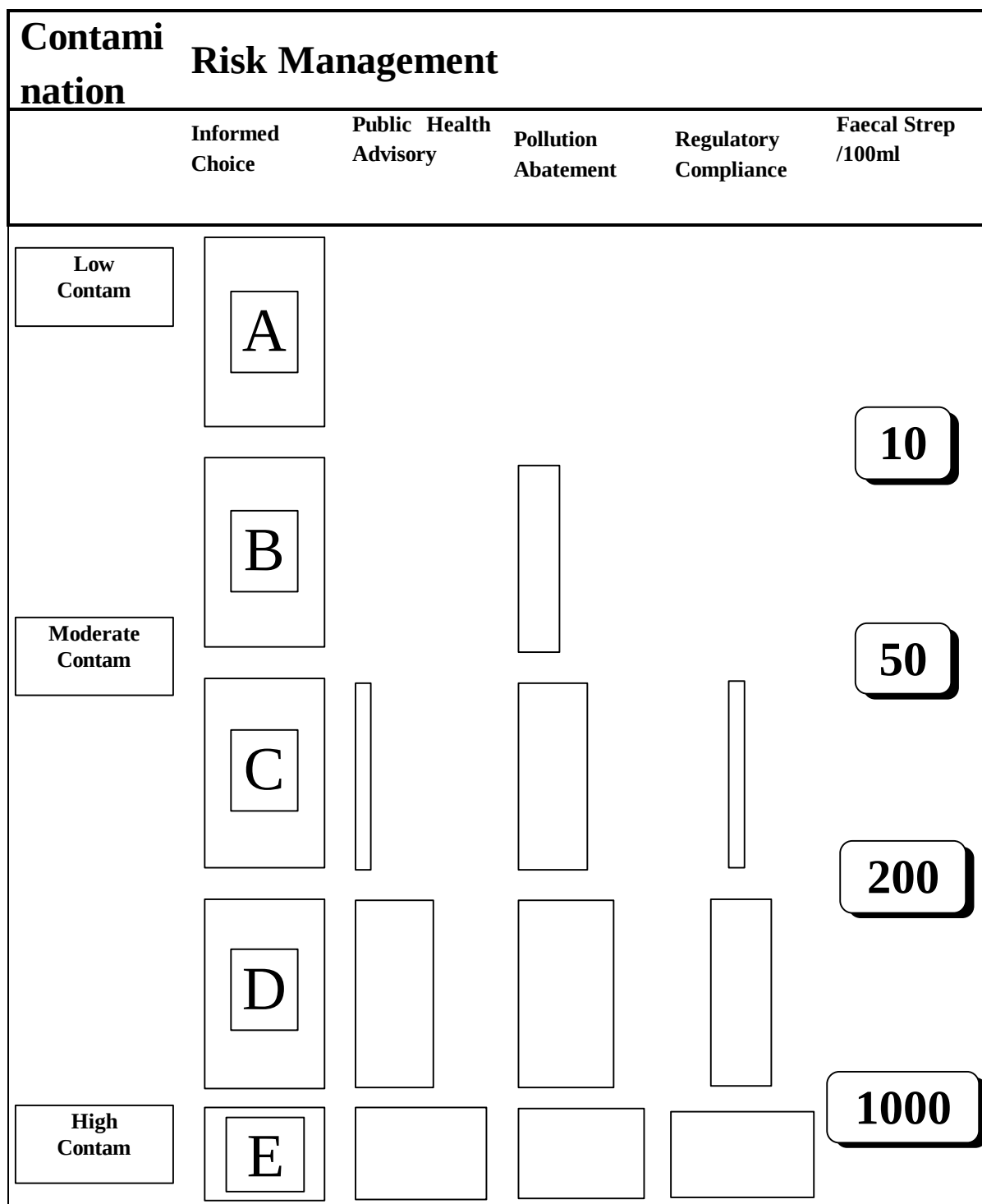


Figure 4.6 Schematic example of the use of Guideline Values for microbiological quality in risk management in relation to specific measures contamination level. A-E represent broad classes of water quality from pristine at A to highly polluted in E.

4.5.3 Pollution Abatement

Pollution abatement activity is directed at the prevention of non-compliance that might be accomplished through:

- appropriate sewerage system design, sewage effluent treatment and discharge.
- the reduction in non-sewage sources of microbial loading.

4.5.4 Enforcement of Regulatory Compliance

Problems exist in the application of regulatory compliance as a principal tool for the protection and improvement of microbiological quality of recreational waters. The two principal problems concern responsibility for cause of failure, and the nature of intervention.

Where a recreational water use location fails a regulatory standard, major problems may exist in defining responsibility. In many locations a number of diverse sources will contribute pollution loading to the overall pollution outcome and the relative importance of different sources may vary greatly with time. Rivers often function as major sources of microbial loads and will in turn be affected greatly by, for instance, rainfall and may themselves be recipients for multiple pollution loads. Approaches to regulatory compliance enforcement which depend upon identifying and requiring change of a discharge/pollution source “responsible” for failure are therefore problematic.

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CHAPTER 5

MICROBIOLOGICAL ASPECTS OF BEACH QUALITY

Beaches represent the unconsolidated sediment that lie at the junction between water and land (seashore, river and lake sides) and are usually composed of sand, mud or pebbles. From a recreational viewpoint, sand beaches are the ones that are sought after. Beaches are liable to flood hazards either from wave action in the sea/lakes or burst river banks. The latter present special characteristics with respect to contamination, health risk and remediation. However in higher latitudes, a significant percentage of time is spent by bathers on the beach itself rather than the water and micro-organisms are a significant component of the beach sand community. Accordingly concern has been expressed that beach sand or similar materials may act as reservoirs or vectors of infection (Roses Codinachs *et al.*, 1988).

5.1 Public Health Basis

The productivity of beach sand is limited by nutrient input. From laboratory studies it appears that nutrients (carbon) pass first through the bacterial community and then into the protozoan and metazoan community (Khiyama and Makemson, 1973). Further studies have shown that microbiological contamination is higher in sand than adjacent waters as the sand behaves as a passive harbour for cumulative pollution (Oliveira and Mendes, 1991, 1992). Water movement causes erosion, transportation and deposition of all beach sediment and subsequent redistribution of micro-organisms. Sand contamination is highly variable over short distances, making interpretation of results very difficult (Aubert *et al.*, 1987; Figueras *et al.*, 1992).

Experience of systematic beach surveillance as a part of pollution control is relatively limited although it has often been recommended for research. The WHO/UNEP, (1992, 1994) have indicated that wet beach sand and sediments should be an integral part of epidemiological and microbiological studies correlating recreational water quality with health effect, but evidence to date indicates that beach sand does not appear to constitute an infectious hazard (Chabasse *et al.*, 1986; Conseil Supérieur d'Hygiène Publique de France, 1990).

5.1.1 Bacteria-indicators of faecal pollution

The presence of total coliforms, faecal coliforms, *Escherichia coli* and of faecal streptococci in beach sand and the relationship of their counts to adjacent waters have comprised a significant area of research with apparently contradictory results. Total coliforms, faecal coliforms and faecal streptococci were isolated from surface sand samples in Marseille and in Agde, France, where faecal streptococci, probably originating from animals, had higher counts than other indicators (Conseil Supérieur d'Hygiène Publique de France, 1990). High numbers of faecal coliforms and faecal streptococci were isolated in beach sand along Taranto coastal waters (Signorile *et al.*, 1992) although a lower incidence of indicators has been recorded in Tel Aviv and in Barcelona swimming areas (Figueras *et al.*, 1992, Ghinsberg *et al.*, 1994). In an Italian study, a significant correlation was found between beach contamination and of adjacent sea waters, although the sand generally had higher bacterial counts than the water (Aulicino *et al.*, 1985). A similar correlation was found in Barcelona beaches, but in contrast to the Italian study the level of contamination did not show any significant difference in sand and sea water (Roses Codinachs *et al.*, 1988). Papadakis *et al.*, (1997) found no correlation between the bacteria indicators of faecal pollution counted on the wet part of the beach and *Staphylococcus aureus* counts, nor with the presence of fungi.

Within the context of an epidemiological study carried out on two beaches in Malaga, Spain, it was found that the indicators had a high significant regression coefficient with dermatophyte fungi on one of the beaches, especially with coliphages. Only *E. coli* showed a significant correlation with *Candida albicans*. At the other beach, faecal streptococci showed the best correlation with dermatophyte fungi. Again, coliphages were the indicators that best correlated with *C. albicans* (Borrego *et al.*, 1991).

5.1.2 Pathogenic micro-organisms

Bacteria, fungi, parasites and viruses, all have been isolated from beach sand. A number of genera and species are potential pathogens which may be encountered through contact with sand, though to date there is no epidemiological evidence for transmission by this route.

Staphylococcus

According to some studies, *Staphylococcus spp.* predominate over other flora in the sand (Dowidart and Abdel-Monem, 1990). Of a total of 85 strains of Gram positive cocci isolated from beach water and sand located at two popular beaches in Chile, 31 per cent were classified as *S. epidermidis*, 9 per cent as *S. haemolyticus*, 24 per cent as *S. aureus* and 36 per cent as *Staphylococcus spp.* (Prado *et al.*, 1994). The origin of *Staphylococcus* in beach sand is attributed to human activity, as its occurrence has been found to correlate with the number of swimmers on the beach and the counts of *S. aureus* were found to correlate with the presence of yeasts of human origin in sand samples (Papadakis *et al.*, 1997). In summer, with a higher density of swimmers on the beach, higher counts of *S. aureus* were recovered from the sand and water than were recovered from winter samples and higher counts of *S. aureus* were recovered from sand than from water samples (Ghinsberg *et al.*, 1994, Papadakis *et al.*, 1997).

Investigations carried out along the Thyrranian coasts showed higher densities of *Staphylococcus spp.* in sand of areas characterised by breakwaters than in sands found in open areas. *S. epidermidis* was the predominant species (Bonadonna *et al.*, 1993a).

Pseudomonas aeruginosa

In an Israeli study, both seawater and sand on a number of beaches were found to contain various levels of *Pseudomonas aeruginosa*. The isolation of *Pseudomonas aeruginosa* and of other *Pseudomonas spp.* was proportionally higher in sand than in sea water samples (Ghinsberg *et al.*, 1994). The pathogen was isolated from sandy beaches in Portugal under various tidal conditions, all containing similar counts of the pathogen (Mendes *et al.*, 1993).

Vibrio spp.

Vibrio parahaemolyticus isolates have been found in marine or brackish water and sand specimens collected from sand banks in Africa. *Vibrio harvey* has been isolated from seashore water and sand samples collected on coarse sand or pebble beaches (Aldova, 1989).

Enteric bacteria

Bacteria causing gastro-enteritis have been isolated from sand samples. However their presence comprises no apparent health threat to sunbathers. *Clostridium perfringens* isolated from sand beaches in Portugal under various tidal conditions all contained similar

counts of the pathogen (Mendes *et al.*, 1993). Bonadonna *et al.*, (1993b), have suggested that *Clostridium perfringens* could be a better indicator of faecal contamination in sand sediment. Low levels of *Campylobacter jejuni* were recorded in both coastal waters and sand on a number of Israeli beaches, the beach sand containing higher counts than adjacent shore waters (Ghinsberg *et al.*, 1994). In a U.K. survey on thermophilic campylobacters obtained from intertidal zone sediments, results showed that the sediments served as a substantial reservoir for campylobacters and could contribute significantly to bacteria numbers in surface waters, especially in rough weather (Obiri-Danso *et al.*, 1997). Dabrowski, (1982), has also demonstrated that *Shigella spp.* were isolated from beach sand and water in Gdansk bay.

Fungi

Studies by Soussa (1990), in the Portuguese central coastal area showed the presence of dermatophytes in 42 per cent of the sand beaches analysed. The most common dermatophytes were *Trichophyton mentagrophytes*, *T. rubrum* and *Microsporum nanum*, all isolated from sandy, non-flooded areas showing organic residues. Saprophyte fungi were isolated in the flooded and intermediate areas in high tidal conditions (*Aspergillus candidus*, *A. ochraceus* and *A. fumigatus*) (Izquierdo *et al.*, 1986).

Candida albicans and other *Candida* species have been isolated from sand beaches in the South of France (Bernard *et al.*, 1988). In the same study eight keratinophilic and eleven non-keratinophilic species, all potential pathogens, were isolated. Izquierdo *et al.*, (1986) isolated 16 species of fungi from beach sand along the north Mediterranean coast of Spain, among them some potentially pathogenic strains. Most of the isolates belonged to the species *Penicillium*, *Aspergillus* and *Cladosporium*.

Ghinsberg *et al.*, (1994) isolated fungi in all beach sand samples, but not in sea water samples. Boiron *et al.*, (1983) investigated the same fungal species in seawater and in the seashore sand, concluding that the similarity of bacterial species in sand and sea water added to the fact that no *Candida albicans* was isolated, and that the isolated yeasts were of marine origin. The isolated fungi belonged to the species *C. tropicalis*, *C. parapsilosis*, *C. langeronii*, *C. guilliermondii*, *Trichosporon cutaneum* and *Toluropsis sp.* The most frequently isolated genera from beach sand samples in another Spanish study were *Penicillium*, *Aspergillus*, *Cladosporium*, *Altenaria*, *Mucor*, *Monilia*, *Cephalosporium*, *Verticillium* and *Chrysosporium* (Roses Codinach *et al.*, 1988). Absence or low incidence of *C. albicans*, also has been recorded by other researchers (Roses Codinach *et al.*, 1988; Figueras *et al.*, 1992).

The fungal density of 180 samples of sand collected from 42 Spanish Mediterranean beaches has been found to reach several hundred thousand cfu/g of sample. The most commonly isolated genera were: *Penicillium*, *Cladosporium*, *Aspergillus*, *Acremonium*, *Altenaria* and *Fusarium* (Larrondo and Calvo, 1989). In a study carried out in the Attica area, Greece, fungal isolations included *Candida albicans*, *C. krusei*, *C. tropicalis*, *C. puilliermondi*, *C. rugosa*, *Pitirosporum orbiculare*, *Fusarium*, *Penicillium*, *Mucor*, *Helminthosporium* and *Aspergillus niger* (Papadakis *et al.*, 1997). *Candida albicans*, other *Candida* species, *Fusarium* and *Pitirosporum orbiculare* were included amongst the isolated pathogens.

5.1.3 Viruses

Very little information exists concerning the presence of viruses in beach sand. In a Romanian 3-year study by Nestor *et al.*, (1984) results showed that the incidence of

enteroviruses depended on the season, with no viruses being present in water and beach sand during non-vacation seasons.

5.1.4 Parasites

Little information exists concerning the presence of parasites in beach sand. From a study of two sand beaches of Marseille, France, *Toxocara canis* was found to be the most common parasite, being present on average per 150 g of sand (Conseil Supérieur d'Hygiène Publique de France, 1990). However, in a study carried out on "dog beaches" in Perth, Australia, a total of 266 samples, showed no traces of *Toxocara canis* eggs or other eggs/larvae of parasitic nematodes. (Dunsmore *et al.*, 1984). It was emphasised in this latter study, that the major risk to humans was from an environment in which puppies were found, and not older dogs. The influence of other parasites transmitted by water (Marshall *et al.*, 1997), which have *not* been investigated in recreational sand areas may also be of importance.

5.2 Dispersion and fate of micro-organisms in beach sand

The survival of enteric bacteria on the surface of dry sand may essentially be of short duration, the bacteria being destroyed mostly by environmental pressure. Wet sand, the area where young children typically spend most of their time on the beach, is the most relevant. Wet sand, enriched with organic substances, provides a favourable environment for enteric bacteria that enables them to survive longer than in sea water.

Fungi are often encountered in sand and their survival is longer due to their capacity to form resistant spores. Anderson (1979), in an *in vitro* study, found four pathogenic fungi, *Trichosporon cutaneum*, *Candida albicans*, *Microsporum gypseum* and *Trichophyton mentagrophytes*, that survived for at least one month in non-sterile sand inoculated propagules of such fungi. In a similar study, five species of dermatophytes (*Epidermophyton floccosum*, *Microsporum canis*, *M. gypseum*, *Trichophyton mentagrophytes* and *T. rubrum*) and *Scopulariopsis brevicaulis*, survived 25-360 days (Carrillo-Munoz *et al.*, 1990).

Various environmental and anthropogenic factors have been proposed as encouraging dispersion of indicators and pathogens on beach sand. Borrego *et al.*, (1991), reported higher bacterial counts and longer survival time in beaches close to sewage outlets. Mendes *et al.*, (1993) studied the influence of tides on counts of indicators and pathogens in sand without finding any clear differences. Obiri-Danso *et al.*, (1997), analysed UK sediment samples for thermophilic campylobacters and faecal indicators before and after tidal cover over a 12 month period. Fifty three per cent of the samples were positive for campylobacters before tidal cover which was significantly different from the 64 per cent recovered after tidal disposition. However, there was no significant difference for indicator numbers with respect to samples taken before or after tidal cover. In the same study a seasonal variation was observed in campylobacters with the highest isolation rate in winter (100 per cent) followed by secondary peaks in spring (33-67 per cent) and autumn (67-78 per cent). Lowest counts were found in summer, which correlated with the incidence of campylobacters in surface waters. Nestor *et al.*, (1984), found that the incidence of some pathogens depended on the season, with no viruses present in seawater and sand of beaches outside the holiday season.

Intensively-used water-recreation areas provide opportunities for person-to-person transmission (section 5.4.2) of pathogens (e.g. dermatophytes). Transmission may occur because individuals shed pathogens on sand, by direct contact or through other means, although neither of these ways of transmission has been positively demonstrated.

Papadakis *et al.*, (1997) collected water and sand samples from two beaches - one more, the other less popular - in summer and winter, and the numbers of swimmers present on the beaches were counted. In addition, microbiological tests for counts of coliforms, faecal coliforms, enterococci, *S. aureus*, yeasts and moulds were carried out. Water and sand samples were very low in indicator organisms of faecal pollution. Human species of yeasts were present in water and sand samples from both sites. *S. aureus* was isolated from water and sand samples only twice in winter when swimmer presence was exceptional. A significant correlation appeared between swimmer numbers present on the beach and *S. aureus* counts in water samples, the correlation being more pronounced on the more popular beach. In sand samples *S. aureus* counts correlated with the number of swimmers present on the beach only at the more popular beach. Yeasts of human origin correlated with the number of swimmers on the more popular beach, both in water and sand samples.

5.3 Epidemiological Investigations

Concern about actual and potential health risks from exposure to the sandy beach has been expressed (Nestor *et al.*, 1984; Mendes *et al.*, 1997). However, at present, epidemiological evidence for such risks has not been found.

5.4 Management Actions

5.4.1 Animal/canine excreta

The principal microbiological risk to human health encountered upon beaches and similar areas is that arising due to contact with animal excreta - notably that of dogs, where for example such areas are used for exercising pets. Regulations, often local in character, may restrict access or place an obligation upon the owner to remove animal excreta. Increased public awareness may contribute to reducing exposure, especially amongst young children. Whilst beach cleaning - see below- may contribute to the removal of animal excreta it is more often undertaken for aesthetic reasons or to attempt to remove sharp materials such as broken glass. Virtually all beach management award schemes e.g. The Blue Flag, Tidy Britain Group Seaside Awards, would not give an award to a beach that allowed dogs during the bathing season.

5.4.2 Person-to-person transmission

The possibility of person-to-person transmission of disease in densely-used beach areas is not specific to recreational water use areas and whilst hypothesised is not supported by a significant body of evidence.

In several countries, particularly at resort areas, machine sand cleaning is a common practice that can eliminate visible garbage mixed with the sand, reducing the amount of organic matter especially in the strandline and therefore further development of micro-organisms which produces a conflict of interest with respect to beach management (Llewellyn and Shackley, 1996). Strategies that have eliminated the development of sand contamination over the years have shown a clear improvement of microbiological quality when general levels of hygiene and cleanness have increased (Fernandez and Ferrer, 1982). Particularly important are procedures dealing with faecal contamination by animals, dealt with in section 5.4.1.

Chemical products such as disinfectants are applied in certain cases in recreational water areas without regard to their effectiveness or possible ecotoxicological affects. The Supérieur d' Hygiène Publique de France (1990), has argued that there is not enough evidence to demonstrate the efficiency of beach disinfection. When beach treatment is

necessary, simple methods, such as brooming and aeration should be applied, together with constant beach supervision in order to prohibit access to animals. Education of the public in personal hygiene and the use of towels for sitting on the beach is believed to be of great importance (Conseil Supérieur d' Hygiène Publique de France, 1990).

5.5 Conclusions and Recommendations

Various studies and reports have been published concerning microbiological beach quality but they are not directly comparable, leading to difficulties in drawing meaningful conclusions. Epidemiological studies, whose objectives are to demonstrate cause-effect or to define a clear dose-response relationship linking microbiological quality with skin, eye, ear and gastrointestinal symptoms are essential. It appears from the limited available evidence that:

- Bacteria-indicators of pollution and several pathogens have been isolated from beach sand, though their capacity to infect bathers remains undemonstrated and the real extent of their threat to public health is unknown. There is no evidence to support establishment of a Guideline Value for indicator organisms on beach sand.
- Factors promoting the survival and dispersion of pathogens may include the nature of the beach, tidal phenomena, sewage outlets, the season, the presence of animals and number of bathers.
- Routine monitoring of beach sand for indicator organisms is not justified, although it is often suggested as an additional factor affecting bathers' health, or as a subject of research.
- Whilst there is no proven human health hazard associated with macro-waste it may be appropriate in some circumstances to use machines to remove macro-waste where it is aesthetically unpleasant. Animal access to the beach may be restricted seasonally on frequently used beaches. Education the public about personal hygiene using towels to sit upon on a beach and to wash them regularly may also be appropriate.

5.6 References

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CHAPTER 6

ALGAE AND CYANOBACTERIA IN COASTAL AND ESTUARINE WATERS

Algal blooms, both toxic and non-toxic, in the sea have occurred throughout recorded history, but during recent decades they have been increasing (Anderson, 1989; Smayda, 1989a; Hallegraeff, 1993). In several areas (e.g. the Baltic and North Seas, the Adriatic Sea, Japanese coastal waters and the Gulf of Mexico) algal blooms have now become a recurring phenomenon and the increased frequency has accompanied nutrient enrichment of coastal waters on a global scale (Smayda, 1989b). Progressive extension of the occurrence of toxic algae can be associated with the growing anthropogenic impact upon coastal areas, which can be responsible for changes in nutrient availability within coastal waters that could promote growth of toxic algae.

Blooms of non-toxic phytoplankton species can influence the value of recreational waters due to reduced transparency, discoloured water and scum formation. Furthermore, bloom degradation can be accompanied by unpleasant odours. In coastal waters and lagoons, mass occurrences of macro algae can have similar effects. The resultant aesthetic problems and their investigation are described in chapter 11.

In the marine environment many toxic species of dinoflagellates, diatoms, nanoflagellates and cyanobacteria occur and several human diseases have been reported in association with them (WHO, 1990; WHO, 1994a). The toxicity of these algae to humans is due to some of their constituents, primarily algal toxins:

- after consumption of shellfish and fish, which concentrate algal toxins, causing syndromes known as paralytic shellfish poisoning (PSP), diarrhetic shellfish poisoning (DSP), amnesic shellfish poisoning (ASP) and neurotoxic shellfish poisoning (NSP);
- through dermal contact, causing severe contact dermatitis known as "swimmers' itch" or "seaweed dermatitis";
- through inhalation of sea spray aerosols; and
- through ingestion of water or algal scums.

Marine algal toxins become a problem primarily because they concentrate in shellfish and fish which are subsequently eaten by man. In spite of the importance of this exposure route for humans, this chapter deals *only* with the possible risks associated with recreational activities in (or near) marine and estuarine waters.

6.1 Health Hazards

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

6.1.1 Exposure through dermal contact

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 (Grauer and Arnold, 1961). The symptoms are itching and burning within a few minutes to a few hours after swimming in the sea where fragments of the cyanobacteria are suspended. Visible dermatitis and redness develops after 3-8 hours, followed by blisters and deep desquamation (Grauer and Arnold, 1961). Some toxic components, such as for instance aplysiatoxin, debromoaplysiatoxin and lyngbyatoxin A, have been isolated from marine cyanobacteria (Mynderse *et al.*, 1977; Fujiki *et al.*, 1985; Shimizu, 1996). These toxins are highly inflammatory and are potent skin tumour promoting compounds by utilising mechanisms similar to phorbol esters through the activation of protein kinase C (Gorham and Carmichael, 1988; Fujiki *et al.*, 1990). More research is needed on possible tumour promotion risks on human

populations. To date, outbreaks have only been reported from Japan and Hawaii (Grauer and Arnold, 1961; WHO, 1984; Yasumoto and Murata, 1993). The cyanobacteria *Lyngbya majuscula* is known to produce debromoaplysiatoxin and lyngbyatoxin A and the cyanobacteria *Oscillatoria nigroviridis* and *Schizothrix calcicola* are known to produce debromoaplysiatoxin (Mynderse *et al.*, 1977).

6.1.2 Exposure through ingestion (of water or scum)

Nodularia spumigena was the first cyanobacteria recognized to cause animal death (Francis, 1878). The toxin produced by *Nodularia spumigena* called nodularin, is a cyclic pentapeptide. Nodularin acts as a hepatotoxin, in that it induces massive haemorrhages in the liver of mammals, causes disruption of the liver structure and has some effects on the kidneys (Eriksson *et al.*, 1988; Sandström *et al.*, 1990). The inhibition of serine-threonine protein phosphatases represents the mechanism of action of nodularin (Fujiki *et al.*, 1996).

In the 19th century, several toxic blooms and accumulations of *Nodularia spumigena* were registered. Published literature relates to blooms of *N. spumigena* associated with poisoning of ducks (Kalbe and Tiess, 1964), dogs (Edler *et al.*, 1985; Nehring, 1993), young cattle (Gussmann *et al.*, 1985) and sheep (Main *et al.*, 1977). To date, there have been no reports of human poisoning by *Nodularia spumigena*, but humans may be as susceptible to the toxins as other mammals. Therefore, it is possible that small children in particular may accidentally ingest toxic material in an amount which may have serious consequences. For example, liver damage that is not immediately diagnosable.

Some species of cyanobacteria are capable of causing dense scums which contain high concentrations of cells. Since most toxin is intracellular, scums caused by toxigenic strains may contain elevated concentrations of toxin. Scum frequency is more familiar in lakes during quiescent after mixed conditions than it is in coastal areas. The existence of a cyanobacterial scum caused by a toxigenic species represents an increased human health hazard.

Algal species producing DSP, PSP, ASP, NSP toxins pose a risk to human health, associated with the seafood consumption, as they accumulate in the food chain. As to the risk associated to recreational activities in marine waters, no evidence of adverse effects on humans is available.

6.1.3. Exposure through inhalation

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 (Baden *et al.*, 1984; Scoging, 1991). The signs and symptoms are severe irritation of conjunctivae and mucus membranes (particularly of the nose) followed by persistent coughing and sneezing and tingling of the lips. The asthma-like effects are not usually observed more than a few kilometres inland (Pierce, 1986). Brevetoxins accumulated in seafood can cause NSP (Neurotoxic Shellfish Poisoning) (Steidinger, 1993) and brevetoxins can also kill fish, invertebrates and seabirds and possibly lead to mortalities in manatees and dolphins (Abbot *et al.*, 1975; Forrester *et al.*, 1977; O'Shea *et al.*, 1991).

Brevetoxins are produced by the unarmored marine dinoflagellate *Gymnodinium breve*. For many years these blooms were only reported from the south-east United States and Eastern Mexico (Steidinger, 1993), but in 1993, NSP was detected in New Zealand (Fernandez and Cembella, 1995).

6.1.4 Species toxic for marine animals

Several marine dinoflagellates and flagellates have been associated with the death of fish and/or death of invertebrates. Some of the most common are the dinoflagellates: *Gyrodinium cf. aureolum* (Tangen, 1977; Southgate *et al.*, 1984; Potts and Edwards, 1987); *Gyrodinium galatheanum* (Nielsen, 1993); and *Pfiesteria piscicida* (Burkholder *et al.*, 1995), the raphidophycean flagellates: *Heterosigma akashiwo* (White, 1988), *Chattonella antiqua* and *Chattonella marina* (Endo *et al.*, 1985) and the prymnesiophycean flagellates: *Prymnesium parvum* (Shilo, 1969), *Chrysochromulina polylepis* (Rosenberg *et al.*, 1988) and other *Chrysochromulina* species (Moestrup, 1994).

These algae have caused important damage to aquaculture and natural resources. The toxins have strong ichthyotoxic effects and for more species (e.g. *Chrysochromulina polylepis* and *Prymnesium parvum*.) severe cytotoxic effects have been demonstrated (Underdal *et al.*, 1989; Yasumoto *et al.*, 1990). *Gyrodinium aureolum* and *Gyrodinium galatheanum* can cause severe necrotising degeneration of the gills and produce toxins with hemolytic effects (Jones *et al.*, 1982; Yasumoto *et al.*, 1990; Nielsen, 1993). In addition, *Pfiesteria piscicida* produces an unidentified neurotoxin (Burkholder *et al.*, 1992). Toxins from some of the species have been found to accumulate in seafood like mussels and oysters, and there may also be an accumulation in other marine organisms during exposure to sub lethal toxin levels (Underdal *et al.*, 1989, Stabell *et al.*, 1993).

Human intoxications have not been registered in connection to blooms of these ichthyotoxin producing species. There is however a need for further information on the effects on humans both after dermal contact and after ingestion of water or seafood contaminated with these ichthyotoxins.

6.2 Identification of Marine Toxic Algae and Cyanobacteria

Detailed information on sampling, identification and cell counts of marine toxic phytoplankton are reported in Andersen (1996) and for cyanobacteria in Chorus and Bartram (1999).

6.2.1 Analysis of algal and cyanobacteria toxins

In some cases, the mere identification of an algal or cyanobacteria species is *not* sufficient to establish whether or not it is toxic, because more strains with different toxicity may belong to the same species. As a consequence, in order to ascertain whether the identified species includes toxic strains there is a need to characterise the toxicity. The most commonly employed method is the mouse bioassay. The mouse bioassay has been successfully applied in the cases of cyanotoxins (Falconer, 1993), PSP (WHO, 1984), NSP (McFarren *et al.*, 1960) and DSP toxins (Yasumoto *et al.*, 1984). This method is not specific but within a few hours provides a measure of the total toxicity. Toxicity is tested by i.p. injection followed by 24 h. observation. The mouse assay is not sensitive enough for testing ASP toxins. Many analytical methods based on HPLC are now available to determine the occurrence of specific ASP (Lawrence *et al.*, 1989), DSP (Lee *et al.*, 1987), NSP (Pierce *et al.*, 1985), PSP (Sullivan and Wekell, 1987) toxins and cyanotoxins (Lawton *et al.*, 1994; Chorus and Bartram, 1999).

Immunoassays are currently the most sensitive and specific methods for rapid sample screening for microcystins (Ueno *et al.*, 1996). These methods have also been developed for PSP (Cembella *et al.*, 1995), and DSP (Levine *et al.*, 1988; Usagawa *et al.*, 1989).

6.2.2 New technologies

In some cases, satellite imagery can be very successfully used as a part of the proactive monitoring program. For example, movements of the Gulf Stream and subsequent elevated water temperatures play a key role in *G. breve* blooms; Gulf Stream temperatures monitored by remote sensing of infrared radiation can provide information on the likelihood of a bloom and its subsequent transport (Hungerford and Wekell, 1993).

6.3 Guideline Values

Available data indicates 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, although authorities in affected or not affected areas should be aware of the potential hazard and act accordingly.

6.4 Precautionary Measures

Within areas subject to the occurrence of marine toxic algae or cyanobacteria it is important to carry out adequate monitoring activities and give information to the potentially involved population. Surveillance programmes should be planned in other potentially interested areas with the aim of preventing human exposure in areas affected by blooms of toxic algae or cyanobacteria. When they do occur, information should be made available to the general public.

Long data records on phytoplankton populations (toxic, harmful and others) may help obtain a more comprehensive understanding of phytoplankton dynamics and the ecosystem function which could lead to more efficient monitoring. If for instance long time series of data concerning phytoplankton populations exists, it would be possible to decide if the sudden appearance of a species is new to the area, or if endemic species have become toxic. Important supporting parameters include temperature, salinity, chlorophyll (phytoplankton biomass), and surface current circulation (transport of harmful algae). Knowledge of the temporal and geographic distribution of inorganic nutrients and their sources, as well as other phytoplankton growth factors, will also be important when planning and operating a monitoring programme (Andersen, 1996).

When conditions favourable to algal or cyanobacteria blooms are recognised, monitoring activities should be intensified and include taxonomic ranking of potentially toxic species and eventually analysis of the algal toxins.

6.4.1 Information

In some areas, information on harmful algal blooms are distributed instantly to users of the monitoring system by telephone, telephone answering machine, fax, E-mail and Internet e.g. as The Baltic Sea Algaline, found in:

Internet World Wide Web: <http://www.fimr.fi> (Andersen, 1996).

Professional information

In affected areas, it is appropriate to provide general practitioners and medical clinics with information regarding the health problems associated with algal blooms and toxic algae, the diagnosis and treatment of poisonings, the surveillance of groups who could be at risk and reporting procedures to Public Health Authorities.

Public information

In affected areas, health information should be made available to the general public and to recreational water users in particular. Information may be disseminated through various means including schools, on-site notices, mass media and specific brochures. This would contain information about algal blooms and toxic algae, the possible health effects, reporting procedures for any health problems thought to be possibly linked with water-based recreation and recommended protective measures.

As a precaution, the following guidelines are recommended for all marine and fresh water-based recreation (refer to Chapter 7 with regard to freshwaters) and should be included in the public information:

- Avoid areas with visible algal concentrations and/or algal scums in the sea as well as on the shore. Direct contact or swallowing appreciable amounts are associated with the highest chances of a health risk;
- On the beach, avoid sitting downwind of any algal material drying on the shore which could form an aerosol and be inhaled (particularly in areas with *Gymnodinium breve* blooms).
- If sailing, wind surfing or undertaking any other activity likely to involve accidental water immersion in the presence of algal blooms, wear clothing which is close fitting in the openings. The use of wet-suits for water sports may result in a greater risk of rashes, because algal material in the water trapped inside the wet-suit will be in contact with the skin for long periods of time.
- After coming ashore, shower or wash yourself down to remove any algal material.
- Wash and dry all clothing and equipment after any contact with algal blooms and scum.
- If any health effects are subsequently experienced and whatever the nature of the exposure, medical advice should be promptly sought.

6.4.2 Prevention of marine algal blooms

During the last few decades several attempts have been carried out to develop practical methods for controlling algal blooms. The use of dust, herbicides, metals, chelators, artificial turbulence, dinoflagellate parasites and zooplankton, all have been the subject of research. Unfortunately many of these methods are not practical and may have adverse ecological side effects.

Algal blooms result from a complicated interaction between hydrographic, meteorological, biological and chemical conditions of which only a few can be controlled. Without essential nutrients, principally nitrates and phosphates, algae will not reach bloom proportions. Proliferation of nutrients from land-based sources is one of the most influential promoting factors and only minimisation of the nutrients availability, will allow control of algal growth.

Implementation and enforcement of comprehensive and integrated coastal management plans to control nutrient discharges at point sources (rivers, pipes and drains) as well as diffuse sources, are therefore necessary to avoid recurrent algal blooms.

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