Development of Microbiological Standards

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SCOTLAND & NORTHERN IRELAND FORUM FOR ENVIRONMENTAL RESEARCH

WRc plc

R & D Note 165

NRA
National Rivers Authority

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NRA proposals for SWQO's (Dec, 1991) recognised water contact sports within the use-related classes suggested for controlled waters. This report summarises the research which lead to the proposal of a hierarchical scheme of standards based on health-related risks associated with different water sports.

The report should be read in conjunction with other R & D outputs dealing with other components of the scheme and future output on Bathing Water Epidemiology

3. Approval For Status and Use

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DEVELOPMENT OF MICROBIOLOGICAL STANDARDS

E B Pike and P Gale

Research Contractor:
WRc plc
Henley Road Medmenham
PO Box 16 Marlow
Buckinghamshire SL7 2HD

National Rivers Authority
Rivers House Waterside Drive
Almondsbury Bristol
Avon BS12 4UD

R & D Note 165

National Rivers Authority
Rivers House Waterside Drive
Almondsbury Bristol BS12 4UD

Tel: 0454 624400
Fax: 0454 624409

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Research contractor
This document was produced under R&D Contract 037 by:

WRc plc
Henley Rd Medmenham
PO Box 16 Marlow
SL7 2HD

Tel: 0491 571531
Fax: 0491 579094

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NRA Project Leader
The NRA's Project Leader for R&D Contract 037:

D Lowthion - Southern Region

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FOREWORD

This three-year project was initiated in April 1989 in the programme area Recreation and Public Health, Project-Development of Microbial Standards (5.2.1a) of the Environmental Research Programme of WRc. It has proceeded in parallel with the project, Principal Sources of Microbial Contamination (5.1.1a), with the aim of providing a unified approach to the respective problems of:

1. Assessing risks to health from recreational uses of water and formulating guidelines or standards based upon risk

2. Quantifying inputs of faecal bacteria, viruses and parasites to natural waters and measuring their impacts on water quality.

With the embodiment of the National Rivers Authority in late 1989, the objectives of these two projects were rationalized somewhat, to include marine recreation in the standards project (now designated NRA Reference Nº A11.037) and to include field studies of water quality and additional research on decay of micro-organisms in the sources project, which has been re-designated Environmental Behaviour of Microbial Contaminants (Reference Nº A11.034/036). Both projects have been co-funded, by approximately 13%, by the Scotland and Northern Ireland Forum for Environmental Research (SNIFFER).

Over the same period, WRc has managed the Department of the Environment's (DoE's) contracts on Health Effects of Sea Bathing (DoE Reference Nºs PECD 7/7/337 and PECD 7/7/377), to which the NRA has contributed about one-third of the total funding, under its contract, Bathing Water Epidemiology (A11.1). This study will be be completed in May 1993, but the results of the pilot study in 1989 and of the first parts of the definitive epidemiological studies in 1990-91 are available.

Together, this information, which has been obtained from literature searches, desk studies and researches in the field, will provide a strong basis for formulating practicable standards for water quality, linked to an assessment of risks, known patterns of variability in quality and the needs of particular sports.

This research is timely, because of the need, under the Water Act 1989, consolidated in the Water Resources Act 1991, for the Secretary of State to prescribe and the NRA to enforce statutory water quality objectives. The NRA (1991) in its Proposals for Statutory Water Quality Objectives, has proposed that the main elements will include, for each stretch of controlled waters, identification of the class of use, corresponding quality standards (including those of relevant EC Directive) and dates for compliance. One of the classes of use proposed is 'Water Contact Activities'. In the proposals, NRA has noted that, dependent upon the research in this project, decisions will need to be made upon whether or not a risk-related classification scheme, with different standards according to the kind of activity, is warranted.

Because of this urgency and because the programme of research was organized into discrete tasks, WRc has presented the findings as five largely self-contained and completed Interim Reports, rather than incomplete parts in a series. These contain complete derived data. This present Report is a succint presentation of the major findings and conclusions together with recommendations for future research, presented at the time, when they will be of most value in the formulation of statutory water quality objectives.

ACKNOWLEDGEMENTS

WRc wishes to thank the officers of the Sports Council and the secretaries/medical officers of the following national bodies for individual sports who provided information upon national participation and their perception of health risks to participants:

Amateur Rowing Association
Amateur Swimming Association
British Canoe Union
British Long Distance Swimming Association
British Sub-Aqua Club
British Surfing Association
British Water Ski Federation
National Federation of Anglers
Royal Yachting Association

Thanks are also due to the secretaries of the 209 sports clubs, who returned a second questionnaire requiring more detailed information upon membership, participation and experience of illness.

Wardens and park rangers at the lake complexes of two leisure parks provided information upon the lakes and the numbers of tickets for boats sold on survey days.

Observational studies at the National Water Sports Centre's canoe slalom course, Holme Pierrepont, near Nottingham and at the Welsh Canoeing Association's National White-water Centre, Canolfan Tryweryn, near Bala, were conducted under the umbrella of epidemiological studies (partly funded by NRA) carried out by the Centre for Research into Environment and Health, St David's University College, Lampeter, with the agreement of its Directors, Dr D Kay and Professor F Jones.

British Waterways supplied information on recreational usage of their waters and microbiological data. Microbiological data was also supplied by the following:

National Rivers Authority (from Regional Environmental Quality Managers in liaison with the Project Leader, Mr D Lowthion).

Water Companies: Bristol, Bournemouth and District, Colne Valley, North Surrey, Portsmouth, South Staffordshire, West Hampshire, York

Public Health Laboratories: Luton, Manchester

Central Scotland Water Development Board

Strathclyde Regional Council

Bradford City Council

The Project Leader, Mr D Lowthion (Southern Region), has provided much information, advice and encouragement throughout this project.

EXECUTIVE SUMMARY

This is the Final Report covering nearly three years research on this topic. It is timely, because of the need for the NRA to define use-related classes for stretches of water and to implement Statutory Water Quality Objectives. All relevant literature has been reviewed to define the health hazards associated with water recreation. Three classes of illness have been recognised:

1. Waterborne infections - contracted by inhaling or swallowing faecally polluted water.

2. Water-contact illnesses, e.g. cyanobacterial toxicosis, leptospirosis and swimmers' itch, which are contracted by contact with water containing the agent but are not directly associated if at all, with faecal pollution.

3. Waterwashed infections, in which prolonged contact with water disturbs the body's defence mechanisms, allowing opportunistic or transient pathogens on the skin to set up infection.

Questionnaire returns from national sports bodies and from clubs have defined the extent of participation in sports and awareness of health hazards and, together with observations in the field, have enabled sports to be classified by the degree of contact with water, i.e. whole-body contact, incidental contact and no contact. National participation in non-contact recreation is three times that in sports involving whole-body and incidental contact with water.

Evidence linking the degree of contact with water to the risk of contracting each of three classes of illness has been used to formulate guidelines and control measures for the three classes of recreation to protect health and amenity. An interim microbiological standard is proposed for controlling health hazards from waterborne illness for whole-body contact sports, pending evaluation of the results of current epidemiological research into water recreation. This proposal is for 95 percent of samples not to exceed 2000 faecal coliform bacteria per 100 ml, as in the bathing water Directive 76/160/EEC. Examination of nationally collected data for faecal coliform bacteria and field studies at recreational lakes have established that the order of decreasing quality is lakes and reservoirs, marine beaches, estuaries, rivers and that variability in count is similar for estuaries, beaches, lakes and reservoirs, but lower for rivers. This data shows that only 10% of river sites and 20% of estuarial sites would be able to meet the proposed faecal coliform standard, compared with 70% of marine and lake/reservoir sites. Recommendations are made for implementation of the guidelines and control measures and for future research.

KEY WORDS

Recreation, recreational waters, diseases (waterborne), disease (water-transmitted), algae-blue-green, leptospirosis

1. INTRODUCTION

1.1 Background

In the United Kingdom, only coastal waters are used extensively for bathing, but other sports involving a greater or lesser degree of contact with water and hence different risks of acquiring infection from waterborne pathogens, are becoming extremely popular and involve all surface waters. Although the bathing water Directive 76/160/EEC applies to all surface waters used for bathing, it is inapplicable to waters used for other recreation. The National Rivers Authority (NRA 1991) is currently in discussion with the Secretary of State for the Environment over the creation and implementation of statutory Water Quality Objectives under Section 105 of the Water Act 1989 (now consolidated into the Water Resources Act 1991). The process will involve identifying uses to which waters will be put - including basic amenity and contact recreation - and the establishment of standards and appropriate monitoring programme, incorporating the requirements of relevant EC Directives. Dates will be set by which these standards and those of the New General Classification scheme for water quality, must be met. Since protection of health is a paramount consideration for contact recreation and it is appropriate that such standards are microbiological, it is important that they should be related to risk. A key task of this project has been to classify various recreational uses according to risk and to degree and duration of exposure to water, since this will influence risk. Another has been to measure the statistical variability in the microbiological qualities of different surface waters and to assess the extent to which they comply with the microbiological criteria of the EC bathing water Directive 76/160/EEC. This will determine the allowances which will have to be made for variability as well as the frequencies and locations of sampling when standards are drafted. It will also indicate to what extent this Directive could be used as a point of reference.

1.2 Objectives

The specific objectives of this research project are given in Table 1.1, which also lists the studies which were carried out in order to achieve them.

1.3 Approaches to the derivation of standards

1.3.1 Basic questions

Any standard for water quality must be easily understood, must be capable of being easily enforced and monitored and must provide the way for a steady improvement in quality. Before formulating a standard it is necessary to ask some basic questions (Pike 1992a), which, in turn, require information to be gathered. These questions are:

1. What are the recreational activities needing protection?

Table 1.1 The objectives of this research and details of the studies which they prompted

	Objectives	Studies carried out or information used	References in this Report (and elsewhere*)
1.	To review all relevant literature on the health risks associated with recreational uses of inland waters and on the relationship between health risk and microbiological quality of such waters	Literature review UK Sea Bathing project.	Chapter 2, (Pike *et al* 1989, Pike and Gale 1992, Pike 1992*, Pike 1990, 1991, 1992b)*
2.	To develop a scheme of classifying the various recreational uses of tidal and non-tidal waters according to degree of contact. Such a classification should be based on a scientific assessment of the risks.	Questionnaires to national governing bodies for ten sports and to secretaries of 209 clubs. Observations of water contact and behaviour at nine venues.	Chapters 3, 5 & 6 (Gale *et al* 1990, Gale 1991, Pike and Gale 1992)
3.	To collate available data upon microbiological and virological quality of inland waters used for recreation and assess in relation to existing standards.	Field studies fortnightly for one year at three leisure park lake complexes. Analysis of monitoring data for 444 marine beaches, 55 rivers, 31 estuaries and 21 lakes/reservoirs.	Chapter 7 (Gale *et al* 1990, Gale 1991, Gale 1992)
4.	To review the risks associated with recreation involving different degrees of contact with tidal and non-tidal waters of varying quality and so far as is possible from the present state of knowledge, establish the relationship between various uses and health.	As Objectives 1 and 2.	Chapters 1, 2, 3, 5, 6, and 9 (Pike 1990, 1991, 1992b, Pike *et al* 1989)
5.	To identify future research needs in both tidal and non-tidal waters.	Sections 2, 3, 8 and 9 of this Report.	Chapter 11

Notes: * Not carried out as part of this programme but used as an additional source. Other references are to Interim Reports submitted to the NRA. Executive summaries to these Reports are given in Appendix A.

1. What are the hazards from poor water quality?

2. What level of risk is acceptable, knowing that absolute freedom from risk is unattainable?

3. What indicator of risks shall be chosen?

4. At what level shall the standard be set?

5. What allowance shall be made for variability in the levels of the indicator?

6. How shall the standard be enforced and what action shall be taken in the case of failure to comply?

7. How shall the standard be revised as water quality improves and better methods of analysis are adapted?

The objectives (Table 1.1) are intended to give direct answers to Questions 1, 2, 4, 5 and 6. The answers to the remaining questions are matters of opinion and will be considered in the Discussion (Chapter 10).

1.3.2 Relationships of existing standards to risk

The development of risk-related standards for recreational waters in the United States and Canada has been carefully analysed in a review paper (Pike 1992a). Some of the arguments used can be summarized thus:

1. Empirical setting of microbiological standards unrelated to epidemiology or risk, with the aim of securing European harmonization, improving tourism and amenity and informing the public about bathing water quality. Criteria for salmonellae and enteroviruses may reflect the feeling that they should be absent from the largest volumes it is possible to analyse. Bathing Water Directive 76/160/EEC.

2. Using epidemiology (Stevenson 1953) to show the level of bacterial counts at which risk becomes barely significant and defining geometric mean value at half this level (National Technical Advisory Committee, NTAC 1969, United States Environmental Protection Agency, USEPA 1976). In drafting it was necessary to re-calibrate the bacterial indicator system from total coliform most probable number, which was used in the epidemiology, to faecal coliform bacteria.

3. Defining the risk inherent in Example 2 as 'acceptable' on the basis of long public acceptance and re-calibrating the bacterial levels from the predictive models of risk developed in the USEPA's epidemiological studies (Cabelli 1983, Dufour 1984), to obtain risk-related criteria (USEPA 1986).

4. A practical approach, derived from 2 and 3, but supported by local microbiological information and regular environmental health assessment (Canadian Ministry of National Health and Welfare, MNHW 1992).

5. Having recognised the difficulty in statistical definition of meaningful microbiological standards and having demonstrated that serious illness is rare, except where sea water is grossly polluted, recommending that no standards should be set, but that a steady improvement in discharges, including comminution, should be maintained to assist mortality and dispersion of pathogens (Medical Research Council 1959, Committee 1959, Working Party on Sewage Disposal 1970).

6. Using a season's results from bacteriological monitoring to grade beaches according to risk (attack rates) from gastro-intestinal symptoms, calculated from a predictive model based on epidemiology - Hong Kong beaches (Cheung *et al* 1991).

1.3.3 Statistical considerations

One of the major difficulties in setting credible standards is that of accommodating the very rapid and considerable variations in water quality, which take place at single locations with time (Gameson, Bufton and Gould 1967, Fleischer and McFadden 1980). Because microbial counts at individual locations are usually distributed log-normally, the appropriate statistics used to describe central tendency and variability are, respectively, the geometric mean (or median) and the standard deviation of log counts.

The bathing water Directive 76/160/EEC defines the Imperative (I-values) and Guideline (G-values) for the microbial determinands in terms of percentile values (95, 90 or 80 percentile). Comparability between different waters is only assured if the standard deviations are the same. This is unlikely and was shown not to be so by the Medical Research Council (1959a,b) for British coastal waters. It was a major reason given by the MRC for not advocating bacteriological standards.

The USEPA (1986) assumed values of 0.7 for marine waters and 0.4 for freshwaters for the standard deviation of log enterococcal counts in its criteria and used them to set single-sample upper limit values (e.g. designated beach at the 75 percentile value, infrequently used beach 95 percentile). These upper limit values are additional to a geometric mean (five samples over 30 days) of 33 enterococci/100 ml (or 126 *Escherichia coli*/100 ml) for freshwater or 35 enterococci/100 ml for marine waters. Statistical considerations show that for a given quality of water, the imposition of a single-sample upper limit means that any beach runs a finite risk of failing - and therefore of being closed - and that the frequency of failure will be greatest for the most frequently used beaches.

Sampling strategies should also taken account of the frequency and position of sampling and what allowances, if any, need to be made for storm and other weather.

The need to take account of those statistical considerations is addressed by Objective 3 and the studies of data from monitoring and field studies in Chapter 6.

2. MEASURING RISKS TO HEALTH

2.1 Hazard and risk

2.1.1 Defining hazard and risk

Popularly, these terms are used interchangeably. In this report, a hazard is a set of circumstances that could lead to harm, harm being illness or loss of life. Some instances of hazard in water recreation were given by Lacey and Pike (1989) in a review:

1. Prolonged head immersion, leading to drowning

2. Impact against hard surfaces or sharp objects. The impact may be driven by the participant (e.g. in diving) or by force of wind or water

3. Chilling

4. Ingestion of water, chemically polluted

5. Infection by water-borne bacteria or viruses which might be

   - naturally present
   - derived from other participants or
   - present as a result of pollution

6. Attack by animals (e.g. jelly fish, shark)

7. Failure of man-made safety devices, e.g. pool chlorination plant

The risk of such a particular event is the probability that it will occur as a result of exposure during a defined amount of exposure. During actual observations risk is estimated as a rate of incidence (or attack rate), i.e. the number of occurrences during a given time of exposure. Risks can be estimated or measured from experience but hazards are potential, i.e. accidents waiting to happen.

Bare statements of risk are usually not very helpful when decisions have to be taken for managing risks or developing policies for controlling them. For example, in considering the number of deaths from drowning, it is of interest to know whether the incidence rate is increasing, because this may highlight a causal factor. One wishes to know the proportion of cases which were accidental, or suicidal, those which could have been avoided by proper training, supervision and by wearing buoyancy aids and how many were in pursuit of sport or occupation. The concepts of trends and relative risks are all important in epidemiology and other statistical studies, when one is exploring associations between various activities and trying to infer causes.

2.1.2 Controlled experimentation and relative risk

In any scientific study of the causes or underlying factors in illness or other harm, controlled design is essential. A group of people is selected who are exposed to the agent under study and their attack rate is compared with that of a control group who should be as far as possible identical (e.g. in age, sex, state of health, social background) as the exposed group except that they are not exposed to the agent. Scientifically, one tests the hypothesis that exposure to the agent presents a hazard which can be measured as an increase in attack rate. Statistically, the assumption is made at the outset that there is no difference in attack rates between the two groups (the 'null hypothesis') unless a statistically significant difference - one unlikely to have arisen by chance - is demonstrated by the results.

This rigour of controlled experimentation is necessary. There are many reasons why participants in water sports may become ill, for example:

- from swallowing polluted water containing pathogens
- from eating contaminated food, purchased at the event
- by contact with others, who are also ill at the event
- by contact with water lowering the body's natural defences

Relative risk compares the measurement of risk in the exposed group to that in the control group and so against the background of risks from the other confounding causes. By definition, if the background risk of illness, which we may call, p, is increased by a factor, a, by participating in the sport, the rate of illness in the sports participants is ap and the relative risk is therefore ap/p or a.

Relative risk is easy to understand and is often used in reporting epidemiological findings, together with another measure, the 'odds ratio' i.e. the odds of attack in the exposed group to that in the control group. When the attack rates are less than about 10%, the two terms relative risk and odds ratio are nearly identical in value.

Both these terms avoid the over-simple idea that risk is additive, i.e. that whatever the background attack rate is in the unexposed, exposure to the hazard merely adds a constant increment. It may well be that background rates are high because the population chosen are unduly susceptible, so it is logical to assume that their susceptibility to the hazard will also be heightened. Relative risk therefore corrects for such tendencies and gives a better indication of risk to the individual than the additive approach. The additive approach (i.e. bathing-associated risk = risk to bathers - risk to non-bathers) was used in the United States Environmental Protection Agency's (USEPA's) studies of bathing water quality and health (Cabelli 1983, Dufour 1984) and was criticized recently (Fleischer 1991) for the reasons given.

2.2 Cause and effect

The list of possible confounding factors given in the previous section show why one must be careful before assuming causal relationships between exposure to an event and untoward effects. The popular type of argument, *post hoc, ergo propter hoc*, that because the unfortunate victim did something, that must have been the reason - does not stand up to scrutiny, because life is full of coincidence. Common sense shows that care must be taken over the design and conduct of studies to relate health effects to exposure, such as:

- selecting simple well-defining hypotheses
- defining the illnesses or other hazards at the outset
- careful matching of exposed and control groups
- collecting information in an unbiased way
- distinguishing between infection and symptoms
- attempting to disprove the null hypothesis
- care to avoid drawing the wrong conclusions

The need for care before concluding that an association indicates a causal relationship, arises because the association may be as a result of extreme chance (e.g. less than one in twenty or more trials) or that it may be spurious, arising from a combination of associated factors. Bradford Hill (1965) suggested a list of criteria which could be used to assess whether a true link existed between exposure and disease (Table 2.1). Generally, the more criteria than can be demonstrated, the more likely it is that a true cause - effect relationship exists. These criteria were used at the outset of this research (Pike *et al* 1989) and in the national project on Health Effects of Sea Bathing (Pike 1990, 1991, 1992b) to examine reports in the literature of case histories and epidemiological studies of illnesses in bathing and other water sports. The conclusions from this analysis will be presented below in Sections 2.4-2.7.

2.3 Infection and immunity

We do not live in a sterile world. Micro-organisms and viruses capable of causing disease (i.e. pathogens) are widely distributed in air, water and food, since they are excreted by those who are infected. Infection depends upon sufficient pathogens being able to invade and overcome the body's immune defences and multiply, thereby setting up infection in the body and producing the symptoms of the illness. A single case of illness may yield an outbreak or epidemic if the cycle of infection from case, through environmental transmission to new hosts with multiplication and excretion, results in a net 'loop gain' in numbers of pathogens over the cycle, so that secondary cases appear. It is usual for decay and dispersion of pathogens in the environment and for the body's immune mechanisms

Table 2.1 Criteria to be used in assessing causality between environmental exposure and disease (Bradford Hill 1965)

Criterion		Explanation
1.	Strength of association	Difference in rates of illness between exposed and non-exposed groups. Chi-square test provides a measure.
2.	Consistency	Has it been repeatedly observed by different people at different places and times?
3.	Specificity of association	A particular type of exposure is linked with a particular site of infection or a particular disease.
4.	Temporality	A 'cart and horse' problem - does the exposure predispose to disease or do people susceptible to a particular disease choose that exposure or occupation?
5.	Biological gradient	A dose-response curve can be detected. The more severe the exposure, the greater is the incidence of disease.
6.	Plausibility	Does the relationship seem likely in terms of present knowledge? But present knowledge may change.
7.	Coherence	The cause and effect interpretation of the data should not conflict with what is known about the biology of the disease.
8.	Experiment	Because of an observed association, some action is taken. Is the frequency reduced? If so, this is strong evidence for causation.
9.	Analogy	If one agent is shown to cause disease, it would be reasonable to expect it of a related agent.

to limit or prevent infection occurring. Public health engineering measures, such as sewage treatment, water treatment and food hygiene impose environmental barriers to transmission of infection.

Immunity is of two kinds, innate and acquired. Innate immunity is conferred by biological factors such as age, sex, nutrition, by socio-economic and by geographic considerations. The body itself has natural barriers to overcome challenge by pathogens. The skin is normally impregnable, except when injured. Tears and mucus contain an enzyme, lysozyme, which rapidly lyses and destroys many bacteria. Mucus secreted in the nasal and naso-pharyngeal tracts and in the passages of the lungs traps micro-organisms and viruses and is propelled by ciliary currents from within, to be swallowed. The stomach acid and digestive enzymes largely destroy pathogens. A further defence is provided by the phagocytic white cells in the blood, which are prompted to scavenge and devour pathogens invading the tissues.

Acquired immunity results from challenge by pathogens and their toxins and the stimulation of antibody production in the blood. Not all pathogens or toxins are equally effective in setting-up antibody production. With many waterborne viruses immunity is short-lived, whereas with some enteric bacterial pathogens the immune response may be low.

Infection is the unfavourable outcome of challenge to the body by pathogens in which multiplication is taking place. Symptoms of the illness result from irritation, elevation of the temperature, increase of blood supply to the site of infection and by the effects of toxins released by the pathogen. The patient recovers when immune responses control and eliminate infection, but in some cases, a carrier state may remain, in which pathogens are excreted asymptomatically.

2.4 Toxicoses

It is necessary to realize that illness can arise through contact with chemical pollutants in water or through ingesting chemically polluted water. A particular case is illness caused by absorbing toxic substances released by microbial growth in water. Certain species of cyanobacterial ('blue-green algae') produce toxins during periods of intense growth ('blooms') or senescence. On contact or by ingestion, these cause various skin irritations, allergic reactions, and by absorption, liver damage, gastro-intestinal disorders and pneumonia in man and animals (NRA 1990). Other examples of toxicoses from water, but which do not affect water recreation are paralytic shellfish poisoning, from consumption of shellfish containing saxitoxins produced during blooms of certain marine dinoflagellate algae ('red tides') and botulism occurring in waterfowl which have ingested *Clostridium botulinum* toxins from muds during warm weather.

2.5 Aspects of experimental epidemiology

2.5.1 The nature of epidemiology

Epidemiology is the study of the ways in which diseases are transmitted. It may be used in a variety of ways, such as:

1. The study of case histories and outbreaks. This involves rapid mobilisation of investigators, once an outbreaks is suspected, the collection of clinical samples from the patients or of objects, food or water which might have acted as vehicles of infection and the interviewing of subjects and carefully matched well controls in an attempts to relate the illness to a common source. This type of study is retrospective (i.e. cases and controls are examined after illness is discovered). It may not give reliable attack rates because the total number exposed to the hazard may be unknown. If a pathogen, known to cause the illness is found in the supposed vehicle, as well as in the cases, a causal link is proven.

2. National surveillance. In the United Kingdom the Communicable Disease Surveillance Centre and its Scottish equivalent receives notifications of pathogens isolated from clinical specimens submitted to Public Health Laboratories. Immediate action is taken to investigate causes, as in 1. above, when unusually levels of isolations or clusterings occur. The Office of Population Censuses and Surveys (OPCS) keeps records of notifications of notifiable diseases and causes of death.

3. Experimental epidemiology. If properly designed, this is a powerful tool. Proper design means that the objectives must be clear at the outset. The study should aim to prove or disprove a hypothesis concerning the cause of illness. It will involve demonstrating that the attack rates and relative risk of acquiring the illness are significantly greater than in an identical control group not exposed to the hazard. The subjects are assigned into the two groups or 'cohorts', exposed and unexposed control, before the exposure and their states of health are measured before, during and for a suitable time after exposure, to enable the effects to be expressed and measured. Such a study is prospective and measurement of attack rates is inherent.

Retrospective studies are usually simple to carry out and are rapid but usually do not measure relative risks or attack rates. They are dependent upon careful matching of exposed and control groups. This method was used in the early UK studies (Medical Research Council 1959, Committee 1959) to investigate a supposed relationship between poliomyelitis and bathing in the sea. The same Committee used a study of case histories and national surveillance of typhoid and paratyphoid fever to show that these were not significantly more prevalent in coastal regions than inland and that only a few well-defined outbreaks were related to bathing and these in grossly polluted waters.

Most of the other studies described in this report have been prospective. A major difficulty is that the pathogenic agents which may be responsible for complaints reported by water sports participants cannot be identified, either in clinical samples or in polluted water. Reliance has to be made on subjects' perception of symptoms and by counting numbers of faecal indicator bacteria in water. The period of exposure is often undefined and variability in microbiological quality makes it difficult to quantify the hazard. Other major difficulties are the subjectivity of subjects' reporting of symptoms and the effects of confounding causes of illness (e.g. food, person-to-person transmission). The only study so far to address all of these problems has been the controlled cohort study of sea bathers (Jones *et al* 1991), which is a complementary part of the UK's national studies on Health Effects of Sea Bathing (Pike 1990, 1991, 1992b).

2.5.2 Dose-response curves

It is reasonable to suppose that risk of acquiring infection from water will depend upon the following factors:

- the numbers of pathogens in the water
- the amount and duration of contact
- the nature of contact (splashing, immersion, swallowing)

Because immunity varies between individuals and invasiveness and pathogenicity between strains of pathogens, the relationships between numbers of pathogens in the water and risk to health is not linear. In waterborne complaints affecting sports participants, the pathogens are not usually identifiable, and may be diverse. Their numbers, like those of associated faecal indicator bacteria will be highly variable with location and in time. Data from experimental studies of infectivity show that curves relating attack rates to numbers of pathogens are sigmoid i.e. a small proportion of the population are either very susceptible or highly resistant.

In epidemiological studies of water quality and health, the actual doses of pathogens encountered is not known and exposure is measured by the content of faecal indicator bacteria in the water and/or the duration of contact with water. The illness response is best measured relative to the illness rates in the control population as a 'relative risk' since this compensates for any differences in susceptibility in the population, if the exposed and non-exposed control populations are properly matched. The dose-response curves which are obtained resemble that in Figure 2.1, showing increase in relative risk with increasing exposure, together with an uncertainty in estimating the relative risk, as shown by the statistical confidence intervals. Because the relationship is continuous, it provides no rational point at which to set a standard and indeed implies that no absolute freedom from risk is attainable, unless there is no exposure at all. However, the degree of exposure at which the relative risk becomes significantly elevated (i.e. where the lower 95% confidence interval exceeds a relative risk of 1.0) has precedent for use as a decision point for formulating a standard, as in the United States National Technical Advisory Committee's report (NTAC 1989), which recommended that a faecal coliform standard should be set at half the level at which an epidemiological effect became statistically significant.

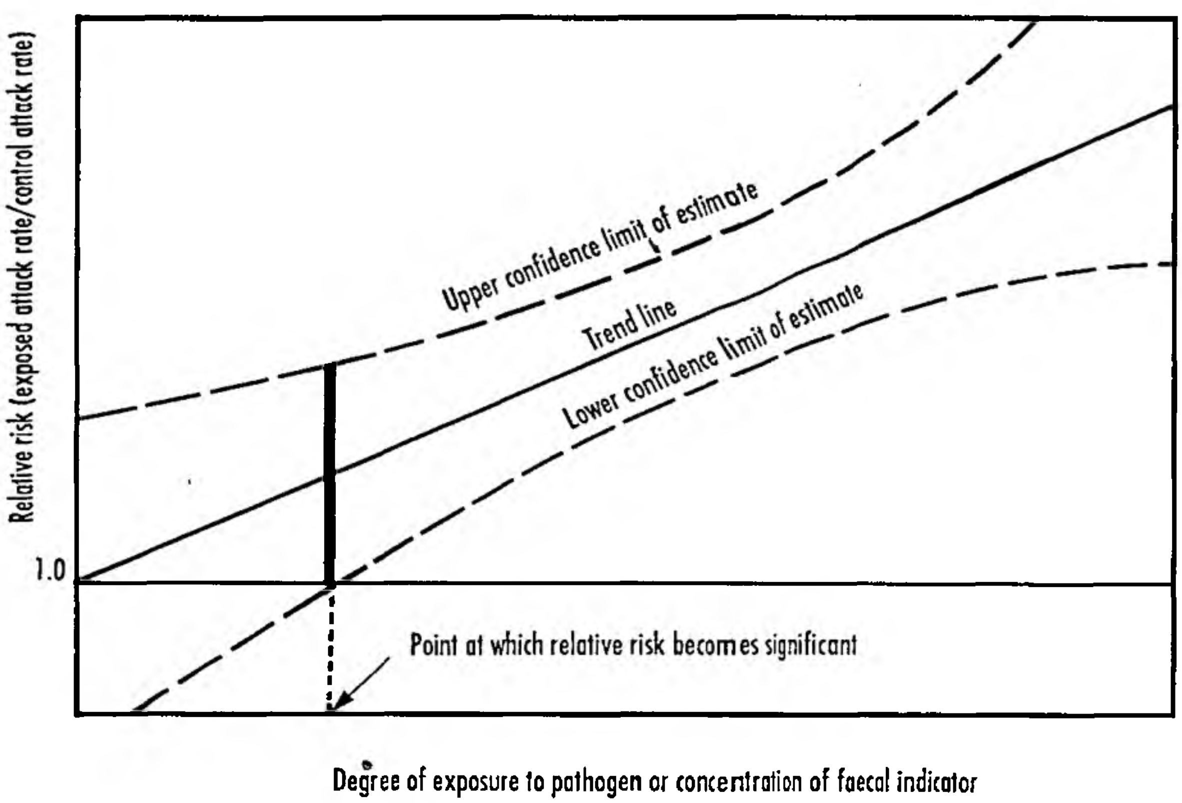

Figure 2.1 Empirical relationship between degree of exposure to a pathogen or concentration of faecal bacteria in water and relative risk of illness

2.5.3 Faecal indicators, faecal pathogens and risk

Because the pathogens responsible are difficult or impossible to enumerate in polluted water, standards for microbiological quality of water specify indicators of faecal pollution, with the assumption that their numbers indicate the degree of faecal contamination of the water and, thus, the likelihood that waterborne pathogens may be present. There is no constancy between the ratio of numbers of pathogens and faecal bacteria, because the latter are always present in faeces whereas pathogens are only excreted by infected subjects and by carriers. This poses a real difficulty, if it is desired to set risk-related standards based upon levels of faecal indicator bacteria, in water because the indicator/pathogen/risk relationship may vary from place to place and with time, depending on illness rates in the excreting community. Fleischer's (1991) critical re-analysis of the USEPA's epidemiological data for marine waters (Cabelli 1983) has shown differences in the relationships between gastro-intestinal symptoms related to bathing and faecal streptococcus count at the three sites used (Boston Harbour, New York, Lake Pontchartrain) and that significant trends only occurred at Boston Harbour.

Another difficulty arises when the pathogens decay at different rates from the faecal indicators which is chosen. This means that the indicator/risk relationship will change with position and period of transit from the point of discharge of sewage. Any sewage treatment process using disinfection, which destroys the infectivity of pathogens and faecal indicators differentially, will affect this relationship similarly. For example, it is to be doubted how far the predictive models of risk from gastro-intestinal complaints predicted in the USEPA's studies in freshwater (Dufour 19894) are universally applicable, because some, but not all, of the waters examined received chlorinated discharges of treated sewage effluent.

2.5.4 Infection and symptoms

Infection has occurred when the body's defences have been overcome and the pathogens are multiplying in the tissues. Infection can usually be determined by clinical or microscopic examination of the infected region or of specimens, such as of faeces, body fluids or swabs for presence of the pathogen. This is usually difficult or impossible in epidemiological surveys of water quality and health because of the ethical constraints upon involving minors, and using invasive procedures, such as taking samples of blood, which may carry a finite, but small, hazard and will inconvenience subjects. Clinical trials with adult volunteers have featured in the controlled prospective cohort studies forming part of the UK studies on the Health Effects of Sea Bathing (Jones *et al* 1991, Pike 1990, 1991, 1992b), but have been restricted to healthy adults and to waters meeting the imperative (I-value) microbiological criteria of the bathing water Directive 76/160/EEC. Other studies have relied upon careful interview of subjects to determine perception of symptoms suggestive of infection by the subject. The controlled cohort studies have shown little association between clinical examinations of specimens taken and symptoms reported after the days of exposure. This may mean, that one or more of the following reasons applied:

1. Subjects reported irritations by sea water, unrelated to infection.

2. The symptoms are caused by a normal and successful response to challenge by pathogens.

3. The subjects were infected, but the pathogens were not detected or detectable in the examination.

This means that great care must be taken when interpreting the results of epidemiology in this subject, because, except for serious illness and grossly polluted water, one is working in the region between perception and illness.

2.6 Medical assessment of risks in water recreation

Medical aspects of the risks to health in water recreation and the factors which influence them have been reviewed by Cartwright (1992). The key points in his paper are as follows:

1. Man is a terrestrial animal and water is a hostile environment.

2. The skin normally carries a complex microflora of bacteria and fungi, which rarely infect normally immune persons. It may also transiently carry well-recognized pathogens, which may infect under certain circumstances.

3. The skin, ears, eyes and upper respiratory tract all have recognised barriers to infection which operate optimally in air, but which can be disturbed through contact with water, enabling micro-organisms which normally live symbiotically or commensally to become pathogenic.

4. Chains of infection involve successively the source, the reservoir, the route of spread and the susceptible host. Control of disease aims to break one or more links in this chain.

5. In water recreation, the source and reservoir merge and can be the natural microflora of water, pathogens excreted with sewage or by animals and opportunistic or transient organisms on the skin or other body surfaces wetted by water.

6. The routes of spread are direct contact, inhalation or ingestion.

7. Infection will only occur if the subject is unable to cope with the challenging pathogens, firstly when the body's defences are breached and secondly when the immune mechanisms are inadequate.

It is convenient, at this stage, to classify illness associated with water recreation according to the route of infection:

1. Waterborne, in which the pathogens are transmitted by faecally contaminated water.

2. Water contact, in which the pathogens or toxic agents are carried by water, initiate illness by contact but are not directly related to faecal pollution.

3. Water-washed, in which contact with water lowers the body's defences, allowing opportunist or transient organisms on the body surfaces to infect.

The nature and significance of thee three classes of illness will now be reviewed in the light of what epidemiological information is available. It will then be shown that this classification lends itself to suggesting the types of standards or control measures which could be imposed to protect participants in water recreation. It will also indicate the value of the practical information collected in this research project.

3. REVIEW AND CLASSIFICATION OF ILLNESSES ASSOCIATED WITH WATER RECREATION

3.1 Waterborne infections

3.1.1 Case histories

Case histories (reviewed by Pike *et al* 1989, Pike 1990, 1991, 1992b) have shown that the following illnesses have been associated with bathing or other recreation in grossly polluted waters:

- Typhoid and paratyphoid fever
- Shigellosis
- Infectious hepatitis (hepatitis A)
- Pharyngo-conjunctival fever (Adenovirus type 4)

There is also circumstantial evidence that cryptosporidiosis can be transmitted by bathing or playing in polluted water (Casemore 1990, Gallagher *et al* 1989).

Microbiological standards or guidelines for water quality are appropriate for controlling risks from waterborne illnesses.

3.1.2 Epidemiological studies of bathing

The gastro-intestinal symptoms associated with bathing in polluted water have an incubation period of about 48 hours and attack rates suggesting a viral aetiology (Cabelli 1983). They are now thought to be caused by the Norwalk virus or related small round viruses. Epidemiological and case history for bathing has been extensively reviewed as part of the UK study (Pike 1990, 1991, 1992b). The general trends are as follows:

1. Swimmers report a higher incidence of symptoms than non-swimmers.
2. The rate of reporting symptoms is related to the degree of contact with water e.g. not entering the water <wader <swimmer <diver/surfer.
3. In the UK studies, the age group reporting symptoms most frequently was 15-24 years and there were no differences between the sexes.
4. Relative risks of reporting gastro-intestinal and throat symptoms by water users increase with increasing counts of faecal bacteria.

However, these statements need qualifying. Usually, the attack rates have been related to counts of faecal bacteria (Cabelli 1983, Dufour 1984, Foulon *et al* 1983, Cheung *et al*

1990, Seyfried *et al* 1985a,b) but in some studies this has not been significant (New York - Stevenson 1953, Ontario - Lightfoot 1989, New Jersey - NJDOH 1989), or significant only for faecal indicators other than the coliform group (staphylococci, Ontario - Seyfried *et al* 1985b, enterococci, marine waters - Cabelli 1983; faecal streptococci, Ardèche River - Ferley *et al* 1989, faecal streptococci and staphylococci, UK study at Moreton - Pike 1991), or significant only when counts of faecal indicators were particularly high (Chicago - Stevenson 1953).

It is difficult to compare attack rates across studies because of the difficulties in locations and the different units of measurement (see Pike 1990 for a full analysis). However, it is apparent that absolute rates in both bathers and non-bathers vary greatly, depending on the location (Cabelli 1983, Fleischer 1991)). As extremes, the lowest attack rates were displayed in the Hong Kong marine study (Cheung *et al* 1989) at 0.41% for 'highly credible' gastro-intestinal symptoms in bathers and the highest were recorded for gastro-intestinal and other symptoms in snorkel swimmers in Bristol City Docks (21/77, 27%) compared with unexposed controls (4/170, 2.3%) when the geometric mean count was 1650 *Escherichia coli*/100 ml (Philipp *et al* 1985).

In the UK national studies (Pike 1990, 1991, 1992b) attack rates for one or more gastro-intestinal symptoms in those entering the water have ranged between 3.2% (Langland Bay beach survey) to 44.1% (Southsea cohort study) and respective relative risks 0.8-1.8. This study will not be completed until March 1993, although interim findings have been published (Pike 1992b). Hence it is not possible at this stage to state the relationships found between counts of faecal indicator bacteria and absolute or relative risks under British conditions, although there are positive trends between counts of faecal bacteria, or degree of water activity and relative risk of reporting gastro-intestinal symptoms. However, at Langland Bay when counts of total and faecal coliform bacteria met the imperative, I-value, requirement of the Directive 76/160/EEC (geometric means were 260 and 158 per 100 ml respectively) gastro-intestinal symptoms reported by bathers were not significantly different from those of persons not entering the water (odds ratio 0.69 (Pike 1990)). Conversely, at Ramsgate, where 12% of samples exceeded the I-value for faecal coliform bacteria (geometric mean 550 per 100 ml), bathers reported significantly more gastro-intestinal symptoms (odds ratio 1.47) and diarrhoea (1.88) (Pike 1990, Balarajan *et al* 1991). If these trends are continued in the 1991 and 1992 studies at eight beaches then it should be possible to draw conclusions concerning water quality and relative risks to bathers and hence to use this information to base standards for this and similar recreation on a more objective basis.

Outline details have been communicated by Havelaar *et al* (1992) of the results of a study of triathletes using the Zegerplas (a recreational lake in the Netherlands). Triathletes showed significantly higher rates of gastro-enteritis than non-competitors (odds ratio 14.7) and viruses were found in faeces from 6/12 competitors. Water of the Zegerplas contained 750 faecal coliform bacteria/100 ml and 20 faecal streptococci/100 ml and received treated sewage effluent.

Results of the USEPA's studies in marine and freshwaters (Cabelli 1983, Dufour 1984) have been taken to suggest that for a given level of faecal bacteria (e.g. enterococci), the risks to bathers are greater in freshwaters, supposedly because saline waters result in a greater relative rate of decay of waterborne viruses. Apart from the re-analysis of the marine data by Fleischer (1991), which has shown site-specifity of the count/risk relationship, there is the unquantified problem that some, but not all, of the discharges of treated sewage, to the inland waters in Dufour's (1984) studies were chlorinated, thereby altering the relationship of faecal bacteria to viruses.

3.1.3 Recreation other than bathing

Apart from bathing, very little epidemiology has been carried out upon water recreation. The Bristol Docks snorkel race study has been mentioned above. A study of 84 competitive windsurfers and 41 unexposed employees, exposed to the same food, took place at the baie de Beauport, Québec on the River St Lawrence, over the nine days of the windsurfer Western Hemisphere Championship in 1984 (Dewailly *et al* 1986). The median count of faecal coliform bacteria exceeded 250 per 100 ml and was estimated to be 1000 per 100 ml at high tide when most of the races took place. Relative risks (competitors/employees) were significantly elevated in the case of diarrhoea (6.7), all digestive symptoms (5.5) and all symptoms (abdominal, digestive, skin, ear, eye, 2.9).

The NRA has partly funded two prospective studies, carried out in the spring of 1991, to quantify the possible health effects of white-water canoeing. Preliminary results have been reported (Fewtrell 1992). At the more polluted site, Holme Pierrepont, Nottingham, the geometric mean count of faecal coliform bacteria was 281 per 100 ml and the average enterovirus count 198 pfu/10 litres. At the other site, Afon Tryweryn, the values were 23 per 100 ml and undetectable in 10-litres samples respectively. Canoeists using Holme Pierrepont reported significantly more gastro-intestinal and upper respiratory symptoms, 5-7 days after exposure than either the unexposed control group (supporters) or the canoeists using Afon Tryweryn. This research team (Centre for Research into Environment and Health, St Davids University College, Lampeter) has carried out further studies in 1991-92 of water sports in canals and an estuarial river, partly funded by NRA.

3.1.4 Degree and duration of contact

It is to be expected that that rates of attack from waterborne illnesses or reporting of symptoms will increase as the duration and frequency of contact increases. Attack rates, per 1000 days of swimming, were related to numbers of swimming days in the early US studies at Chicago and Dayton, Ohio but not at New York (Stevenson 1953). Significant trends were also shown in the following studies:

1. Brittany beaches (Foulon *et al* 1983). Non-head immersers reported significantly more ear, eye and skin symptoms than non-bathers but fewer abdominal pains. Head-immersers reported more itching eyes, ear and throat symptoms than non-head immersers.

2. Windsurfers, River St Lawrence, Québec (Dewailly *et al* 1986), respiratory and gastro-intestinal symptoms increased with rates of falling-in (Figure 3.1). Highly significant.

3. Sydney, Australia, Health-Surf Study (Water Board 1990), for ear, eye and gastro-intestinal symptoms, the rate of increase being greater for freshwater than marine.

4. Ontario Lakes (Seyfried *et al* 1985a): ear, respiratory and gastro-intestinal symptoms greater in head-immersers than non-head immersed swimmers and non-swimmers.

5. In the UK beach survey studies at Langland Bay and Ramsgate, the odds ratios for reporting of one or more 'major symptoms' up to a fortnight after exposure increased in the following order: not entering the water <wading <swimming <diving or surfing (Figure 3.2).

This evidence shows that it is desirable for the degree or duration of contact with water to be taken into account when devising standards to protect participants in various sports.

3.2 Water contact illnesses

These illnesses are associated with contact with water but not directly, if at all, with faecal pollution.

- Leptospirosis, particularly Weil's disease
- Allergies and other toxic effects of Cyanobacteria
- Swimmers' itch (schistosomiasis)

Contact with water and canoeing are two risk categories for leptospirosis and accounted for 20 and 29 cases respectively, out of a total of 229 reported to the Communicable Disease Surveillance Centre of the Public Health Laboratory Service (CDSC, PHLS) in 1985-89 (Ferguson 1990). Conversely, in Scotland, there were only four cases related to water sport, reported in the 22 years, 1969-1990 (Thakker and Reilly 1991). The causative organism, *Leptospira interrogans*, is released in the urine of infected rats and other aquatic rodents and by cattle and deer. Infection is by contact of abraded skin with the urine or contaminated water. The incidence appear to be static. Infections with the Figure 3.1 Relative risks of pollution-related symptoms in competitive windsurfers and unexposed employees (Dewailly et al 1986). Number of subjects shown serovar *ichterohaemorrhagiae*, usually carried by rodents, may be severe, leading to liver damage and death, if not recognised early and treated. The incidence of the illness is unrelated to faecal pollution.

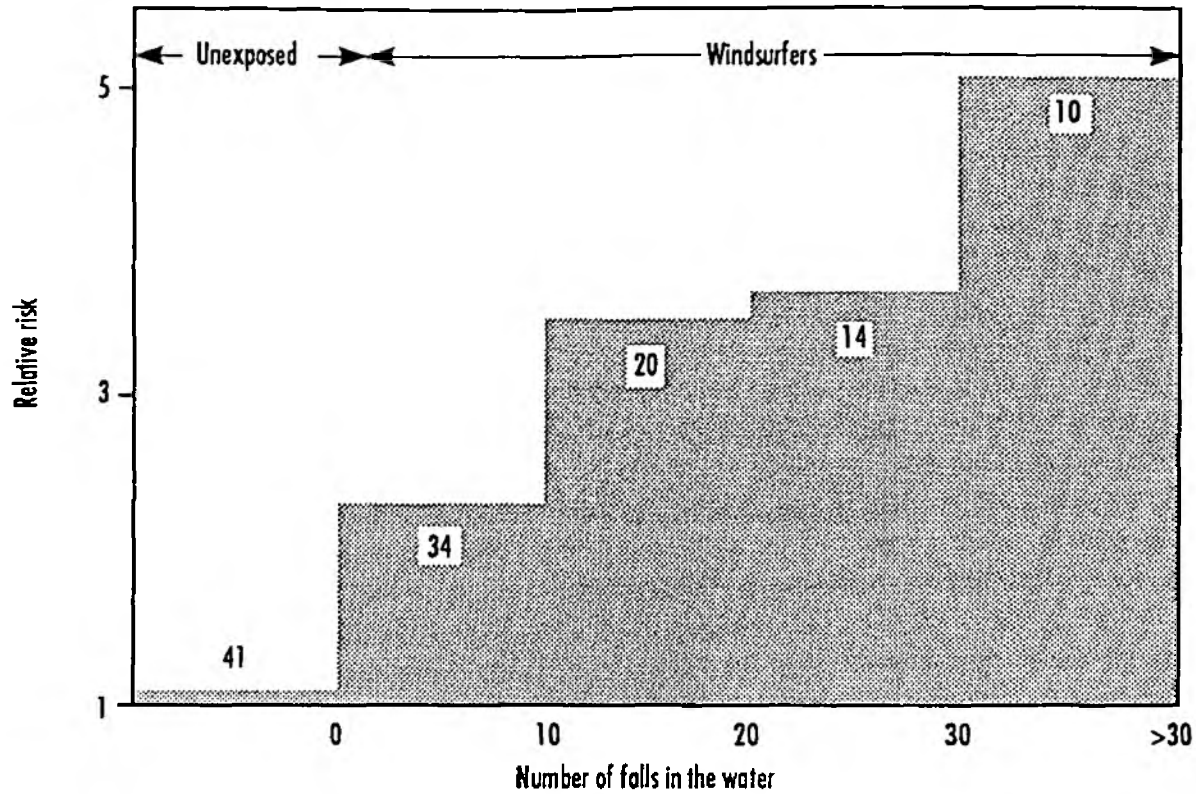

Figure 3.1 Relative risks of pollution-related symptoms in competitive windsurfers and unexposed employees (Dewailly *et al* 1986). Number of subjects shown

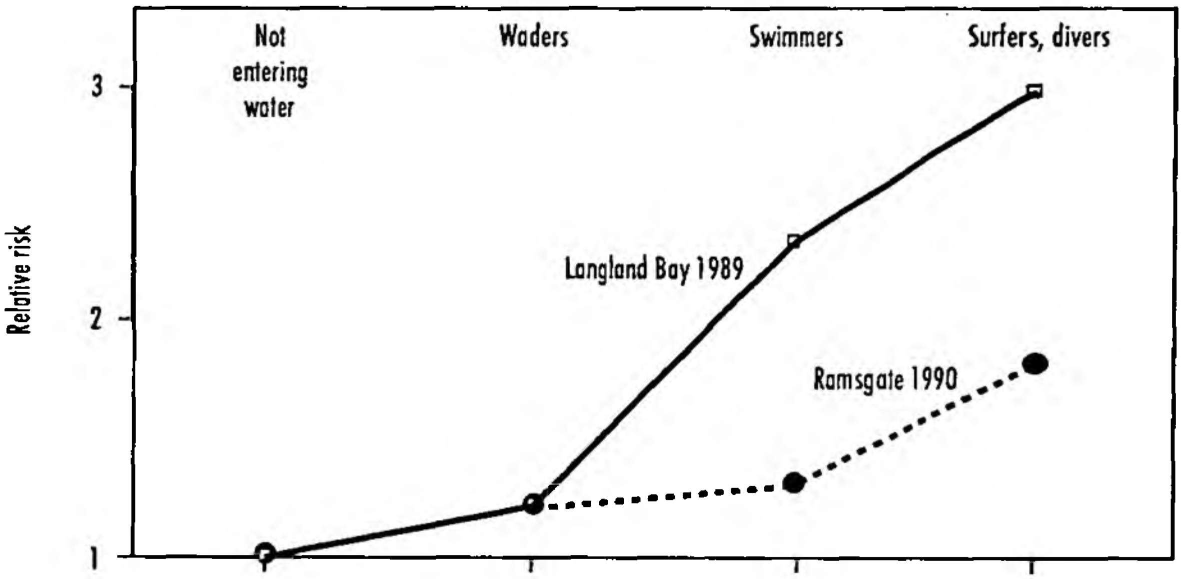

Figure 3.2 Relative risks of reporting one or more major symptoms by beach-goers in UK sea bathing studies (Pike 1990, 1991)

A serological study of 24 regular windsurfers and water-skiers using the Bristol City Docks yielded one which displayed antibodies to the serovar *ichterohaemorrhagiae* and who had suffered jaundice when nine years old and had a history of repeated water contact over many years (Philipp *et al* 1989). Little significance can be attached to this result as the study was small and uncontrolled.

Contact with the scums of certain Cyanobacteriaceae species ('blue-green algae') during blooms has resulted in allergic reaction and skin irritations and gastro-enteritis on ingestion of the water. In one severe case, two army canoeists practising capsize and 'eskimo roll' procedures suffered pneumonia and liver damage (NRA 1990, Turner *et al* 1990).

A rare condition is 'swimmers itch'. Aquatic snails are the intermediate hosts of certain flukes, infesting cattle, water fowl and other vertebrates. Infected snails release large numbers of motile cercariae which infect the primary host by puncturing the wet skin or upon ingestion. Occasionally in Britain, outbreaks of pustular dermatitis, with itching, have occurred in bathers in lakes, infested with snails, during warm weather (e.g. Eastcott 1988).

For completeness, it is necessary to mention primary amoebic meningo-encephalitis, a disease, usually fatal, caused by inhaling water containing the amoebae, *Naegleria fowleri*. These are able to multiply in warm, nutrient-enriched waters, usually contaminated with soil, e.g. in hot springs. The only recorded case in Britain was an 11-year old, who had bathed in the thermal spring waters at Bath (Galbraith, Barrett and Stanwell-Smith 1987).

By definition, the risk of acquiring water-contact illnesses increases with the duration and intensity of contact with water. The NRA (1990) classified water sports upon the level of risk of contact, when advising upon action to be taken in the event of cyanobacterial blooms on recreational waters (Table 3.1).

Table 3.1 Classification of risk from cyanobacterial blooms for various water activities (NRA 1990)

High	Medium	Low
Paddling, swimming	Canoeing	Fishing
Diving, windsurfing	Sailing	Irrigation of crops
Water skiing	Rowing	Pleasure cruising
Livestock watering	General public amenity	

Because none of these water-contact illnesses are directly related to faecal contamination, bacteriological or virological standards are inappropriate.

3.3 Water-washed illnesses

This term is used here to denote the class of conditions in which violent or prolonged contact of the body, including the skin, eyes, nasopharyngeal passages and the outer ear canal, disturbs the normal defence mechanisms and washes in opportunistic or transient pathogens from the skin, enabling them to set up infection. This class of illness is unrelated to the degree of pollution or the microbiological quality of the water but is influenced by the duration and intensity of contact with water. A well-known example is outer ear canal infection *(otitis externa)*, which is fairly common in frequent users of indoor swimming pools and is related to length of exposure and warm, humid conditions (Calderon and Mood 1982). It may also include those symptoms of the eyes, ears, nose and skin, which appear to be commoner in bathers than non-bathers but which are unrelated to the microbiological quality of the water, e.g. Stevenson 1953).

3.4 Conclusions: classifying water activities by hazards of illness

It is now possible to present the broad classification of illnesses associated with water recreation and to suggest appropriate control measures and standards which could be applied to reduce risks (Table 3.2).

To complete the aims of this research, as set out in Table 1.1, it will be necessary to classify sports according to hazards of illness and degree of contact with water, so that the information can be combined with the classification of illness proposed in Table 3.2. The practical part of the research, which follows in Chapters 4-6, collected information for various water activities upon the factors influencing risk, such as:

- duration of contact
- frequency of participation
- intensity of contact
- part of body wetted
- type of water used

This was done in three ways, by seeking the views of national governing bodies for organized water sports and of individual clubs and by observing water activities directly. The methods used in these studies are described in Chapter 4. Measurements of the degree of contact with water and its assessment as a hazard are described in Chapter 5. Chapter 6 assesses the perceptions of illness and other hazards provided by the national governing bodies and sports clubs. It also summarises the extent and nature of participation in various sports, since these also define the extent of any hazard.

Table 3.2 A classification of the types of illness associated with water recreation and the most suitable control measures and water quality standards

Classes of illness (with examples)	Appropriate control measures and water quality standards
1. Waterborne - pathogens deriving from faecal pollution (typhoid, paratyphoid, shigellosis, infectious hepatitis, pharyno-conjunctival fever, gastro-enteritis, cryptosporidosis).	- Licensing and control of discharges of sewage, treated effluents, storm-sewage and slurries. Microbiological standards of water quality enforced.
2. Water contact - agents unrelated to faecal pollution contact the skin and mucous membranes.	- standards for ecological and biological quality. Advice to sports clubs and public.
(a) Leptospirosis	(a) Bankside management to control rodents.
(b) Cyanobacterial blooms - contact allergies, absorption of toxins	(b) Control of eutrophication, monitoring of cyanobacterial population, curtailment of recreation during blooms
(c) Swimmers' itch	(c) Awareness of a rare problem Control of snail-infested vegetation in warm, still waters
3. Water-washed - low-grade, opportunist pathogens, deriving from the skin and other body surfaces. Water interferes with body's defence mechanisms and washes pathogens on to sensitive sites.	- No water quality standards or water management policies appropriate. Curtailment of activity or protection of eyes and ears may reduce risks but will interfere with enjoyment of sport.

4. PARTICIPATION IN WATER ACTIVITIES AND PATTERNS OF USE

4.1 Survey of national governing organizations for sports

Preliminary enquiries were made of the Sports Council, which is the national controlling agency for organized sports. These confirmed that there was no simple method for measuring national participation in various sports, because in the majority of cases, central records of individual members of clubs are not held and there is much activity by people who are not members of clubs. The following national governing organizations were identified, with the advice of the Sports Council and provided information.

1.	Angling	National Federation of Anglers
2.	Canoeing	British Canoe Union
3.	Rowing	Amateur Rowing Association
4.	Sailing, yachting	Royal Yachting Association
5.	Surfing	British Surfing Association
6.	Swimming, long-distance swimming	Amateur Swimming Association British Long Distance Swimming Association
7.	Sub-aqua diving	British Sub-Aqua Club
8.	Water-skiing, aquaplaning	British Water Ski Federation
9.	Windsurfing	Royal Yachting Association

A questionnaire was developed, with the advice of the NRA's project leader (Pike and Gale 1992, Appendix A) and with the aim of obtaining the following information.

- Numbers of participants nationally
- Distribution by age and sex
- Frequency of participation
- Effect of season on participation
- Degree of contact with water
- Awareness of health hazards
- Incidence of drowning

Questionnaires were sent to the governing bodies listed above, following by telephone calls to their offices to explain the purpose and to elicit more detail from their response.

Replies were received from the governing bodies listed. Some sent supplementary information. The British Canoe Union sent reports on illness and water quality and compiled statistics on accidents and orthopaedic problems for canoeists. The Royal Yachting Association replied as the national body for all kinds of sailing on marine and inland waters, including windsurfing (sailboarding) and power-boat racing. It supplied copies of letters to club secretaries and information sheets on the hazards of cyanobacterial blooms to users of inland lakes. It drew attention to an independent report on boating and water sports (Leisure Consultants 1989), which had analysed national participation, by examining statistics from various sources including OPCS and the national governing bodies.

4.2 British Waterways

British Waterways (BW) own, or are the navigation authority for nearly 3200 km (2000 miles) of canals and navigable rivers and for 90 reservoirs and dock basins. They provide a multi-leisure resource for activities such as fishing, boating, walking and nature study. The waterways are classed thus:

1. Commercial - 555 km (345 miles), for carriage of freight

2. Cruising - 1875 km (1165 miles), for cruising, fishing and other recreation

3. Remainder - 809 km (503 miles)

Bathing is expressly prohibited because of the hazard of drowning. BW provided information on numbers of people using their facilities.

4.3 Survey of individual sports clubs

Analysis of the returns from the national governing bodies showed that they were unable to provide detailed information to the information requested. A second questionnaire (Pike and Gale 1992, Appendix B) was devised for this purpose and sent to 604 clubs, identified on the Sports Council's registers, of which 209 responded.

4.4 Behavioural studies of participants

The objectives of the research called for a limited number of studies to be undertaken at selected venues to observe activities of participants and to estimate the degree of contact with water.

Table 4.1 lists the sites and activities which were studied. Water quality at the lakes of Leisure Parks 1 and 2 and Frensham Great Pond was measured by fortnightly sampling. Leisure Parks 1 and 2 are purpose-designed and constructed for recreation and are in south-east England. The respective District Council officers, co-operating in these studies requested anonymity of the locations. Bathing is permitted in a designated area of Frensham Great Pond.

Table 4.1 A description of sites used for observing behaviour of participants in various water activities

Sites (and National Grid Reference)	Activities studied	Dates and times
1. Leisure Park 1 (not given):		
Boating Lake, area 1.2 ha	Walking, illicit paddling, dogs, childrens' canoes	6 May 1990 (Sun) 0900-1900 27 May 1990 (Sun) 0900-1900
Sailing Lake, area 4.3 ha	Dinghy sailing, windsurfing	As Lake D
2. Leisure Park 2 (not given)		
Boating Lake, area 6.2 ha	Rowing dinghy and childrens' canoe hire	27 May 1990 (Sun) 0900-1900
Sailing Lake, area 7.1 ha	Dinghy sailing, windsurfing	27 May 1990 (Sun) 0900-1900
3. Frensham Great Pond, Farnham, (SU 846 405)	Bathing, sailing, windsurfing, canoeing	6 and 27 May 1991 (Suns), 1000-1800
4. National Water Sports Centre, Holme Pierrepont, Nottingham (SK 613 391)	White-water canoeing	27 April 1991 (Sat) 0930-1700
5. Welsh Canoeing Association's National White Water Centre, Canolfan, Tryweryn, Bala (SH 889 297)	White-water canoeing	11 May 1991 (Sat) 0915-1600
6. Kirton's Farm lakes, Reading (SU 693 699)	European water-ski championships	26 May 1991 (Sun)
7. Theale lakes, Reading (SU 652 704)	Windsurfing	3 June 1991 (Sun)

Table 4.1 continued

Sites (and National Grid Reference)	Activities studied	Dates and times
8. Westhorpe lakes, Little Marlow (SU 863 863)	Water skiing, windsurfing	10 June 1991 (Sun)
9. Towans beach, Newquay (SW 81 62)	Surfing	12 August 1991 (Mon) 1500-1700
10. Lepe Foreshore Country Park, New Forest (SZ 455 984)	Water skiing, windsurfing	25 August 1991 (Sun)

The studies of white-water canoeing at Holme Pierrepont and Canolfan Tryweryn were made at the same time as the epidemiological studies by the Centre for Research into Environment and Health (Fewtrell 1992). At Holme Pierrepont, water from the River Trent above Holme Sluice is diverted down an artificial slalom course at rates of discharge varied by a weir. Canolfan Tryweryn is located on the Afon Tryweryn, a rocky, upland stream, fed on days of activity by controlled releases of water from the Llyn Celyn dam.

Lakes 6-8 are reclaimed gravel pits, adjoining the River Thames, which have been developed for water sports. Towans beach is a recognised venue for surfing and with Lepe foreshore, is recognised for monitoring under the EC bathing water Directive.

Behaviour and degree of contact with water were estimated by making timed observations of individuals at convenient vantage points on the bank or by analysis of video recordings made at the events. Results of water quality studies are given fully in Gale *et al* (1990) and analysis of behaviour and water contact in Pike and Gale (1992).

5. CONTACT WITH WATER AS A RISK FACTOR

5.1 Assessment of the degree of water contact by questionnaire

5.1.1 Scope

Duration and degree of contact with water were recognized in Section 2.7.4 as risk factors in the transmission of illnesses in water sports. The views of national governing organizations and of individual clubs were sought in the questionnaires and these were supplemented by observations of particular sports (Table 3.2) given in Section 4.2.

5.1.2 National governing organizations

The national governing organizations for the six sports of Table 5.1 were asked to comment upon the nature and frequency of wetting.

Table 5.1 Extent and frequency of water contact, expressed by national governing bodies for seven sports

Water contact	Long distance swimming	Sailing/ wind-surfing	Surfing	Water skiing	Canoeing	Angling
1. Extent						
Whole body	Y		Y	Y		
Chance of swallowing	Y	Y	Y	Y	Y	
Splashing of face	Y	Y	Y	Y	Y	Y
Limbs only		Y				
Hands only						Y
2. Frequency						
All the time	Y	Y*	Y	Y		Y+
Once every outing				Y		

Notes: * For windsurfing
+ Of the hands but no other part of the body
Categories of wetting 'up to neck' and 'up to waist' and frequencies 'once every other outing' and 'very infrequently' yielded negative responses. Other national bodies did not respond to this part of the questionnaire.

The responses call for comment. The 'splashing of face' in angling, e.g. when lifting the line from the water or casting is not comparable with that in the other sports where it is recorded. 'Canoeing' does not distinguish between canoe touring on still or slow-running waters and white-water canoeing and no response was made to the questions on frequency.

5.1.3 Sports clubs

Sports clubs were asked seven questions about degree of contact with water (Table 5.2) in competent participants. As expected, there is an inverse correlation between the responses for active or complete immersion and immersion of hand only, or feet, legs or arms only.

Table 5.2 Percentages of responding clubs reporting categories of water contact*

Sport (and nº of clubs responding)	Active immersion or complete wetting	Swallowing	Splashing face	Feet, legs, arms only	Hands only
Surfing (7)	100	57	29	0	0
Sub aqua (22)	100	27	14	5	0
Water skiing (30)	80	37	23	10	7
Windsurfing (9)	77	56	33	22	0
Canoeing (35)	36	46	77	43	51
Sailing (35)	9	37	57	57	29
Rowing (70)	0	16	57	29	43

Notes: * No clubs responded to categories 'up to neck' or 'up to waist'. Questionnaire asked for degree of contact in competent participants.

The responses need qualifying. Sub-aqua clubs tended to regard the wearing of a neoprene suit, face mask and demand valve as limiting exposure to water and only six of the 22 clubs regarded swallowing water as a hazard. Canoeing incudes white-water and canoeing touring and responses indicated that water contact depended on experience and prevailing conditions, the type of canoeing (facial splashing in the case of marathon and sprints, immersion in rolls and slalom) and that, to some extent it depended on choice. In rowing and dinghy sailing, whole-body immersion was mainly a feature of capsizing and intensity of splashing a feature of wind and weather.

5.2 Observations of sports

Visual records on-the-spot at the two canoeing venues (Table 5.3) and videorecorded records (Table 5.4) at the other sites of Table 4.1 were used to estimate the duration and frequency of exposure quantitatively and to compare the type and violence of contact. No information was collected upon bathing in the sea. However, in the controlled cohort study of sea bathing at Moreton (Wirral), 66% of the adult bathers spent 10-14 minutes in the sea and immersed completely at least three times (Kay and Wyer 1992). In the beach survey study at Ramsgate (Pike 1991), of the total water activity, 60% was swimming, 14% diving off inflatable rafts and toys and 26% paddling and wading, all mainly by children. On this basis, active swimming has been placed in Table 5.4 for comparison. Table 5.4 does not show the average total time spent in the water. This information was obtained only for canoers and rafters at Holme Pierrepont (Table 5.3) and for bathers at Moreton.

Table 5.4 indicates that immersion, swimming, violence of contact and frequency of facial splashing were greater in championship water skiing that in competent sport. It is difficult to compare the four different measurements of contact in this table, but if they are all given equal weight and ranked in order, the sum of the rankings gives the following order of increasing contact:

- windsurfing, beginner;
- water skiing, competent;
- surfing, competent:
- white-water canoeing, regional;
- water skiing, championship.

Table 5.3 Measurements of the degree of water contact in white-water canoeing and rafting, from visual observations

Measurement	Canoeing		Rafting,
	Holme Pierrepont	Afon Tryweryn	Holme Pierrepont
Duration of session (h):			
Whole event	6.3	7.5	5.0
Individual average	0.7	4.2	0.1
Immersion:			
Nº/person-session	4.8		0.04
Duration (s/person-session)	23	-	-
Force of immersion	Violent	Violent	Violent
Splashing of face and trunk	Frequent	Frequent	Frequent
Force of splashing	Violent	Violent	Violent
Wetting of limbs	Constant	Constant	Frequent

Table 5.4 Measurement of water contact, estimated from videorecording, for four sports, compared with swimming in the sea

Sport: level of skill and location	Time immersed s/min	Swimming and immersed (% of time)	Violence of immersion	Frequency of splashing to face (min^{-1})
Water skiing:				
championship, Kirton's Farm	0.6	76	Very violent, unexpected	10
competent low skill; Lepe	0.3	41	Violent, unexpected	Negligible
White-water canoeing:				
regional, Holme Pierrepont and Afon Tryweryn	0.5	2.8*	Violent, unexpected	11
Surfing; competent, Newquay	1.2	c.70	Moderate, predictable	0.9
Windsurfing; low-beginner, Lepe	0.3	35	Gentle, unexpected	None
Swimming in sea, holiday maker+	0.4	c.50	Moderate, expected	0.4

Notes: * From visual and videorecorded information
+ Estimated from Pike (1991) and Kay and Wyer (1992), see Section 5.2 text, visual observations. Assumes 14 minutes in water, three immersions each lasting two seconds.

5.3 Classification of sports by degree of contact with water

It is unlikely that a completely acceptable grading of aquatic sports will be obtained, because of differences in the following factors:

- perception of contact by clubs and national governing bodies;
- degrees of competence;
- weather conditions and type of water;
- the keenness and adventurousness of participants.

The classification presented in Table 5.5 is based upon the total information presented in this section. It is considered that the relative position of sports within one of the three classes would be decided to some extent by these factors, but that only over-riding circumstances would make it necessary to place a sport in another class. Some over-riding examples would be:

1. In dinghy sailing, considerable contact with water and a requirement for training in capsize drills.

2. The differences between white water canoeing and non-competitive touring by canoe on still or slowly flowing waters.

3. Exploratory and predatory activities by children and 'larking-about' by teenagers, since these usually result in falling-in. Young children may be tempted to drink the water.

Table 5.5 A classification of water recreation, based upon degree and duration of contact with water

Class and definition	Examples
1. Whole-body contact: Those in which the whole body, or the face and trunk, are frequently wetted by spray and where it is likely that water will be swallowed.	Sub aqua diving, long-distance swimming, surfing, water skiing, white-water canoeing, rafting, sea bathing, windsurfing, dinghy sailing, exploratory and predatory activities by children, paddling by young children.
2. Incidental contact: Those in which only the limbs are regularly wetted and in which greater contact is not a consistent normal feature.	Rowing, yachting, canoe touring, paddling in the sea.
3. Non-contact: Those in which there is normally no contact with water but where water is essential to enjoyment of the activity.	Angling, boating under power, walking, sun-bathing, picnics, bird-watching.

6. PARTICIPATION IN SPORTS AND PERCEPTION OF ILLNESS

Full results are presented in an Interim Report (Pike and Gale 1992).

6.1 Participation

Information was obtained from nine national governing organizations (Section 4.1), British Waterways and 209 clubs. There are various difficulties in assessing participation in aquatic sports, notably that of accounting for casual users and those not attached to clubs. Table 6.1, which combines information from three sources, nevertheless shows clearly that activities which do not normally involve contact with water, such as angling, walking and boating under power, are the largest class, with about 9.3 million people participating annually in Great Britain. This is three times the participation in the other activities, in which the whole body can be immersed (2.1 million) and those in which body contact is incidental (1.5 million). Table 6.1 and information from clubs suggest that participation in these sports is primarily male, particularly for surfing. The modal ages for participating are 15-24 for rowing, canoeing and surfing, 25-34 for windsurfing, water skiing and sub-aqua diving and 35-44 for sailing.

Rowing clubs pursued their sport all year and with the highest frequency (three days weekly). Apart from surfing, other sports clubs reported a significant drop in activity during the winter.

There were marked regional differences in participation in canoeing, surfing, long-distance swimming and water skiing, which probably reflect the availability of suitable waters, as well as concentrations of population.

6.2 Perception of illness

The information obtained gives a cross-sectional view, sport by sport, upon those illnesses and hazards which the national governing bodies and individual clubs thought to be relevant for them. It is likely, in the case of clubs, that those clubs which responded positively or, at all, were those whose members were aware of a problem through personal experience. There is none of the element of control, which should be part of an epidemiological study, in the responses, so that comparisons of experience between different sports and relative risks to participants within a sport are unreliable. Apart from this, the frequency of reporting symptoms by clubs may reflect the quality of the type of water preferred for the sport. For example, water skiing is usually carried out inland and in lakes, where water quality is generally high, whereas surfing is carried out offshore and surfers may encounter slicks from submarine sewage outfalls.

Table 6.1 National participation in various water sports, from the survey of governing bodies and other sources

Sport	Participation (thousands)	Percentage male	Percentage of adult population, Great Britain(4)
1. Whole-body contact sports			
Windsurfing	600	nd	1.4
Water skiing, aquaplaning	>400, 14[1]	68	0.9
Canoeing	100[2], 1000[3], 800[4]	85	1.8
Sub-aqua	>100	75	0.2
Surfing	30	>90	nd
Long-distance swimming	0.3	72	nd
Jet skiing	90[4]		0.2
2. Incidental contact sports			
Rowing	12[5], 400[4]	75	0.9
Sailing	1500[4]	nd	3.4
3. Non-contact sports			
Angling[6]	2200, 770[5]	99.9	nd
Walking	4830[5]	nd	nd
Boating, inland	1040[5]	nd	nd
Power boating	1000[4]	nd	2.3

Notes:
(1) Membership of the British Water Ski Federation
(2) Regular participants
(3) Try canoeing at least once a year
(4) From Leisure Consultants (1989)
(5) From British Waterways; adults and children using their waters
(6) Coarse angling; total anglers in Great Britain estimated at 3.9 million
nd No data provided

For these reasons, the information given in this section is summarized from the detailed account given in an Interim Report (Pike and Gale 1992).

6.2.1 National governing bodies

The national governing bodies were questioned about the illness and hazards in Table 6.2. This shows that the commonest concerns were for the diarrhoea, vomiting, nausea and stomach ache symptoms, suggestive of viral gastro-enteritis, followed by those of the ears, eyes, nose and throat. Four organizations were concerned about leptospirosis and the British Sub-Aqua Club reported an average of three cases annually involving the sport. The Royal Yachting Association has issued detailed advice upon avoiding cyanobacterial toxicoses to secretaries of clubs using inland lakes, particularly where children are instructed in sailing.

Table 6.2 Illness and hazards which the national governing bodies perceived to be relevant for them

Illness or hazard	Long-distance	Surfing	Sailing, wind-surfing	Canoeing	Water skiing	Angling
Acute diarrhoea	Y	Y	Y	Y		?
Vomiting	Y	Y	Y	Y		?
Stomach ache/nausea, with fever	Y	Y	Y	Y		
Ear complaints	Y	Y	Y			
Eye complains	Y	Y	Y			
Sore throat	Y	Y			Y	
Skin complaints	Y	Y	Y			
Leptospirosis+	Y			Y	Y	Y
Cyanobacterial blooms			Y			
Sewage pollution		Y	Y	Y		
Drowning (cases per year)		1-2	≤5	9*	0	0

Notes: Y = yes
* = British Canoe Union reported 123 fatalities in the years 1971-1985
\+ = Awareness of leptospirosis was recorded for long-distance swimming

A question upon frequency of drownings was included, since this is a real and quantifiable risk. The British Canoe Union maintains detailed records of drownings and injuries to canoeists and states that of the 123 drownings which occurred in the 15 years 1971-1985, about one per year involved experienced canoeists and that the remainder occurred mainly in calm waters and involved non-swimmers and those not wearing buoyancy aids.

6.2.2 Clubs

The questionnaire asked club secretaries to indicate whether or not they were aware of any particular cases of the complaints shown in Table 6.3 among members of the club. In this table, the order of sports (from left to right) corresponds with increasing reporting of the complaints (the order of the average ranking of reporting complaints by sports). There is a marked difference between surfing, sub-aqua and canoeing clubs (those reporting complaints most frequently) and the remaining clubs, where the incidences of reporting do not exceed 13% for any complaint.

Table 6.3 Percentages of clubs returning questionnaires which reported various symptoms among their members*

Symptoms	Water skiing	Sailing	Rowing	Wind-surfing	Sub-aqua	Canoeing	Surfing
One or more	11	18	9	29	55	54	71
Acute diarrhoea	4	13	13	7	23	37	57
Vomiting	4	0	3	14	5	29	57
Stomach ache/ nausea, with fever	0	12	6	21	14	31	29
Ear	4	0	0	14	41	11	57
Eye	0	3	4	7	9	6	57
Throat	4	3	4	7	41	31	57
Skin	4	6	0	7	5	11	29
Nº of clubs responding	27	34	70	14	22	35	7

Notes: * In this table, the overall rank order for reporting symptoms by clubs increases from left to right. Additionally, one case of swimmers' itch in a water skier, one case of viral kidney infection in a windsurfer

6.3 Relationships between contact and perception of hazard

Comparison of the reports from clubs concerning water contact (Table 5.2) and perception of symptoms (Table 6.3) does not reveal any significant rank correlation between the ordering of clubs. This is probably because degree of water contact is not the only factor involved in risk of acquiring illness and that there are other confounding factors such as quality of the waters normally used and the perceptions of the persons answering the questionnaires. Nevertheless, the following general relationships can be noted:

1. Sailing and rowing clubs report the least active immersion or wetting and high rates of hands only or feet, legs and arms immersion. They also show low reporting of all symptoms.

2. Sub-aqua diving, canoeing and surfing feature active immersion and wetting and high rates of reporting of most or of all symptoms.

There are anomalies. Canoe clubs report symptoms highly but report only moderate contact. This may be because some canoeing is in polluted lowland rivers and because of the gradations in contact between touring and competitive canoeing. The behavioural study rated white-water canoeing as a high contact sport. Water skiing, particularly when competitive, also involves a high degrees and violence of contact (Table 5.4), but tends to be carried out in inherently unpolluted waters.

The findings of Chapters 5 and 6 do not negate the idea that the classifications of water-associated illnesses (Table 2.3) and of water sports by degree of contact with water (Table 5.5) can be related to provide a basis for relating sports and risks to health. Rather, the findings confirm that the principle is generally correct, within the limitations of the survey and observational data. This point will be expanded in Chapter 9, when the basis for setting microbiological standards for recreational waters is explored.

Meanwhile, the setting of credible standards requires that account is taken of prevailing and typical qualities in different types of water and of the degree of variability in quality. This is the subject of Chapter 7.

7. STATISTICAL DESCRIPTION OF THE BACTERIOLOGICAL QUALITY OF WATERS

7.1 Introduction

Bathing water standards are based on the concentrations of faecal indicator bacteria, in particular, total and faecal coliform bacteria and faecal streptococci. Identified EC bathing beaches are routinely monitored during the bathing season and consequently national data are available for marine sites. However, no inland bathing waters are recognised, although there is considerable monitoring of drinking water supplies at abstraction points and some incidental monitoring of waters used for recreation. A major aim of the project was to collect, statistically analyse and compare all available bacteriological data recently recorded in the four different recreational water types: marine bathing beaches (both EC designated and others), river estuaries, inland rivers and inland lakes/reservoirs. Some data for canals and marine harbours were also assessed. Although recreational activities are not specifically encouraged at many of the sites, the data reflect typical water qualities and are invaluable for the purposes of designing microbiological standards for recreational waters.

In addition, WRc recorded bacteriological concentrations at fortnightly intervals over a sampling period of one year at selected sites on three inland lake systems (Table 4.1; Leisure Parks 1 and 2, Frensham Great Pond) dedicated to recreational water sports activities. The data obtained provide insight into the design of sampling strategies for recreational water sport standards on inland lakes.

In this section, distributions of faecal coliform counts in different types of waters are summarised in terms of the central tendency and dispersion. The proportions of sites which fail the EC imperative (I-value) standard are discussed. Implications for the drafting of standardised are considered.

7.2 Explanation of the statistical procedures used

Simple descriptions of some of the statistical terms used in this chapter are given in the Glossary (Appendix B). The most important statistical parameters ('statistics') which will be used, are as follows:

1. Measures of central tendency or average conditions: the arithmetic mean (i.e. the average), the median (or middle value of a set of numbers) and the geometric mean.

2. Measures of variability or dispersion in a set of numbers: the standard deviation and the logarithmic standard deviation (the standard deviation of logarithms of numbers).

It is usual for sets of microbiological counts from individual sampling stations to be distributed approximately log-normally, i.e. for the logarithms of counts to conform to a normal distribution. This was found here, without exception. In this case, arithmetic means are much higher than median values and statistical tests have to be carried out on the logarithms of the values to obtain reliable results. Hence, in this section, central tendency is described as the geometric mean or median (which ideally are identical values) and dispersion as the logarithmic standard deviation. When the values given were indeterminate e.g. 'zero', or 'less than' or 'greater than', the geometric mean could not be calculated and the median was derived instead.

The logarithmic standard deviation was calculated as the slope of the straight line when the determinate logarithmic values of bacterial counts were plotted against percentile points of the standard normal distribution function. Decimal logarithms ($\log_{10}$) were used.

7.3 Nationally collected bacteriological data

7.3.1 Sources and availability of bacteriological data

Bacteriological concentration data for the various water types were obtained from the following sources:

- NRA regions (10)
- Water Companies (8)
- British Waterways Board
- Public Health Laboratories (2)
- Central Scotland Water Development Board
- Strathclyde Regional Council
- Bradford City Council

The data were examined both collectively for all 55 river sites, 31 estuary sites, 444 marine bathing beaches identified for monitoring in 1990 and 21 lakes or reservoirs, and for individual sites within the four classes of water.

7.3.2 Collective comparison of the four classes of water

Data from individual sites were aggregated into the four classes of Table 7.1 and analysed to derive the key statistics shown.

Table 7.1 Statistics calculated from all counts of faecal coliform bacteria (per 100 ml), amalgamated into four classes of water

Water	Nº of samples analysed	Geometric mean	Median	Log_{10} SD*	Range	Percent >2000 /100 ml
River	7 924	956	1000	0.88	<1- 725 000	38
Estuary	1 829	367	400	1.16	>1-3 994 158	26
Marine	11 049	57	nd	1.07	<1-2 450 000	7
Lake/reservoir	3 563	18	17	0.89	<1- 180 000	2

Notes: * Standard deviation of log_{10} counts

Table 7.1 indicates that the greatest collective variability was shown by estuarial waters, followed by marine, doubtlessly reflecting effects of tidal regimes as well as of location. Lake and reservoir waters collectively were of highest quality whereas rivers were of the lowest quality. The near agreement of the geometric mean and median counts reflects the inherent log-normal distribution of the data.

7.3.3 Comparison of median counts by sites

Median counts and logarithmic standard deviations of faecal coliform counts were calculated for each site. They were then aggregated by the four classes of water in order to obtain grand representative values.

Table 7.2 Grand medians and logarithmic standard deviations of faecal coliform counts for four classes of water calculated from median values at individual sites

Water	Number of sites	Counts per 100 ml		
		Grand median	Range	log_{10} SD
River	55	1 110	1 - 44 500	0.73
Estuary	33	520	20 - 74 000	0.92
Marine (1990)	446	50	<1 - 2 500	0.77
Lake/reservoir*	21	49	1 - 6 000	1.01

Notes: * Sites which in general were of high quality from Southern, Thames, Northumbrian and Anglian NRA regions could not be used because not enough data were available

Table 7.2 displays grand medians with their ranges and logarithmic standard deviations, calculated from median faecal coliform counts at individual sites. Having thus removed the temporal effects upon variability, the same order of the classes of water by bacteriological quality remains as in Table 7.1, with lakes and reservoirs of highest quality and rivers of least. However, the variability in overall quality, shown by the logarithmic standard deviation by median counts is greatest between reservoirs and lakes and least between rivers. In the case of the lakes and reservoirs, this may reflect the different sources of waters. Thus, for example, one reservoir (median count, 6000 /100 ml) is supplied by water from a river downstream of some sewage works while another reservoir (median count, 4/100 ml) is supplied by borehole water. Furthermore, the size of a lake may influence the microbiological water quality, because larger volume lakes offer a greater diluting effect (see Section 7.4 and Gale *et al* 1990). The variation in microbiological water quality between sites in estuarine waters may reflect the mixing of poor quality river water with higher quality marine water and a gradation in qualities between those of river and marine sites would be expected.

7.3.4 Comparison of variability in counts by sites

In Table 7.3 have been calculated the average values (arithmetic mean) of the logarithmic standard deviations for individual sites, to display their general values. The deviations were approximately normally distributed, which means that their average value rather than the median, best displays central tendency. The overlapping 95% confidence intervals for estuaries, marine beaches and lakes/reservoirs show that the values of logarithmic standard deviation to not differ significantly. Later in this report, the grand average of 0.75 is used for describing variability in these classes of water. In rivers, overall variability is significantly lower, i.e. 0.58. Nevertheless, the spread of individual values is high, which means that the grand average value should not be used for describing variability within a standard if it is suspected that variability at a particular site is significantly higher or lower.

Table 7.3 Mean values and ranges of the logarithmic standard deviation* of faecal coliform bacteria at individual sites grouped into four classes of water

	Number of sites (n)	Arithmetic mean (and 95% c.i.)	Range
River	55	0.58 (0.53-0.62)	0.27-1.01
Estuary	31	0.75 (0.66-0.83)	0.37-1.15
Marine (1990)	444	0.72 (0.70-0.74)	0.16-1.57
Lake/reservoir	21	0.77 (0.65-0.89)	0.32-1.31

* Standard deviations of $\log_{10}$ values

7.3.5 Comparison of waters by compliance with the imperative value for faecal coliform bacteria

The bathing water Directive 76/160/EEC requires that 95% of samples taken during the bathing season should not contain more than 2000 faecal coliform bacteria per 100 ml (Imperative or I-value). Table 7.4 shows the medians of 95-percentile values from individual sites and the percentages of sites complying with this I-value.

Table 7.4 Statistics calculated from 95 percentile faecal coliform counts (per 100 ml) recorded at individual sites

Water type	Number of sites	Median 95 percentile count (and range)	log10 SD	Percentage compliance+
River	55	9 469 (395-273 403)	0.54	9
Estuary	31	10 973 (267-603 148)	0.87	19
Marine (1990)	444	834 (15-117 851)	0.64	78
Lake/reservoir*	21	915 (50- 54 962)	0.88	76

Notes: * Sites which, in general, were of high quality, from Southern, Thames, Northumbrian and Anglian NRA regions could not be used because not enough data were available.
+ Percentage of sites where 95% of samples contained not more than 2000 faecal coliform bacteria per 100 ml.

This tables shows that it is unusual for rivers or estuary sites to meet the I-value requirements. Thus it would be unrealistic to expect most waters in rivers or estuaries to meet the microbiological requirements of the Directive for bathing. The percentage of lakes and reservoirs meeting this requirement would have been greater, had not some been excluded because the amount of data was limited.

7.4 Field studies at recreational lakes

Three lake systems, developed for recreational activities, were sampled fortnightly for approximately one year at several places. The lake systems, which are described in Gale *et al* (1990) and Gale (1991) and are listed in Table 4.1) are:

- Leisure Park 1: Boating and Sailing Lakes
- Leisure Park 2: Boating and Sailing Lakes
- Frensham Great Pond

The main conclusions from these studies are as follows:

1. For some of the lakes the levels of faecal indicator bacteria appeared to show seasonal variation, with median faecal coliform concentrations being elevated between 3-fold and 14-fold in the late summer months compared to the rest of year.

2. The lakes at Leisure Park 1 were unusual, being artificially created and supplied only with urban run-off water from the separately-sewered drainage system. The Boating and Sailing Lakes were respectively the fourth and fifth in a series of lakes, counts of faecal coliform bacteria in the two lakes were elevated over 150-fold when rain had occurred during the two days prior to sampling, compared to samples taken after dry weather.

3. At Frensham Great Pond there was statistically no difference between the geometric mean counts of faecal coliform bacteria at the 12 sampling sites, implying a homogeneous distribution of pollution throughout the lake. Each sampling site complied with the I-value of the bathing water Directive.

4. Although overall a lake may meet the I-value criterion, individual sites within a lake may fail, for example because of a localised input of polluted water or roosting wildfowl (Table 7.5). At Frensham Great Pond there was no significant difference in geometric mean counts of faecal coliform bacteria at the 12 sampling stations (grand geometric mean 15 per 100 ml in 181 samples; logarithmic standard derivation 0.7). At this lake, the Guideline (G-value) requirement (not exceeding 100 per 100 ml in 80% of samples) was met.

7.5 Implications for the drafting of standards

7.5.1 Median and other percentile values

Standards may be defined in terms of:

- A value which must not be exceeded by a given percentage of samples, i.e. a percentile value
- a central value (average, median or geometric mean)
- A maximum upper limit concentration

In the context of water recreation, microbiological quality may change very abruptly, e.g. after rain or with tidal state. It is necessary for a standard to give protection to users during adversely extreme conditions, but not to prevent the use of the water because these very rare events may occur. Thus, a percentile value is necessary. The measure of central tendency - for bacterial counts the median or geometric mean - enables waters to be graded on overall quality. The central value is unaffected by variability. The maximum upper limit concentration is untenable on statistical and practical grounds, since it makes no allowance for variability.

Table 7.5 Statistics for faecal coliform counts (per 100 ml) at different sites on the Sailing Lakes of two Leisure Parks

Site	Number of samples	Median	Range	log10 SD	Estimated 95 percentile
Leisure Park 1					
1	20	80	5-3450	0.783	1110
2	16	19	6- 395	0.583	263
3	18	56	8-5300	0.855	1989*
4	16	90	3- 500	0.744	786
5	15	21	1- 409	0.667	333
6	21	49	1-1200	0.725	593
Leisure Park 2					
1	19	250	21-5900	0.62	3400*
2	16	62	<1- 280	0.61	410
3	17	28	<1- 210	0.48	227
4	17	85	5-2200	0.70	1123
5	15	40	3- 306	0.62	293
6	18	66	11- 340	0.47	354

Notes: Calculated from analyses of samples taken fortnightly for one year
* Site fails to meet I-value criterion of the EC bathing water Directive

The epidemiological research that has and is being pursued will define risks to health for various median or geometric mean bacterial counts. The relationship to a percentile limit can be made, if the logarithmic standard deviation is known. The research in this chapter indicates that a value of 0.75 is appropriate for most estuarial, marine and lake/reservoir sites and of 0.58 for most rivers (Table 7.3). It is interesting to note that the USEPA (1986) Guidelines quote typical values of 0.7 for marine beaches and 0.4 for inland beaches, but do not quote supporting data.

7.5.2 Sampling strategies

Studies of the three recreational lakes highlighted the following questions about water management strategies:

How many sampling sites on a lake should be selected?

Where on the lakes should sites be located - on the edges or in the middle of the lake?

How often should the sites be sampled?

Should they be sampled after or during periods of heavy rain, which has been shown to elevate bacterial levels?

These are questions, which need to be considered carefully when compiling guidelines for sampling.

8. ENVIRONMENTAL HEALTH SURVEYS TO ASSESS HAZARDS TO HEALTH

8.1 Past experiences

Past experiences often go unrecorded. One of the unwritten rules of environmental health is that sampling and analysis is not a proper substitute for seeing conditions as they exist in the field and making judgements from them concerning the likelihood of pollution and likely hazard to health. For example:

1. It would be unwise to permit water contact activities or abstraction of water for irrigating fruit and salad crops immediately downstream of a discharge of treated sewage or industrial wastewater into a river.

2. The appearance of rank weeds, black mud and sewage fungus in a ditch draining into a stream denotes that farm waste is not being contained and that excessively high levels of faecal indicator bacteria and ammoniacal nitrogen could be discharged after heavy rain.

Neither of these examples needs microbiological monitoring to be detected. It is perhaps because environmental health criteria are self-obvious that they are not codified and seldom have appeared in official guidelines concerned with water recreation.

8.2 United States policies

The NTAC (1969) recognised that aesthetic criteria were essential for the enjoyment of water and stated that:

> "All surface waters should contribute to the support of life forms of aesthetic value."

Achievement of criteria designed to meet the needs of fish, waterfowl and other wildlife was regarded as an integral requirement for water recreation. The report of NTAC (1969) recommended detailed chemical, physical and microbiological criteria for various water uses, which were intended to be used in monitoring schemes. It is surprising that on-the-spot assessment is not considered. Microbiological monitoring has remained the basis for assessing suitability of designated and other recreational waters for bathing and other primary contact sports, e.g. USEPA (1986).

8.3 A scoring scheme for envirionmental health assessment

Jones and Godfree (1989) noted that microbiological examination of surface waters used for recreation was uncommon and that no mandatory or guideline standards applied to waters other than marine beaches recognised for monitoring under the EC bathing water Directive. They noted that this made it difficult to give advice on the suitability of particular stretches of water for recreation. They presented a scoring scheme, based on their experience with North West Water, which could be used to combine existing records and inspections on site to provide an overall semi-quantitative score as an assessment of risks to health. The outline is shown in Table 8.1. The score (graded 0-4) for each of five criteria is added to give a final score of 0-20. Suitability for primary contact recreation is indicated for a score of 0-10, for secondary contact (i.e. for sports where contact with water is incidental) 0-16, and use for recreation is not advised for scores of 16-20. This scoring is qualified by an assessment of physical hazards likely to cause injury or drowning. It is stressed that anomalous scores (e.g. high microbiological count) should be investigated further.

Table 8.1 Scoring scheme for environmental health assessment of waters intended for recreation (Jones and Godfree 1989)

Assessments	Scores awarded 0	1	2	3	4
1. NWC River/Estuary classification	1a/A	1b/A	2/B	3/C	4/D
2. Proportion of effluent (%)	<1	<10	10-25	25-50	>50
3. Distance from effluent discharge (m)	>1000	1000-500	500-250	250-50	<50
4. Bacterial count/100 ml, *E. coli* (or faecal streptococci)	<100 (<10)	<1000 (100)	<2000 (<500)	$<10^4$ (<1000)	$>10^4$ (>1000)
5. Environmental health factors*	None or insign-ificant	Occasionally present	Present	Common	Very common

Notes: * Subjective assessment, based on local knowledge, e.g. agricultural pollution, industrial discharges, abattoirs, leachates, 'fly-tipping', animal or bird excrement, vermin.

Interpretation of total score: 0-10 suitable for primary contact sports, 0-16 suitable for secondary contact sports, >16 not suitable. This must be supplemented by assessment of physical hazards, e.g.

A No unforeseeable hazards - minimal risks
B Suitable, caution - provide life-saving equipment and/or safety boats and supervision
C Generally not recommended except for experts - fast-flowing, holes in river bed, unpredictable conditions
D Dangerous, high risk of drowning or accident - not recommended

The advantage of this scheme is that it is easy to use and that apart from the microbiological criteria, the remaining information will be available (e.g. river or estuary classification) or is assessed in the field.

8.4 The Canadian guidelines

Revised Canadian guidelines of the Ministry of National Health and Welfare (MNHW 1992). In addition to recommending bacteriological criteria for recreational water quality, modified by local experience, an annual environmental health assessment is recommended. This should be carried out prior to the bathing season, both on the watershed supplying the recreational area, as well as at the site itself. The check points are as follows:

1. The risk of pollution (faecal, chemical) from discharges or spills.

2. Knowledge of all outfalls and drainage that may contain sewage, including storm water and agricultural run-off.

3. Inspection for physical hazards.

4. Assessment of seasonal variability of hazards, density of bathers, water temperature, circulatory patterns in the water, changes in depth, frequency of algal blooms.

5. Fluctuation of water quality with rainfall.

6. Reporting mechanisms to ensure that health authorities are informed of changes in waste treatment facilities or malfunction.

8.5 Appraisal

The scoring scheme of Jones and Godfree (1989) is intended to give a rapid assessment for decision-making purposes. The Canadian environmental health assessment (MNHW 1992) is an annual pre-season requirement forming part of the ongoing scheme of monitoring existing bathing waters. The authors consider that the NRA might have a use for both approaches, for example, during the period in which statutory water quality objectives are being set and a rapid assessment of suitability for recreation is needed.

If such an assessment is made periodically, it will provide an ongoing permanent record to supplement ongoing microbiological and other monitoring at existing sites.

The value of regular assessment is that it should supply the reasons for deterioration in microbiological quality as well as highlighting hazards, where action needs to be taken. It is true that microbiological monitoring is a highly sensitive indication of faecal contamination, but it is, nevertheless, only an instantaneous indication in time and is labile, because bacterial counts are subject to decay and rapid variability. Both types of assessment record hazards which are constant or subject only to slow change. Because of this, they provide an integral view of hazard.

It has not been possible to consider and test the applicability of either type of environmental health assessment within the terms of the present contract. The authors consider that such an appraisal would be worthwhile for the reasons given. It could well be done at a number of sites and take the form of a multi-variate analysis of field assessment, existing microbiological records and biological classifications, supplemented by local experiences (environmental health records, experiences of clubs).

9. DISCUSSION; DEVELOPMENT OF RISK-RELATED STANDARDS FOR RECREATION

9.1 Feasibility

9.1.1 The basic questions

In Section 1.3.1, eight basic questions were asked, needing consideration before a credible standard for water quality could be proposed. It is now appropriate to consider these in turn, to show how for the information gathered in this project could be used to develop risk-related standards for water recreation.

9.1.2 What are the recreational activities needing protection?

In this project, all forms of water recreation have been considered. On the basis of returns from the two questionnaires and observations, three classes of recreation have been recognized on the basis of the degree of contact with water (Table 5.5).

- whole-body contact
- incidental contact
- non-contact

9.1.3 What are the hazards from poor water quality?

Medical considerations (Section 2.6) and results from case history and epidemiology have been used to classify illnesses and symptoms by the ways in which water is associated with their spread, i.e.

- waterborne (Section 3.1)
- water contact (Section 3.2)
- water-washed (Section 3.3)

The waterborne illnesses are those contracted by swallowing or inhaling water which is faecally contaminated and therefore may contain enteric pathogens. Examples of serious illnesses which have been contracted by recreation in heavily polluted waters are typhoid and paratyphoid fevers, shigellosis, Hepatitis A, pharyngo-conjunctival fever (Adenovirus-type 4) and, possibly, cryptosporidiosis. Less well-defined viral infections such as gastro-enteritis are also waterborne. By definition and as indicated in Sections 3.1 and 6.3, waterborne illnesses are a hazard of whole-body contact sports.

Water-contact illnesses are defined as those which are not directly related to faecal contamination and are caused by contact with the vehicle in water. The principal hazards are leptospirosis from urine of rats and other carriers frequenting water and toxicoses from the toxic growth products of cyanobacteria.

By definition, participants, in whole-body contact sports are at most risk from water-contact illnesses. However any contact with cyanobacterial scums or with leptospires - which may equally occur in urine-contaminated water or bankside soil and vegetation - is hazardous. Therefore participants in incidental contact or even non-contact sports are also at risk, if they do not take care to avoid these situations.

Water-washed illnesses are those caused when prolonged or violent contact with water lowers the body's defence mechanisms allowing opportunistic or adventitious pathogens, normally present on the skin, to invade and infect. They are not related to water quality. Water-washed illnesses, again by definition, present the greatest hazard to whole-body contact sports and probably little, if any, to participants in other sports, except in the case of actual immersion.

9.1.4 What level of risk is acceptable?

Risk can never be eliminated. However, at low levels it will either merge with those caused by confounding factors or will not be perceived by those exposed. The level at which corrective action is needed could be set at, or just below, that where an effect can be detected with statistical significance (e.g. NTAC 1969, USEPA 1986, Cheung *et al* 1990). It might also be that level of risk which the public has already accepted in an existing standard over many years (USEPA 1986). Neither point of view is completely objective, because large epidemiological studies will detect significant risks at lower absolute levels and public acceptance is arbitrary and based upon perception.

In the UK, the only enforced recreational water quality standard is the bathing water Directive 76/160/EEC (Statutory Instrument 1991, Nº 1597), which applies only to bathing and to recognised bathing beaches. It is, however, regarded by the public, the news media and environmental group as giving protection. There is a tendency for these to argue for compliance with the very restrictive guideline criteria (G-values), rather than the mandatory criteria (I-values). The 1992 Blue Flag Awards, administered in the UK by the Keep Britain Tidy Group, requires compliance with G-values and the star-rating system of the Marine Conservation Society (1992) takes into account past achievements with both G and I criteria.

In the UK sea bathing studies rates of reporting diarrhoea and gastro-intestinal symptoms were significantly elevated in holidaymakers entering the water at Ramsgate, where 12% of samples failed to meet the I-value for faecal coliform bacteria (Pike 1991, Balarajan *et al* 1991), but not at Langland Bay (Pike 1990), where this criterion was met. If this association is confirmed by the studies at eight beaches in 1991-92 and the four cohort studies, there will be good reason to use the coliform and faecal streptococci criteria of the Directive as yardsticks for setting microbiological standards for waters used for water contact recreation. At present this seems the best interim approach and will be presented in Section 9.2.

9.1.5 What indicator of risks shall be chosen?

In Table 3.2, where the classification of illnesses is presented, the types of standard and controls measures appropriate for the three classes of illness are listed.

Since it is only the waterborne class of illness which is related to faecal pollution, it follows that microbiological standards, based upon detecting faecal indicators of pollution, are appropriate. They are not appropriate for water-contact or water-washed illnesses.

There is currently debate about the most appropriate indicator organisms to use. An analysis of this topic, from the results of epidemiology, has shown no consensus (Pike 1990, p47 and Tables 1 and 2). In part, this may be because of different decay rates of faecal indicator bacteria and the pathogens concerned - which are unidentifiable, but are probably viral. Furthermore, indicator bacteria are always present in faeces and sewage but enteric pathogens are only excreted when people in the community are ill. Another reason may be that the illness are not waterborne, using the definitions in this report. It has also been suggested that staphylococci, which are normally present on the skin in high numbers, could be an indication of bather density and thus an indication of the likelihood of person-to-person transfer when bather density is high. This is most likely in swimming pools, because staphylococci are moderately resistant to chlorination. There is also some circumstantial evidence from epidemiology (Calderon *et al* 1991), or reasoning based on association with illness rates for eye and skin complaints (Seyfried *et al* 1985b), or bather density (Cheung *et al* 1991). It has not been established whether staphylococci are shed in sufficient numbers for an effect on water quality to be measurable or, indeed, whether they are also present in faeces in sufficiently high numbers to be regarded as an additional faecal indicator.

The Salmonella and enterovirus criteria of the bathing water Directive can be criticised, because they are not the pathogens involved in the waterborne illnesses and because the tests are very imprecise and are difficult and expensive. It may well be that the test for male-specific (F^+) RNA coliphages (Havelaar 1991, Morinigo *et al* 1992) could prove a sensitive indicator for viral contamination. The choice of appropriate indicator is being considered in the UK study on Health Effects of Sea Bathing. At present, there are no firm grounds for abandoning the tests for faecal coliform bacteria and faecal streptococci.

For the water-contact illnesses, different approaches are needed. Measures based upon public awareness and control are most appropriate, since they directly take action against the hazard. Sports clubs and organizations most likely to be affected by leptospirosis and cyanobacterial toxicoses are aware of of the problem and of measures for limiting risk to their members. Routine tests for isolating *Leptospira* spp are not available. While NRA has initiated research into development of a rapid test for cyanobacterial toxins, it has also disseminated advice to water sports organizations and has arbitrarily taken as an action limit, the presence of six cyanobacterial countable units for 0.5 ml of water.

9.1.6 At what level shall the standard be set?

This is directly linked with the question on acceptable risk (Section 8.1.4), if the decision is taken to place the standard at or just below the level at which risk become discernible from background.

9.1.7 What allowance shall be made for variability in the levels of the indicator?

The study of microbiological water quality data presented in Chapter 6 shows that two statistics are needed to describe water quality:

- for central tendency - the geometric mean
- for variability - the standard deviation of $\log_{10}$ counts

Knowledge of the standard deviation of $\log_{10}$ counts enables any given percentile to be related to the geometric mean. Both statistics are essential, because a water may be generally good, but susceptible to intermittent pollution, whereas another may be consistently poor, although displaying a similar geometric mean. In theory, use of the geometric mean or an upper percentile value alone (as in the bathing water Directive) does not allow these two extreme cases to be distinguished.

The study of variability in Chapter 6 shows that the average standard deviation of $\log_{10}$ counts of faecal coliform bacteria is approximately 0.75 for lakes, reservoirs, estuaries and marine beaches (i.e. the reference value adopted by the USEPA 1986) and 0.58 for rivers. In practice, unless there are particular local conditions giving greatly different values, this knowledge enables bacteriological standard to be set by geometric mean or upper percentile only.

9.1.8 How shall the standard be enforced?

This question and that of the action to be taken in the case of failure to comply cannot properly be answered here. These are questions which will arise when the uses to which particular stretches of water may be put are identified and when attainment of the appropriate quality of water becomes a statutory objective.

There is a distinction between stretches of water, which are already being used and have been used in the past for recreation and those which are the subject of proposal for development as recreational waters. In the former case, the users have accepted the conditions they find as being reasonable for the sport, even though they may not be ideal. In the latter case, it could be argued that a decision to recognize the use implies a recognition of fitness for purpose.

The study of water quality data (Chapter 7) has shown great differences between different classes of water and the percentages of sites meeting the I-value criterion of 2000 faecal coliform bacteria per 100 ml in 95% of samples, i.e:

- rivers, 9%
- estuaries, 19%
- lakes and reservoirs, 76%
- marine beaches 78% in 1990

This means that the number of river or estuarial sites which could be considered to be satisfactory, if this criterion is accepted, is relatively small. It would appear that the best administrative approach might be to recognize recreational uses requiring water of this quality only on stretches of water where the quality is capable of being achieved. In some cases, the timetable for achievement may be very long or even impossible.

9.1.9 How shall the standard be revised as water quality improves and better methods of analysis are adapted?

Progressive improvement in water quality can be recorded and recognized within a general classification scheme, such as those adopted by the former National Water Council for biological/ecological quality of rivers and estuaries. Such a scheme provides an incentive for improvement. Steady improvement in quality of bathing waters is also inherent in an embryonic form, in the concept of I- and G- values in the bathing water Directive. The scoring concept of the environmental health assessment scheme of Jones and Godfree (1989) has the characteristics of a general classification scheme for recreational waters.

The methods and conditions of microbiological analysis can greatly influence the numerical values of counts and hence influence compliance. Harmonization of those microbiological methods for water quality, which are embodied in EC Directives, is being undertaken by the European Committee for Standardization (CEN) as part of the work programmes at Technical Committee 230 on Water Quality, Working Group 3 - Microbiological Methods (CEN/TC 230/WG3).

9.2 Proposed interim standards for water quality

The proposals which follow in Section 9.2 are made by WRc, on the basis of the information surveyed in this contract, and are for NRA, DoE and the Department of Health to consider as interim standards.

9.2.1 Standards for whole-body contact recreation

The recommendations in Table 9.1 are interim, since, apart from bathing in identified waters, the criteria finally adopted may depend upon the results of the UK study on the Health Effects of Sea Bathing and ongoing epidemiological studies on the effects of water quality on the health of participants in other sports.

Table 9.1 Proposed interim standards and guidelines for protecting participants in whole-body contact recreation from three classes of illness

Definition of whole-body contact recreation, with examples:	Classes of illness (with examples)	Appropriate standards and control measures
Those in which the whole body, or the face and trunk, are frequently immersed, or the face is frequently wetted by spray and where it is likely that water will be swallowed.	1. Waterborne - pathogens deriving from faecal pollution (typhoid and paratyphoid fevers, shigellosis, infectious hepatitis, pharyngyo-conjunctival fever, gastro-enteritis, cryptosporidiosis	1(a) Microbiological standards (Table 9.2) 1(b) Licensing and control of discharges of sewage, treated effluents, storm-sewage, slurries 1(c) Regular environmental health assessments (Chapter 8)
• Sub-aqua diving • Long-distance swimming • Surfing • Water skiing • White-water canoeing • Rafting • Sea bathing • Windsurfing • Dinghy sailing • Exploratory and predatory activities by children • Paddling by young children	2. Water-contact - agents, unrelated to faecal pollution, contact the skin and mucous membranes: (a) Leptospirosis (b) Cyanobacterial toxicoses (c) Swimmers' itch	2. Standards for ecological and biological quality. Advice to sports clubs. (a) Bankside management to control rodents (b) Control of eutrophication, monitoring of cyanobacterial populations, curtailing recreation during blooms (c) Awareness of a rare problem. Control of snail-infested vegetation in warm, still waters.
	3. Water-washed - low grade opportunist pathogens derived from the skin and other body surfaces. Water interferes with body's defences and washes pathogens on to sensitive sites.	3. No water quality or water management policies appropriate. Curtailment of activity or protection of eyes and ears may reduce risk, but will interfere with enjoyment of sport.

The sports listed in Column 1 of Table 9.1 are in approximate order of water contact, those with greatest contact by extent, duration or violence being highest on the list. These sports exposed users to the three classes of illness, of which only the waterborne illnesses are unique.

For the reasons given in Section 9.1.4, it is recommended that the interim microbiological standard for water used for whole-body contact recreation should be the I-value for faecal coliform bacteria in the bathing water Directive 76/160/EEC. Except for defined bathing water, where this Directive is enforced by regulations (Statutory Instrument 1990, Nº 1597), there is no need to supplement this by a criterion for total coliform bacteria, which have less specificity as indicators of faecal contamination. The level of compliance, specified by numerical value and percentile and the choice of indicator organism should be re-considered when further epidemiological information becomes available. Similarly, there is little or no information upon typical variability in counts of faecal streptococci in different waters. Because their decay rates are different from those of faecal coliform bacteria, it is likely that the standard deviation of log counts will differ from those of faecal coliforms.

The frequency of monitoring - at least fortnightly during the bathing season - required for identified bathing waters is unlikely to be suitable for other sports, which are less defined by season and will probably be dictated by resources. For these reasons Table 9.2 displays the 95 percentile value of 2000 faecal coliform bacteria per 100 ml with values of other quantiles - which may also be appropriate - calculated from the values of standard deviation of $\log_{10}$ counts given in Section 6.3.4. If variabilities are greatly different at particular sites, appropriate values of standard deviation should be substituted.

Table 9.2 Other percentile values satisfying the requirement for 95% of samples not to exceed 2000 faecal coliform bacteria in 100 ml

Compliance (fraction of samples passing)	Percentile	Faecal coliform bacteria/100 ml in: Estuaries, marine beaches, lakes, reservoirs (σ=0.75)	Rivers (σ=0.58)
1/2	50 (median)	120	220
3/4	75	370	550
4/5	80	500	680
9/10	90	700	1 200
19/20	95	2 000	2 000

Notes: σ is the standard deviation of $\log_{10}$ bacterial counts

Table 9.1 makes other recommendations, which are readily understandable or will already be in operation.

The studies of contact with water (Chapter 5) emphasised that, for certain sports, degree and violence of water contact would be greater in competitive events than generally. It is clear that water of higher standard is appropriate for competitive activities. However, apart from this general recommendation, there are, as yet, no firm objective reasons for setting precise values. The survey of water quality data suggested that very few inland waters, apart from some lakes, would meet the guideline (G) values of the bathing water Directive.

9.2.2 Standards and Guidelines for incidental contact recreation

These are proposed in Table 9.3. Unless immersion or swallowing occurs, the participants are not exposed to the hazards of waterborne illnesses, but to those incurred through contact with the agents concerned. The guidelines and control measures are readily understandable.

9.2.3 Guidelines for non-contact recreation

Guidelines for non-contact recreation are proposed in Table 9.4. Apart from the measures for controlling the hazard from leptospirosis, not health-related standards are appropriate for non-contact recreation. The requirements for angling are specifically those protecting fish and other aquatic life. The hazard of leptospirosis extends to bankside activities and to boating, where indirect contact with rodents can occur. The ecological and biological requirements are desirable for all forms of non-contact recreation, because they enhance enjoyment.

Table 9.3 Proposed standards and guidelines to protect participants in incidental contact recreation from water-contact illnesses*

Definition of incidental contact recreation, with examples	Cause and types of of water-contact illness	Appropriate control measures and water quality guidelines
Those in which only the limbs are regularly wetted and in which greater contact is not a usual feature	Agents, unrelated to faecal contamination contact the skin and mucous membranes.	Standards for ecological and biological quality. Advice to sports clubs and the public. Regular environmental health assessments (Chapter 8).
• Rowing • Yachting • Canoe touring • Paddling in the sea+	1. Leptospirosis	1. Bankside management to control rodents. Treat and cover cuts and abrasions. Seek medical advice if 'flu'-like symptoms are noticed a few days after recreation.
	2. Cyanobacterial toxicoses	2. Control of eutrophication, monitoring of cyanobacterial population, curtailing recreation during blooms.
	3. Swimmers' itch.	3. Awareness of a rare problem. Control of snail-infested vegetation in warm, still waters.

Notes: * Unless immersion or swallowing of water occurs, little risk from water-borne or water-washed illnesses (Table 9.1)
+ Young children's paddling is regarded as a whole-body contact activity (Table 9.1)

Table 9.4 Guidelines to protect participants in non-contact recreation

Definition of non-contact recreation, with examples	Hazards which have been identified	Appropriate control measures and water quality guidelines
Those in which there is normally no contact with water, but where water is incidental to enjoyment of the activity		Standards for ecological and biological quality to protect fish, other aquatic life and vegetation. No specific standards to protect health of water users, but regular environmental health assessments (Chapter 8)
• Angling • Boating under power • Walking • Sun-bathing • Picnics • Bird watching	1. Leptospirosis	1. Bankside management to control rodents. Treat and cover cuts and abrasions. Seek medical advice if 'flu'-like symptoms are noticed a few days after recreation.
	2. Fish deaths, anaerobic conditions, visible oil, scums and detritus	2. Control and licensing of discharges from sewage works, industry, storm-sewer outfalls, agriculture, landfills, river craft

10. CONCLUSIONS

10.1 Introduction

For the convenience of the reader, the Conclusions are grouped by Chapter in this report and the Section where the arguments can be found is given in parentheses at the end of each conclusion.

1. Although water-based recreation is extremely popular and, in some sports, contact with water is greater than in bathing, the only microbiological standards for water quality which are enforced in the UK are the mandatory total and faecal coliform standards of the EC bathing water Directive 76/160/EEC. This Directive applies only to waters identified for bathing and where bathing takes place (1.1).

2. Before credible and readily enforceable standards can be drafted, some basic questions must be addressed (1.3.1). These include defining the sports to be protected, the hazards to be addressed, the level of risk which is acceptable, an indicator of risk, the level at which the standard shall be set and the allowance to be made for natural variability in the indicator. The methods for enforcement and for revision must also be considered.

3. Past and existing standards are reviewed and show no common approach towards relating water quality and risks to health (1.3.2).

10.2 Measuring risk to health

4. Measurement of risks to health presents great difficulty. Controlled experimentation is necessary. Because people can become ill because of reasons others than exposure to water, risks from exposure are best expressed as relative risks or odds ratios (2.1.2).

5. Care must be taken when attempting to ascribe causes to observations of illness (2.2).

10.3 Classification of illnesses

6. Medical considerations and the biology of pathogens have been reviewed, leading to a classification of three types of illness associated with exposure to water (2.6). These are:

    - Waterborne infections which are contracted by swallowing or inhaling faecally polluted water (3.1).

    - Water contact illnesses, which are contracted by contact with water containing the agent but are not directly associated, if at all, with faecal pollution (3.2).

- Water-washed infections, in which prolonged contact with water disturbs the body's defence mechanisms allowing opportunistic or transient pathogens, present on the skin, to set up infection (3.3).

7. Examples of waterborne illnesses which have been contracted by recreation in highly polluted waters are typhoid and paratyphoid fevers, shigellosis, infectious hepatitis (Hepatitis A), pharyngo-conjunctival fever (Adenovirus type 4) and, circumstantially, cryptosporidiosis (3.1). Symptoms suggestive of viral gastro-enteritis are commonly reported in connection with recreation in polluted waters and the risks have been shown to be related to microbiological quality of the water (3.1.2).

8. The risk of contracting gastro-intestinal upsets has been shown to be related directly to the degree or duration of immersion (3.1.4).

9. Water-contact illnesses which have been defined are (a) the toxicoses resulting from contact with blooms of cyanobacteria ('blue-green algae'), or swallowing these waters, (b) leptospirosis, particularly Weil's disease and (c) swimmers' itch (schistosomiasis) (3.2).

10. Water-washed illnesses include external ear canal infection (*Otitis externa*) and symptoms of the eyes, ears, nose and skin.

11. The classification of three types of illness suggests appropriate control measures and water quality standards (3.4, Table 3.2). Microbiological standards for water quality, using faecal indicator bacteria, are appropriate only for controlling waterborne illnesses.

10.4 Methods and scope of surveys

12. Survey information was obtained by questionnaire and correspondence from nine national governing bodies for aquatic sports, from 209 individual clubs and from British Waterways (4.1). Visual observations of participation and water contact were made at ten venues (Table 4.1).

10.5 Contact with water as a risk factor

13. An attempt was made to made to classify sports by the degree of contact with water, using the information provided from questionnaires and observations of sports in the field(5). It was considered that a definitive classification by contact could not be obtained because of:

    - differences in perception by clubs and national bodies
    - water contact increasing with competence and adventurousness

- grades of activity within a sport e.g. canoe touring and white-water canoeing, or competitions and casual sports

- weather and water conditions

14. Nevertheless, three classes of recreation were recognized, based on the degree of contact with water, from questionnaire returns and observation (5.3, Table 5.5).

    - whole-body contact
    - incidental contact
    - non-contact

15. Whole-body contact sports are defined as (5,3, Table 5.5; 9.2, Table 9.1) those in which the whole body, or the face and trunk, are frequently immersed, or the face is frequently wetted by spray and where it is likely that water will be swallowed. Examples are:

    - sub-aqua diving
    - long-distance swimming
    - surfing
    - water skiing
    - white-water canoeing
    - rafting
    - sea bathing
    - windsurfing
    - dinghy sailing
    - exploratory and predatory activities by children
    - paddling by young children.

16. Incidental contact sports are defined (5.3, Table 5.5; 9.2, Table 9.3), as those in which only the limbs are regularly wetted and in which greater contact is not a usual features, e.g.

    - rowing
    - yachting

- canoe touring
- paddling in the sea

17. Non-contact sports are defined (5.3, Table 5.5; 8.2, Table 9.4) as those in which there is normally no contact with water, but where water is essential to enjoyment of the activity.

    - angling
    - boating under power
    - walking
    - sun-bathing
    - picnics
    - bird-watching

10.6 Participation in sports and perception of illness

18. Activities which do not normally involve contact with water such as angling, walking and boating under power outnumber, by about three times in terms of people participating (9.3 million), whole-body contact sports (2.1 millions) and incidental contact sports (1.5 millions) taken together (Table 6.1).

19. National governing bodies and sports clubs reported awareness of complaints involving the eyes, ears, nose, throat and skin and gastro-intestinal symptoms. Clubs for surfing, sub-aqua diving and canoeing reported those complaints most frequently. The lowest rate of reporting particular illnesses was from water skiing, sailing and rowing clubs (6.2.2, Table 6.3).

20. Awareness of leptospirosis was provided by the governing bodies for long-distance swimming, canoeing, water skiing and angling and of cyanobacterial toxicoses by the Royal Yachting Association, which is responsible for all forms of sailing and for windsurfing (6.2.1, Table 6.2). Some of these bodies had provided their members with detailed advice.

10.7 Statistical description of the bacteriological quality of waters

10.7.1 Analysis of nationally collected data

21. Results of monitoring for faecal coliform bacteria were obtained from 55 river sites, 33 estuaries, 446 marine beaches and 21 lakes and reservoirs (7.3). In addition WRc

examined water quality fortnightly for about a year at five lakes used recreationally (7.4).

22. Counts of faecal coliform bacteria at individual sites are distributed approximately log-normally. The best measures of central tendency are the median or the geometric mean and of variability, the standard deviation of $\log_{10}$ counts (7.2).

23. Whether the data were considered as a whole or for individual sites, the median numbers of faecal coliform bacteria increase in the order lakes and reservoirs < marine beaches < estuaries < rivers (7.3.1, 7.3.2).

24. The variability of faecal coliform counts was least in rivers (mean value of $\log_{10}$ standard deviation from individual sites, 0.58) and was higher (mean 0.75) in estuaries, marine beaches, lakes and reservoirs (7.3.4).

25. Individual sites were examined for compliance with the imperative (I-value) requirement in the bathing water Directive for faecal coliform bacteria not to exceed 2000 per 100 ml in 95% of samples. Compliance was achieved at 76% of lake and reservoir and at 78% of marine sites, but only at 19% of estuarial and 9% of river sites (7.3.5). It would be unrealistic to expect this I-value to be achieved in most rivers or estuaries.

26. Two artifically created lakes were observed. These were only fed from surface run-off water. Geometric mean counts taken within two days from rain were 150 times higher than those taken in dry weather.

27. Water quality at Frensham Great Pond, a natural lake used for bathing, as well as sailing, attained the guideline (G-value) for faecal coliform bacteria (6.4).

10.8 Environmental surveys to assess hazards to health

28. Aesthetic criteria should be an essential part of recreational water quality standards (8.1).

29. Two examples (British, Canadian) of on-the-spot environmental health surveys were assessed. They are considered to have some value for the NRA in the following situations:

- during the establishment of water quality objectives
- when a rapid assessment is needed
- when the NRA is asked for an opinion upon the suitability of a stretch of water for recreational development
- when an regular record of suitability is required

The values of this approach are rapidity and its ability to give an assessment integrated in time instead of the instantaneous picture given by microbiological analysis (8.4).

10.9 Development of risk-related standards

30. The features of risk assessment explored in previous chapters are brought together (9.1) and the basic questions asked (1.3.1, Conclusion 2) are examined in the light of the research carried out. The following relationships between class of recreation and hazards to health have been identified generally:

    - whole-body contact recreation: waterborne, water-contact and water-washed illnesses (9.21, Table 9.1)

    - incidental contact recreation: water-contact illnesses (9.2.2, Table 9.2)

    - non-contact recreation: Leptospirosis (8.2.3, Table 8.4).

31. Microbiological standards are appropriate only for controlling waterborne diseases, since only this class of illness is directly spread by faecal pollution. Because the relationships between counts of faecal indicator bacteria and risks to health are not fully established and await the results of current UK research in marine and freshwater, it is proposed that an interim microbiological standard should be imposed in this case. This proposal is for 95% of samples not to exceed 2000 faecal coliform bacteria per 100 ml (9.2.1). Suggestions are made for adopting other percentile values, related to this primary criterion by the inherent variability implied in the logarithmic standard deviation of counts (9.2.1, Table 9.2).

11. RECOMMENDATIONS

11.1 For action

This research project has aimed to develop standards for recreational waters to protect health of participants. It has done this as far as is possible upon existing health information and in anticipation of the results of epidemiological studies now in progress or considered to be warranted.

It is recommended that the proposed standards, guidelines and recommendations presented in Chapter 9 and summarized in Tables 9.1 to 9.4, should be considered for adoption. The suggested actions comprise:

1. Adoption of an interim microbiological standard of water quality based on the imperative I-value for faecal coliform bacteria in the EC bathing water Directive 76/160/EEC (95 *percentile* 2000 faecal coliform bacteria per 100 ml). This is intended to control within acceptable levels, risks to health of participants in whole-body contact sports from defined waterborne diseases.

2. The need for regular, environmental health assessments on-the-spot and using existing data. These could be developed into a recreational water quality classification scheme.

3. Providing advice to clubs and the public upon identifiable problems. Some national governing bodies for water sports have already taken this action.

4. The issuing of consents to discharge and control of eutrophication, with regard to use of water for leisure, will help to control waterborne and water contact illnesses.

11.2 For research or development

The report has identified some areas where there is a deficiency of knowledge or where development work could be undertaken. These are as follows:

1. Epidemiological work is currently being undertaken in the UK National Study of the Health Effects of Sea Bathing, which will be completed in 1993. Limited research partly funded by NRA is also being undertaken on water recreation, notably canoeing and regatta events, by the Centre for Research into Environment and Health. The results should be assessed before more is planned. It may then be possible to confirm or revise the interim microbiological standard for whole-body contact recreation (Section 9.2, Table 9.1).

2. Confirmation is needed for the supposition that, for a given level of faecal indicator bacteria, the relative risks of gastro-intestinal illness are greater in fresh water than in sea water (Section 3.1.2).

3. The choice of the most appropriate predictive faecal indicator needs to be resolved (Sections 3.1.2, 9.1.5).

4. The recommendation for carrying out regular environmental health assessments at recreational sites (Chapter 8 and Section 11.1) as part of the proposed standards and guidelines needs to be investigated and calibrated. If successful, a protocol will then need drafting.

5. It must not be assumed that existing microbiological methods for bathing water quality are optimal or will remain recommended for use within the EEC. Recent action in CEN TC 230 has recognised the need to re-define standard European methods for the different classes of water covered by EC Directives, except those for sulphite-reducing clostridia. There may be benefit in further development work in the UK water field on adapting microbiological methods to progress or to support their continued use (Section 9.1.9).

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APPENDIX A - EXECUTIVE SUMMARIES OF INTERIM REPORTS SUBMITTED UNDER THIS CONTRACT

HEALTH RISKS OF FRESHWATER RECREATION AND THE DEVELOPMENT OF MICROBIAL STANDARDS

Report No: PRS 2313-M

November 1989

Authors: E B Pike, P Gale and J J Bryan

Contract Manager: E B Pike

Contract No: 4736

Clients Reference No: 5.2.1a

RESTRICTION: This report is restricted to the National Rivers Authority and equivalent bodies in Scotland and Northern Ireland

Any enquiries relating to this report should be referred to the author at the following address:

Water Research Centre (1989) plc, Henley Road, Medmenham, PO Box 16, Marlow, Buckinghamshire SL7 2HD. Telephone: Henley (0491) 571531

HEALTH RISKS OF FRESHWATER RECREATION AND THE DEVELOPMENT OF MICROBIAL STANDARDS

E B Pike, P Gale and J J Bryan

SUMMARY

This interim report is the first in a three-year study to assess the health risk associated with recreational use of water and to formulate guidelines or standards based on health-related indicators.

A detailed review of the literature of case histories and epidemiology shows that serious illnesses such as typhoid fever, shigellosis, leptospirosis and viral gastro-enteritis have been associated with bathing or immersion in waters highly polluted by sewage. Epidemiology has shown that bathers in freshwater meeting local standards or at the borderline have reported a barely significant excess of gastroenteritis, eye, ear, nose and throat symptoms and skin rashes compared with non-bathers and that the risks are related to bacteriological quality of the water.

The rationale of existing microbiological standards and their relationship to risk is discussed. It is argued that standards should take account of the type of recreation based upon the degree of contact with water and the likelihood that it will be swallowed. Microbiological standards must take account of temporal variability in water quality, which appears to be great. Research priorities are discussed and it is stressed that great care must be given to the design of epidemiological studies. Finally, details are given of progress with studies at two field sites.

Report No PRS 2313-M November 1989, 57 pages, 1 figure, 8 tables, 50 references, 2 appendices.

DEVELOPMENT OF MICROBIAL STANDARDS: MICROBIOLOGICAL QUALITY COMPLIANCE AND RECREATIONAL USAGE AT TWO PURPOSE-DESIGNED LAKE COMPLEXES, INTERIM REPORT 1989 - 1990.

Report No: NR 2635

December 1990

Authors: P Gale, J J Bryan and E B Pike

Contract Manager: E B Pike

NRA Project Leader(s): D Lowthion/Southern

Contract No: 4033

Client's Reference No: A11.037

Any enquiries relating to this report should be referred to the author at the following address:

WRc plc, Henley Road, Medmenham, PO Box 16, Marlow, Buckinghamshire SL7 2HD. Telephone: Henley (0491) 571531

DEVELOPMENT OF MICROBIAL STANDARDS: MICROBIOLOGICAL QUALITY COMPLIANCE AND RECREATIONAL USAGE AT TWO PURPOSE-DESIGNED LAKE COMPLEXES, INTERIM REPORT 1989 - 1990

P Gale, J J Bryan and E B Pike

SUMMARY

This interim report outlines the basis upon which health-related guidelines or standards for water recreation could be based and then gives a detailed account of field work carried out under the contract at two purpose-designed recreational lake systems used for a variety of water-based activities and leisure. Both were sampled bacteriologically fortnightly for 12 months. On two Bank Holiday Sundays in May, the diversity and intensities of activities were recorded.

The median/geometric mean and the standard deviation of log counts of faecal indicator bacteria were good descriptors of water quality. Counts were elevated in the late summer and by rain in the first system and decreased with passage through the series of lakes. Roosting wildfowl, or perhaps dog faeces, may have elevated counts in one lake. It was demonstrated that the mandatory EC standard of the EC bathing water Directive and the USEPA's (1976) criteria for primary contact sport can be met in such lakes. Variability of quality at positions within a lake showed a need either for multiple sampling sites or for delimiting use zones for sensitive sports. Illicit bathing and wading by children showed the need for microbiological standards even at locations where these are prohibited.

Recommendations for further study are made, but it is recommended that any epidemiology should be deferred until results of the DoE/NRA-sponsored sea bathing study are known.

Report Nº NR 2635, November 1990
48 Pages, 10 Figures, 21 Tables
Project reference: A11.037

DEVELOPMENT OF MICROBIOLOGICAL STANDARDS

Statistical Analysis of Bacteriological Quality of Recreational Waters And Participation In Water Sports

Interim report November 1990 - April 1991

Authors: P Gale

Date: July 1991

Research Contractor: WRc plc

WRc Report No: NR 2825

WRc Contract No: 4221

NRA Project Leader: D Lowthion

NRA Ref No: A11.037

DEVELOPMENT OF MICROBIOLOGICAL STANDARDS

Statistical Analysis of Bacteriological Quality of Recreational Waters and Participation in Water Sports
Interim report, November 1990 - April

P Gale

SUMMARY

Bacteriological and virological data for waters, many of which are used for the pursuit of recreational activities, have been obtained from a variety of sources including Anglian, Southern, South-West, Severn Trent, Northumbrian, North-West, Thames and Wessex NRA regions, the Central Scotland Water Development Board and British Waterways. The bacterial counts, including those for total coliform, faecal coliform and faecal streptococci are presented as logarithmic frequency distribution plots such that the general quality of the waters from inland lakes and reservoirs, rivers, canals, estuaries and marine sites may be compared and assessed in terms of the EC Bathing Directive and the USEPA (1976) bathing standard. Geometric means and log standard deviations are calculated. In addition, comparisons of bacteriological qualities within particular types of water are made between the different regions of the country. In general, inland lakes appear to be of the highest bacteriological quality, while inland rivers demonstrate the poorest quality. For the Anglian, Northumbrian, and Southern NRA Regions the marine bathing waters are of higher quality than the river and estuarine waters. Data obtained from the governing bodies for the various water sports regarding numbers of participants, nature of contact with water and awareness of illnesses contracted from exposure to the water are analysed.

KEY WORDS

Recreational water quality, logarithmic frequency distributions of faecal indicator bacteria counts, participation in water sports

Report Nº NR 2825, June 1990
61 Pages, 35 Figures, 42 Tables,
Project reference: A11.037

DEVELOPMENT OF MICROBIOLOGICAL STANDARDS

Statistical Analysis of Bacteriological Quality of Marine, River, Estuary and Lake Waters

P Gale

Research Contractor:
WRc plc
Henley Rd Medmenham
PO Box 16 Marlow
SL7 2HD

National Rivers Authority
Rivers House Waterside Drive
Almondsbury Bristol BS12 2UD

NRA Interim Report 037/4/S

EXECUTIVE SUMMARY

Data for faecal indicator bacteria recorded in rivers, estuaries, marine beaches and lakes/reservoirs have been collected and analysed statistically. Geometric mean *E. coli* concentrations calculated for 7924 river samples, 1829 estuary samples, 11 049 marine samples and 3563 lake samples show that the degree of faecal pollution decreases in the order; river > estuary > marine > lake. Median and 95%ile concentrations and logarithmic standard deviations for distributions of *E. coli* concentrations were calculated individually for 444 EC designated marine bathing beaches, 55 rivers, 31 estuaries and 21 lakes/reservoirs. Logarithmic standard deviations for estuaries, marine bathing beaches and lakes/reservoirs were statistically similar, while river sites demonstrated significantly less within-site dispersion. Median and 95%ile *E. coli* concentrations in river and estuary sites are typically higher than for marine beaches and lakes/reservoirs. Some 80% of estuary sites and 90% of river sites failed the EC Bathing Directive with the 95%ile *E. coli* concentration exceeding 2000 counts per 100 ml. In contrast only 30% of marine sites and individual lakes/reservoirs failed the EC Bathing Directive with respect to *E. coli* concentrations. However, there were not sufficient data to analyse individual lakes in four of the NRA regions. The general quality of lakes in these four NRA regions was high and overall less than 30% of lakes may fail the EC Bathing Directive. Estuaries and lakes/reservoirs exhibit greater between-site variation in the degree of pollution compared to sites in the sea or rivers as judged from the distribution of median and 95%ile concentrations.

KEY WORDS

Water quality, bacteria, coliforms, statistical analysis, rivers, estuaries, lakes, marine.

R&D Interim Report 037/4/S

DEVELOPMENT OF MICROBIOLOGICAL STANDARDS
Patterns of water usage, contact and risks in water sports

E B Pike and P Gale

Research Contractor:
WRc plc
Henley Road Medmenham
PO Box 16 Marlow
Buckinghamshire SL7 2HD

National Rivers Authority
Rivers House Waterside Drive
Almondsbury Bristol
Avon BS12 2UD

NRA Interim Report 037/6/S

EXECUTIVE SUMMARY

This is the fourth Interim Report produced under this Contract. It describes four inter-related tasks, which have been carried out to meet the objective of developing a scheme of classifying the various recreational uses of tidal and non-tidal waters according to degree of contact, by using a scientific assessment of the risks. Firstly, published information was used to identify three classes of illness, related to recreational use of water:

(a) waterborne, spread by ingesting or inhaling faecally polluted water;

(b) water contact, not directly related to pollution (e.g. cyanobacterial toxins, leptospirosis); and

(c) water-washed, caused by opportunist skin organisms washed in by water.

Secondly, surveys of national governing bodies for various water sports and of 209 responding clubs and limited observations of sports activities have been used to classify sports according to degree of water contact and, hence, risk. The classes derived are:

(a) whole-body contact, with immersion, facial wetting and risk of swallowing (e.g. long-distance swimming, surfing, sub aqua, water skiing, white-water canoeing, windsurfing, sea bathing, children's wading and dabbling);

(b) incidental contact, with wetting of limbs only (rowing, canoe touring, sailing) and non-contact (angling, boating, walking).

Perception of risks from gastrointestinal, ear, eye, nose and throat symptoms was greatest among clubs for whole-body contact and certain sports were aware of leptospirosis and cyanobacterial toxins. The greatest activity was for non-contact sports involving about one-sixth of the population and twice the participation of the other two classes together. The only quantifiable risks nationally are for leptospirosis and drowning. It is considered that epidemiology is needed should it be required to quantify risks of waterborne and water contact illnesses more definitively.

KEY WORDS

Recreation, Recreational waters, Diseases (waterborne), Diseases (water-related), Algae - blue-green, Leptospirosis.

NRA Interim Report 037/6/S

APPENDIX B - GLOSSARY OF TERMS

Algae

Simple plants which may be microscopic, or very large plants but which lack true stems, all of which are capable of photosynthesis. Algae occur in water.

Bacteriophage

The term given to viruses which specifically attack and destroy bacteria. Those bacteriophages which attack *Escherichia coli* (see coliform bacteria) are termed 'coliphages'.

Biological classification

A way of placing waters in categories according to the status of biological communities. Data on macro-invertebrates are particularly useful for this purpose.

Blooms

A term used to describe the enormous growths of algae or cyanobacteria which occur in bodies of water during the warmer months of the year. They are usually recognized by floating masses or scums.

'Blue-green algae'

A popular name for cyanobacteria (q.v.) because of their blue-green photosynthetic pigments and the colour of the scums which they form.

Coliform bacteria

A group of bacteria which are found in very large numbers in faeces of man and animals and are therefore used as indications of recent faecal contamination of water. They are recognized by biochemical tests, usually the ability to grow in the presence of surfactants and to ferment lactose. The most specific indicator of faecal pollution in this group is *Escherichia coli*. Those bacteria with similar properties are termed 'coliforms'. Standard tests enumerate either total coliform bacteria or those which, like *E. coli*, can grow at the relative high temperature of 44 °C ('thermotolerant' or 'faecal' coliform bacteria).

Compliance assessment

A procedure applied to the results of a monitoring programme to determine whether or not a water has met its agreed Quality Standards.

Consent

A statutory document issued by the NRA to indicate any limits and conditions on the discharge of an effluent to a controlled water.

Controlled waters

All rivers, lakes, groundwaters, estuaries and coastal waters to three nautical miles from the shore.

Criterion

Used in this report to describe the numerical value attached to a standard for water quality.

Cyanobacteria

Popularly called 'blue-green algae', since they were previously thought to be a type of algae. A class of filamentous bacteria which produce blue-green photosynthetic pigments. In the warmer months of the year, they can grow enormously producing floating blankets and scums ('blooms'). Certain species produce toxins (q.v.), which can be absorbed by contact with the skin or through swallowing water.

Directive

A type of legislation issued by the European Community which is binding on Member States in terms of the results to be achieved.

Faecal bacteria

Bacteria found in the human gut and present in faeces in large numbers. See Indicator bacteria.

Faecal coliform bacteria

See coliform bacteria.

Faecal streptococci

A group of faecal indicator bacteria (see Indicator bacteria.

Indicator bacteria

Bacteria which are found in large numbers in faeces of man and higher animals, including birds, and which specifically indicate that water has been contaminated by faeces or sewage.

Leptospirosis

The group of diseases caused by infection with *Leptospira* species, which are carried by rats and other rodents and by other animals, notably deer and cattle. The leptospiral bacteria are transmitted by urine from carriers and by contact with injured skin. The severest form of illness is Weil's disease or leptospiral jaundice, caused by the serovar *ichterohaemorrhagiae* of *Leptospira interrogans*.

Log-normal distribution

A type of variation from the normal distribution (q.v.). In the context of this report, if a collection of bacterial counts from one place are plotted by size and frequency it is noticed that there are more small values than large and the distribution curve is not symmetrical. If the logarithms of the values are plotted, the resulting frequency distribution curve is usually approximately symmetrical, i.e. obeys a normal distribution. Data which behaves in this way is said to be log-normally distributed. It is a property of this distribution that the geometric mean and the median (q.v.) are identical, but the arithmetic mean (average) is much higher and does not describe central tendency properly.

Mean

The measure of central tendency. Arithmetic means are generally called 'averages'. A geometric mean of a set of data is obtained by multiplying all the n terms and taking the nth root or more easily by finding the average of the logarithms of the original numbers and taking its antilogarithm.

Median

If a set of numbers is arranged in order of size (ranked), the median value is the middle value. The median is the 50-percentile value (see Percentile).

Normal distribution

All measurements are imprecise and deviate from the true value. The normal distribution is one of several statistical descriptions of these deviations. If the deviations are normally distributed, then plotting the measurements by frequency and size gives a bell-shaped symmetrical curve. See also log-normal distribution. It is a property of normally-distributed measurements that the mean and median are identical.

NWC class

A summary of the quality of river water based largely on the measured chemical quality for the purposes of classification and reporting; originally devised by the National Water Council.

95-percentile

In this report, a level of water quality, usually a bacterial count or concentration, which is exceeded for 5% of the time. See Percentile.

95-percentile standard

In this report, a level of water quality, usually a bacterial count or concentration, which must be achieved in at least 95% of samples taken.

Pathogen

An agent which causes an infectious disease. Pathogens may be bacteria, viruses, fungi and protozoa, but not toxins (q.v.) or chemical agents.

Percentile

If a set of numbers or measurements is arranged in order of size, greatest last, a percentile value is the position of of that number in the order as a percentage of the number of values of equal or lower size. See 95-percentile. In this report, a level of water quality, usually a count of bacteria, or concentration which may not be exceeded in a given percentage of samples; hence, 95-percentile (q.v.).

Quality objective

The level of water quality that body of water should achieve, in order to be suitable for its agreed uses.

Quality standard

A level of a substance or any calculated value of a measure of water quality, which must be met in order to protect a given use of a water body. The standard is expressed as a pairing of a specific concentration or level of a substance with a summary statistic such as a percentile (q.v.) or a maximum value.

Rank

A rank is a set of numbers arranged in order of size.

Standard deviation

A statistic which describes the extent of variability within a set of measurements, which are distributed normally (see Normal distribution). In very large sets of data, which are normally distributed, those between the 16th and 84th percentiles lie within one standard deviation from the mean (i.e. 68% of values) and those between the 2.3th and 97.7th percentiles (i.e. 95% of values) within two standard deviations.

See 'Percentile'.

Statistics

Either figures collected by surveys to display trends (e.g. cases of drowning) or the scientific, mathematical study of the laws of chance. A 'statistic' is a measurement made during a statistical study, such as the mean, and standard deviation, median and percentile (q.v.).

Statistically significant

A description of a conclusion which has been reached after making proper allowance for the effects of random chance. An observation which is unlikely to have arisen by chance, typically by less than one chance in 20 trials.

Statutory water quality objective

A quality objective to be given a statutory basis by a notice served on the NRA in accordance with the procedures in Section 105 of the 1989 Water Act.

General classification

A classification of water quality designed to be used as a measure of absolute quality and to monitor change.

Toxins

Poisonous chemical substances produced by micro-organisms and either contained within their cells or released into water during their growth. Toxins can exert their effect on contact with the skin or on being swallowed. See 'Cyanobacteria'.

Toxicoses

Illnesses produced by toxins, after they are ingested or absorbed by the body.

APPENDIX C - LIST OF ACRONYMS

Acronyms are written in full in the text, when they are first used.

BWB	British Waterways Board
CEN	Comité Européen de Normalisation (European Committee for Standardization)
DoE	Department of the Environment
EC,EEC	European Community i.e. the European Economic Community
IAWPRC	International Association for Water Pollution Control and Research
IWEM	Institution of Water and Environmental Management
MNHW	Canadian Ministry for National Health and Welfare
NGR	National Grid Reference (Ordnance Survey)
NRA	National Rivers Authority
NJDOH	New Jersey Department of Health
NTAC	National Technical Advisory Committee to the Secretary of the Interior (United States)
NWC	National Water Council
OPCS	Office of Population Censuses and Surveys
PHLS	Public Health Laboratory Service
UK	The United Kingdom of Great Britain and Northern Ireland
USEPA	United States Environmental Protection Agency
SD	Standard deviation