Standards for Recreational Water Quality

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An FWR Guide

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Summary

Bathing water has been recognised as carrying potential risks for decades. These risks, other than physical risks such as drowning, mostly arise as a consequence of the pollution of recreational water with micro-organisms that are present in faeces. Although there have been microbiological standards for recreational waters for many years in both North America and Europe, these have not been soundly based and they lacked epidemiological evidence that could support the argument that they were health-evidence-based. In order to improve this situation, epidemiological studies were carried out in the UK to quantify the potential health effects of bathing in recreational waters. These studies provide a scientific basis for developing standards based on practical measurements of contamination and the defined health risks which, mostly, relate to health outcomes with low levels of severity. The World Health Organization (WHO) has recognised that more information is needed from both fresh waters and from non-temperate conditions. However, the WHO has utilised the UK information to develop Guidelines for Safe Recreational Water Environments which were published in 2003. The approach used in those Guidelines offers a means of deriving standards that seek to limit health risks to clearly defined and acceptably low levels.

This approach has been the primary basis for the development of a new Bathing Water Directive for Europe. The new microbiological criteria for marine waters outlined in the 2006 Bathing Water Directive are, in part, based on the WHO criteria, but the derivation of the freshwater standards in the Directive is, at least partly, based on a German replication of the UK epidemiological research protocol.

Real time management of risk, through prediction of bathing water quality, has been suggested by the WHO in the 2003 Guidelines and is accommodated in the new Bathing Water Directive. Prototype systems, using electronic signs, are deployed in Scotland and this approach offers considerable scope particularly where microbiological pollution is episodically associated with rainfall causing runoff from livestock farming areas.

There is a review of the 2006 Bathing Water Directive criteria scheduled for 2008 and this may offer an opportunity to accommodate new scientific information from European Union (EU) studies coordinated by one of the authors of this report, from recently completed work and work underway, and to reconsider any inconsistencies identified.

1 Introduction

It has long been known that bathing in water that is contaminated can lead to disease in a proportion of bathers. As a consequence, water quality standards have been developed to protect bathers. These standards have been controversial because: (i) they were not based on transparent scientific evidence; and (ii) the expenditures needed to achieve the standards were very significant. Recent research efforts have been initiated to clarify the actual risks of ill health associated with recreational waters and, in particular, bathing. Better scientific evidence is now available and this has been the trigger for the development of new quality standards for recreational water that will help to ensure that bathing and swimming remain both a safe leisure activity and an excellent form of exercise. However, because of the differing circumstances of bathing sites and the fact that bathing waters vary significantly, there is a need for flexibility as well as a strong science base if standards are to be successful. While it would be easy to introduce precautionary standards that would guarantee safety, these would be so difficult to meet that few bathing waters would be usable, or the costs of meeting the standards would be so great as to render it impractical. A sensible balance therefore needs to be struck that provides adequate protection of public health while allowing the undoubted benefits to health of recreational water-use to also be available. The enormous economic benefits associated with recreational waters also need to be taken into account since many communities depend on the attraction of beaches and bathing for much of their livelihood. The availability and use of good science is increasingly vital in developing standards that provide a fulcrum for balancing safety and practicality.

Developing health-based water quality standards can be a very complex process for three reasons; firstly there is a huge variation in exposure between individuals in any recreational water, secondly there is a wide range of susceptibility between individuals and thirdly there is a significant potential for illness that is not directly associated with bathing water but is associated with other related exposure routes such as beach fouling, personal hygiene and food contamination. However, considerable efforts have been made to study the disease outcomes associated with recreational waters and the processes that lead to contamination of recreational waters. This has resulted in the continuing development of new water quality criteria for recreational waters in North America, Europe and in other parts of the world. This process was begun by the development of the World Health Organization (WHO) guidelines for safe recreational water environments covering both environmental waters and artificial swimming pools and Spas.

As with all standards and the process of their design, credibility and acceptance by the stakeholder community requires transparency and peer review. The lack of a transparent evidence-base can result in an inappropriate response by public health authorities, bathers and the media which can damage the reputation of a bathing resort and disrupt recreational activities.

2 What causes pollution of recreational water?

Recreational water will contain both micro-organisms and chemicals that are from natural sources and which are an important part of the ecology of both fresh and marine waters. Most of these micro-organisms are of no concern for human health but a few are capable of opportunistically infecting wounds, ears, eyes and the respiratory and gastrointestinal tract. Chemicals are generally of no consequence for health in recreational water; although a small number of substances that are produced by some kinds of algae can be of concern. However, the greatest problems for recreational waters arise from microbial contaminants that are a consequence of the pollution of either fresh or marine waters through direct or indirect introduction of faecal matter, from animals or man, that contains pathogens of concern to human health.

These pathogens can be bacteria, viruses or parasites, which are discussed in more detail in section 4. Their numbers will depend on many factors, including the discharge of treated or untreated wastewater, dilution and dispersion in the receiving water, the nature of the contributing population and the incidence of disease in that population. They will also depend on bather density and the level of hygiene practiced by bathers. Watercourses that flow into the bathing water, the nature of the catchment of the water courses and the extent and nature of agricultural activity in that catchment are also major factors in determining bathing water quality, particularly when livestock are present. However, all of these can vary significantly with time and so the process of setting standards that are practical is made even more complex.

Chemical contaminants are normally present as a consequence of discharges from industrial effluent but current controls in most countries means that such discharges will not present a threat to bathing waters. In particular controls on discharges to protect aquatic life mean that the concentrations of hazardous substances will normally be extremely low. The presence of high levels of nutrients can give rise to significant blooms of algae or dinoflagellates. These usually are only a problem for relatively still or slow flowing fresh waters or coastal waters. They appear intermittently but in large numbers can be a threat to health because of the range of substances that they can produce, which may be toxic or allergenic. Further information is available from another FWR publication[1].

There are other factors that can impact on the quality of the bathing experience that are not necessarily associated with direct contamination of the bathing water. These relate to litter and debris on the beach and in the water and to factors such as whether dogs are allowed to foul the beach or immediate area, and the general provisions for the hygiene of bathers such as showers and toilets. While these are not specifically considered in the standards set at governmental level, they are an important and integral part of award schemes such as the “Blue-Flag” awards, which also consider a wider range of requirements including environmental education and information along with provisions for bather safety from drowning and beach management.

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[1] Cyanobacterial Toxins in the Water Environment. A Review of Current Knowledge. FR/R0009. February 2004. Published by Foundation for Water Research.

3 The need for new evidence-based standards

Standards for bathing water quality were published by the European Commission in 1976 but it was widely accepted that there was no transparent evidence-base for the microbiological standards set out in that original European Bathing Water Directive. This was raised as a concern by Parliamentary committees in the UK examining the early Commission attempts to suggest revised standards for a new Directive in 1994. It was a significant problem because failures of the standards impacted on bathing resorts and resulted in demands for major investments in sewage treatment, but even where these investments were made failures still occurred at many UK sites. Evidence began to emerge that there were other sources of pathogens that could impact on the quality of bathing water, particularly rain induced run-off from catchments feeding water courses that impacted on beaches. The lack of a sound evidence-base resulted in the value of the standards being questioned.

WHO considered the new evidence that was emerging on the relationship between pathogens in bathing water and health effects in bathers and developed new guidelines for recreational water that were published in 2003. However, the WHO expert advisers recognised that the scientific evidence-base of the 2003 Guidelines was still relatively narrow with insufficient coverage of tropical, Mediterranean and fresh recreational water environments. To fill these information gaps, additional epidemiological studies are required and the first of these have been completed in Germany and North America. Additional work, funded by the European Union (EU), is underway in Hungary and Spain and will be reported in late 2008 (see www.epibathe.eu and www.voribathe.org) It is therefore possible that there will be changes in standards if these studies provide significant new information.

This area of water management and regulation therefore remains very dynamic with the potential for further policy developments.

4 Principal pathogens of concern

The primary concern for public health associated with bathing in contaminated water comes from micro-organisms that are largely derived from faecal contamination. There are many potential microbial pathogens that can be present in the environment and which can reach water, whether it is freshwater or seawater. These pathogens are well known and may cause disease following consumption of contaminated drinking water. The key pathogens are presented in Table 1. However, measuring some of these pathogens in the environment is very difficult; often their potential presence is inferred if sewage discharges are known to enter a specific water environment. An example of such a pathogen is norovirus, which is thought to be the principal cause of viral gastroenteritis in the developed world. Other viruses, such as adenovirus and enterovirus, can be detected using culture methods, which probably explains the inclusion of enterovirus in the original 1976 Bathing Water Directive; i.e. it was included because it could be measured rather than because it was predictive of illness. However, although they may be present in the environment many of the organisms listed in Table 1 have not been proven to cause disease in humans as a consequence of exposure in bathing water.

Pathogen	Infection	Water type
Aeromonas spp.	wound infection, gastroenteritis	fresh/marine
Campylobacter spp	enteritis	fresh/marine
Clostridium spp.	botulism, gastroenteritis	fresh/marine
Escherichia coli O157:H7	gastroenteritis	fresh/marine
Helicobacter pylori	gastroenteritis, ulcers, anaemia	fresh
Klebsiella spp.	pneumonia	fresh/marine
Legionella spp.	legionellosis	fresh
Leptospira spp.	leptospirosis	fresh
Listeria spp.	listeriosis	fresh/marine
Mycobacterium avium	respiratory and gastrointestinal tract infection	
Plesiomonas spp.	meningitis, cellulites, gastroenteritis	fresh/marine
Salmonella spp.	enteric gastroenteritis	fresh/marine
Shigella spp.	bacillary dysentery	fresh/marine
Staphylococcus spp.	soft tissue infections, bacteraemia	fresh/marine
Vibrio spp.	cholera, wound infections	marine/extuarine
Yersinia spp.	gastroenteritis	fresh/marine
Candida albicans	dermatitis, thrush	fresh/marine
Cryptosporidium spp.	gastroenteritis	fresh/marine
Giardia spp.	gastroenteritis	fresh/marine
Naegleria spp.	primary amoebic meningoencephalitis (PAM)	Fresh especially thermal pools
Trichobilharzia spp.	swimmers' itch	fresh/marine

Table 1 Pathogens found in environmental waters (Fewtrell *et al*., 1994; WHO, 2003.)

Because pathogens are both difficult and expensive to measure reliably in water, the normal approach is to use more easily measured organisms that act as an 'indicator' of the presence of faecal contamination in the water. This has been applied successfully to drinking water, although the use of 'indicator organisms' is supported by additional measurements that show whether drinking water treatment processes are working effectively.

Another consideration is that the analysis of pathogens would provide a very poor 'risk' assessment tool because the absence of a pathogen, for example norovirus, could simply mean that infection rates in the specific population contributing to the sewage source were very low. It would not be possible for a regulator or public health official to infer that there was no risk of infection at some future time when the pathogen's presence in the sewage effluent was elevated by illness in the contributing population. Nor could a negative test for one pathogen provide adequate reassurance that other pathogens were not present. Some pathogens also have distinct seasonal patterns and would be absent throughout portions of the year in most communities. Therefore, if pathogen analyses became the principal regulatory tool, then many species would need to be monitored to ensure public safety, greatly increasing monitoring costs and complexity.

For these reasons, it is highly likely that regulatory monitoring of environmental waters will continue to principally utilise bacterial faecal indicators. These are organisms that are always present in faecal material, although they may not cause disease. The indicator organisms that are most commonly used are *Escherichia coli* (*E. coli*), total coliforms, faecal coliforms and faecal streptococci (now termed intestinal enterococci), although *E. coli* and enterococci are considered to be the best of this group. Currently, the methods used to enumerate faecal indicator organisms require the culture of the organisms in the laboratory. This takes 24-48 hours which means that the information is only available well after the time of sampling. By this time, the risk to bathers is likely to have changed from that at the time of sample collection. Progress is being made with new, more rapid (2-4 hours) methods and in due course these may revolutionise the way in which we manage recreational waters.

One of the complicating factors is that pathogens and indicators will not survive indefinitely in water, particularly seawater, because of predation by other organisms and because of the effect of ultraviolet energy in sunlight, which kills micro-organisms. The survival times for different pathogens and indicators will vary and they are affected by differing environmental conditions such as light penetration and turbidity. It is, therefore important that the indicators chosen provide a reasonable reflection of the survival of pathogens.

5 The scientific basis for establishing bathing water standards

The only practical means of protecting the health of the public from contaminants in bathing water is to establish standards based on an acceptable risk of health effects. Such an approach means that there is a need for credible evidence on the risks of infection associated with increasing levels of faecal contamination. The science behind this evidence is based on the epidemiological study of bathers in various circumstances of exposure to water with varying levels of faecal indicator organisms.

There is a significant body of epidemiological evidence derived from studies conducted world-wide and dating from the 1950s, which suggests that contact with recreational waters is associated with clearly identified elevations in illness. However, most studies examined elevations in self-reported and generally self-limiting minor illness. The studies relied on diary-based recollection of bathing water contact and illness and they were susceptible to bias caused by variability in background rates of minor illness in the general population. Very few epidemiological studies have sought to quantify the risks of acquiring more serious illnesses such as poliomyelitis and/or enteric fever, but these are less likely to be acquired than the minor illnesses, largely because the organisms, if they are present, will be present in much lower numbers. However, reports about outbreaks of illness associated with bathing waters suggest that the risk of infection by *Shigella sonnei*, *E. coli* O157 and protozoan parasites cannot be dismissed.

Following these early epidemiological studies a series of ‘prospective’ interview-based studies were carried out. These studies were designed to record the level of illness after bathing compared with an equivalent control group present on the beach but not entering the water. They were an improvement on the diary-based approach although they were still difficult and expensive to carry out with a sufficient level of scientific rigour. The most influential of these studies was that carried out by Cabelli and his colleagues in the USA published in 1982. This investigation was sponsored by the United States Environmental Protection Agency (USEPA) and was based principally on self-reported gastroenteritis in bathers using fresh, marine and brackish waters. This study identified a clear dose-response relationship between self-reported and normally self-limiting gastroenteritis, with water quality as measured by the faecal indicators, total coliforms, faecal coliforms and intestinal enterococci. The key conclusion from this study was that a significant increase in minor self-limiting illness could occur at faecal indicator levels below those defined in EU and US regulatory standards of the time. In other words, the standards were insufficiently protective of the health of bathers from minor and, by implication, severe illness.

Figure 1 shows the dose response curves reported in this study and illustrates how these relate to the Bathing Water Directive of 1976 criteria. However, another important conclusion was that in marine waters, enterococci (or intestinal enterococci) were probably the best predictors of gastroenteritis.

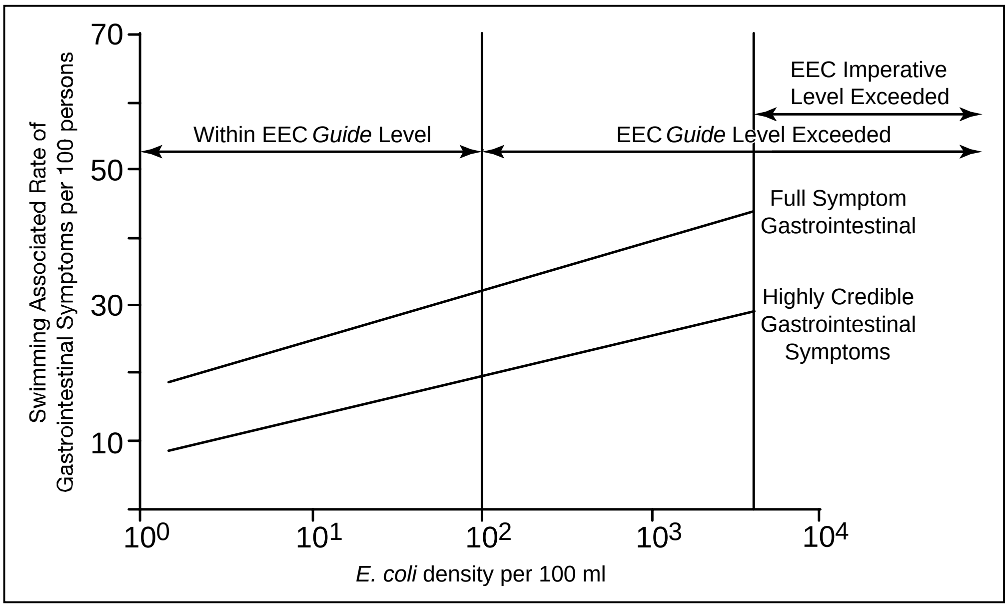

Figure 1 The dose-response relationships determined from the Cabelli studies in relation to the 1976 EU faecal coliform standards for recreational waters.

The USEPA funded studies by Cabelli led to a number of investigations worldwide and the prospective approach he developed became a standard protocol which was recognised by WHO and many international agencies. However, at the same time other experts examined the studies and identified a number of weaknesses, including probable bias in the results. One of the problems was that the dose-response curves at each of the three sites that Cabelli studied, exhibited marked differences (differences in slope) but data from all sites had been simply combined ignoring this fact. Another problem was that the measure of exposure (i.e. enterococci concentration) did not accurately reflect the water quality at the time and place of bathing because the number of indicator organisms varies significantly over time and the measure used was an average (see Figure 2). These and other criticisms undermined the faith that had been placed in these studies generating a need for more rigorous studies. It is worth noting that environmental epidemiological studies are very difficult to carry out and learning from the work that had already been done is an essential step in developing the most reliable information on which to base standards that may have significant social and economical impact.

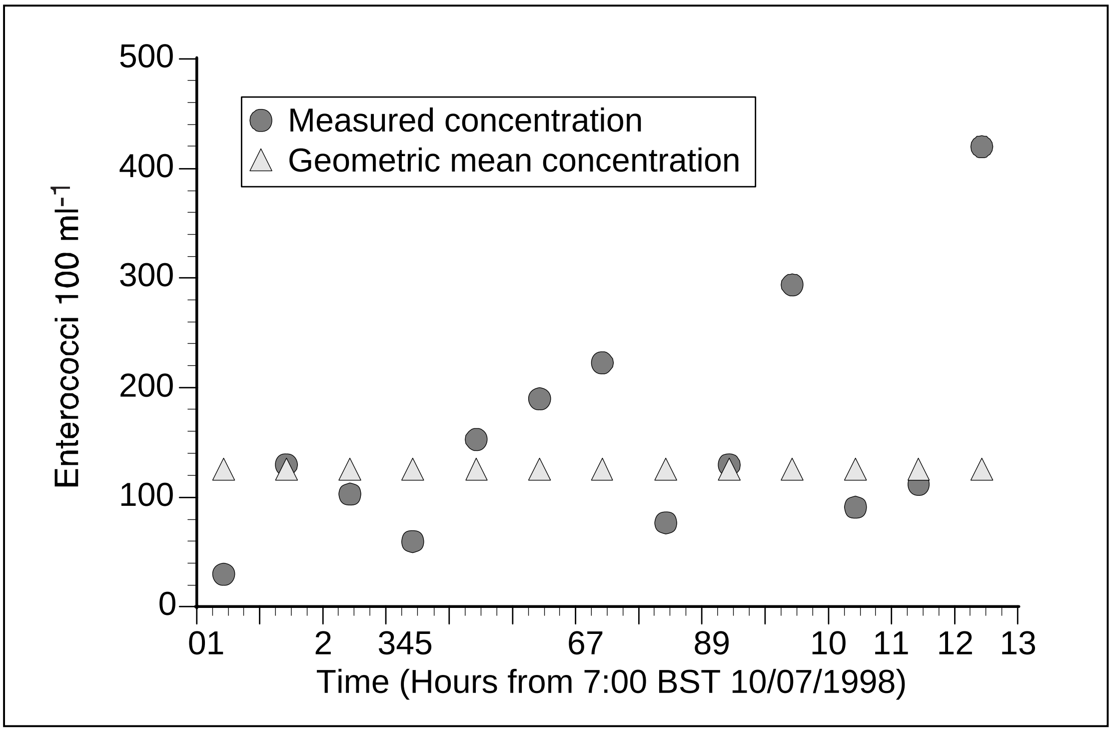

Figure 2 Enterococci concentrations in hourly samples at Jaywick near Clacton (circles) and the daily geometric mean values (triangles)

The search for alternative protocols led to one based on a prospective design using healthy adult volunteers who were randomised into bather and non-bather groups prior to being exposed to sea water at UK beaches that passed the *Imperative* standards contained in the then current EU Directive (76/160/EEC). These standards are shown in Table 2.

Parameter	***Guide* /100 ml**	***Imperative* /100 ml**
Total coliforms	500	10,000
(Compliance %)	(80%)	(95%)
Faecal coliforms	100	2,000
(Compliance %)	(80%)	(95%)
Intestinal enterococci	100	
(Compliance %)	(90%)	

Table 2 Faecal indicator standards for EU identified bathing waters

Four beaches were used for this research between 1989 and 1992, namely, Langland Bay, Moreton, Southsea and Southend. The characteristics of the employed protocol were as follows:

- adult volunteers over 18 years of age were recruited from the general population 4 weeks to 1 week before the day of the experiment;
- all volunteers were interviewed prior to the exposure day (3 days to 1 day before) by trained interviewers, this being the first of four such interviews, the remainder being, immediately following exposure, at 1 week after exposure and a postal questionnaire administered 3 weeks after exposure;
- randomisation status was allocated on arrival at the beach on the day of the exposure;
- all volunteers were given a packed lunch and a sample of these was analysed for faecal indicators and pathogens, this was done to limit as far as possible other food types;
- bathers were exposed to sea water for a minimum period of 10 minutes during which they were required to immerse their heads on 3 occasions;
- they were positioned in swim zones marked by ropes which were 20 meters apart;
- water quality was measured synchronously in each swim zone every 20 minutes and at three depths (surf zone, at 1 meter depth and at adult chest depth, the last two were taken at 30 cm below the water surface) during the 3 hour exposure period and analysed for total coliform, faecal coliform, faecal streptococci *Staphylococcus aureus* and *Pseudomonas aeruginosa,*; additionally, bulked samples were analysed for enterovirus and *Cryptosporidium*; and
- non-bathers travelled to the beach and ate their packed lunch on the sand, thus, being exposed to the same risks as the bathers except for the exposure to sea water.

Clearly, this design is not a ‘double-blind’ randomised controlled trial as might be employed in a pharmaceutical trial because it is impossible to ‘blind’ a volunteer to immersion in UK sea water at approximately 16^{o}C. However, they were ‘blind’ to the ‘exposure’ because they had no idea what the faecal indicator concentrations encountered were and interviewers and data entry personnel were also ‘blind’ to the exposure status (whether the person interviewed was a bather or non-bather) and the exposure level (faecal indicator concentrations) of the bather group. It might, therefore be termed semi-blind. It is interesting that the UK studies did not identify a relationship between gastroenteritis and the principal parameters used in the 1976 Bathing Water Directive; the coliform organisms and the parameters measured at the depth that is used in measuring compliance with the Directive were not predictive of illness. A robust relationship was obtained between faecal streptococci (enterococci) measured at chest depth and gastroenteritis. This indicator was also predictive of upper respiratory tract illness (termed acute febrile respiratory illness by WHO). Faecal coliforms measured at chest depth were predictive of reported ear symptoms. However, the link between gastroenteritis and bathing water quality is the most significant relationship and it has been used as the basis of new guidelines and standards. The relationship between reported gastroenteritis and the concentration of faecal streptococci to which bathers were exposed is shown in Figure 3.

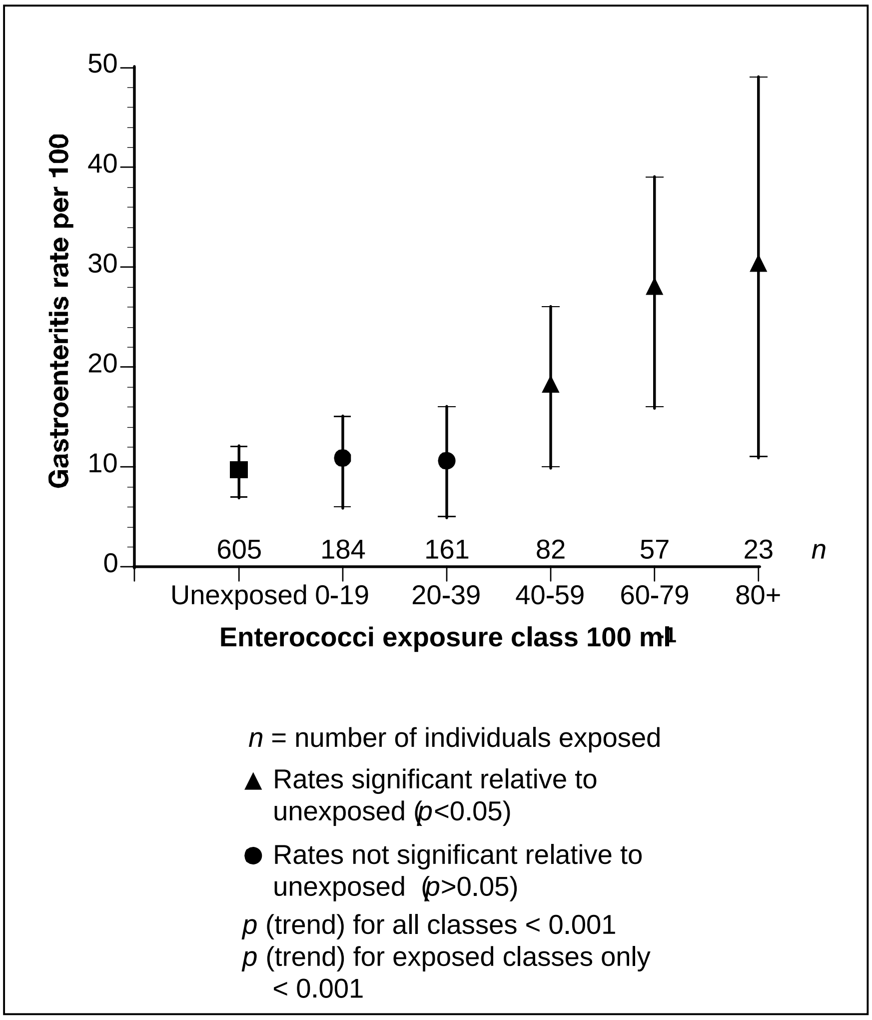

Figure 3 Categorical analysis and dose response relationship linking gastroenteritis and enterococci concentration.

WHO carried out a review of all of the evidence as part of the process for developing their 2003 Guidelines for safe recreational environments and concluded that there was clear evidence that faecal indicator concentrations, particularly faecal enterococci, were predictive of minor illness in exposed populations of bathers. It was also clear that existing standards were inadequate to protect bathers from potentially significant levels of minor illness. However, there was very little evidence from previous epidemiological investigations, to support the contention that transmission of serious life threatening illness is commonly associated with bathing in untreated environmental waters.

There was concern about basing international guidelines on a single UK study. In light of this concern and the policy implications, the UK Government sponsored a re-examination of the data derived from the original studies, which suggested very similar results. Although WHO used the UK studies to develop guidelines they also called for international replication of the study using the same design. Results of these studies are now emerging.

6 Epidemiological studies reported since the WHO (2003) guidelines

The first replications of the UK studies were performed in Germany at five freshwater recreation sites. This study sought to replicate the protocol as far as possible, as suggested by WHO. However, the German team was allowed to use children, over 4 years of age, in the exposed and unexposed cohorts at four of the five study locations. Child volunteers had been precluded from the UK work because of the perceived problem of obtaining ethical approval. The German study filled the largest obvious information gap in the original UK data, i.e. exposure to fresh recreational waters.

The researchers carried out extensive statistical analysis to ensure that there was no bias in the studies and they analysed their data to quantify the effects of confounding factors. Volunteers were required to immerse their heads in the water while bathing as this would be a means of increased exposure resulting in some ingestion of water and water would enter the ears. Some 95.2% of the samples collected during all studies were within the Directive 76/160/EEC standards for *E. coli* of 2,000/100 ml. The range in *E. coli* concentrations was 4.7 to 5,344/100 ml in all five studies and the intestinal enterococci range was 3.0 to 1,504/100 ml.

Significant differences between the crude incidence rates for gastroenteritis and skin ailments between bathers and non-bathers were observed at one week after exposure. The background level in non-bathers for the first gastrointestinal definition was 1.4% and 5.2% for the second definition. This shows why such care is required in establishing control levels in epidemiological studies. The German researchers analysed the data to determine a no observed adverse effect level (NOAEL) for the concentration of faecal indicator bacteria (*E. coli* and enterococci). This would be the concentration of faecal indicator bacteria at which there was no increase in adverse health effects over the non-bathers. The NOAEL was determined to be between 20 and 30 colony forming units (CFU) of enterococci per 100 ml. The affect of swallowing water above and below the NOAEL is illustrated in Figure 4 and this shows a clear increase in risk of contracting low-level gastroenteritis.

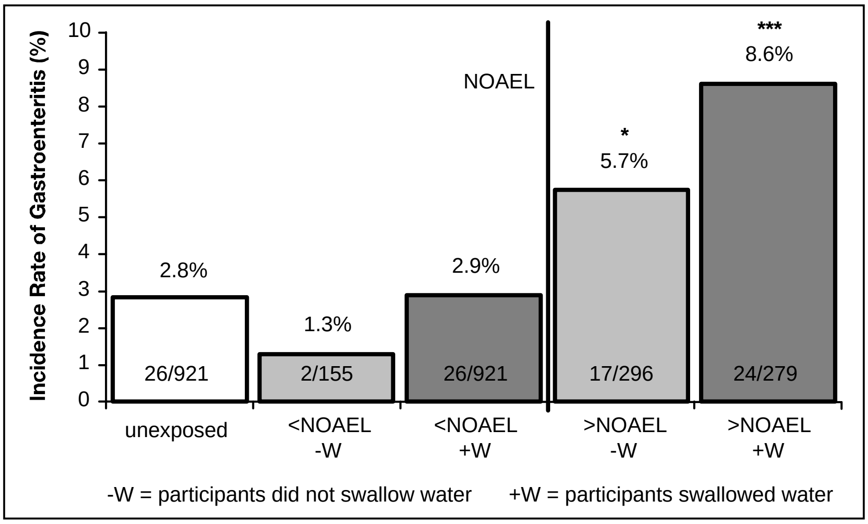

Figure 4 Affects of swallowing water (+W) and not swallowing water (-W) above (>) and below (<) the NOAEL. Percentages refer to the GI incidence rate at one week (source Wiedenmann *et al.*, 2006)

There were some differences between this study and the UK studies in terms of the percentages of affected individuals. Since the German study was on fresh water and the UK study on seawater, in which dilution is normally greater, this remains an outstanding question to be resolved.

Additional studies are being carried out in other parts of the world and these will all contribute to refinement of standards in the future. These studies include the investigation of new measures of faecal indicators, including rapid methods of analysis that give results in hours rather than the days. Such methods show significant promise and will certainly contribute to better, and more usable, standards in the future. In particular, they will provide a means of real-time management of beaches and bathing water that are a key part of new approaches to developing more flexible bathing water standards.

7 From epidemiology to evidence-based standards

In a series of five international expert consultations over the period 1996 to 2001, the WHO, together with partner organisations, including the USEPA, the Commission of the European Communities and a group of independent experts, developed methods for expressing the relationship between exposure (concentration of enterococci as faecal indicator organisms) and the risk of contracting mild gastrointestinal illness. The outcome of these deliberations was the WHO Guidelines for Safe Recreational Water Environments published in 2003.

The findings are based on a number of mathematical and statistical calculations that resulted in the WHO Guidelines, which are outlined in Table 3 with the levels of risk associated with different concentrations of bacterial faecal indicators. The 95th percentile is the 95% confidence limit of the range of values found in epidemiological studies and provides a suitably protective value. The following notes are important when referring to Table 3.

Notes:

1. Abbreviations used: AFRI = acute febrile respiratory illness; GI = gastrointestinal; LOAEL = lowest-observed-adverse-effect level; NOAEL = no-observed-adverse-effect level.

2. The functional form used in the dose–response curve assumes no excess illness outside the range of the data (i.e., at concentrations above 158 faecal streptococci/100 ml). Thus, the estimates of illness rate reported above are likely to be underestimates of the actual disease attributable to recreational-water exposure.

3. This table would produce protection of "healthy adult bathers" exposed to marine waters in temperate north European waters.

4. It does not relate to children, the elderly or immuno-compromised, who would have lower immunity and might require a greater degree of protection. There are no available data with which to quantify this, and no correction factors are therefore applied.

5. Epidemiological data on fresh waters or exposures other than bathing (e.g., high-exposure activities such as surfing or slalom canoeing) were considered inadequate to present a parallel analysis for defined reference risks. Thus, a single microbiological value was proposed, (i.e. in 2003), for all recreational uses of water, because insufficient evidence existed to do otherwise. However, it was recommended that the severity and frequency of exposure encountered by special interest groups (such as bodysurfers, board riders, windsurfers, sub-aqua divers, canoeists and dinghy sailors) was taken into account.

6. Where disinfection is used to reduce the density of indicator bacteria in effluents and discharges, the presumed relationship between faecal enterococci (as indicators of faecal contamination) and pathogen presence may be altered. This alteration was, and is, poorly understood. In water receiving such effluents and discharges, enterococci counts may not provide an accurate estimate of the risk of suffering from mild gastrointestinal symptoms.

7. Risk attributable to exposure to recreational water is calculated after the method given by Wyer et al. (1999), in which a log10 standard deviation of 0.8103 was assumed.

8. Note that the values presented in this table do not take account of health outcomes other than gastroenteritis and AFRI. Where other outcomes are of public health concern, then the risks should be assessed and appropriate action taken.

Table 3 The microbiological criteria and risk levels set out by WHO in the 2003 water quality guidelines for safe recreational water environments

Grade = 95th percentile value of intestinal enterococci/100 ml (rounded values)		
Grade	**Basis of derivation**	**Estimated risk**
A **≤40**	This range is below the NOAEL in most epidemiological studies.	**<1% GI illness risk** **<0.3% AFRI risk** The upper 95th percentile value of 40/100 ml relates to an average probability of less than one case of gastroenteritis in every 100 exposures. The AFRI burden would be negligible.
B **41–200**	The 200/100 ml value is above the threshold of illness transmission reported in most epidemiological studies that have attempted to define a NOAEL or LOAEL for GI illness and AFRI.	**1–<5% GI illness risk** **0.3–<1.9% AFRI illness risk** The upper 95th percentile value of 200/100 ml relates to an average probability of one case of gastroenteritis in 20 exposures. The AFRI illness rate at this upper value would be less than 19 per 1000 exposures, or less than approximately 1 in 50 exposures.
C **201–500**	This range represents a substantial elevation in the probability of all adverse health outcomes for which dose–response data are available.	**5–10% GI illness risk** **1.9–3.9% AFRI illness risk** This range of 95th percentiles represents a probability of 1 in 10 to 1 in 20 of gastroenteritis for a single exposure. Exposures in this category also suggest a risk of AFRI in the range of 19–39 per 1000 exposures, or a range of approximately 1 in 50 to 1 in 25 exposures.
D **>500**	Above this level, there may be a significant risk of high levels of minor illness transmission.	**>10% GI illness risk** **>3.9% AFRI illness rate** There is a greater than 10% chance of gastroenteritis per single exposure. The AFRI illness rate at the 95th percentile point of >500/100 ml would be greater than 39 per 1000 exposures, or greater than approximately 1 in 25 exposures.

The new EU microbiological criteria are outlined in Table 4.

Inland Waters			
Parameter	**Excellent**	**Good**	**Sufficient**
intestinal enterococci/100ml	200*	400*	330**
E. coli 100ml^{-1}	500*	1000*	900**
Coastal and Transitional Waters			
intestinal enterococci/100ml	100*	200*	185**
E. coli/100ml	250*	500*	500**
* Based on a 95th percentile ** Based on a 90th percentile			

Table 4 Microbiological criteria outlined in the EU Bathing Water Directive published in 2006

There is some correspondence between the evidence-base used to derive the EU criteria and the WHO guidelines. For example, the EU ‘Good’ enterococci category for marine waters is equivalent to the WHO grade ‘B’. However, the derivation of the *E. coli* standards is not as transparent. Perhaps most surprising, is the implication of lower risks attributable to recreation in fresh waters than marine environments (i.e. by the higher allowed faecal indicator concentrations in fresh recreational waters). This might be the case if, for example, a given indicator concentration in fresh waters was generally associated with lower pathogen presence than experienced in marine systems. However, this assumption seems counter intuitive because freshwaters generally present less dilution of sewage effluents than would be experienced in marine environments. In the very few UK reports where viruses (generally enterovirus) and faecal indicators have been measured, higher incidence of viruses for a given indicator concentration have been found in fresh recreational water systems, which would imply that tighter, rather than less stringent, faecal indicator standards would be required for fresh recreational waters, i.e. if equivalent health protection was required in fresh and marine systems.

The terminology of the new EU microbiological criteria is also somewhat surprising, specifically the introduction of the ‘Sufficient’ standards. This is defined by a 90th percentile value not the 95th percentile, which is used by WHO (2003) and the CEC for the ‘Excellent’ and ‘Good’ classifications (CEC, 2006). This produces a lower numerical value in the published table, which might appear more ‘palatable’ to a lay audience but the rationale for the introduction of this new term into the 2006 Bathing Water Directive is unclear. Unlike the WHO Guidelines there is always a significant political dimension to EU Directives. Whilst such a dimension is inevitable in the development of standards that have statutory force, it is unfortunate and undesirable that the reasons remain obscure, even if they are a result of a political compromise. However, Article 14 of the 2006 Bathing Water Directive does outline a schedule for a review of the standards. This will take place in 2008, following EU sponsored research studies and could provide a timely opportunity to address some of these apparent inconsistencies.

8 Real time management and prediction

The final policy challenge deriving from the WHO Guidelines and carried forward to the 2006 Bathing Water Directive is the incorporation of a practical management system for bathing waters that takes into account what actually happens in bathing waters and allows a more effective and flexible approach to regulating and management. This sets out the potential for real-time prediction of microbiological water quality to inform appropriate public 'advisory' notices when bathing water quality may be 'impaired' due to pollution reaching rivers and coastal waters by runoff from land following rainfall. The WHO rationale for such management is based on the fact that beach classification at the end of a bathing season when statistical calculations are conducted to define a numerical 'compliance' threshold is ineffective in protecting public health. The fact that relatively simple statistical models, using rainfall and river flow, seem able to predict poor microbiological quality at many beaches offers the potential to protect human health by real time prediction. Electronic signs have been trialled at a number of Scottish beaches. Parallel work on model development has been completed, as part of an EU funded project, managed by the North West Region of the Environment Agency. Such an approach recognises that protecting public health is actually more important than meeting arbitrary values that may be exceeded under conditions which are largely outside of the control of environmental managers.

In regulatory terms, the most important aspect of this policy development is that an EU member state can discount up to 15% of samples from those collected at a beach if an appropriate management system was deployed to warn the public of impaired water quality. This is the basis of the Scottish trial with electronic notice boards that provide information on the predicted state of the water at a particular beach, allowing bathers to make their own decisions as to their chosen activities. In the Defra regulatory impact assessment of an early draft of the new Bathing Water Directive the value of a discounting approach was summarised as follows:

Although precise details have still to be considered the active management/discounting approach ……… shows considerable potential for reducing costs and maintaining benefits. The additional costs of operating such a system cannot be calculated until its details are elaborated but they are likely to be insignificant compared to the potential savings in costs. (Anon, 2002b)

In summary, the policy context of bathing water management is:

i. new health based and tighter standards in a new Bathing Water Directive which define '*good*' water quality as broadly equivalent to the existing Directive '*Guide*' level (these standards will be reviewed in 2008 in light of any new epidemiological information derived from new studies now underway in Hungary and Spain using the UK protocol;
ii. a requirement on the UK regulators, to achieve these health-evidence-based standards through integrated catchment management of both point and diffuse sources of faecal indicator fluxes within the requirements of the Water Framework Directive;
iii. the potential public health and expenditure benefits of implementing 'real-time' water quality prediction and the resultant 'beach management', at

appropriate sites with signs to facilitate ‘advisories’ which could be administered by the Environment Regulators and/or local authorities.

The policy also reflects the fact that there is currently no suitable system available to determine the dynamics of faecal indicators at a catchment scale to underpin the design of appropriate on-farm ‘field-scale’ remedial measures for controlling diffuse sources of microbial contaminants. It is, therefore, highly practical. Until such future time as this level of catchment control is possible then the policy provides for protection of public health, while not being so onerous as to close many otherwise excellent bathing beaches where microbiological pollution is episodically associated with rainfall that causes runoff from livestock farming areas.

9 Chemical contaminants

There are no formal standards for chemical contaminants in marine or fresh recreational waters and the potential risks from most chemical contaminants are insignificant compared to the risks from pathogens. WHO has considered the issues regarding chemicals (WHO 2003) and the key point is that the amount of water ingested is very small and only extremely polluted water would be of any concern. It is also the case that the great majority of chemical contaminants only cause toxicity after long periods of exposure and, for recreational water users, the exposure is intermittent with generally very small water volumes ingested or absorbed through the skin.

The substances that can be of concern are natural toxins produced by phytoplankton present in both marine and fresh waters. See the publication in the footnote to section 2. These algae are always present and generally pose no risk but they are capable of rapid growth forming blooms in which there are massive numbers of these organisms and it is this circumstance that is of concern. The algae that are most commonly associated with risks to recreational users in freshwaters are the cyanobacteria. This is a diverse group of organisms that can produce a range of substances that are known to be toxic. However, in general the presence of blooms is easily detectable by the naked eye and can be avoided. In marine waters, dermal contact with a number of species of cyanobacteria can give rise to problems for swimmers and bathers. For example *Lyngbia majuscule,* which grows on rocks and seaweeds in tropical waters, is a contact irritant and fragments suspended in the water, usually after storms, can give rise to irritation and itching of skin, eyes and respiratory tract. This is particularly pronounced if trapped against the skin under equipment such as bathing suits. Skin irritation may result from a number of other marine cyanobacteria but information is limited. As conditions change in sub-tropical and temperate waters, due to climate change, it is conceivable that such problems will become more widespread and more attention will be warranted by authorities responsible for coastal and estuarine bathing waters. However, the move to a system of warning when water quality is unsuitable will also be of benefit in managing any such problems.

Other cyanobacteria that are found in estuarine waters form dense blooms that form scums on the surface. *Nodularia spumigena* is one such species that can produce a liver toxin called nodularin. Ingestion of the scums or water containing very high densities of organisms has been known to cause severe toxicity, or even death, in some stock and dogs but there have been no reports of toxicity in humans, primarily because humans would tend to avoid such waters and would be careful not to ingest large amounts of such water.

A number of marine dinoflagellates can also form blooms and these can also produce toxins, effects on humans are primarily associated with the consumption of shellfish that have been ingesting the organisms by filter feeding.

Cyanobacteria in fresh water are known to form blooms quite frequently and for some waters these are a common feature. These blooms occur in some still or slow flowing waters, which are usually nutrient rich, during periods of fairly still or stable weather and when the blooms form a surface scum this can drift into the shore under the influence of even relatively light winds. A range of species are capable of producing toxins that can cause toxicity to the liver or the nervous system. Examples of the former are the microcystins of which there is a large number of congeners, nodularin and cylindrospermopsin, while examples of the latter are anatoxin-a, anatoxin-a(s) and saxitoxin. These compounds are highly toxic by ingestion but as indicated above the risks of ingestion in recreational waters are much lower than drinking water because ingestion is accidental and the amount ingested is small. The hazard is also easily avoided by posting warnings of the presence of potentially toxic cyanobacteria in large numbers in a particular water body. Appropriate safe practices in managing recreational waters have been proposed (WHO 2003 and Chorus and Bartram 1999). These indicate that for high contact recreational users, a concentration of 20,000 cyanobacterial cells per ml (or 10 µg/litre of chlorophyll *a* under conditions of cyanobacterial dominance) has a low probability of health effects, 100,000 cyanobacterial cells per ml (or 50 µg/litre of chlorophyll *a* with a dominance of cyanobacteria) poses a moderate probability of adverse effects, and contact with scums constitutes a high risk of health effects following ingestion or aspiration.

The National Rivers Authority (1990) in the UK investigated the problems associated with toxic algae and equated the potential risks to recreational users with the extent of contact with the water containing blooms of cyanobacteria. High risk activities were paddling (particularly small children who may fall), swimming, diving, sail-boarding, water-skiing, medium risk were canoeing, sailing (small boats that can easily capsize), rowing and general public amenity (primarily related to access by dogs) and low risk activities included fishing and pleasure cruising.

In view of the above discussion it is clear that the situation involving toxic algae is complex and the scientific basis for specific standards is not strong. In view of the ease of management the need for standards seems to be limited.

10 Conclusions

1. Historical microbiological standards for recreational waters in both North America and Europe are not based on robust epidemiological information i.e. they cannot be considered health-evidence-based.
2. The WHO Guidelines for Safe Recreational Water Environments were based on UK epidemiology and offer a methodology for standards derivation which seeks to limit health risk to clearly defined levels.
3. The scientific basis of the WHO criteria is however very narrow and further work outside temperate northern Europe is urgently needed.
4. This work is underway in the United States of America and Europe.
5. The new microbiological criteria for marine waters outlined in the 2006 Bathing Water Directive are, in part, based on the WHO criteria, but derivation of the freshwater standards in the Directive seems somewhat counter-intuitive. Furthermore, the 'Sufficient' standard lacks internal consistency with the other criteria because of the percentile value employed (i.e. the 90th percentile not the 95th percentile used for Excellent and Good criteria) and the move away from the word 'Good' to define the legally required compliance level runs counter to the ethos of the Water Framework Directive and its other daughter Directives.
6. Real time management of risk, through prediction of bathing water quality, has been suggested by WHO in their 2003 Guidelines and is accommodated in the new 2006 Bathing Water Directive. Prototype systems, using electronic signs, are deployed in Scotland and this approach offers considerable scope particularly where microbiological pollution is episodically associated with rainfall causing runoff from livestock farming areas.
7. There is a review of the 2006 Bathing Water Directive criteria scheduled for 2008 and this may offer opportunity to accommodate new scientific information and reconsider apparent inconsistencies.
8. North American research has suggested the potential of molecular methods for the rapid enumeration of faecal indicators in recreational waters. It has been further suggested that these methods are predictive of health effects. This area is worthy of further investigation in Europe.
9. Achievement of microbiological criteria at identified bathing waters in Europe is to be accomplished through implementation of the Water Framework Directive. It is surprising, therefore, that so little attention has been given to date to the general area of catchment microbial dynamics or water quality by the UK Technical Advisory Group addressing implementation of the Water Framework Directive. Rectification of this policy and scientific omission is likely to become urgent as the implications of the new Directive standards become apparent.
10. Chemicals in natural bathing waters are much less of a consideration than pathogens but the toxins produced by some algae are of significant concern when there are large blooms, particularly in slow-flowing or still fresh water. Although these are not specifically considered in standards, they should be covered by management procedures and warnings.

11 References

Cabelli, V.J., Dufour, A.P., McCabe, L.J. and Levin, M.A. (1982) Swimming-Associated Gastroenteritis and Water-Quality. *American Journal of Epidemiology 115(4)*, 606-616.

CEC (1976) Council of the European Communities. Council Directive 76/160/EEC of 8 December 1975 concerning the quality of bathing water. *Official Journal of the European Communities L31*, 1-7.

CEC (2000) Council of the European Communities. Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy. *Official Journal of the European Communities L327*, 1-72.

CEC (2006) Directive 2006/7/EC of the European Parliament and of the Council of 15th February 2006 concerning the management of bathing water quality and repealing Directive 76/160/EEC. . *Official Journal of the European Communities L64*, 37-51.

Chorus, I., and Bartram, J. (Eds) (1999) Toxic cyanobacteria in water. A guide to their public health consequences, monitoring and management. Published by E & FN Spon on behalf of the World Health Organization.

Crowther, J., Kay, D. and Wyer, M.D. (2001) Relationships between microbial water quality and environmental conditions in coastal recreational water: the Fylde coast, UK. *Water Research 35*, 4029-4038.

Kay, D., Bartram, J., Pruss, A., Ashbolt, N., Wyer, M.D., Fleisher, J.M., Fewtrell, L., Rogers, A. and Rees, G. (2004) Derivation of numerical values for the World Health Organization guidelines for recreational waters. *Water Research 38(5*), 1296-1304.

Kay, D., Fleisher, J.M., Salmon, R.L., Jones, F., Wyer, M.D., Godfree, A.F., Zelenauch-Jacquotte, Z. and Shore, R. (1994) Predicting the likelihood of gastroenteritis from sea bathing - Results from randomized exposure. *The Lancet 344(8927*), 905-909.

McPhail, C. and Stidson, R. (2004) The Scottish Signage Project. *Water and Environment Magazine 9(4*), 12-14.

National Rivers Authority (1990) Toxic blue-green algae. The report of the National Rivers Authority, Water Quality Series No2.

NTAC (1968) *Water Quality Criteria*. National Technical Advisory Committee, Federal Water Pollution Administration, Department of the Interior, Washington, DC.

PHLS (1959) Sewage contamination of coastal bathing waters in England and Wales: a bacteriological and epidemiological study. *Journal of Hygiene Cambridge 574*, 435-472.

Stevenson, A.H. (1953) Studies of bathing water quality and health. *American Journal of Public Health 43*, 529-538.

USEPA (1986) *Ambient water quality criteria for bacteria*, United States environment Protection Agency, Washington DC

WHO (2003) *Guidelines for safe recreational water environments Volume 1: Coastal and freshwaters*, 219, World Health Organization,, Geneva.

Wiedenmann, A., Krüger, P., Dietz, K., López-Pila, J., Regine Szewzyk and Botzenhart, K. (2006) A randomized controlled trial assessing infectious disease risks from bathing in fresh recreational waters in relation to the concentration of Escherichia coli, intestinal enterococci, Clostridium perfringens and somatic coliphages. *Environmental Health Perspectives 8115*, 1-41.

Wyer, M.D., Kay, D., Fleisher, J., Jackson, G. and Fewtrell, L. (1999) An experimental health-based standard system for marine waters. *Water Research 33(3*), 715-722.