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Guidelines: the current position

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The setting of guidelines is a key normative function of the World Health Organization. This chapter examines the development of the current water-related WHO guidelines. Within the area of water, microbiology and guideline setting there are three distinct but related areas, namely:

- drinking water;
- wastewater reuse; and
- recreational water.

The following explores the background to the current guidelines, highlighting the different pathways to their formation.

2.1 INTRODUCTION

The aim of the water-related WHO guidelines is the protection of public health. They are intended to be used as the basis for the development of national standards and as such the values recommended are not mandatory limits, but are designed to be used in the development of risk management strategies which may include national or regional standards in the context of local or national environmental, social, economic and cultural conditions. The main reason for not promoting the adoption of international standards is the advantage provided by the use of a risk-benefit approach to the establishment of specific national standards or regulations. This approach is thought to promote the adoption of standards that can be readily implemented and enforced and should ensure the use of available financial, technical and institutional resources for maximum public benefit.

2.2 GUIDELINES FOR DRINKING-WATER QUALITY

The WHO Guidelines for Drinking-Water Quality (GDWQ) have a long history and were among the first environmental health documents published by the Organization. The first WHO publication dealing specifically with drinking-water quality was published in 1958 as International Standards for Drinking-Water. It was subsequently revised in 1963 and 1971 under the same title. To encourage countries of advanced economic and technological capabilities in Europe to attain higher standards, and to address hazards related to industrial development and intensive agriculture, the European Standards for Drinking-Water Quality were published in 1961 and revised in 1970. In the mid-1980s the first edition of the WHO guidelines for Drinking-Water Quality was published in three volumes:

- Volume 1: Recommendations
- Volume 2: Health criteria and other supporting information
- Volume 3: Surveillance and control of community water supplies.

The second editions of the three volumes were published in 1993, 1996 and 1997 respectively. In 1995, a co-ordinating committee decided that the GDWQ would be subject to rolling revision, and three working groups were established to address microbiological aspects, chemical aspects and aspects of protection and control of drinking water quality.

As with all the water-related guidelines the primary aim of the GDWQ is the protection of human health, and to serve as a basis for development of national water quality standards. The guideline values recommended for individual constituents are not mandatory limits but if they are properly implemented in light of local circumstances will ensure the safety of drinking water supplies through the elimination, or reduction to a minimum concentration, of constituents of water that are known to be hazardous to health.

The GDWQ cover chemical and physical aspects of water quality as well as the microbiological aspects which are the focus of this publication. Within the GDWQ it is emphasised that the control of microbiological contamination is of paramount importance and must never be compromised. Likewise, it is stated that disinfection should not be compromised in attempting to control chemical by-products.

Chemical, physical and radiological contaminants are extensively covered by critical review and summary risk assessment documents published by international bodies such as the International Programme on Chemical Safety (IPCS), the International Agency for Research on Cancer (IARC), Joint FAO/WHO Meetings on Pesticide Residues (JMPR) and Joint FAO/WHO Expert Consultation on Food Additives (JECFA). These documents are mainly based on animal studies. For most chemicals, the risk assessment results in the derivation of a threshold dose below which no adverse effects are assumed to occur. This value is the basis for a Tolerable Daily Intake (TDI), which can be converted into a guideline value for a maximum allowable concentration in drinking water using a series of assumptions and uncertainty factors. For genotoxic carcinogens a threshold value is not assumed to exist, and the guideline value is based on extrapolation of the animal dose–response data to the low dose region typically occurring through drinking water exposure. Concentrations associated with an excess lifetime cancer risk of 10^{-5} are presented as guideline values. For both types of chemical substances, with and without threshold values, the guidelines take the form of end-product standards, which can be evaluated by chemical analysis of the finished water or the water at the point of consumption. However, guideline values are not set at concentrations lower than the detection limits achievable under routine laboratory operating conditions and are recommended only when control techniques are available to remove or reduce the concentration of the contaminant to the desired level.

Microbiological risks are treated very differently. In Volume 2, reviews are available of the characteristics of many different pathogenic micro-organisms, and an Addendum covering new information on a number of important pathogens is in preparation (Table 2.1).

Table 2.1. Pathogens reviewed in GDWQ (Volume 2, 1996 and Addendum, in preparation)

Bacteria	Viruses	Protozoa and Helminths
Salmonella	Picornaviruses (inc. Hep A)	*Giardia*
Yersinia	Adenoviruses	*Cryptosporidium*
Campylobacter	Parvoviruses	*Entamoeba histolytica*
Vibrio cholera	Small round structured viruses	*Balantidium coli*
Shigella	Hepatitis E virus	*Naegleria + Acanthamoeba*
Legionella	Papovaviruses	*Dracunculus medinensis*
Aeromonas		*Schistosoma*
Ps. Aeruginosa		*Cyclospora cayatenensis*
Mycobacterium		
Cyanobacterial toxins		

However, the information on pathogens is barely used in the derivation of guidelines for the production of safe drinking water. Instead, the guidelines are based on tried and tested principles of prevention of faecal pollution and good engineering practice. This approach results in end product standards for faecal indicator organisms and operational guidelines for source water protection and adequate treatment. These aspects are complementary but only loosely connected.

2.2.1 Faecal indicator organisms

The rationale for using faecal indicator organisms as the basis for microbiological criteria is stated as follows:

It is difficult with the epidemiological knowledge currently available to assess the risk to health presented by any particular level of pathogens in water, since this risk will depend equally on the infectivity and invasiveness of the pathogen and on the innate and acquired immunity of the individuals consuming the water. It is only prudent to assume, therefore, that no water in which pathogenic micro-organisms can be detected can be regarded as safe, however low the concentration. Furthermore, only certain waterborne pathogens can be detected reliably and easily in water, and some cannot be detected at all. (WHO 1996 p. 93)

Escherichia coli and to a lesser extent thermotolerant coliform bacteria are considered to best fulfil the criteria to be satisfied by an ideal indicator. These are:

- universally present in large numbers in the faeces of humans and warm-blooded animals;
- readily detected by simple methods;
- do not grow in natural waters; and
- persistence in water and removal by water treatment similar to waterborne pathogens.

It is recommended that when resources are scarce it is more important to examine drinking-water frequently by means of a simple test than less often by several tests or a more complicated one. Hence, the recommendations are mainly based on the level of *Escherichia coli* (or thermotolerant coliform organisms). Basically, the criterion is that *E. coli* must not be detectable in any 100 millilitre (ml) sample. For treated water entering, or in, the distribution system the same recommendation is also given for total coliform bacteria, with a provision for up to 5% positive samples within the distribution system. The rationale for this additional criterion is the greater sensitivity of total coliforms for detecting irregularities (not necessarily faecal contamination) in treatment and distribution. The concept of indicators is covered in detail in Chapter 13.

In many developing countries, high quality water meeting the *E. coli* criterion is not readily available, and uncritical enforcement of the guideline may lead to condemnation of water sources that may be more appropriate or more accessible than other sources, and may even force people to obtain their water from more polluted sources. Under conditions of widespread faecal contamination, national surveillance agencies are recommended to set intermediate goals that will eventually lead to the provision of high quality water to all, but will not lead to improper condemnation of relatively acceptable supplies (this is expanded upon in Volume 3 of the GDWQ).

2.2.2 Operational guidelines

The GDWQ do not specify quantitative criteria for virus concentrations in drinking water. Estimates of health risks linked to the consumption of contaminated drinking-water are not considered sufficiently developed to do so, and the difficulties and expense related to monitoring viruses in drinking water preclude their practical application. Similar considerations preclude the setting of guideline values for pathogenic protozoa, helminths and free-living (parasitic) organisms. Instead, the importance of appropriate source water protection and treatment related to the source water quality are emphasised. Recommended treatment schemes include disinfection only for protected deep wells and protected, impounded upland waters. For unprotected wells and impounded water or upland rivers, additional filtration is recommended and more extensive storage and treatment schemes are recommended for unprotected watersheds. Different treatment processes are described in Volume 2 (WHO 1996) in some detail. Performance objectives for typical treatment chains are also outlined, including, for example, the recommendation that turbidity should not exceed 1 Nephelometric Turbidity Unit (NTU) under average loading conditions, and 5 NTU under maximum loading.

The experience gained in surveillance and improvement of small-community supplies through a series of WHO-supported and other demonstration projects is reflected in Volume 3 (WHO 1997). This gives detailed guidance on all aspects of planning and executing surveillance programmes, emphasising the importance of sanitary inspection as an adjunct to water quality analysis. There is also guidance on technical interventions to improve water quality by source protection, by affordable treatment and disinfection and by household water treatment and storage.

2.3 SAFE USE OF WASTEWATER AND EXCRETA IN AGRICULTURE AND AQUACULTURE

All around the world, people both in rural and urban areas have been using human excreta for centuries to fertilise fields and fishponds and to maintain the soil organic fraction. Use of faecal sludge in both agriculture and aquaculture continues to be common in China and south-east Asia as well as in various African countries. In the majority of cases, the faecal sludge collected from septic tanks and unsewered family and public toilets is applied untreated or only partially treated through storage.

Where water-borne excreta disposal (sewerage) was put in place, the use of the wastewater in agriculture became rapidly established, particularly in arid and seasonally arid zones. Wastewater is used as a source of irrigation water as well as a source of plant nutrients, allowing farmers to reduce or even eliminate the purchase of chemical fertiliser. Recent wastewater use practices range from the piped distribution of secondary treated wastewater (i.e. mechanical and biological treatment) to peri-urban citrus fruit farms (e.g. the city of Tunis) to farmers illegally accessing and breaking up buried trunk sewers from which raw wastewater is diverted to vegetable fields (e.g. the city of Lima). Agricultural reuse of wastewater is practised throughout South America and in Mexico and is also widespread in Northern Africa, Southern Europe, Western Asia, on the Arabian Peninsular, in South Asia and in the US. Vegetable, fodder and non-food crops as well as green belt areas and golf courses are being irrigated. In a few countries (such as the US and Saudi Arabia) wastewater is subjected to advanced treatment (secondary treatment, filtration and disinfection) prior to use.

The use of human wastes contributes significantly to food production and income generation, notably so in the fast-growing urban fringes of developing countries. Yet, where the waste is used untreated or health protection measures other than treatment are not in place, such practice contributes to the 'recycling' of excreted pathogens among the urban/peri-urban populace. Farmers and their families making use of untreated faecal sludge or wastewater, as well as consumers, are exposed to high risks of disease transmission.

2.3.1 History of wastewater reuse guideline development

The wastewater reuse guidelines enacted in California in 1918 may have been the first ones of their kind. They were modified and expanded and now stipulate a total coliform (TC) quality standard of 2.2/100 ml (seven-day median) for wastewater used to irrigate vegetable crops eaten uncooked (State of California 1978). This essentially means that faecal contamination should be absent and there should be no potential risk of infection present (although low coliform levels do not necessarily equate to low pathogen levels). The level of 2.2 TC/100ml is virtually the same as the standard expected for drinking water quality and was based on a 'zero risk' concept. The standard set for the irrigation of pastures grazed by milking animals and of landscape areas with limited public access is also quite restrictive, and amounts to 23 total coliforms/100 ml. Such levels were thought to be required to guarantee that residual irrigation water attached to vegetables at the time of harvest would not exceed drinking water quality limits. However, vegetables bought on open markets that are grown with rainwater or freshwater (which is often overtly or covertly polluted with raw or partially treated wastewater) may exhibit faecal indicator counts much higher than this. The Californian standards were influential in the formulation of national reuse guidelines by the US Environmental Protection Agency (US EPA/USID 1992), which are designed to guide individual US states in the formulation of their own reuse regulations. They also influence countries which export wastewater-irrigated produce to the US, as the exporting country is under some pressure to meet the water quality standards of the US.

The formulation of the 'California' standards was strongly influenced by the wastewater treatment technologies in use in industrialised countries at the time. This comprised secondary treatment (activated sludge or trickling filter plants) for the removal of organic contaminants, followed by chlorination for removal of bacteria. Such technology can result in very low coliform levels, especially if heavy chlorination is used, allowing the standard to be achievable. Coliforms, as indicators of faecal bacteria, were the only microbiological criterion used (Hespanhol 1990).

California-type standards were adopted in a number of countries including developing countries, as this constituted the only guidance available at the time. However, the very strict coliform levels were not achievable in developing countries due to the lack of economic resources and skills to implement and operate the rather sophisticated treatment technology in use, or thought to be available, at the time. Hence, standards in these countries existed on paper only and were not enforced. Although the standards set by the State of California had limited applicability on a worldwide scale, they were probably instrumental in enhancing the acceptance of wastewater reuse among planners, engineers, health authorities, and the public in industrialised countries.

WHO published wastewater reuse guidelines for the first time in 1973 (WHO 1973). The group drafting the guidelines felt that to apply drinking water-type standards (2.2 coliforms/100 ml) for wastewater reuse was unrealistic and lacked an epidemiological basis. Moreover, recognition was given to the fact that few rivers worldwide used for irrigation carry water approaching such quality. The group was further convinced that few, if any, developing countries could meet such standards for reused wastewater. As a result of these deliberations, a guideline value of 100 coliforms/100 ml for unrestricted irrigation was set. The guidelines also made recommendations on treatment, suggesting secondary treatment (such as activated sludge, trickling filtration or waste stabilisation ponds (WSP)) followed by chlorination or filtration and chlorination. However, the implementation of such wastewater treatment technologies (with the exception of WSP) remained unattainable for most developing countries and, in some circumstances, this led to authorities tolerating the indirect reuse of untreated wastewater. Indirect reuse being the abstraction of water for irrigation from a water body containing wastewater (the quality of which may vary markedly as dilution depends on the seasonal flow regime in the receiving water body).

In the past two decades, recycling of urban wastewater for agricultural use has been receiving increasing attention from decision makers, planners and external support agencies, largely as a result of the rapid dwindling of easily accessible freshwater sources (groundwater in particular) and the consequent sharp rise in cost of procuring irrigation water. Reduction in environmental pollution caused by wastewater disposal was seen as a benefit from the recycling of human waste. With this change of paradigm in (urban) water resources management, a renewed need for informed guidance on health protection arose. As a result, WHO, United Nations Development Programme (UNDP), the World Bank, United Nations Environment Programme (UNEP), Food and Agriculture Organisation (FAO), and bilateral support agencies commissioned reviews of credible epidemiological literature related to the health effects of excreta and wastewater use in agriculture and aquaculture. The results are documented in Blum and Feachem (1985) and in Shuval *et al*. (1986). The above stakeholders, with the aid of independent academic institutions and experienced scientists, aimed to develop a rational basis for the formulation of updated health guidelines in wastewater reuse, which would be applicable in many different settings, i.e. in economically less developed as well as in industrialised countries. Reviews of the relationships between health, excreted infections and measures in environmental sanitation (Feachem *et al*. 1983), on survival of excreted pathogens on soils and crops (Strauss 1985) were conducted at the same time.

Earlier regulatory thinking was guided largely by knowledge of pathogen detection and survival in wastewater and on irrigated soils and crops, i.e. by what constitutes the so-called potential risk. In the light of the reviews undertaken, it was concluded that potential risk should not, alone, automatically be interpreted as constituting a serious public health threat. This can be estimated only by determining actual risks, which are a result of a series of complex interactions between different factors (Figure 2.1), and which can be measured using epidemiological studies.

A relative ranking of health risks from the use of untreated excreta and wastewater was determined from the review of epidemiological studies (Shuval *et al*. 1986). Use of untreated or improperly treated waste was judged to lead to:

- a high relative excess frequency of intestinal nematode infection;
- a lower relative excess frequency of bacterial infections; and
- a relatively small excess frequency for viruses.

For viruses, direct (i.e. person-to-person) transmission is the predominant route and immunity is developed at an early age in endemic areas. The excess frequency for trematodes (e.g. *Schistosoma*) and cestodes (e.g. tapeworms) vary from high to nil, according to the particular excreta use practice and local circumstances. A major factor determining the relative ranking is pathogen survival on soil and crops. Figure 2.2 (derived from Feachem *et al*. 1983 and Strauss 1985) shows this for selected excreted pathogens. Pathogen die-off following the spreading of wastewater or faecal sludge on agricultural land acts as an important barrier against further transmission, and results in a diminished risk of infection for both farmers and consumers.

Figure 2.1. Pathogen–host properties influencing the sequence of events between the presence of a pathogen in excreta and measurable human disease attributable to excreta or wastewater reuse (Blum and Feachem 1985; reproduced by permission of the International Reference Centre for Waste Disposal).

Waste stabilisation ponds had, meanwhile, been proven to be a low-cost, sustainable method of wastewater treatment, particularly suited to the socio-economic and climatic conditions prevailing in many developing countries. Well-designed and operated WSP schemes, comprising both facultative ponds (to remove organic contaminants) and maturation ponds (to inactivate pathogenic micro-organisms), can reliably remove helminth eggs and consistently achieve faecal coliform effluent levels of <1000/100 ml. No input of external energy or disinfectants is, therefore, needed. This means that the production of effluent that is likely to satisfy reasonable quality standards has become within the reach of developing countries.

Representatives from UN agencies, including the World Bank, and various research institutions convened in 1985 (IRCWD 1985) and in 1987 to discuss and propose a new paradigm to quantify the health impacts of human waste utilisation. The meetings recommended the formulation of new guidelines for the reuse of human waste. A document was produced, pertaining to both wastewater and excreta use and also addressing the planning aspects of waste utilisation schemes (Mara and Cairncross 1989). The meetings resulted in the formation of a WHO Scientific Group, which was mandated to recommend revised wastewater reuse guidelines. WHO published the current guidelines in 1989 (WHO 1989).

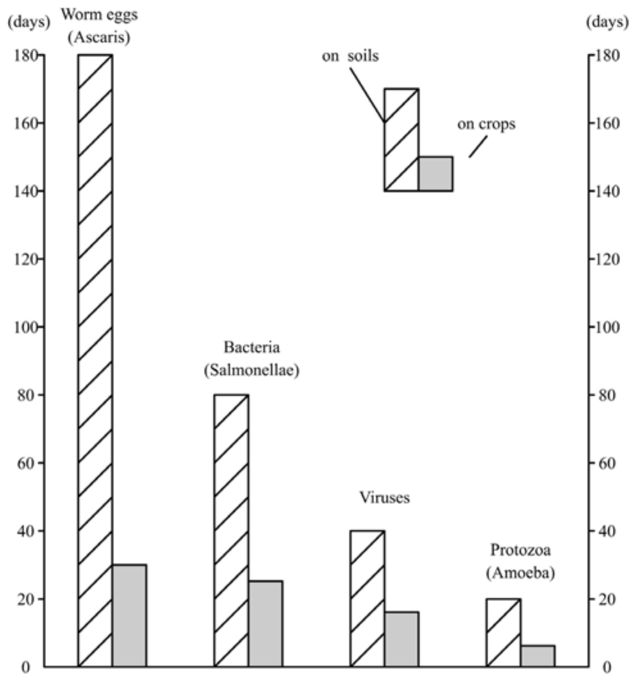

Figure 2.2. Survival of excreted pathogens on soils and crops in a warm climate.

2.3.2 How the current WHO (1989) guidelines were derived

The purpose of the guidelines was to guide design engineers and planners in the choice of waste treatment technologies and waste management options. The guideline levels were derived from the results of the available epidemiological studies of wastewater use, along with a consideration of what was achievable by wastewater treatment processes. A great deal of evidence was available on the risk of exposure to raw wastewater and excreta, and on the risks to farm workers and populations living nearby spray-irrigated areas of use of partially-treated wastewater (Shuval *et al*. 1986). However, there was less evidence of the effect of use of treated wastewater, particularly in relation to consumption of vegetable crops. Where epidemiological evidence was not sufficient to allow the definition of a level (microbiological quality) at which no excess risk of infection would occur, data on pathogen removal by wastewater treatment processes and pathogen die-off in the field, and prevailing guidelines for water quality were taken into account.

The recommended microbiological quality guidelines are shown in Table 2.2.

Table 2.2. Recommended microbiological quality guidelines for wastewater use in agriculture[a] (WHO 1989)

Cat.	Reuse conditions	Exposed group	Intestinal nematodes[b] (/litre*[c])	Faecal coliforms (/100ml**[c])	Wastewater treatment expected to achieve required quality
A	Irrigation of crops likely to be eaten uncooked, sports fields, public parks[d]	Workers, consumers, public	≤1	≤1000	A series of stabilisation ponds designed to achieve the microbiological quality indicated, or equivalent treatment
B	Irrigation of cereal crops, industrial crops, fodder crops, pasture and trees[e]	Workers	≤1	None set	Retention in stabilisation ponds for 8-10 days or equivalent helminth removal
C	Localised irrigation of crops if category B exposure of workers and the public does not occur	None	n/a	n/a	Pre-treatment as required by the irrigation technology, but not less than primary sedimentation

[a] In specific cases, local epidemiological, sociocultural and environmental factors should be taken into account, and the guidelines modified accordingly
[b] *Ascaris* and *Trichuris* species and hookworms
[c] During the irrigation period
[d] A more stringent guideline (≤200 faecal coliforms/100ml) is appropriate for public lawns with which the public may come into direct contact
[e] In the case of fruit trees, irrigation should cease two weeks before the fruit is picked and none should be picked off the ground
* Arithmetic mean
** Geometric mean

An intestinal nematode egg guideline was introduced for both unrestricted (category A) and restricted (category B) irrigation because epidemiological evidence showed a significant excess of intestinal nematode (*Ascaris*, *Trichuris*, hookworm) infections in farm workers and consumers of vegetable crops irrigated with untreated wastewater. A high degree of helminth removal was therefore proposed, especially as there were some data indicating that rates of infection were very low when treatment of wastewater occurred. The level was set at ≤1 egg per litre, equivalent to a removal efficiency of up to 99.9% (3 log removal). This level is achievable by waste stabilisation pond treatment (with a retention time of 8–10 days) or equivalent treatment options. The intestinal nematode egg guideline was also meant to serve as an indicator for other pathogens, such as helminth eggs and protozoan cysts.

A bacterial guideline of ≤1000 faecal coliforms (FC) per 100ml (geometric mean) was recommended for unrestricted irrigation (category A). Epidemiological evidence, particularly from outbreaks, indicated the transmission of bacterial infections such as cholera and typhoid through use of untreated wastewater. It was thought that transmission was less likely to occur through treated wastewater, considering the degree of bacterial removal achievable through treatment and the relatively high infectious dose for some bacterial infections. Data on pathogen removal from well-designed waste stabilisation ponds showed that at an effluent concentration of 1000 FC/100ml (reflecting >99.99% removal) bacterial pathogens were absent and viruses were at very low levels (Bartone *et al*. 1985; Oragui *et al*. 1987; Polpraset *et al*. 1983). Natural die-off of pathogens in the field, amounting to 90–99% reduction over a few days, represented an additional safety factor that was taken into consideration when formulating the guidelines. In addition, the level set was similar to guidelines for irrigation water quality and bathing water quality adopted in industrialised countries. These were 1000 FC/100ml for unrestricted irrigation with surface water promulgated by the US EPA (US EPA 1973) and 2000 FC/100ml for bathing water stipulated by the EU (CEC 1976). No bacterial guideline was recommended for restricted irrigation (category B) as there was no epidemiological evidence for the transmission of bacterial infections to farm workers when wastewater was partially treated.

Health protection measures were also considered. They included:

- crop selection
- wastewater application measures
- human exposure control.

These are management practices, the aim of which is to reduce exposure to infectious agents. The concept was based on the principle of interrupting the flow of pathogens from the wastewater to the exposed worker or consumer, and the measures described act as barriers to pathogen flow whereas the use of treatment achieves removal of the pathogens. In this way, crop restrictions would reduce consumers' exposure to contaminated raw vegetables, wastewater application through drip irrigation would reduce contamination of low-growing crops and farm worker exposure, and wearing protective clothing would reduce the risk for farm workers. Integration of these measures and adoption of a combination of several protection measures was encouraged. A number of possible combinations are shown in the model of choices of health protection measures (Figure 2.3) (Blumenthal *et al*. 1989); for example, partial treatment of wastewater to a level less stringent than that recommended in the guidelines would be adequate if combined with other measures e.g. crop restriction.

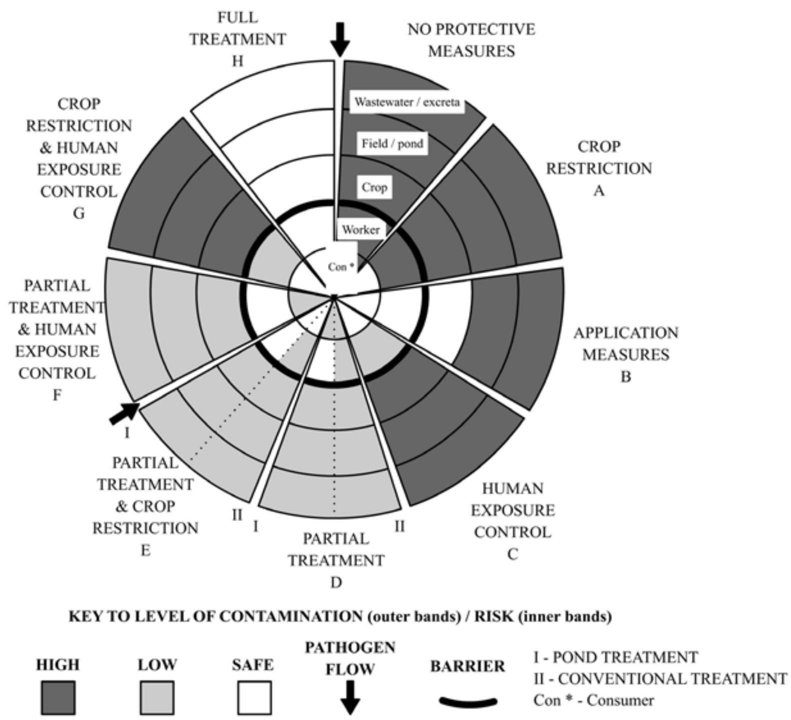

Figure 2.3. Generalised model illustrating the effect of different control measures in reducing health risks from wastewater reuse (adapted from Blumenthal *et al*. 1989; WHO 1989).

Combinations of measures could be selected to suit local circumstances. For example, where there was a market for cereal crops and good institutional capacity but insufficient resources to treat wastewater to category A quality, crop restrictions with partial wastewater treatment could be used. In situations where wastewater treatment could not be provided for a number of years, combinations of management options could be used in the interim (e.g. crop restrictions and human exposure control). The model of combinations of management practices and treatment processes drew on experience of reuse practices in the field (Strauss and Blumenthal 1990).

The main features of the WHO (1989) guidelines for wastewater reuse in agriculture are therefore as follows:

- Wastewater is considered as a resource to be used, but used safely.
- The aim of the guidelines is to protect against excess infection in exposed populations (consumers, farm workers, populations living near irrigated fields).
- Faecal coliforms and intestinal nematode eggs are used as pathogen indicators.
- Measures comprising good reuse management practice are proposed alongside wastewater quality and treatment goals; restrictions on crops to be irrigated with wastewater; selection of irrigation methods providing increased health protection, and observation of good personal hygiene (including the use of protective clothing).
- The feasibility of achieving the guidelines is considered alongside desirable standards of health protection.

Similar principles were applied to the derivation of guidelines for the use of excreta in agriculture and aquaculture (Mara and Cairncross 1989), and to tentative guidelines for the use of wastewater in aquaculture (WHO 1989). The latter are based on, among other things, extensive wastewater-fed aquaculture field studies (Edwards and Pullin 1990).

2.3.3 How WHO (1989) guidelines have been incorporated into standards

In the WHO (1989) guidelines, it was specified that in specific cases of standard setting, ‘local epidemiological, socio-cultural and environmental factors should be taken into account and the guidelines modified accordingly’. The microbiological quality guidelines have been used as the basis for standard setting in several countries and regional administrations. In some situations, the microbiological quality guideline levels have been adopted unchanged as standards, e.g. the Balearic Islands and Catalonia in Spain (Bontoux 1998). In other situations the quality guideline levels have been adopted, but within a more cautious approach where management practices and restrictions are closely specified. In France, for example, sanitary recommendations for the use of wastewater for the irrigation of crops and landscapes, drawing on the WHO guidelines, were published in 1991. These recommendations are used to guide wastewater reuse projects. Standards will be formulated and enacted, following evaluation of these projects (Bontoux and Courtois 1998). The French recommendations stipulate additional safety measures besides restricting the use of wastewater according to the quality of the treated effluents (for which WHO microbiological guideline values are used). Special measures include the protection of groundwater and surface waters, distribution networks for treated wastewater, hygiene regulations at treatment and irrigation facilities, and the training of operators and supervisors.

Standard setting in other countries has been influenced by the WHO guidelines, but often with some modification of the microbiological guidelines before adoption as standards. In Mexico, large areas are irrigated with untreated wastewater and crop restrictions are enforced. A standard of ≤5 eggs per litre has been set for restricted irrigation (Norma Oficial Mexicana 1997). The revised standards for unrestricted irrigation are 1000 FC/100ml (monthly mean) and ≤1 helminth ova per litre (similar to WHO). The rationale for this relates to what is practicable through currently available or planned treatment technology, and it was believed that a stricter helminth standard for restricted irrigation would require the use of filters in treatment plants, which would be unaffordable (Peasey et al. 1999). In Tunisia, the WHO guideline for restricted irrigation has been adopted (≤1 helminth ova per litre) but irrigation of vegetables to be eaten raw with reclaimed wastewater is prohibited (Bahri 1998; République Tunisienne 1989). The effluent of secondary treatment plants (supplemented by retention in ponds or reservoirs where necessary) is mainly used to irrigate fruit trees, fodder crops, industrial crops, cereals and golf courses.

2.3.4 Controversy over WHO guidelines on wastewater reuse

Controversy arose over the WHO guidelines on wastewater reuse shortly after their introduction in 1989. The criticism raised was that they were too lenient and would not sufficiently protect health, especially in developed countries. The rationale for the opposing views may well originate from a difference in underlying paradigm. Views critical of the WHO recommendations appear to be based largely on a ‘zero-risk’ concept (an idea explored in more detail in Chapter 10) which results in guidelines or standards where the objective is to eliminate pathogenic organisms in wastewater. WHO guidelines, however, are based on the objective that there should be no excess infection in the population attributable to wastewater reuse and that risks from reuse in a specific population must be assessed relative to risks of enteric infections from other transmission routes. Achieving wastewater quality close to drinking water standards is economically unsustainable and epidemiologically unjustified in many places.

2.4 SAFE RECREATIONAL WATER ENVIRONMENTS

In 1998, WHO published 'Guidelines for Safe Recreational Water Environments' in Consultation Draft form (Anon 1998). These guidelines deal with many different hazards including drowning, spinal injury, excess ultra-violet (UV) and so on. However, this section will consider the material relating to faecal contamination of coastal and freshwater. The publication followed a series of four expert meetings held between 1989 and 1997. Amongst broader management issues, these meetings considered:

- epidemiological protocol design and data quality
- appropriate data for use in guidelines design
- statistical treatment of data
- alternative guideline systems.

The following outlines the stages in guideline derivation for this aspect.

2.4.1 The process of microbiological guideline design for recreational waters

Ideally, a scientifically supportable guideline value (or numerical standard) is defined to provide a required level of public health protection, measured either in terms of 'acceptable' disease burden and/or some percentage attack rate of illness in the population which, again, is felt to be acceptable.

Derivation of such a numerical standard depends on the existence of:

- A dose–response curve linking some microbial concentration in the recreational waters with the 'outcome' illness, generally gastroenteritis.
- An understanding of the probability that a defined population would be exposed to a given water quality.

2.4.1.1 Epidemiology

Very few microbiological standards currently in force could claim good data on the first of these requirements, let alone the second. For example, current European Union mandatory standards for recreational waters are based on Directive 76/160/EEC (CEC 1976) which does not appear to have a firm epidemiological foundation. Subsequent attempts to revise these, now dated, European standards (Anon 1994a) have met with resistance from the competent authorities in member countries due to the lack of epidemiological evidence to underpin proposed changes (Anon 1994b, 1995a,b,c).

In the US, new standards were derived in 1986 (US EPA 1986), based on the work of Cabelli *et al.* (1982) which resulted in a dose–response relationship linking microbiological water quality and disease outcome (principally gastroenteritis). However, these studies have received a strong methodological critique (Fleisher 1990a,b, 1991; Fleisher *et al.* 1993) which has cast some doubt on the validity of the dose–response relationships reported.

In effect, the problem facing the WHO expert advisers was the plethora of epidemiological investigations in this area which had:

- adopted different protocols
- measured different exposure variables
- employed different sampling protocols for environmental and health data
- applied different case definitions to quantify the outcome variables
- assessed and controlled differently for potential confounding variables.

Thus, precise comparison between studies was difficult. However, a consistent finding of the body of evidence presented by these investigations was that significant illness attack rates were observed in populations exposed to levels of water quality well within existing standard parametric values and that a series of dose–response relationships were evident, suggesting increased illness from increasingly polluted waters.

To clarify the utility of available epidemiological evidence for guideline design, WHO commissioned an internal review of epidemiological investigations in recreational water environments (Prüss 1998). Following an exhaustive literature search and a pre-defined set of criteria, this paper classified some 37 relevant studies and concluded that the most precise dose–response should derive from the studies which had applied a randomised trial design because this approach:

- facilitated acquisition of more precise exposure data, thus reducing misclassification bias; and
- allowed better control of, and data acquisition describing, potential confounding factors.

Published data from studies of this nature were, however, only available (at the time) from government-funded studies in the UK conducted between 1989 and 1993 (Fleisher *et al*. 1996; Kay *et al*. 1994) and a pilot study conducted in the Netherlands by Asperen *et al.* (1997).

2.4.1.2 Water quality data

A key problem in using microbiological data to define standards is the inherent variability of microbiological concentrations in environmental waters. Many workers have reported changes of several orders of magnitude occurring over short time intervals of a few hours (e.g. McDonald and Kay 1981; Wilkinson *et al*. 1995; Wyer *et al*. 1994, 1996). However, analysis of 'compliance' data (and special survey information) from recreational waters suggested that the bacterial concentrations approximated to a $\log_{10}$-normal probability density function (pdf) which could be characterised by its geometric mean value and $\log_{10}$ standard deviation. This was true of UK coastal beaches (Kay *et al*. 1990) and EU-identified bathing waters.

Thus, the bacterial probability density function could be used to calculate the probability of exposure to any given water quality for any specific bathing water. Clearly, this assumes that historical 'compliance' data adequately characterises current water quality to which bathers are exposed.

2.4.1.3 Combining epidemiological and environmental data

The first stage in guideline design can be characterised by disease burden estimation. This requires the combination of the dose–response curve with the probability of exposure to different levels of water quality predicted by the probability density function of bacterial distribution. Figures 2.4–2.6 illustrate this process using UK compliance data and the dose–response curve linking faecal streptococci and gastroenteritis published in Kay *et al.* (1994), assuming a population exposed of 1000 individuals and a resultant disease burden of 71 cases of gastroenteritis.

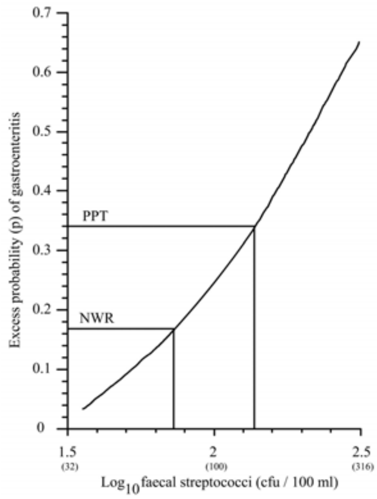

Figure 2.4. Dose–response curve linking faecal streptococci with excess probability of gastroenteritis (reproduced from Kay *et al*. 1999 with permission of John Wiley and Sons Limited). PPT: person to person transmission; NWR: non-water related.

Assuming universally applicable relationships, the policy maker could simply define the 'acceptable' level of illness in the exposed population and use this to derive a feasible region of the probability density function geometric mean and standard deviation values to comply with the accepted disease attack rate.

The approach adopted used the disease burden model outlined in Figure 2.6 and the concept of an 'acceptable' number of gastroenteritis incidents in a 'typical' bather. For example, one case in 20 exposures, one case in 80 exposures and one case in 400 exposures. These were derived from the theoretical proposition that, on average:

- the bather experiencing 20 exposures in a season might experience one case of gastroenteritis
- the family of 4 experiencing 20 bathing events might experience one case of gastroenteritis
- the family of 4 experiencing 20 bathing events per year for 5 years might experience 1 case of gastroenteritis.

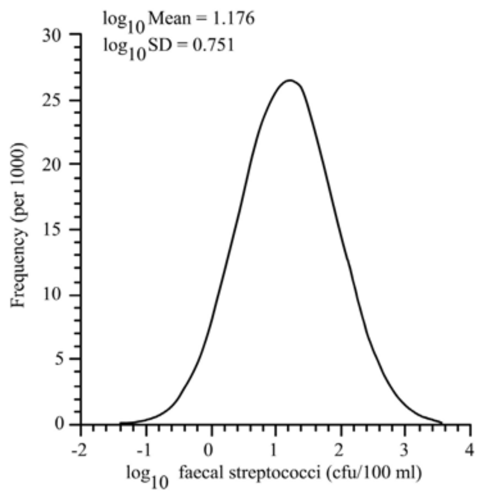

Figure 2.5. Probability density function of faecal streptococci in bathing waters – curve adjusted to have a total area of 1000 (reproduced from Kay *et al*. 1999 with permission of John Wiley and Sons Limited).

Using the average $\log_{10}$ standard deviation for over 500 EU bathing locations, these disease burden levels were used to define the 95 percentile points of the theoretical probability density function that would produce this risk of exposure. These correspond approximately to the 200, 50 and 10 faecal streptococci cfu/100ml levels.

The final guideline is not a 95 percentile but an absolute level of 1,000 faecal streptococci cfu/100ml, which if exceeded should lead to immediate investigation and follow-up action. This level was derived from the 1959 Public Health Laboratory Service (PHLS) investigation of serious illness in the UK, which suggested that paratyphoid might be possible where total coliform concentrations exceeded 10,000 cfu/100ml (PHLS 1959). Converting to faecal streptococci concentrations, this gave an approximate level of 1000 which the WHO committee considered should represent a maximum acceptable concentration because of the risk of serious illness.

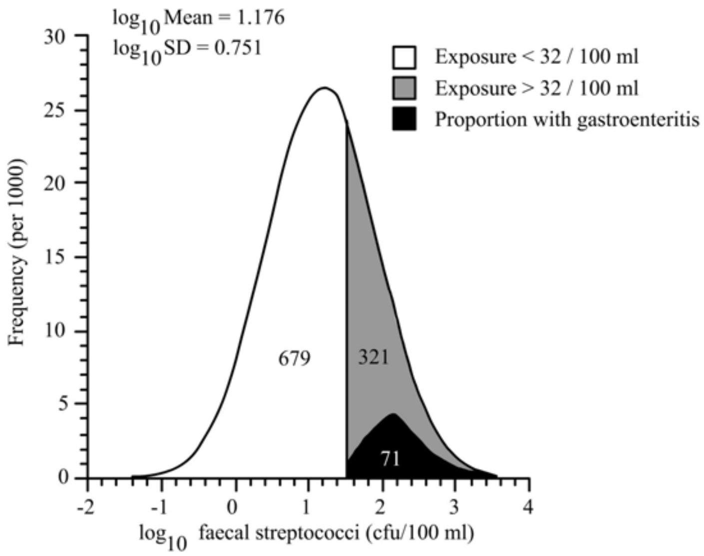

Figure 2.6. Example of an estimated disease burden (reproduced from Kay *et al*. 1999 with permission of John Wiley and Sons Limited).

2.4.1.4 Problems with this approach

The epidemiological database is very narrow and potentially culturally specific. It derives from the UK marine investigations and was chosen because of the greater accuracy in dose–response curve construction produced by randomised studies. However, its application worldwide must be questioned. This highlights the urgent need for further implementations of the randomised trial protocol to the quantification of recreational water dose–response relationships in other water types (e.g. fresh waters), in other regions (e.g. Mediterranean and tropical) and with other risk groups (e.g. canoeists, surfers etc.).

The nature of the randomised trial can mean that the exposed population is restricted. For example, the UK studies used healthy adult volunteers, and children were excluded because they were not considered able to give informed consent. Thus, significant risk groups that the standards seek to protect can be systematically excluded. However, this problem was not encountered in the studies of Asperen *et al.* (1997) in the Netherlands.

If a single number is required to define the guideline, e.g. a geometric mean or 95 percentile, then some assumption must be made concerning the other parameters of the probability density function. In this case a uniform $\log_{10}$ standard deviation was assumed. However, it is known that this parameter changes at compliance points in response to, for example, non-sewage inputs such as rivers and streams. The standard deviation of the probability density function certainly affects the probability of exposure to polluted waters and thus the disease burden.

2.5 IMPLICATIONS FOR INTERNATIONAL GUIDELINES AND NATIONAL REGULATIONS

It can be seen from the outline of the three guideline areas that although there are similarities, they have very different histories and there is little commonality in the way they have been derived. Key to all three areas is the hazard of primary concern, namely human (and animal) excreta. These three areas should not, ideally, be considered in isolation but should be examined together and subject to integrated regulation and management. The harmonised framework should allow further development and future revisions of the guideline areas to be carried out in a consistent way, allowing the consideration of the water environment in general rather than components of it in isolation. It is important to bear in mind that guidelines represent the international evidence base and they require adaptation prior to implementation in order to be appropriate for individual national circumstances.

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