SOUTH AFRICAN WATER QUALITY GUIDELINES FOR COASTAL MARINE WATERS

Volume 2:
Guidelines for Recreational Use

environmental affairs

Department:
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EXECUTIVE SUMMARY

This document contains the *revised guidelines for recreational waters of South Africa's coastal marine environment*, which addresses some of the shortcomings of the previous version (DWAF, 1995). The aim is to provide managers and governing authorities with the background and guidance to define target ranges for recreational waters, as well as to provide guidance on the implementation thereof.

In preparing this document, the approach followed was to conduct an international review of similar guidelines from a selection of countries and organizations, considered to be the global leaders in this regard, whilst also considering the previous version of South Africa's water quality guidelines for coastal marine waters: Recreational use. Projects undertaken in the southern African region aimed towards developing regional guidelines, such as Benguela Current Large Marine Ecosystem (BCLME) programme and the Project "Addressing Land-based Activities in the Western Indian Ocean" (WIO-Lab), were used as the basis for the review. Based on the outcome of this international assessment, target values for the selected water quality indicators, as well as implementation practices were identified and adapted for the South African situation, pending the acquisition of suitable local scientific data and knowledge.

The ultimate goal in the management of coastal systems is to keep the resource suitable for all designated uses. In terms of recreational use of coastal marine waters, this goal translates into broad environmental quality objectives stating that:

Environmental quality is suitable for recreational use from an aesthetic, safety and hygienic point of view.

Typical water quality problems associated with recreational use of coastal marine waters include[1]:

Aesthetics (e.g. bad odours, discolouration of water and presence of objectionable matter);

Human health and safety (e.g. gastrointestinal problems, skin, eye, ear and respiratory irritations, physical injuries and hypo-/hyperthermia); and

Mechanical interference (e.g. clogging and choking of mechanical equipment in the waters such as boat engines and diving gear).

Key water quality properties/constituents typically used to assess the water quality status with regard to the above-mentioned problem categories are as follows:

PROPERTY/CONSTITUENT	PROBLEM CATEGORY		
	AESTHETICS	HUMAN HEALTH & SAFETY	MECHANICAL INTERFERENCE
Objectionable matter	●	●	●
Microbiological indicator organisms		●	
Physico-chemical parameters (pH & temperature)		●	
Toxic substances (chemical compounds & toxic algal blooms)		●	

[1] All categories apply to contact recreation, while non-contact recreation is mostly affected by aesthetic problems.

Recommended Target Values

Recommended target values (or scientific yardsticks) for the water quality properties (or indicators) considered appropriate for assessing fitness of coastal marine waters for recreational use are listed in the following tables.

Objectionable matter:

INDICATOR	RECOMMENDED TARGET
Objectionable Matter	*Water should not contain litter, floating particulate matter, debris, oil, grease, wax, scum, foam or any similar floating materials and residues from land-based sources in concentrations that may cause nuisance.* *Water should not contain materials from non-natural land-based sources which will settle to form objectionable deposits.* *Water should not contain submerged objects and other subsurface hazards which arise from non-natural origins and which would be a danger, cause nuisance or interfere with any designated/recognized use.* *Water should not contain substances producing objectionable colour, odour, taste, or turbidity.*

Physico-chemical indicators:

INDICATOR	RECOMMENDED TARGET
pH	*pH of water should be within the range 5.0–9.0, assuming that the buffering capacity of the water is low near the extremes of the pH limits.*
Temperature	*For prolonged exposure, temperatures should be in the range 15 – 35 °C*

Risk-based ranges for intestinal enterococci and E. coli (microbiological indicator organisms):

CATEGORY	ESTIMATED RISK PER EXPOSURE	ENTEROCOCCI (Count per 100 ml)	E. coli (Count per 100 ml)
Excellent	*2.9% gastrointestinal (GI) illness risk*	*≤ 100 (95 percentile)*	*≤ 250 (95 percentile)*
Good	*5% GI illness risk*	*≤ 200 (95percentile)*	*≤ 500 (95 percentile)*
Sufficient or Fair (minimum requirement)	*8.5% GI illness risk*	*≤ 185 (90 percentile)*	*≤ 500 (90 percentile)*
Poor (unacceptable)	*>8.5% GI illness risk*	*> 185 (90 percentile)*	*> 500 (90 percentile)*

In tropical areas an additional microbiological indicator - Clostridium perfringens, a spore-forming obligate anaerobe - may need to be included. The target value recommended for C. perfringens is:

INDICATOR	RECOMMENDED TARGET
C. perfringens	*Geometric mean ≤ 5 counts per 100 ml*

With reference to ***toxic substances*** (chemical compounds), it is proposed that South Africa's drinking water quality guidelines (e.g. SANS, 2005) be consulted to make preliminary risk assessments in areas where these substances are expected to be present at levels that pose a risk to human health as long as care is taken in the application. Drinking water quality targets relate, in most cases, to lifetime exposure following consumption of 2 litres of drinking water per day. For recreational water contact, an intake of 200 ml per day - 100 ml per recreational session with two sessions per day - may often be reasonably assumed. It should be noted that this approach may, however, not be appropriate to substances of which the effects are related to direct contact with water, e.g. skin irritations.

The increasing presence of chlorine, used by local authorities to treat/disinfect wastewater effluent or wastewater spills, has been highlighted as a concern. It is therefore recommended that managers responsible for monitoring of beach water quality, specifically observe for the presence of chlorine contamination (e.g. as an item on the monitoring log sheet). Where contamination is suspected, appropriate monitoring must be carried out by reputable scientists to establish potential health risks.

With regard to toxins from ***harmful algal blooms***, no specific target values are prescribed, but when the presence of such harmful algal proliferation occurs, appropriate monitoring must be carried out by reputable scientists to establish potential health risks.

Monitoring Protocols

Monitoring protocols described here primarily focuses on *microbiological data* as part of long-term monitoring programmes to assess water quality of recreational waters in the coastal marine environment (observations on *aesthetic quality* of recreational waters are recorded during microbiological sampling). With regard to *physico-chemical* parameters and *toxic substances,* regular monitoring is not required. However, where toxic contamination occurs or is suspected, and a health risk is identified or presumed, appropriate monitoring must be carried out by reputable scientists and/or analytical laboratories to enable timely identification of health risks. Adequate management measures including information to the public must be taken immediately to prevent exposure.

To ensure that all related information is captured during sampling (e.g. information necessary for interpretation of microbiological data, recording of aesthetic conditions and potential presence of toxic substances) a sampling log sheet should be completed at each sampling point on every sampling occasion.

Microbiological samples should be collected during all periods when coastal waters are used for contact recreation. A systematic random-sampling regime is recommended. Samples should be collected as a minimum, every two weeks during daylight, regardless of the weather although there may be exceptions if conditions present a health and safety hazard, in which case samples should be collected as soon after the programmed time as possible. In support of such a random-sampling regime, a monitoring calendar should be drawn up for each year.

The specific sampling location at a recreation area should be selected on the basis of information gathered during the sanitary inspection. The location/s should be representative of the water quality throughout the whole contact recreation area. The sampling depth should be 15 to 30 cm below the surface where the depth of the water is approximately 0.5 metres. Samples should be collected on the seaward side of a recently broken wave, taking care not to collect backwashing water.

Samples for the analyses of both intestinal enterococci and *E. coli* must be collected. In sub-tropical areas, it may also be necessary to collect samples for the analysis of *C. perfringens* to assist with interpretation of microbiological indicator results.

Seawater samples collected from *E. coli* analyses must be analysed on the same day of sampling – preferably within 6-8 hours after sampling - due to the rapid die-off of this microbiological parameter in water with a high salt content. Seawater samples collected for intestinal enterococci and *C. perfringens* analyses must be analysed within 24 hours of sampling.

A reputable (preferably an ISO 17025 accredited) laboratory must undertake microbiological analyses, using recognised analytical methods prescribed by the South African Bureau of Standards (SABS) or any equivalent methods provided in *Standard Methods for the Examination of Water and Wastewater.* If a laboratory is not accredited it is should participate in a national inter-laboratory proficiency scheme (e.g. National Laboratory Association). Samples from any one area should be tested by the same method and preferably the same laboratory in order to provide reliable long-term data sets. A list of available methods is provided in the Table 5.1 of the main document. For South Africa, the non-parametric method (i.e. using data ranking) is used for the calculation of percentile values for microbiological parameters. The Hazen method is the preferred procedure although the Excel spreadsheet method can also be applied where users do not have access to a suitable Hazen template.

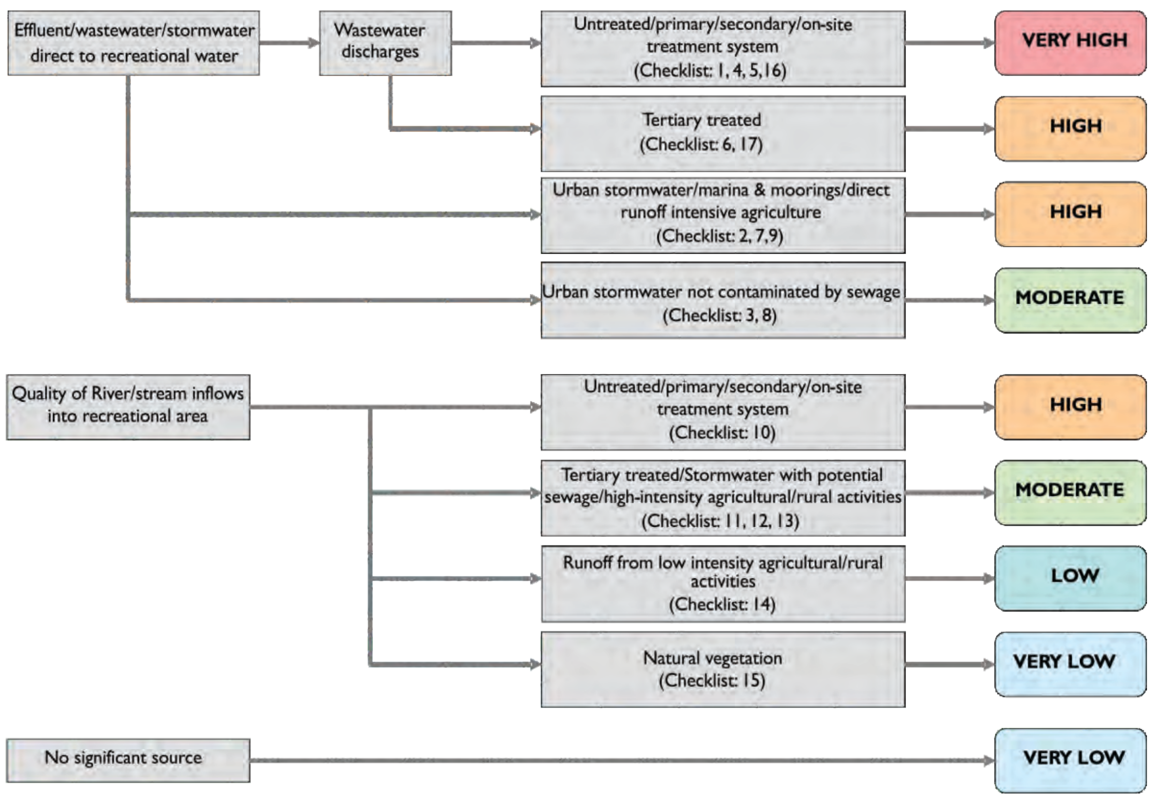
Implementation Framework

Based on international best practice the implementation framework for assessing the quality of recreational waters should ideally comprise:
- A classification system for recreational waters; and
- An operational management system (for day-to-day management).

Classification System for Recreational Waters:

The classification system for recreational waters is primarily based on a combination of:
- A sanitary inspection; and
- A microbiological quality assessment (based on microbiological indicator counts).

Results from the sanitary inspection are rated as follows:



The microbiological assessment is based on an evaluation of microbiological indicator data, collected over a fixed period of time, typically five years. Microbiological quality is graded into four possible categories:

GRADE	INTESTINAL ENTEROCOCCI (counts per 100 ml)	*E. coli* (counts per 100 ml)
Excellent	≤ 100 (95 percentile)	≤ 250 (95 percentile)
Good	≤ 200 (95 percentile)	≤ 500 (95 percentile)
Sufficient/Fair	≤ 185 (90 percentile)	≤ 500 (90 percentile)
Poor	> 185 (90 percentile)	> 500 (90 percentile)

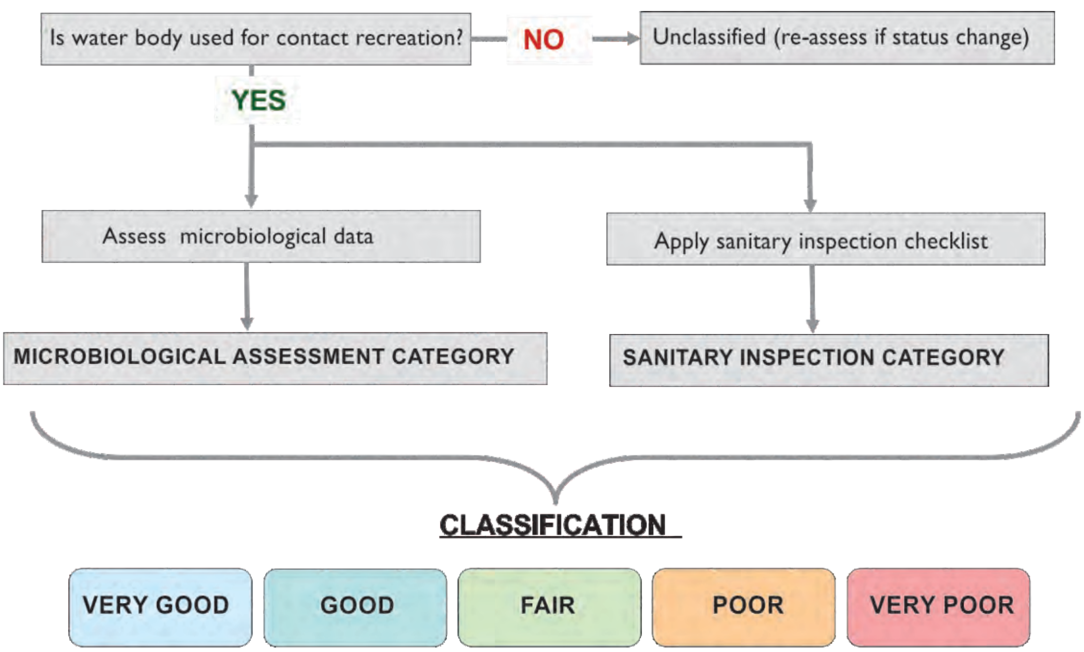
The Classification of recreational waters is based on a combination of the Sanitary Inspection Category and Microbiological Quality Assessment Category, as indicated below:

		MICROBIOLOGICAL QUALITY ASSESSMENT CATEGORY				
		Excellent	*Good*	*Sufficient*	*Poor*	*Exceptional circumstances*[3]
SANITARY INSPECTION CATEGORY	*Very Low*	*Very good*	*Very good*	*Follow-up*[1]	*Follow-up*[1]	
	Low	*Very Good*	*Good*	*Fair*	*Follow-up*[1]	
	Moderate	*Good*[2]	*Good*	*Fair*	*Poor*	
	High	*Good*[2]	*Fair*[2]	*Poor*	*Very poor*	
	Very high	*Follow-up*[2]	*Fair*[2]	*Poor*	*Very poor*	
	Exceptional					*Action required*

1 *Implies non-sewage sources of faecal indicators (e.g. livestock), and this should be verified.*

2 *Indicates possible discontinuous/sporadic contamination (often driven by events such as rainfall). This is most commonly associated with Combined Sewer Overflow presence. These results should be investigated further and initial follow-up should include verification of the sanitary inspection category and ensuring samples recorded include "event" periods. Confirm analytical results. Review possible analytical errors.*

3 *Exceptional circumstances relate to known periods of higher risk, such as during an outbreak with a pathogen that may be waterborne, sewer rupture in the recreational water catchment, etc. Under such circumstances, the classification matrix may not fairly represent risk/safety and a grading would not apply until the episode has abated.*



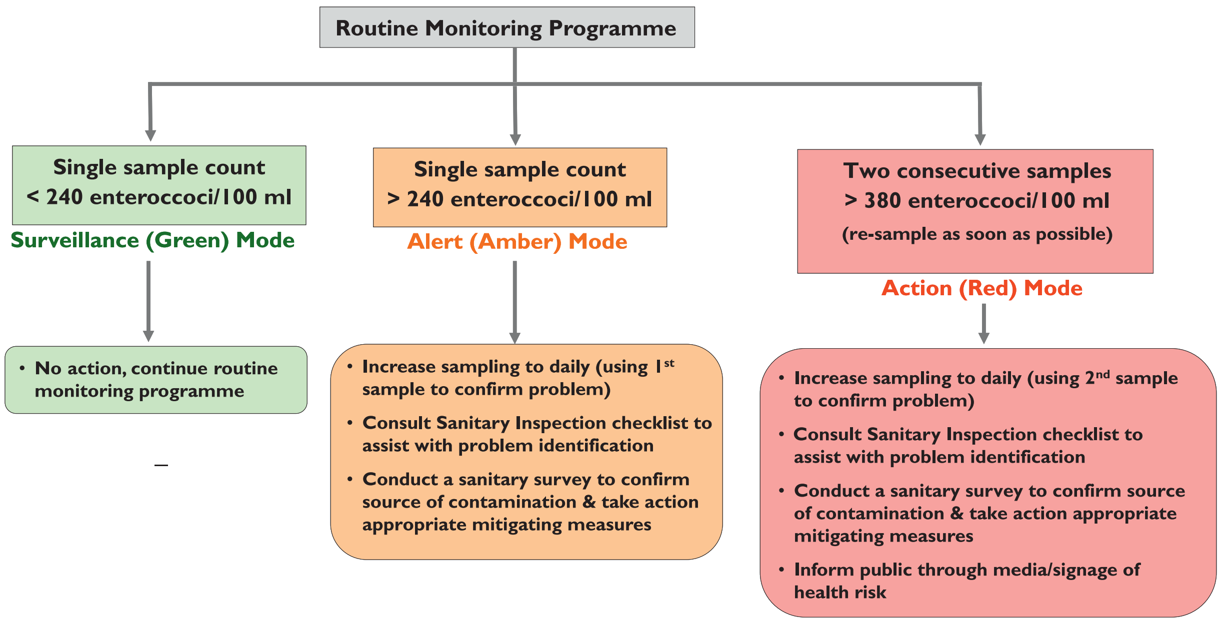
The process for classification of recreational waters (adopted from WHO, 2003)

The sanitary inspection should be conducted at least annually. However, when there is reason to believe that the sanitary inspection category may have changed markedly within a year, the inspection should be repeated and the revised category should be applied in the classification process.

The microbiological quality assessment should be based on microbiological data over a running 12 month period, considered most appropriate for the South African situation where the microbiological quality of recreational waters can change markedly over short period. This approach allows for a more real-time classification process (e.g. monthly rather than yearly), recognising such variability.

Proposed Operational Management System:

A proposed operational management process for South Africa is illustrated below:



It is recognised that, in the short-term, capacity constraints may prevent local authorities from effectively establishing such operational management systems at all recreational beaches. However, these systems are crucial for effective management of recreational waters and local authorities should be encouraged to incorporate the implementation thereof in their medium- to long-term strategic plans.

Local authorities are encouraged to implement the proposed operational management system at selected recreational areas in order to test its applicability to the South African situation. In particular, the single value targets need to be confirmed.

GLOSSARY OF TERMS

ACR	Acute-Chronic Ratio
Adsorption	Attachment of molecules or ions to a substrate by manipulation of electrical charge or pH.
Aerobic	Where oxygen is available or where molecular oxygen is required for respiration.
Anaerobic	Where insufficient oxygen is available or where molecular oxygen is not required for respiration.
Anoxic	Limited or no oxygen availability.
Anthropogenic	Caused by humans or their activities, e.g. storm water is an anthropogenic source of pollution to the sea.
ANZECC	Australia and New Zealand Environment and Conservation Council
ANZFA	Australia New Zealand Food Authority
AQUIRE	Aquatic Toxicity Information Retrieval Database
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
AWRC	Australian Water Resources Council
Bacteria	Extremely small, relatively simple prokaryotic microorganisms .
BCLME	Benguela Current Large Marine Ecosystem
Benthic	Inhabiting the bottom of a water body.
Biomass	The dry weight of living matter, including stored food, present in a species population and expressed in terms of a given area or volume of habitat.
BOD	Biochemical Oxygen Demand
Buffering capacity	A measure of the relative sensitivity of a solution to pH changes on addition of acids or bases.
CCME	Canadian Council of Ministers of the Environment
CCREM	Canadian Council of Resource and Environment Ministers
CEC	Council of European Community
Chlorophyll a	Chlorophyll a Refers to the green pigment in plants and algae which is fundamentally part of the process of photosynthesis. Chlorophyll is used as a measure of the amount of algae (phytoplankton) in water.
Chromatographic	Preferential absorption of chemical compounds (gases or liquids) in an ascending molecular weight sequence onto a solid adsorbent material, such as activated carbon, silica gel or alumina.
Clarity	Refers to the depth to which light can penetrate in a water body.
Coastal zone	For the purpose of these documents, it refers to coastal marine waters.
COD	Chemical Oxygen Demand
Colloidal suspension	A mixture of two substances, one of which, called the dispersed phase (or colloid), is uniformly distributed in a finely divided state through the second substance, called the dispersion medium (or dispersing medium). Both phases may be a gas, liquid or solid.
Coriolis force	A velocity-dependent pseudo force in a reference frame which rotates with respect to an inertial reference frame. It is equal and opposite to the product

	of the mass of the particle on which the force acts and its Coriolis acceleration.
Demersal fish	Fish living near or at the bottom of the sea.
Diarrhetic shellfish poison	Algal toxin causing gastrointestinal problems.
Dinoflagellate	An order of flagellate protozoan, most members having fixed shapes determined by thick covering plates.
DWA	Department of Water Affairs (South Africa)
EC	European Community
EC_{50}	Effective concentration the dosage at which the desired response is present for 50 % of the population.
Ecosystem	A functional system which includes the organisms of a natural community together with their abiotic environment.
EEC	European Economic Community
Effluent standard	Legally enforceable limit set for specific property/constituent in wastewater or effluent.
Effluent limit value	See *effluent standard*
ELV	Effluent limit value
Environmental Quality Objective	A broad, narrative statement describing the desired quality levels (or goals) for a particular environment, in this case geographically defined units in the coastal zone
Environmental Quality Target	Numerical or narrative target values for water and sediment quality parameters in receiving coastal environment that will ensure compliance with EQOs.
EQO	Environmental Quality Objective
EQT	Environmental Quality Target
Euphotic zone	The surface water layer up to a depth where 1% of the surface illumination still penetrates.
Eutrophication	Excessive algal or plant growth caused by high nutrient concentrations.
Fauna	Animal life characterising a specific geographic region or environment.
FEE	Foundation for Environmental Education
Fitness for use	The suitability of the quality of water for one of the following five recognised uses: domestic use, agricultural (mariculture) use, industrial use, recreational use and water for the natural environment.
Flora	Plant life characterising a specific geographic region or environment.
Gas chromatography	A separation technique whereby a sample is distributed between two phases. One of these is a stationary bed of large surface area, and the other a gas (carrier gas) which percolates through the stationary phase.
GEF	Global Environmental Facility
GPA/LBA	Global Programme of Action for the Protection of the Marine Environment from Land-based Activities
Gram-positive	Refers to bacteria which hold the colour of the primary stain when treated with Gram's stain.
Heterotrophic	Obtain nourishment from the ingestion and breakdown of organic matter.
High performance liquid chromatography	A separation technique in which the sample is introduced into a system of two phases. Differences in the distribution shown by the solutes cause them to travel at different speeds in the system.

Humic substances	A general category of naturally occurring, biogenic, heterogeneous organic substances that can be characterised as being yellow to black in colour, of high molecular weight, and refractory.
Hyper-	Excessive, exceeding, above, over.
Hypo-	Low, under, below .
Hypoxia	Lack of sufficient oxygen.
In situ	In the original location.
Industrial uses	For the purpose of these documents, industrial use of seawater means 'water that is taken from the sea to be used in industrial processes or to be processed for a particular use outside the sea'. Industrial uses of seawater therefore include: - seafood processing; - salt production; - desalination; - water supply to commercial aquaria/oceanaria; - harbours/ports (excluding recreational use, mariculture practices, natural environment - these will be addressed elsewhere); - cooling water; - ballast water; - coastal mining; - make-up water for marine outfalls; - exploration drilling; - scaling and scrubbing.
ISO	International Organization for Standardization
Lachrymal fluid	Tear -like fluid.
LC_{50}	Concentration that is lethal to 50% of the test organisms
Limpet	Several species of gastropod molluscs which have a conical or tent-like shell with ridges extending from the apex to the border.
LOEC	Lowest Observable Effects Concentration
Macrophytes	Refers to macroscopic forms of aquatic plants and includes of algae and aquatic vascular plants.
MAF	Ministry of Agriculture and Fisheries (New Zealand)
MPN	Most probable number
$mg\ l^{-1}$	Milligrams per litre
NHMRC	National Health and Medical Research Council (Australia)
NOEC	No Observable Effect Concentration
Norm	Yardsticks by which changes in water quality can be measured .
NTU	Nephelometric Turbidity Units (a measure of turbidity of water)
NZME	New Zealand Ministry of Environment
Offshore drift	Movement of materials by currents flowing away from the shore
Oxic	Sufficient oxygen availability
Ozonation	Disinfection using ozone, an oxidising agent .

Paralytic shellfish toxin	Algal toxin which may cause neurological effects.
Pathogen	(Pathogenic) Causing disease
Pelagic	Living in the water column in contrast to living on the bottom of a water body.
Photic zone	*see* Euphotic zone
Photometrically	(Photometry) The calculation and measurement of quantities describing light, such as luminous intensity, sometimes taken to include measurement of near - infrared and near-ultraviolet radiation as well as visible light.
Problems	For the purpose of these documents, problems specifically refer to 'problems encountered by a particular use or user of marine water which are caused by a particular water quality property or constituent'.
Protozoa	A diverse phylum of eukaryotic micro-organisms; the structure varies from a simple uninucleate protoplast to colonial forms. The body is either naked or covered by a cyst. Locomotion is by means of pseudopodia or cilia or flagella .
Recreational use	For the purpose of this document, recreational use is water that is used for: - contact recreation (e.g. swimming, water skiing, windsurfing); - non-contact recreation (e.g. fishing, bird watching, etc.) .
RSA	Republic of South Africa
SABS	South African Bureau of Standards
Salinity	Refers to the salt content of soil or water.
SANS	South African National Standard
Seasonality	Refers to changes associated with the four seasons of the year.
Site specific	Refers to conditions that are unique or specific to a certain site or location.
Surf zone	The area between the landward limit of wave up-rush and the furthest seaward breaker.
Target value/range	The value or range of a water quality property or constituent where there is no known impairment of use, or significant effect on a particular water use. It is this range which describes the desirable water quality and which should be strived for.
Thermocline	A temperature gradient as in a layer of seawater in which the temperature decrease with depth is greater than that of the overlying and underlying water.
Titrimetrically	A technique where the substance to be determined is allowed to react with an appropriate reagent added as a standard solution, and the volume of solution needed for complete reaction is determined.
Treatability	The ability and extent to which undesirable properties or constituents can be removed or converted from a water body.
UNEP	United Nations Environmental Program
Upwelling	The phenomenon by which deep, colder and nutrient-rich ocean waters are introduced into the well-mixed surface layer.
US-EPA	United States Environmental Protection Agency
US-FDA	United States Food and Drug Administration
Virus	A typical virus consists of nucleic acid (DNA or RNA) neatly wrapped in a protective protein coat (capsid). The latter carries a receptor site which will attach to matching receptor sites only on certain cells. This matching determines the host specificity of viruses.
Water quality	(US EPA) A designated concentration of a constituent that, when not

	exceeded, will protect an organism, an organism community or a prescribed water use or quality with an adequate degree of safety. (Canada) Scientific data evaluated to derive recommended limits for water uses. (Australia) Scientific and technical information used to provide an objective means for judging the quality needed to maintain particular environmental value (water use).
Water quality guideline	(South Africa) A description of the effects of changes in water quality of a water quality constituent on a recognised use in terms of selected norms. (Canada) A numerical concentration or narrative statement recommended to support and maintain designated water use. (Australia) Water quality guidelines translate the criteria into a form that can be used for management purposes.
Water quality property/constituent	A chemical (or biological) substance or physical property that describes the quality of a water body. For the purpose of this document water quality refers to water quality constituent, substance or property only.
WHO	World Health Organisation
WIO-LAB	Addressing Land-based Activities in the West Indian Ocean
WQG	Water Quality Guideline

CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION

1.1 Water Quality Guidelines in Perspective

The ultimate goal in the management of coastal systems is to keep the resource suitable for all designated uses, both existing and future. This includes the 'use' of designated areas for biodiversity protection and ecosystem functioning.

The uses of coastal ecosystems are typically divided into four broad categories (ANZECC, 2000a, DWAF, 1995) namely:

- Protection of biodiversity and ecosystem functioning of the natural environment (conservation areas);
- Recreational use (including tourism);
- Marine aquaculture (including collection of seafood for human consumption); and
- Industrial uses (e.g. taking cooling water and water for seafood processing).

In order to manage coastal systems effectively so that they remain suitable for designated uses, objectives and measurable targets should be set for the different factors defining the integrity of the coastal systems taking into account the requirements of designated uses. For example, the integrity of coastal systems used for recreational activities, bathing in particular, is primarily measured in terms of the following:

- *Coastal waters* being aesthetically acceptable and not posing a health risk to bathers (i.e. *water quality* must be acceptable);
- *Beach sediments* being aesthetically acceptable (e.g. free of any objectionable matter) and not posing a health risk to users; and
- *Physical environment* (e.g. rip currents, beach slope, waves) not posing a safety risk to users.

Environmental Quality Objectives (EQOs) are defined as *broad, narrative statements describing the desired goals for a particular environment*, in this case a coastal environment used for recreational activities. These goals, in turn, need to be translated into *measurable target values* (also referred to as Environmental Quality Targets - EQTs) for specific parameters. These are different for effluent standards, as explained in Box 1.1.

In setting such objectives and targets for *water quality*, Water Quality Guidelines aim to provide managers and governing authorities with the background and guidance to define and implement targets and standards in local coastal recreation areas. These types of guidelines present a preferred approach to assessing recreational waters and are not legislated standards that must be adhered to at all times. Once agreed upon by stakeholders, such EQTs for water quality may be adopted into legislation to become legally-binding water quality standards.

It is very important to realise that the existence of EQTs does not imply that coastal water quality should or could automatically be degraded to those levels. A continuous effort should be made to ensure that coastal resources are of the highest attainable quality, taking into account economic and social opportunities and constraints, and considering principles such as:

- Precautionary approach
- Pollution prevention
- Waste minimisation
- Recycling and re-use
- Best available or best attainable technologies.

Box 1.1: Difference between Effluent Standards and Environmental Quality Objectives/Targets

The so-called Uniform Effluent Standard Approach has been followed extensively throughout the world to manage and control wastewater discharges. Uniform effluent standards or effluent limit values (ELVs) are usually industry specific and legally enforceable. Limits specify minimum concentrations or loads to which wastewater discharges must comply prior to discharging into a water resource. The ELVs can be derived in several ways, including the Technology-based Approach and the Ecological Quality Objectives-based (EQO-based) Approach (Ragas, et al 2005).

Although the Technology-based Approach (i.e. deriving wastewater limits based on 'Best available technology', 'Best practicable means' or 'Best available technique not encompassing excessive costs') have great value in terms of enforcing principles like 'Pollution prevention' and 'Waste minimisation' (World Bank Group, 2004), it has shortcomings when used in isolation. Wastewater standards derived in this manner do not necessarily take into account the assimilative capacity of the receiving water environment (particularly with regard to physico-chemical variables, nutrients and other naturally occurring chemicals such as trace metals) or cumulative and synergistic effects of multiple waste discharges. Also, when such ELVs are applied to a discharge into calm, near-stagnant water bodies they could be insufficient to adequately protect the coastal environment and its uses while, when applied to a discharge into dynamic, well-flushed areas, such limits could be too stringent.

To address these shortfalls, many countries adopted the Receiving Water Quality Objectives Approach (or EQO-based Approach) where the physical, chemical and biological processes and uses of a particular (receiving) coastal area dictate the 'limits of discharge'. In turn, this approach led to the development of water quality guidelines to assist managers and governing authorities in setting site-specific environmental quality objective and targets for a particular area. The EQO-based Approach has multiple uses, one of which is to set EQO-based wastewater standards. Another important application is to set long-term monitoring objectives.

The EQO-based Approach does not exclude the Technology -based Approach to set wastewater standards, but should be seen as complimentary. For example, technology-based standards are still very important in terms of controlling the discharge of hazardous chemicals that bio-accumulate in the environment with severe adverse effects on coastal ecosystems. Here the European Union is an example; in addition to managing coastal waters based on EQO-approach, they also enforce technology-based effluent standards for a number of hazardous chemicals, referred to as priority substances (CEC, 2000).

Other initiatives that also assesses the quality of recreational waters is, for example the *Blue Flag Champaign*, an international initiative that was started in the mid-1980s to encourage local authorities to provide clean and safe beaches for local populations and tourists (UNEP, 1996; FEE, 2004). It is a voluntary and non-punitive scheme and is targeted at local authorities, the general public and the tourism industry. The main objectives of the Blue Flag Champaign are to improve understanding of the coastal environment and to promote the incorporation of environmental issues in the decision-making processes of local authorities and their partners. Beaches that meet specific criteria are annually awarded a Blue Flag. Categories for which specific criteria are assigned are:

i) Water quality;

ii) Environmental information and education;

iii) Safety and services; and

iv) Environmental management.

Important to note is that the guidelines provided as part of this document specifically address water quality of recreational areas, i.e. category (i) of the Blue Flag Campaign. Categories (ii) and (iii) stipulated for the Blue Flag Campaign are additional and not within the scope intended for these guidelines.

1.2 Historical Overview of South African Guidelines

In 1983, a marine pollution workshop organised by the South African Committee for Oceanographic Research (SANCOR), initiated the development of South Africa's first water quality criteria for the coastal zone, including criteria (or target values) for direct-contact recreation. The workshop endorsed a recommendation that South Africa prepares its own water quality criteria for marine and estuarine waters and a committee was appointed for this purpose. The first set of guidelines was published in 1984 (Lusher, 1984) (see Appendix A).

In 1992, the Water Research Commission (WRC) of South Africa commissioned a review of the 1984 version of the Water Quality Criteria for the South African coastal zone (WQCSA). Experts and interested parties were requested to comment on the earlier version which was debated at a 2-day workshop attended by a broad spectrum of representatives from the scientific/engineering community, national and local authorities, industries and environmental organisations. An interim report entitled: *Water Quality Guidelines for the South African coastal zone* (DWAF, 1992) was prepared based on the outcome of this workshop (see Appendix A).

In 1995 the then Department of Water Affairs and Forestry (DWAF) embarked on a project to update the Water Quality Guidelines of South Africa, for both fresh and coastal marine waters. The 1992 document (DWAF, 1992) was used as a basis for the update on coastal marine waters, transforming this into a format similar to what was used in the updated freshwater documents, including extensive background information to inform better application of the guidelines. This led to the publication of a series of documents on coastal marine water quality guidelines, one of which was the *South African Water Quality Guidelines for Coastal Marine Waters Volume 2: Recreational Use* (DWAF, 1995). In essence, the target values presented in the updated version (DWAF, 1995) were the same as in the 1992 version (DWAF, 1992) . The updated document merely contained the additional background information (see Appendix A).

Based on an international review of recent developments in the establishment of guidelines for recreational waters in the coastal marine environment (Appendix A), the following shortcomings were apparent in the 1995 South African guidelines:

- <u>*No clear rationale for the selection of the current SA target values for E. coli*</u>

  From the available South African literature the motivation or rationale for the selection of the current microbiological indicators is not apparent. Reference to a similar criterion was made in a proposal by the European Union (CEC, 1994; Kamizoulis and Saliba, 2004) to update the 1976 directive on bathing water quality (CEC, 1976). However, the document also did not provide a clear rationale for the selection of such targets other than "*…epidemiological studies carried out in several countries since 1976 have provided a great deal of information in relation to the use of pollution indicators relating to health protection*". The European Union, however, replaced all previous bathing water directives (or proposals) with the 2006 Directive on bathing waters which stipulates both the microbiological indicator species and target values for marine waters.

  An important consideration in the selection of revised target ranges for South Africa will be the consideration of allowable or acceptable risk to human health. According to the WHO (2003) guidelines "*there is no universally applicable risk management formula. Acceptable or tolerable excess disease rates are especially controversial because of the voluntary nature of recreational water exposure and the generally self-limiting nature of the most studied health outcomes (gastroenteritis, respiratory illness). Therefore, assessment of recreational water quality should be interpreted or modified in light of regional and/or local factors, such factors include the nature and seriousness of local endemic illness, population behaviour, exposure patterns, and socio-cultural, economic, environmental and technical aspects, as well as competing health risk from other diseases including those that are not associated with recreational with recreational water. From a strictly health perspective, many of the factors that might be taken into account in such an adaption would often lead* *to the derivation of stricter standards than those presented* (e.g. considering compromised health of bather as a result of HIV/AIDS). *What signifies an acceptable or tolerable risk is not only a regional or local issue, however, as even within a region or locality children, the elderly and people from lower socio-economic areas would be expected to be more at risk."*

- *E. coli no longer considered only appropriate indicator for marine waters*

  Most countries found enterococci to be the most suitable indicator for marine waters. A number of deficiencies with using thermotolerant coliforms[2] as indicator organisms of health risks in marine waters have been documented and epidemiological studies also showed poorer relationships between thermotolerant coliform densities and illness rates in bathers than are obtained using intestinal enterococci. Furthermore, there is now considerable evidence that thermotolerant coliforms die off faster than some pathogens under certain circumstances and may, therefore, go undetected during beach monitoring programmes, resulting in the disease risks being underestimated. It has been noted that thermotolerant coliforms and *E. coli*, although not well correlated with health risks, may be used as indicators in addition to intestinal enterococci in environmental conditions in which intestinal enterococci levels alone may be misleading. For example, *E. coli* rather than intestinal enterococci should be used as an indicator wherever the primary source of thermotolerant contamination is a waste stabilisation pond (WSP). Enterococci are damaged in WSP, whereas thermotolerant coliforms that emerge from a pond appear to be more sunlight resistant than those that enter it. Thus WSP enterococci are inactivated in receiving water faster than WSP thermotolerant coliforms.

- *Suitable indicators for temperate versus tropical waters (i.e. along the east coast of South Africa)*

  The South African coast spans three biogeographical regions (or climatic zones), namely the cool temperate west coast, warm temperate south coast and subtropical east coast (Brown and Jarman, 1978).

  The potential for indicator microbial survival and re-growth (both *E. coli* and enterococci) in tropical areas has resulted in doubts concerning the interpretation of indicator microbiological concentrations in tropical environments, especially given that the studies used to establish the US-EPA and WHO guidelines were based on studies in temperate regions. Results from these studies may not be representative of tropical regions. In tropical areas, indicator microbiological concentrations can be elevated beyond that from faecal impacts alone primarily due to the persistence and re-growth of these indicators within the environment (Shibata et al., 2004). Internationally this issue is currently being addressed although there is still no clear outcome. The US-EPA plans to conduct an epidemiological study in a tropical region by December 2010 (http://www.epa.gov/waterscience/criteria/recreation/update.html). As an interim the State of Hawaii (USA) currently uses *Clostridium perfringens*, a spore-forming obligate anaerobe to supplement its microbiological monitoring programme. *C. perfringens* is not capable of re-growth in aerobic environments but persists for long periods. Its detection in marine environments is proof of sewage contamination, although not necessarily recent contamination (Hawaii Department of Health, 2000). In conjunction with high numbers of other microbial indicators (*E. coli* and enterococci) it represents a source of concern.

- *Lack of proper implementation practice*

  Currently, in addition to recommended target values, the South African guidelines provide extensive background information on recreational use along the coast, background information on relevant parameters and literature-based cause and effect data. However, the guidelines do not provide clear guidance on implementation that is included in more recent international guidelines such as those of the WHO (2003) and New Zealand (NZME, 2003). Implementation includes, for example, suitability for recreation grading and beach surveillance (day-to-day management) systems.

[2] Previously also referred to as faecal coliforms

1.3 This Document

This document contains the revised guidelines for recreational waters of the South Africa's coastal marine environment, addressing some of the shortcomings of the previous version (DWAF, 1995) listed above. The aim is to provide managers and governing authorities with the background and guidance to define target ranges for recreational waters, as well as to provide guidance on the implementation thereof.

In preparing this document, the approach followed was to conduct an international review of similar guidelines from a selection of countries and organizations, considered to be the global leaders in this regard, whilst also considering the previous version of South Africa's water quality guidelines for coastal marine waters: Recreational use (DWAF, 1995) . Countries and organisations included in this review were (see Appendix B):

- European Community
- World Health Organisation
- New Zealand
- United States of America
- Australia
- Canada.

Projects undertaken in the southern African region aimed towards developing regional guidelines, such as Benguela Current Large Marine Ecosystem (BCLME) programme (Taljaard, 2006) and the Project "Addressing Land-based Activities in the Western Indian Ocean" (WIO-Lab) (Taljaard et al, in prep), were used as the basis for the review.

Based on the outcome of this international assessment, target values for the selected water quality indicators, as well as implementation practices were identified and adapted for the South African situation, pending the acquisition of suitable local scientific data and knowledge. A similar approach was followed by New Zealand when revising their recreation guidelines in 2003 (NZME, 2003) .

The document covers the following:

Chapter 1: Introduction (this chapter)
Chapter 2: South African Situation
Chapter 3: Selection of Water Quality Indicators
Chapter 4: Recommended Target Values
Chapter 5: Monitoring Protocols
Chapter 6: Implementation Framework

Appendices to this report include:

Appendix A: Historical Overview of South African Guidelines
Appendix B: International Review of Guidelines for Recreational Use of Coastal Marine Waters
Appendix C: Background Information on Selected Indicators
Appendix D: Proposed Sanitary Inspection Checklist
Appendix E: Example - Sampling Log sheet.

1.4 Recommendations for Future Research

Although several of the shortcomings listed in the previous section are addressed to some extent in this revised version of the Water Quality Guidelines for Recreational Waters in the Coastal Marine Environment, there are certainly aspects that require further investigation and refinement within the South African context.

To this end it is recommended that a dedicated scientific programme, in collaboration with international role players, be established aimed at conducting such investigations. The following are of particular importance:

- Verification of the applicability of internationally accepted risk to exposure versus intestinal enterococci ranges to the South African situation, where a large proportion of recreational users may have compromised health profiles related, for example to HIV/AIDS, malnutrition and tuberculosis (epidemiological data are mostly collected in recreational waters of the developed world involving healthy adults);
- Suitability of using intestinal enterococci as an indicator of human health risk in sub-tropical waters along the east coast of South Africa; and
- Verification of the equivalent risk for intestinal enterococci versus *E. coli* ranges, an important aspect to consider where *E. coli* needs to be applied as an additional or alternative indicator of risk.

2. SOUTH AFRICAN SITUATION

2.1 South Africa's coastline

The marine and coastal resources of South Africa are a rich and diverse national asset, providing important economic and social opportunities for the human population, which, in turn, has developed a strong reliance on these resources in terms of cultural values, job creation and general economic upliftment in coastal regions One of the most important values of South Africa's coast is linked to recreation and tourism (DEAT, 2006). For some people, the coast is a place of cultural or spiritual significance and many South Africans also see the coast as a place of recreation. Tourism, recreation and leisure activities have grown into a global industry and South Africa's coast has particular value in this regard.

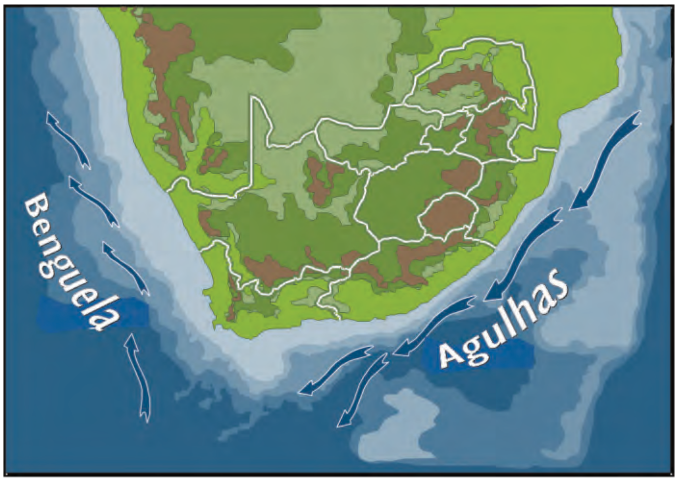


Figure 2.1: South Africa's major coastal circulation system

The 3 000 km coastline of South Africa stretches from the Orange River on the west coast to Ponta do Ouro on the east coast. South Africa is unique in having sharply contrasting currents on opposite coasts (Figure 2.1). The cold Benguela Current on the west coast comprises a general equator-ward flow of cool water in the South Atlantic gyre, with dynamic wind-driven upwelling close inshore at active upwelling sites. The warm western boundary Agulhas Current flows strongly southward along the east coast, bringing nutrient-poor tropical water from the equatorial region of the western Indian Ocean (Lombard *et al*., 2004).

Figure 2.2: Biogeographical regions along the South African coast

The South African coast spans three biogeographical regions (or climatic zones), namely the cool temperate west coast, warm temperate south coast and subtropical east coast (Brown and Jarman, 1978 Figure 2.2).

West coast. The west coast of South Africa is defined as the section of coast extending from Cape Agulhas in the south-east to the Orange River in the north-west. The cold Benguela current has a great influence on the physical and biotic characteristics of the west coast. The western coast of South Africa is dominated by coastal upwelling. This upwelling is driven by south-easterly and southerly winds which, in combination with Coriolis forces, lead to offshore drift of surface waters. Biological communities along the west coast generally exhibit low species richness, with high biomass values being achieved by a few species, including kelps, limpets, black mussels, white mussels, abalone, rock lobsters and a number of fish and bird species. The most important industry along the west coast is fish-processing. The west coast is also a popular tourist area.

South coast. The south coast of South Africa is defined as the section of coast extending from Cape Agulhas to East London. The south coast is considered to be a transition zone between the cold temperate and warm subtropical regions. The Agulhas Bank is a large mixing area between the cold Benguela and warm Agulhas currents. The overlapping of different current systems along the south coast is reflected in the biota which is characterised by high species diversity. Although high in species diversity, not many species occur in abundances to sustain high rates of exploitationFishing efforts are targeted mainly at lobster, demersal fish (e.g. hake and sole), pelagic fish and chokka squid (the only chokka squid line fishery in South African waters).

East coast. The east coast of South Africa is defined as the section of coast extending from north of East London to the Mozambique border. The warm Agulhas current is the greatest factor influencing the coastal marine environment along the east coast of South Africa. Generally, east coast fauna and flora are relatively low in total biomass but species diversity is high with distinct Indo-Pacific affinities. Numerous industries (e.g. paper and pulp, textile and chemical industries) are situated along the southern part of the east coast. The east coast is also a very popular tourist attraction.

Rainfall patterns in the different regions vary greatly as a result of South Africa's highly variable climate. In the cool temperate region, the climate ranges from semi-arid (extended periods of low to no rainfall interspersed with short flash rain events) along the west coast to Mediterranean (dominated by seasonal winter rainfall) along most of the south-western coast. In the warm temperate region along the south coast, rainfall is bi modal, with peaks in spring and autumn, while the subtropical region along the east coast is dominated by seasonal summer rainfall (Davies and Day, 1998).

2.2 Recreational use

Recreational use is made of South Africa's coastal marine waters along the full 3 000 km of coastline. Thousands of tourists visit the popular bathing beaches, especially during the peak holiday seasons. Along the west and south coast of South Africa this usually occurs during the warmer summer months, while it is practised all year round along the subtropical east coast regions. Recreational use of coastal marine waters varies from bathing to mere enjoyment of its scenic aspects.

Recreational use of coastal marine waters is dependent on ambient water quality, since no water treatment or maintenance is practised, except where water is extracted for use in public seawater swimming pools.

The recreational uses of coastal marine waters can be divided into two major categories:

- Contact recreation[3]
- Non-contact recreation.

[3] Previously (DWAF, 1995) a distinction has been made between direct contact recreation (swimming, diving, scuba and snorkelling, water skiing, surfing, paddle skiing and wind surfing) and secondary contact recreation (e.g. boating, sailing, canoeing, wading, angling and parasailing) based on the extent of contact with water. Practically this distinction was not really applied, it is therefore proposed that this distinction be revised.

i. Contact recreation

This category is characterised by the fact that body contact, ingestion of water and inhalation of aerosols are likely to occur throughout the activity. Activities where such contact will be frequent include swimming, diving (scuba and snorkelling), water skiing, surfing, paddle skiing and wind surfing. Contact recreation can also include activities like boating, sailing, canoeing, wading, angling and parasailing, where the user may come into contact with the water, inhale aerosols or swallow water, albeit to a lesser extent than other activities listed above.

Figure 2.3: Swimming, an example of a contact recreation activity

Contact recreation occurs along the entire South African coastline, particularly at coastal cities and holiday towns. More tolerable water temperature is the main reason for the greater density of users along the south and east coast compared to the west coast.

The age group that participates in these activities spans a wide range, from infants to elderly people. The health status of these individuals may also vary. For example individuals may be able to swim despite bad health, while individuals taking part in the more strenuous sports such as wind surfing and skiing, are usually fit and healthy.

ii. Non-contact recreation

Non-contact recreation involves all recreational activities taking place in the vicinity of coastal marine waters, but which do not involve direct contact with the water, such as sightseeing, picnicking, walking, horse riding, hiking, camping, etc. These activities occur all along the South African coastline, particularly at coastal cities and holiday towns, including all coastal areas where coastal development and tourism are important activities.

Figure 2.4: Enjoying the scenic beauty, an example of a non-contact recreation activity

Typical problems associated with non-contact recreation are largely related to unpleasant aesthetics, e.g. bad odours, discolouration of water and presence of objectionable matter.

3. SELECTION OF WATER QUALITY INDICATORS

The ultimate goal in the management of coastal systems is to keep the resource suitable for all designated uses. In terms of recreational use of coastal marine waters, this goal translates into broad environmental quality objectives stating that:

Environmental quality is suitable for recreational use from an aesthetic, safety and hygienic point of view.

From a management perspective, this broad objective needs to be translated into measurable target values (or EQTs). The aim of such target values is to provide scientific yardsticks against which the fitness for use of a particular water body for a designated use may be evaluated. However, the quality of a water body can be described in many different ways. It is therefore important to select specific norms upon which water quality properties/constituents (or indicators) relevant to describing the fitness of a specific use, could be selected. Typically such norms are based on specific problem categories of which the following are considered of key importance to recreational use of coastal marine waters, namely:

Typical water quality problems associated with recreational use of coastal marine waters include[4]:

- *Aesthetics* (e.g. bad odours, discolouration of water and presence of objectionable matter) ;
- *Human health and safety* (e.g. gastrointestinal problems, skin, eye, ear and respiratory irritations, physical injuries and hypo-/hyperthermia); and
- *Mechanical interference* (e.g. clogging and choking of mechanical equipment in the waters such as boat engines and diving gear).

Key water quality properties/constituents typically used to assess the status with regard to the above-mentioned problem categories are indicated in Table 3.1 (refer to Appendix B).

TABLE 3.1: Key water quality properties/constituents (indicators) used to assess different problem categories associated with recreational use of coastal marine waters

PROPERTY/CONSTITUENT	PROBLEM CATEGORY		
	AESTHETICS	HUMAN HEALTH & SAFETY	MECHANICAL INTERFERENCE
Objectionable matter	●	●	●
Microbiological indicator organisms		●	
Physico-chemical parameters (pH & temperature)		●	
Toxic substances (chemical compounds & toxic algal blooms)		●	

[4] All categories apply to contact recreation, while non-contact recreation is mostly affected by aesthetic problem.

4. RECOMMENDED TARGET VALUES

Recommended target values (or scientific yardsticks) for the water quality properties (or indicators) considered appropriate for assessing fitness of coastal marine waters for recreational use (Table 3.1) are discussed here.

4.1 Objectionable Matter

Internationally, targets for objectionable matter are typically presented as narrative statements (see Appendix B). Following this approach the recommended target values for objectionable matter for recreational waters are presented in Table 4.1.

TABLE 4.1: Recommended targets for Objectionable matter in coastal marine waters for recreational use

INDICATOR	RECOMMENDED TARGET
Objectionable Matter	*Water should not contain litter, floating particulate matter, debris, oil, grease, wax, scum, foam or any similar floating materials and residues from land-based sources in concentrations that may cause nuisance.* *Water should not contain materials from non-natural land-based sources which will settle to form objectionable deposits.* *Water should not contain submerged objects and other subsurface hazards which arise from non-natural origins and which would be a danger, cause nuisance or interfere with any designated/recognized use.* *Water should not contain substances producing objectionable colour, odour, taste, or turbidity.*

4.2 Physico-chemical Properties

Internationally, target ranges for recreational waters have been recommended for pH and temperature from a human health and safety perspective (e.g. ANZECC, 2000). These are listed in Table 4.2.

TABLE 4.2: Recommended targets for physico-chemical indicators in coastal marine waters for recreational use

INDICATOR	RECOMMENDED TARGET
pH	*pH of water should be within the range 5.0–9.0, assuming that the buffering capacity of the water is low near the extremes of the pH limits*
Temperature	*For prolonged exposure, temperatures should be in the range 15–35°C*

4.3 Microbiological Indicators

A detailed review of international studies conducted by the WHO in 2003, concluded that in marine waters intestinal enterococci (faecal streptococci) was the only *microbiological indicator* (Box 4.1) that showed a dose–response relationship for both gastrointestinal illness (GI) and acute febrile respiratory illness (AFRI) based on data collected from mainly temperate regions in the world (WHO, 2003; Kay et al., 2004). The target values proposed here for microbiological indicators apply to the water column only and not to beach sediments (Box 4.2).

Box 4.1: Microbiological Indicators

Because it is often impractical and expensive to conduct regular sampling of disease-causing bacteria, viruses and protozoa, "microbiological indicators" are used. These are organisms that may not necessarily cause disease but which show sufficient correlation with disease-causing pathogens and which are more practical and affordable to monitor regularly.

Most countries have found enterococci to be the most suitable indicator for marine waters (ANZECC, 2000a; CMNHW, 1992; US-EPA, 1986a; US-EPA, 2000; WHO, 2003, NZME, 2003). A number of deficiencies with using thermotolerant coliform as indicator organism of health risks in marine waters have been documented (McBride et al., 1991). Epidemiological studies have shown poorer relationships between thermotolerant coliform densities and illness rates in bathers than are obtained using enterococci (Cabelli 1983a & 1983b, Cabelli et al. 1982 & 1983). Furthermore, there is now considerable evidence that thermotolerant coliforms die off faster than pathogens under certain circumstances and may, therefore, go undetected during beach monitoring programmes, resulting in the disease risks being underestimated (CMNHW, 1992).

Thermotolerant coliforms (e.g. *Escherichia coli*), although not well correlated with health risks, may be used as indicators in seawater, in addition to enterococci, under conditions in which enterococci levels alone may be misleading. For example, *E. coli* rather than enterococci should be used as an indicator wherever the primary source of faecal contamination is a waste stabilisation pond (WSP). Enterococci are damaged in WSP, whereas thermotolerant coliforms that emerge from a pond appear to be more sunlight resistant than those that enter it. Thus WSP enterococci are inactivated in receiving water faster than WSP thermotolerant coliforms (NZME, 2003). Estuarine and brackish waters may require a combination of intestinal enterococci and *E. coli*.

Also, while it is correct to infer that water exceeding the guideline values poses an unacceptable health risk, the converse is not necessarily true. This is because wastewater may be treated to a level where the indicator bacteria concentrations are very low, but pathogens such as viruses and protozoa may still be present at substantial concentrations. Specific investigation of this would require the generation of statistically robust data to establish that the treatment process produces an effluent that meets the guideline indicator bacteria values, but at the same time is capable of destroying pathogenic micro organisms. Also, wastewater plants may not always operate 100% of the time (e.g. during high water flows) (NZME, 2003).

Box 4.2: Microbiological aspects of beach sand quality

The WHO (2003) concluded the following on microbiological aspects of beach sand quality, which is also considered relevant to the South African situation:

"Bacteria, fungi, parasites and viruses have all been isolated from beach sand. A number of them are potential pathogens. Factors promoting the survival and dispersion of pathogens include the nature of the beach, tidal phenomena, the presence of sewage outlets, season, the presence of animals and the number of swimmers. Transmission may occur through direct person-to-person contact or by other means, although no route of transmission has been positively demonstrated. Concern has been expressed that beach sand or similar materials may act as reservoirs or vectors of infection. However, the capacity of microorganisms that have been isolated from beach sand to infect bathers and beach users remains undemonstrated, and the real extent of their threat to public health is unknown. There is therefore no evidence to support establishment of a guideline value for index organisms or pathogenic microorganisms in beach sand. The principal microbial risk to human health encountered upon beaches and similar areas is that arising from contact with animal excreta, particularly from dogs. Regulations that restrict access seasonally on frequently used beaches or place an obligation upon the owner to remove animal excreta, increased public awareness and beach cleaning are preventive management actions."

Microbiological water quality guidelines for recreational areas may be developed from two main strands of enquiry into health effects: epidemiological studies or quantitative risk assessment. In epidemiological studies (see Box 4.3) the focus is on direct measurement of health effects while quantitative risk assessment focuses first on pathogen concentrations, with health effects then being inferred using known dose-response relationships (NZME, 2003).

Box 4.3: Epidemiological Studies

In epidemiological studies the aim is to establish the illness record of a number of water users using a recreational site on a particular day when water quality samples were also taken. This involves intensive interviewing of beach users on the sampling day, and follow-up interview some days later to obtain a record of health effects (a record of self-diagnosis is obtained). Associations between health effects of swimmers versus non-swimmers are established to estimate any swimming-associated, pollution-related effects. People interviewed may be those who have decided of their own volition to attend the beach, without knowing that a study was in progress, in which case it is an *uncontrolled prospective study*. On the other hand people may be recruited into the study and taken to a particular beach where they may swim, in which case it is a controlled cohort study. Most epidemiological studies have been of the uncontrolled kind, although more recent studies have used the controlled approach. The WHO endorsed results from a number of controlled cohort studies which were used in the development of their guidelines (WHO, 2003; NZME, 2003).

Internationally, the use of 'single' target values for microbiological indicators to classify recreational waters as either 'safe' or 'unsafe' is no longer considered appropriate. Rather, an approach of applying a range of target values for appropriate microbiological indicators, corresponding to different levels of risk, is used. This approach has been adopted by the World Health Organisation (WHO, 20 03), New Zealand (NZME, 2003) and the European Union (CEC, 2006). This approach supports the principle of informed personal choice and allows for setting achievable improvement targets for high-risk areas (WHO, 2003). The target values for different risk levels are typically derived from epidemiological studies, for example, based on exposure of healthy adult bathers swimming in sewage impacted marine waters in a temperate climate with "exposure" as a minimum of ten minutes of swimming involving three head immersions (WHO, 2003).

Following a similar approach, the recommended target values for microbiological indicators in South African marine waters (using both intestinal enterococci and *Escherichia coli*) are presented in Table 4.3. Corresponding levels of risk from published international sources are adopted (see Appendix B). The "sufficient" (or fair) category is considered the minimum acceptable risk for South Africa (see Box 4.4).

TABLE 4.3: Risk-based ranges for intestinal enterococci and Escherichia coli for recreational waters in the coastal marine environment

CATEGORY	ESTIMATED RISK PER EXPOSURE	ENTEROCOCCI (Count per 100 ml)	E. coli (Count per 100 ml)
Excellent	*2.9% gastrointestinal (GI) illness risk*	*≤ 100 (95 percentile)*	*≤ 250 (95 percentile)*
Good	*5% GI illness risk*	*≤ 200 (95percentile)*	*≤ 500 (95 percentile)*
Sufficient or Fair (minimum requirement)	*8.5% GI illness risk*	*≤ 185 (90 percentile)*	*≤ 500 (90 percentile)*
Poor (unacceptable)	*> 8.5% GI illness risk*	*> 185 (90 percentile)*	*> 500 (90 percentile)*

Although intestinal enterococci were shown to be the most appropriate microbiological indicator for coastal marine waters based on data from mostly temperate regions (WHO, 2003), recent studies have shown the potential for both *E. coli* and intestinal enterococci to survive and re-grow in tropical areas. This has given rise to doubts concerning the interpretation of these microbiological indicator concentrations in tropical environments, especially as the studies used to establish target values excluded tropical regions. The concern is that in tropical regions, microbiological indicator concentrations can be elevated beyond that from faecal impacts alone primarily due to the persistence and re-growth of these indicators within the environment (Shibata et al., 2004).

Box 4.4: Minimum acceptable risk

"Acceptable or tolerable excess disease rates are especially controversial because of the voluntary nature of recreational water exposure and the generally self-limiting nature of the most studied health outcomes (gastroenteritis, respiratory illness). Therefore, assessment of recreational water quality should be interpreted or modified in light of regional and/or local factors (in consultation with relevant stakeholders). Such factors include the nature and seriousness of local endemic illness, population behaviour, exposure patterns, and socio -cultural, economic, environmental and technical aspects, as well as competing health risk s from other diseases, including those that are not associated with recreational water. From a health perspective, many of the factors that might be taken into account in such an adaptation would often lead to the derivation of stricter standards than those presented (e.g. considering compromised health of bathers as a result of HIV/AIDS). What signifies an acceptable or tolerable risk is not only a regional or local issue, however. Even within a region or locality children, the elderly and people from lower socio-economic areas would be expected to be more at risk (WHO, 2003)."

At a technical specialist workshop (10 November 2009), it was agreed that South Africa should adopt the European Community (EC) risk-based ranges for intestinal enterococci and *E. coli* (as listed in CEC, 2006). Workshop participants considered the "excell ent" category more realistic for the South African situation than the WHO (2003) top category (preliminary testing at existing Blue Flag beaches across the world also found that the WHO target of 40 enteroc occi per 100 ml (at 95 percentile) was not practical and difficult to enforce (Alison Kelly, Blue Flag Coordinator South Africa, pers. comm.). Further, the stricter minimum level of the EC targets, compared with the WHO (2003), was also considered more appropriate for the South African situation where many bathers have compromised health or higher susceptibility to illness.

Whilst waiting on the outcome of scientific studies by organisations such as the WHO, measures to mitigate this potential problem include the use of an additional microbiological indicator - *Clostridium perfringens*, a spore-forming obligate anaerobe - in the assessment of recreational waters along tropical coasts (Hawaii Department of Health, 2000). The use of this indicator **does have** shortcomings; e.g. although *C. perfringens* is not capable of re-growth in aerobic environments it does persists for long periods, and its detection in the environment may not be an indicator of recent sewage contamination. The recommended target value for *C. perfringens* is:

INDICATOR	RECOMMENDED TARGET
C. perfringens	*Geometric mean ≤ 5 counts per 100 ml*

4.4 Toxic Substances

With reference to toxic substances (chemical compounds), it is proposed that South Africa's drinking water quality guidelines (e.g. SANS, 2005) be consulted to make preliminary risk assessments in areas where these substances are expected to be present at levels that pose a risk to human health as long as care is taken in the application. Drinking water quality targets relate, in most cases, to lifetime exposure following consumption of 2 litres of drinking water per day. For recreational water contact, an intake of 200 ml per day - 100 ml per recreational session with two sessions per day - may often be reasonably assumed. It should be noted that this approach may, however, not be appropriate to substances of which the effects are related to direct contact with water, e.g. skin irritations.

Box 4.5: Chlorine

The increasing presence of chlorine, used by local authorities to treat/disinfect wastewater effluent or wastewater spills, has been highlighted as a concern. It is therefore recommended that manager responsible for monitoring of beach water quality specifically observe for the presence of chlorine contamination (e.g. as an item on the monitoring log sheet). Where contamination is suspected, appropriate monitoring must be carried out by reputable scientists to establish potential health risks.

With regard to toxins from *harmful algal blooms*, no specific target values are prescribed, but when the presence of such harmful algal proliferation occurs, appropriate monitoring must be carried out by reputable scientists to establish potential health risks.

5. MONITORING PROTOCOL

The monitoring protocol described in this chapter primarily focuses on *microbiological data* as part of long-term monitoring programmes to assess the quality of recreational coastal waters (observations on *aesthetic quality* of recreational waters are recorded during microbiological sampling occasions).

With regard to *physico-chemical* parameters, it is considered unlikely for non-natural sources to modify pH in coastal marine waters beyond the recommended target range (Table 4.2), considering the strong buffering capacity of seawater (at salinity ~35). However, in estuaries strong freshwater inflow could reduce buffering capacity. In such instances the pH target range could be exceeded, for example where highly acidic or alkaline industrial wastewater is discharged into area. Non-natural sources are also not expected to modify temperature beyond the recommended target range (Table 4.2), except in instances where cooling water is discharges into sheltered coastal environment. It is therefore proposed that the inclusion of these physico-chemical indicators only be considered in areas where such contamination is suspected. In such instances specialist input from reputable analytical laboratories must be sourced to assist in appropriate sampling design as well as analytical techniques.

The potential risks from *toxic contamination* of coastal recreational waters along the South African coast - apart from toxins produced by marine biota such as harmful algal blooms - is also considered to be much smaller than the potential risks from microbiological contaminants. It is expected that concentrations of toxic contaminants will typically be below drinking water target values. However, where toxic contamination occurs or is suspected, and a health risk is identified or presumed, appropriate monitoring must be carried out by reputable scientists and/or analytical laboratories to enable timely identification of health risks and adequate management measures must be taken immediately to prevent exposure. These measures should include informing the public.

5.1 Sampling Log Chart

To ensure that all related information is captured during sampling (e.g. information necessary for interpretation of microbiological data, recording of aesthetic conditions and potential presence of toxic substances) a sampling log sheet should be completed at each sampling point on every sampling occasion, capturing the following information (see Appendix E for example):

- Sampling location
- Date and time
- Climatic conditions (rainy, sunny, cloud cover)
- Water temperature (e.g. using an *in situ* probe)
- Salinity (e.g. using an *in situ* probe)
- Presence of objectionable matter
- Presence of potentially harmful algal blooms
- Indication of potential presence of toxic chemical substances (including chlorine)
- Comments: Any other observations that may be of relevance for interpretation of the data.

5.2 Sampling Period and Frequency

Microbiological samples should be collected during periods when coastal waters are used for contact recreation. A systematic random-sampling regime is recommended which implies that samples should be collected at a minimum every two weeks during daylight, regardless of the weather (although there may be exceptions if conditions present a health and safety hazard, in which case samples should be collected as soon after the programmed time as possible). A monitoring calendar should be drawn up for each year.

5.3 Sampling Procedures and Analytical Methods

The specific sampling location at a recreation area should be selected on the basis of information gathered during the sanitary inspection (refer to Chapter 6.1). The location/s should be representative of the water quality throughout the whole contact recreation area. The sampling depth should be 15 to 30 cm below the surface where the depth of the water is approximately 0.5 metres. Samples should be collected on the seaward side of a recently broken wave, taking care not to collect backwashing water.

Samples for the analyses of both intestinal enterococci and *E. coli* must be collected (although enterococci is recommended as the most appropriate indicator for marine waters, there may be instances where *E. coli* may be more appropriate - see Box 4.1). In sub-tropical areas, it may also be necessary to collect samples for the analysis of *C. perfringens* to assist with interpretation of microbiological indicator results.

Samples collected for *E. coli* analyses must be analysed on the day of sampling - preferably within 6-8 hours after sampling - due to the rapid die-off of this microbiological indictor in marine waters (Guardabassi et al., 2002). Samples collected for intestinal enterococci and *C. perfringens* analyses must be analysed within 24 hours of sampling.

A reputable (preferably an ISO 17025 accredited) laboratory must undertake microbiological analyses, using recognised analytical procedures as prescribed by the South African Bureau of Standards (SABS) or any equivalent methods provided in *Standard Methods for the Examination of Water and Wastewater.* (www.standardmethods.org). If a laboratory is not accredited it should participate in a national inter laboratory proficiency scheme (e.g. National Laboratory Association). Samples from any one area should be tested by the same method and preferably the same laboratory in order to provide reliable long-term data sets. SABS analytical methods for the different microbiological parameters are provided in Table 5.1 (also see Box 5.1).

TABLE 5.1: SABS analytical methods for the different microbiological parameters

PARAMETER	METHOD/S
Intestinal enterococci	SANS/ISO 7899-1:1998 Water Quality- Detection and enumeration of intestinal enterococci. Part 1: Miniaturised method (Most Probable Number) for surface waters (www.sabs.co.za). SANS/ISO 7899-2:2000 Water Quality - Detection and enumeration of intestinal enterococci. Part 2: Membrane filtration method (www.sabs.co.za).
Escherichia coli	SANS/ISO 9308-3: 1998 Water Quality - Detection and enumeration of *E.coli* and total coliform bacteria. Part 3: Miniaturised method (Most Probable Number) for the detection and enumeration of *E. coli* in surface waste waters (www.sabs.co.za). SANS/ISO 9308-1: 1998 Water quality Detection and enumeration of *Escherichia coli* and coliform bacteria. Part 1: Membrane filtration method (www.sabs.co.za).
Clostridium perfringens	No SABS method or equivalent in Standard Methods for the Examination of Water and Wastewater. A national standard method applied in the United Kingdom is recommended (Standards Unit, Evaluations and Standards Laboratory, 2005) (www.hpastandardmethods.org.uk/about)_sops.asp

Box 5.1: Commercially available substrate-based methods for microbiological determinations

New substrate-based methods are commercially available for the detection and enumeration of intestinal enterococci and *E. coli* in water are available on the market. For example, Enterolert (IDEXX Laboratories Inc., Westbrook, Maine) is a miniaturised, most probable number method for the determination of intestinal enterococci (Budnick et al. 1996). This method allows for easy, rapid, and accurate detection of enterococci in water. More specifically, Enterolert -E www.idexx.com/view/xhtml/en_us/water/enterolert-e.jsf) was developed for the European market and correlates with the EU Bathing Water Directive standard method for enterococci (ISO 7899-1). A similar product, Colilert (IDEXX Laboratories Inc., Westbrook, Maine) is available for the determination *E. coli* in water (www.idexx.com/view/xhtml/en_us/water/colilert.jsf). Colilert is approved by the US-EPA and is included in Standard Methods for Examination of Water and Wastewater. Care should be taken when using Colilert technique for analyses in seawater as it can produce false positive results (e.g. Pisciotta et al. 2002). Incubation at 44.5°C was found to prevent most false positives caused by marine bacteria.

In the case of microbiological data, statistical analyses are required for comparison with the recommended target values (Table 4.3). Percentile values can be calculated by different percentile calculation approaches, based on data availability, statistical considerations and local resources. Two main approaches can be used, either parametric or non-parametric (WHO, 2003). The parametric approach assumes that the samples have been drawn from a particular distribution, typically the $\log_{10}$ normal distribution for microbiological data, while the non-parametric approach does not assume any particular distribution and uses data ranking (Box 5.2). For South Africa, the non-parametric method (i.e. using data ranking) is used for the calculation of percentile values for microbiological parameters (referring to Box 5.2). The Hazen method is the preferred procedure although the Excel spreadsheet method can also be applied where users do not have access to a suitable Hazen template.

Box 5.2 Calculation of percentile values for microbiological parameters

Parametric: Based upon percentile evaluation of the $\log_{10}$ normal probability density function of microbiological data acquired from a particular bathing water, the percentile value is derived as follows (CEC, 2006):

- **Take the $\log_{10}$ value of all bacterial enumerations in the data sequence to be evaluated (if a zero value is obtained, take the $\log_{10}$ value of the minimum detection limit of the analytical method used instead)**
- **Calculate the arithmetic mean of the $\log_{10}$ values (μ)**
- **Calculate the standard deviation of the $\log_{10}$ values (σ)**

The upper 95 percentile point of the data probability density function is derived from the following equation: upper 95 percentile = antilog (μ + 1,65 σ)

The upper 90 percentile point of the data probability density function is derived from the following equation: upper 90 percentile = antilog (μ + 1,282 σ)

Non-parametric: Firstly the data are ranked into ascending order and then the "rank" of the required percentile calculated using an appropriate formula - each formula giving a different result. There is no one correct way to calculate percentiles in this manner although the Hazen method is typically considered most appropriate as the "middle of the road" option (e.g. the Excel method always give lowest percentile while Weibull method always gives the highest). The Hazen procedure is as follows (NZME, 2003):

- **For n data, X_i, such that i = 1, 2, … , n, rank the n data from lowest to highest where ranked data is Y_i: i = 1, 2, …, n**
- **Compute the percentile fraction (i.e., proportion) as p = P/100 (P is e.g. 95percentile)**
- **Check if there are enough data to make the calculation, i.e., if n >= 1/[2(1 -p)] and n >= 1/(2p) [first limit applies for an upper percentile (p > 1/2), and vice versa]**
- **If there are enough data then calculate the Hazen rank (usually non-integer) $r_{Hazen} = 1/2 + pn$**
- **Interpolate between integer ranks (i.e., ranked data) adjacent to the Hazen rank using Hazen *P*th percentile = $(1\text{-}rf)Y_{ri} + rfY_{ri+1}$, where *ri* = the integer part of r_{Hazen} and *rf* = fractional part of r_{Hazen} [note that the formula still works if there is just enough data, i.e., for equalities, instead of inequalities, in the equations in item 3 above].**

6. IMPLEMENTATION FRAMEWORK

Based on international best practice (Appendix B), the implementation framework for assessing the quality of coastal marine recreational waters should ideally comprise:

- A classification system for recreational waters; and
- An operational management system (for day-to-day management).

In addition to classification and day-to-day management of recreational waters it is also important to respond timeously to any situation that could pose potential risk to human health by implementing appropriate management actions. This is particularly important in areas classified as "Good", "Fair" and "Poor" where there is the potential for faecal contamination events.

6.1 Classification System for Recreational Waters

The classification system for recreational waters is primarily based on a combination of a:

Sanitary inspection; and

Microbiological quality assessment (based on microbiological indicator counts).

The aim of the sanitation inspection is to identify all potential sources of faecal pollution (particularly human faecal pollution) and to grade a recreational area accordingly. In this regard, the three most important sources of human faecal contamination are considered to be:

- sewage (e.g. wastewater discharges, sewage pump station overflow, seepage from septic/conservancy tanks, contaminated storm-water run-off);
- riverine discharges (e.g. where rivers are receiving sewage discharges);
- contamination from bathers (e.g. excreta); and
- shipping and boating activities (e.g. inappropriate sewage disposal practices).

A proposed sanitary inspection checklist for South Africa is presented in Appendix D. The grading of risk, based on the outcome of the sanitary surveys (using the checklist in Appendix D) is presented in Figure 6.1.

The microbiological assessment is based on an evaluation of microbiological indicator data collected as part of a routine monitoring programmes typically over a period of five years (refer to Chapter 5). Microbiological quality is graded into the four possible categories (referring to Table 4. 3):

GRADE	INTESTINAL ENTEROCOCCI (counts per 100 ml)	*E. coli* (counts per 100 ml)
Excellent	≤ 100 (95 percentile)	≤ 250 (95 percentile)
Good	≤ 200 (95 percentile)	≤ 500 (95 percentile)
Sufficient/Fair	≤ 185 (90 percentile)	≤ 500 (90 percentile)
Poor	> 185 (90 percentile)	> 500 (90 percentile)

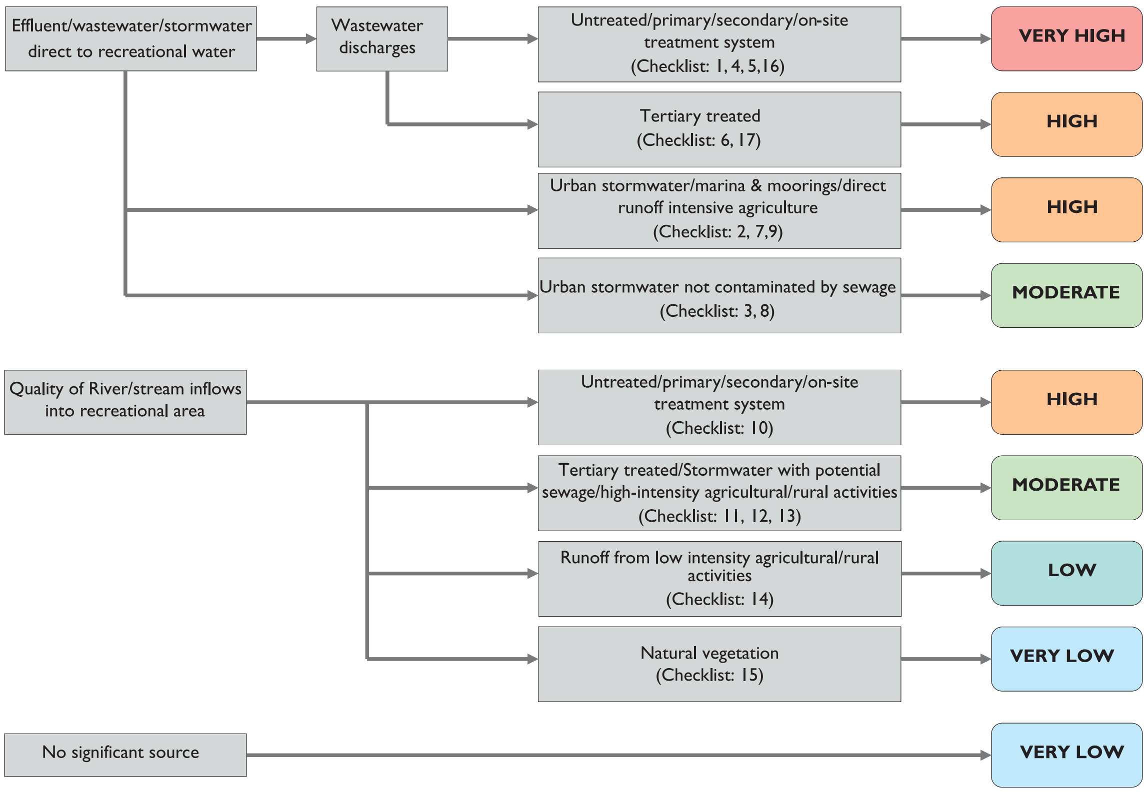


Figure 6.1: Sanitary inspection grading system, based on the outcome of the sanitary inspection (see Appendix D)

The classification of recreational waters is based on a combination of the Sanitary Inspection Category and Microbiological Quality Assessment Category, as illustrated in Table 6.1 and Figure 6.2. A grade of "Very Good" reflects consistent compliance with microbiological targets with few sources of faecal contamination in the area and surrounds. Consequently there is a low risk of illness from contact recreation. At the other extreme "Very Poor" reflects significant sources of faecal contamination and rare compliance with microbiological targets. The risk of illness from contact recreation in such waters is high, and swimming is not recommended.

TABLE 6.1: Classification system for recreational waters

		MICROBIOLOGICAL QUALITY ASSESSMENT CATEGORY				
		Excellent	**Good**	**Sufficient**	**Poor**	**Exceptional circumstances[3]**
SANITARY INSPECTION CATEGORY	**Very Low**	Very good	Very good	Follow-up[1]	Follow-up[1]	
	Low	Very Good	Good	Fair	Follow-up[1]	
	Moderate	Good[2]	Good	Fair	Poor	
	High	Good[2]	Fair[2]	Poor	Very poor	
	Very high	Follow-up[2]	Fair[2]	Poor	Very poor	
	Exceptional circumstances					Action required

1 *Implies non-sewage sources of faecal indicators (e.g. livestock), and this should be verified.*

2 *Indicates possible discontinuous/sporadic contamination (often driven by events such as rainfall). This is most commonly associated with Combined Sewer Overflow presence. These results should be investigated further and initial follow-up should include verification of sanitary inspection category and ensuring samples recorded include "event" periods. Confirm analytical results. Review possible analytical errors.*

3 *Exceptional circumstances relate to known periods of higher risk, such as during an outbreak with a pathogen that may be waterborne, sewer rupture in the recreational water catchment, etc. Under such circumstances, the classification matrix may not fairly represent risk/safety and a grading would not apply until the episode has abated.*

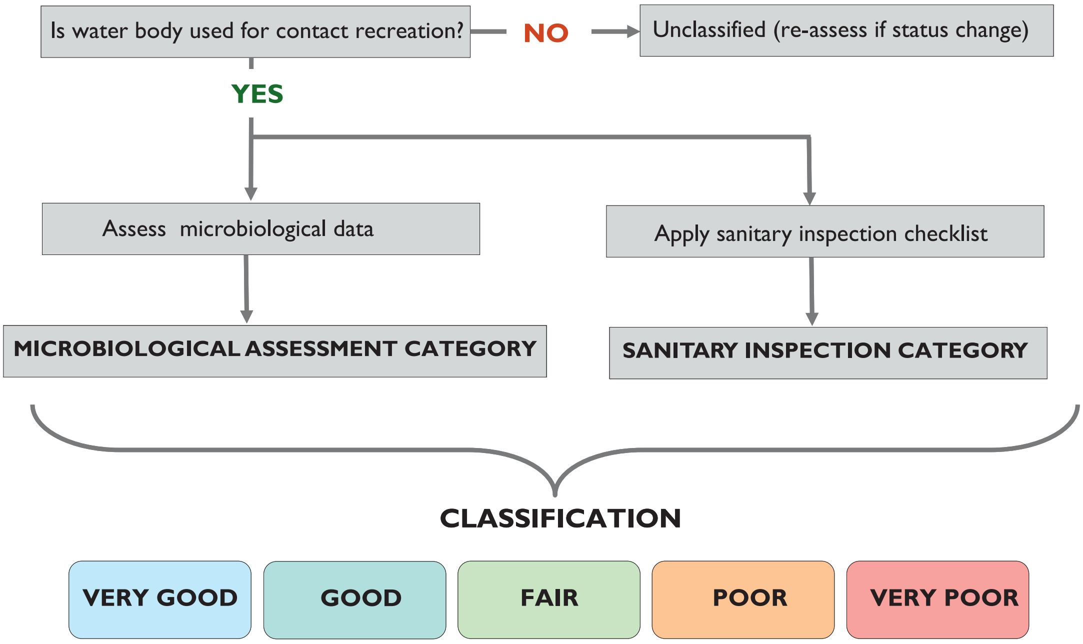


Figure 6.2: The process for classification of recreational waters (adopted from WHO, 2003)

The sanitary inspection should be conducted at least annually. However, when there is reason to believe that the sanitary inspection category may have changed markedly within a year, the inspection should be repeated and the revised category should be applied in the classification process.

The microbiological quality assessment should be based on microbiological data over a 12 month running period. This is considered most appropriate for the South African situation where the microbiological quality of recreational waters can change markedly over short period. This approach allows for a more real-time classification process (e.g. monthly rather than yearly), recognising such variability.

6.2 Operational Management System

The main purpose of an operational management system is to have a process in place that allows timeous response by implementing appropriate management actions to any day-to-day situation that could pose potential risk to human health by implementing appropriate management actions. A proposed operational management process for South Africa, applying single sample target values (Box 6.1), is illustrated in Figure 6.3.

It is recognised that, in the short-term, capacity constraints may prevent local authorities from effectively establishing such operational management systems at all recreational beaches. However, these systems are crucial for effective management of recreational waters and local authorities should be encouraged to incorporate the implementation thereof in their medium- to long-term strategic plans.

Local authorities are encouraged to implement the proposed operational management system at selected recreational areas in order to test its applicability to the South African situation. In particular, the single value targets need to be confirmed.

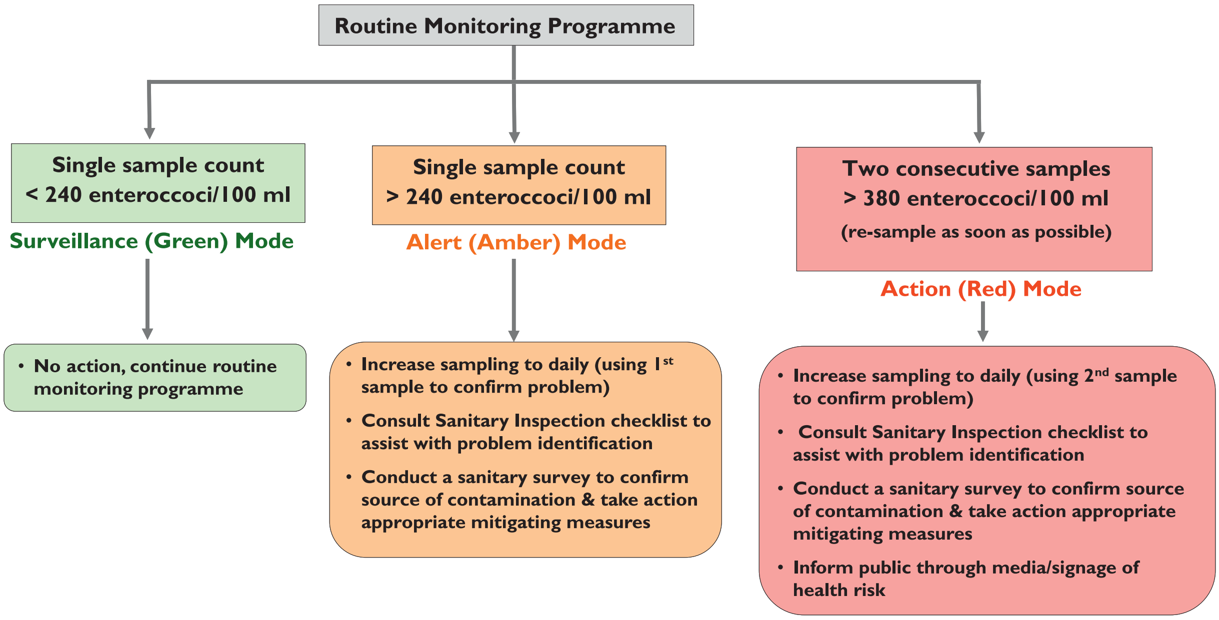
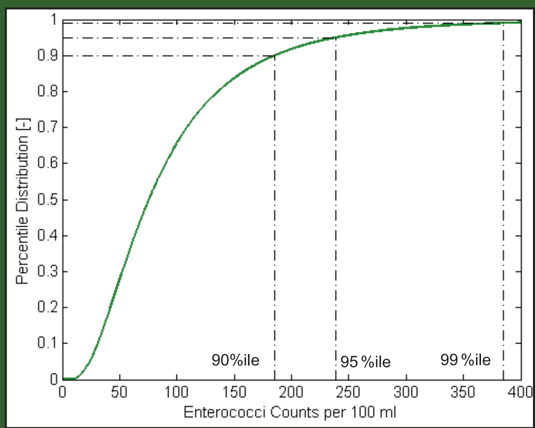


Figure 6.3: Operational management system (adopted from NZME, 2003)

Box 6.1: Single Sample target values

The preliminary single sample target values proposed for the operational management system (Figure 6.3) uses a similar approach to that of New Zealand (NZME, 2003). Recognising numerous limitations the single sample target values were obtained by assuming that intestinal enterococci distributions would be lognormal, that the standard deviation of the logarithms of intestinal enterococci concentration is 0. 7 and that intestinal enterococci concentration limit is at a 90 percentile limit of 185 counts per 100 ml (corresponding to a minimum target recommended for recreational waters). Solving the cumulative distribution frequency of the lognormal and using the bisection method, the alert and action limits were taken as the 95% and 99%, upper one-sided tolerance limits for that distribution, calculated as 239 and 384 enterococci per 100 ml, respectively.



Acknowledging the uncertainty in estimating the standard deviation of the logarithms was considered appropriate to round these values to 240 and 380 enterococci per 100 ml, respectively.

REFERENCES

AMERICAN PUBLIC HEALTH ASSOCIATION 1989 - Standard Methods for the Examination of Water and Wastewater. 16th edition. American Public Health Association, American Water Works Association, Water Pollution Control Federation, Washington, D.C.

AUSTRALIA AND NEW ZEALAND ENVIRONMENT AND CONSERVATION COUNCIL (ANZECC) 2000a - Australian and New Zealand guidelines for fresh and marine water quality. National Water Quality Management Strategy No 4. Canberra, Australia. (www.environment.gov.au/water/publications/quality/index.html).

AUSTRALIA AND NEW ZEALAND ENVIRONMENT AND CONSERVATION COUNCIL (ANZECC) 2000b - Australian guidelines for water quality monitoring and reporting. National Water Quality Management Strategy No 7. Canberra, Australia. (www.environment.gov.au/water/publications/quality/index.html).

BROWN, AC and JARMAN, N. 1978 - Coastal marine habitats. Chapter 8 in Biogeography and Ecology of Southern Africa. Wiener, M.J.A. (Ed.). W. Junk, The Hague. Pp 1239 -1277.

BUDNICK GE, HOWARD RT and MAYO DR 1996 – Evaluation of Enterolert for enumeration of enterococci in recreational waters. Applied and Environmental Microbiology 62(10), 3881 -3884.

CABELLI, VJ 1983a - Public health and water quality significance of viral diseases transmitted by drinking water and recreational water. Water Science and Technology 15, 1 –15.

CABELLI VJ 1983b - Health effects criteria for marine recreational waters. EPA 600/1 -80/031. US Environmental Protection Agency, Cincinnati, Ohio.

CABELLI VJ, DUFOUR AP, McCABE LJ & LEVIN MA 1982 - Swimming-associated gastroenteritis and water quality. American Journal of Epidemiology 115, 606 –616.

CABELLI VJ, DUFOUR AP, McCABE LJ & LEVIN MA 1983 - A marine recreational water quality criterion consistent with indicator concepts and risk analysis. Journal of the Water Pollution Control Federation 55, 1306–1314.

CANADIAN MINISTER OF NATIONAL HEALTH AND WELFARE (CMNHW) -1992 Guidelines for Canadian Recreational Water Quality. Ottawa. ISBN 0-660-14239-2 (www.hc-sc.gc.ca/ewh-semt/pubs/water-eau/guide_water-1992-guide_eau_e.html).

COUNCIL OF EUROPEAN COMMUNITY (CEC) 1994 - Proposal for a Council Directive concerning the quality of bathing water. Document COM(94) 36 final, Commission of the European Communities, Brussels (http://aei.pitt.edu/10452/01/72409_1.pdf).

COUNCIL OF EUROPEAN COMMUNITY (CEC) 1976 - Council Directive of 8 December 1975 oncerning the quality of bathing water (76/160/EEC). Published in Official Journal of the European Communities.

COUNCIL OF EUROPEAN COMMUNITY (CEC) 2000 - 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. Published in Official Journal of the European Communities (http://ec.europa.eu/comm/environment/water/water-framework/index_en.html).

COUNCIL OF EUROPEAN COMMUNITY (CEC) 2002- Proposal for a Directive of the European Parliament and of the Council concerning the quality of bathing water. COM (2002) 581 final.

COUNCIL OF EUROPEAN COMMUNITY (CEC) 2006 – Council Directive 2006/7/EC of the European Parliament And of the Council of 15 February 2006 concerning the management of bathing water quality and repealing Directive 76/160/EEC. Published in Official Journal of the European Communities (http://europa.eu/legislation_summaries/consumers/consumer_safety/l28007_en.htm).

CSIR 1992 - Comments to be considered in the revision of the Water Quality Criteria for the South African Coastal Zone (WQCSA). CSIR Data Report 92005. Stellenbosch 39 pp.

CSIR 2003- Microbiological surveillance programme for the monitoring of beaches and estuaries along the foreshore of the eThekwini municipality. Surveys made in 2002. CSIR Report ENV-D-C-2003-001. 58 pp.

CSIR 2008- Microbiological surveillance program for the monitoring of beaches and estuaries along the foreshore of the eThekwini Municipality. Surveys made in 2008/2009. CSIR Report CSIR/NRE/CO/ER/2009/0061/AQ, Durban.

DAVIES, B and DAY, J 1998. Vanishing Waters. University of Cape Town Press, Cape Town, South Africa. 487 pp.

DEPARTMENT OF WATER AFFAIRS AND FORESTRY (DWAF) 1992 - Interim Report: Water Quality Guidelines for the South African Coastal Zone: Interim Report. Report prepared by the CSIR.

DEPARTMENT OF WATER AFFAIRS AND FORESTRY (DWAF) 1995 - South African water quality guidelines for coastal marine waters. Volume 2: Recreational use.

DEPARTMENT OF WATER AFFAIRS AND FORESTRY (DWAF) 1996 - South African water quality guidelines. Volume 2: Recreational water use. Second Edition (http://www.dwaf.gov.za/documents.asp)

FOUNDATION FOR ENVIRONMENTAL EDUCATION (FEE) 2004 - Blue Flag Campaign (www.blueflag.org/).

GUARDABASSI, L, GRAVESEN, J, LUND, C, BAGGE, L, and DALSGAARD, A. 2002 - Delayed incubation as an alternative method to sample storage for enumeration of E. coli and culturable bacteria in water. Water Research 36(18): 4655-4658.

HAWAII DEPARTMENT OF HEALTH. 2000 - Hawaii Administrative Rules. Water Quality Standards 11-54-08, Honolulu.

KAMIZOULIS, G and SALIBA, L. 2004 - Development of coastal recreational water quality standards in the Mediterranean. Environment International 30: 841 – 854.

KAY, D. 2008 - Development of the WHO guidelines: From retrospective compliance assessment to real-time health risk management. Presentation presented at FEE meeting, Turkey, 25 October 2008. Centre for Research into Environment and Health, University of Wales, Aberystwyth. dvk@aber.ac.uk

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: 1296–1304.

LIVINGSTONE, D J. 1990 - Microbial studies on seawater quality off Durban: 1964 – 1988. CSIR Research Report No. 704. 122 pp.

LUSHER, J A (Ed) 1984 - Water quality criteria for the South African coastal zone. South African National Scientific Programmes Report No. 94. 24 pp plus Appendices.

McBRIDE G B, COOPER A B & TILL D G 1991 - Microbial water quality guidelines for recreation and shellfish gathering waters in New Zealand. NZ Department of Health, Wellington.

NATIONAL HEALTH AND MEDICAL RESEARCH COUNCIL & AGRICULTURE AND RESOURCE MANAGEMENT Council of Australia and New Zealand (NHMRC & ARMCANZ) 1996 updated 2001 Australian drinking water guidelines. ISBN 0 642 24462 6. (www.waterquality.crc.org.au/aboutdw_adwg.htm).

NATIONAL HEALTH AND MEDICAL RESEARCH COUNCIL & AUSTRALIAN WATER RESOURCES COUNCIL (HMRC & AWRC) 1987 - Guidelines for drinking water quality in Australia. Australian Government Publishing Service, Canberra.

NEW ZEALAND, MINISTRY OF ENVIRONMENT (NZME) 2003 - Microbiological water quality guidelines for marine and freshwater recreational area. ISBN: 0-478-24091-0. ME number: 474. Wellington, New Zealand (www.mfe.govt.nz/publications/water/microbiological-quality-jun03/).

PISCIOTTA, JM, DAMON, I RATH, F, STANEK, PA, FLANERY, DM and HARWOOD, VJ 2002 – Marine Bacteria Cause False-Positive Results in the Colilert 18 Rapid Identification Test for *Escherichia coli* in Florida Waters. Applied and Environmental Microbiology 68(2): 539–544.

RAGAS, A M J, SCHEREN, P A G M, KONTERMAN, H I, LEUVEN, R S E W, VUGTEVEEN, P, LUBBERDING, H J, NIEBEEK, G and STORTELDER, P B M. 2005 - Effluent standards for developing countries: combining the technology- and water quality-based approach. Water Science and Technology 52(9): 133-144.

SHIBATA, T, SOLO -GABRIELE, H M, FLEMING, L E and ELMIR, S. 2004 - Monitoring marine recreational water quality using multiple microbial indicators in an urban tropical environment. Water Research 38: 3119 – 3131.

SANS 2005 - South African National Standard 241: Drinking Water (Edition 6). South Africa, Pretoria.

STANDARDS UNIT, EVALUATIONS AND STANDARDS LABORATORY 2005 – Enumeration of *Clostridium perfingens* by membrane filtration. Issue no. 3.1. London, United Kingdom: Health Protection Agency (www.hpa-standardmethods.org.uk/documents/food/pdf/F14.pdf).

TALJAARD S. 2006 - The development of a common set of water and sediment quality guidelines for the coastal zone of the BCLME (Project BEHP/LBMP/03/04) Report submitted to UNOPS as part of the Benguela Current Large Marine Ecosystem Programme. CSIR Report CSIR/NRE/ECO/ER/2006/0011/C. Stellenbosch, South Africa (www.bclme.org).

TALJAARD, S, WEERTS, S, PILLAY, S and RAJKUMAR, A. in prep - Technical Report. Guidelines for the Establishment of Environmental Quality Objectives and Targets in the Coastal Zone the Western Indian Ocean (WIO) Region. Report Prepared for the WIO-LaB Programme.

UNITED NATIONS ENVIRONMENTAL PROGRAMME (UNEP) 1996 - Awards for improving the coastal environment: The example of the Blue Flag. Joint publication of UNEP, World Tourism Organisation and the Foundation of Environmental Education in Europe. ISBN 92-807-1625-5.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY (US -EPA) 1985 - Test Methods for *Escherichia coli* and Enterococci in Water by the Membrane Filtration Procedure. EPA-600/4-85/076, Cincinnati, Ohio.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY (US- EPA) 1986a - Quality criteria for water. US Environmental Protection Agency, Washington DC.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY (US -EPA) 1986b - Ambient water quality criteria for bacteria. January 1986. EPA440/5-84-002. (http://www.epa.gov/waterscience/criteria/humanhealth/microbial/).

UNITED STATES ENVIRONMENTAL PROTECTION A GENCY (US-EPA) 2000 - Methodology for deriving ambient water quality criteria for the protection of human health. October 2000. EPA-822-B-00-004 (http://www.epa.gov/waterscience/criteria/humanhealth).

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY (US -EPA) 2002 - National Beach Guidance and Required Performance Criteria for Grants. June 2002. EPA-823-B-02-004. (http://www.epa.gov/waterscience/beaches/grants/guidance/)

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY (US -EPA) 2002, updated 2003 - National Recommended Water Quality Criteria. November 2002. EPA-822-R-02-047. (http://www.epa.gov/waterscience/criteria/humanhealth/).

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY (US -EPA) 2004 - Implementation Guidance for Ambient Water Quality Criteria for Bacteria. EPA-823-B-04-002 (http://www.epa.gov/waterscience/criteria/humanhealth/microbial/).

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY (US -EPA) 2006 - Water Quality Standards for Coastal Recreation Waters: Using Single Sample Maximum Values in State Water Quality Standards. August 2006. EPA-823-F-06-013 (http://www.epa.gov/waterscience/beaches/rules/singe-sample-maximum-factsheet.htm).

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY (US -EPA) 2007- Report of the experts scientific workshop on critical research needs for the development of new or revised recreational water quality criteria. EPA 823 -R-07-006. (http://www.epa.gov/waterscience/criteria/recreation/).

WORLD HEALTH ORGANISATION (WHO) 1999 - Health-based monitoring of recreational waters: The feasibility of a new approach (The "Annapolis Protocol"). World Health Organisation. WHO/SDE/WSH/99.1. Geneva.

WORLD HEALTH ORGANISATION (WHO) 2001. Bathing Water Quality and Human Health: Protection of the human environment water, sanitation and health. Report WHO/SDE/WSH/01.2. World Health Organization, Geneva.

WORLD HEALTH ORGANISATION (WHO) 2003 - Guidelines for Safe Recreational Water Environments. Volume 1: coastal and freshwaters. Geneva. ISBN 92 4 154580 1. (www.who.int/water_sanitation_health/bathing/srwe1/en/).

WORLD HEALTH ORGANISATION (WHO) 2004 - WHO Guidelines for drinking-water quality, third edition Volume 1: Recommendations Geneva. ISBN 92 4 154638 7. (www.who.int/water_sanitation_health/dwq/guidelines/en/).

APPENDIX A

HISTORICAL OVERVIEW OF SOUTH AFRICAN GUIDELINES

In 1983, a marine pollution workshop organised by the South African Committee for Oceanographic Research (SANCOR) initiated the development of the South Africa's first water quality criteria for the coastal zone, including criteria (or target values) for direct-contact recreation (Lusher, 1984). The objective of this workshop was to establish guidelines for the optimum use of monitoring results in making decision concerning pipeline discharges of effluents to sea and to summarise existing knowledge, identify gaps in knowledge and recommend future priorities for research on safe discharge of effluents to sea. The workshop endorsed a recommendation that South Africa prepare its own water quality criteria for marine and estuarine waters and a committee was appointed for this purpose. All available literature on water quality criteria was surveyed in order to extract the best approach for the South African situation. Simplicity was considered to be of great importance as the criteria would not be used by scientists or experienced administrators alone. The criteria were to provide guidelines on the limits which must not be exceeded for designated uses, but they did not have legal status as opposed to water quality standards, i.e. legally enforceable levels established by the licensing authority.

The criteria developed which related to (direct-contact) recreation were published in 1984 (Table A.1)

TABLE A.1: The criteria developed which related to (direct-contact) recreation were published in 1984 (Lusher, 1984)

Aesthetics and hazard	*Water should not contain floating particulate matter, debris, oil, grease, wax, scum, foam or any similar floating material and residues from land-based sources in concentrations that may cause nuisance or in amounts sufficient to be unsightly or objectionable* *Water should not contain materials from land-based sources which will settle to form putrescent or objectionable deposits* *Water should not contain materials from land-based sources which will produce colour, odours, turbidity or taints or other conditions to such a degree as to be unsightly or objectionable* *Water should not contain submerged objects and other sub-surface hazards which arise from other than natural origins and which would be a danger or cause nuisance or interfere with any designated*
pH	*Should not be more than 0.5 units different from that normally encountered in the area*
Salinity	*Range between 33 and 36*
Turbidity and colour	*Combined effects of turbidity and colour should not reduce the depth of the compensation point for photosynthetic activity by more that 10% from the seasonal background values*
Suspended solids	*Should not be increased by more than 10% of ambient concentrations and should not exceed 80mg l^{-1} except as a result of natural conditions*
Temperature	*Maximum acceptable weekly variation in ambient temperature caused by artificial sources should not exceed the normal range by more than 2°C*
Nutrients	*Water should not contain nutrient and other bio-stimulants from land-based sources in concentrations that are capable of causing excessive or nuisance growths of algae or other aquatic plants or deleterious reductions in dissolved oxygen*
Toxic inorganic material	*Cyanide - 12 µg/l; Fluoride - 5 000 µg/l; Maximum total metal concentrations in µg/l: Arsenic - 12; Cadmium - 4; Chromium - 8; Copper - 5; Lead - 12; Mercury - 0.3; Nickel - 25; Silver - 5; Zinc - 25*
Organics and cumulative	*Multiple hydrocarbons - 15 µg/l; Polynuclear aromatic hydrocarbons (all)- 0.3 µg/l; Chlorinated hydrocarbons in µg/l: Aldrin 1.3; Chlordane – 0.004; Chlorinated naphthalenes – 2.8; Chlorobenzene – 130; Dichlorobenzene – 1 500; DDT and derivatives – 0.001; Dieldrin – 0.001; Endrin – 0.003; Heptachlor – 0.004; Lindane – 0.16; Methoxychlor – 0.03; Pentachlorophenol = 3.7; Polychlorinated biphenyls – 0.03; Toxaphene – 0.07*
Microbiological parameters	*Maximum acceptable count of faecal coliform per 100 ml:* *100 (50% of samples)* *400 (90% of samples)* *2000 (99% of samples)*
Radioactivity	*Concentration of radioactive material present shall not exceed the requirements of the Atomic Energy Corporation of South Africa*

In 1992, the Water Research Commission (WRC) of South Africa commissioned a review of the 1984 version of the Water Quality Criteria for the South African coastal zone (WQCSA). Experts and interested parties were requested to comment on the earlier version which was debated at a 2-day workshop attended by a broad spectrum of representatives from the scientific/engineering community, national and local authorities, industries and environmental organisations. An interim report entitle: *Water Quality Guidelines for the South African coastal zone* (DWAF, 1992) was prepared based on the outcome of this workshop.

This document sub-divided recreational use into two major groups; Primary contact recreation (including swimming, diving, canoeing, surfing, windsurfing, waterskiing and wading) and secondary contact recreation (including boating, fishing and sailing).

The 1992 target values pertaining to recreation remained largely similar to that of the 1984 version except for microbiological parameters which changed to the following (applying to direct-contact recreation):

Microbiological parameters	*Maximum acceptable count of faecal coliform per 100 ml:* *100 (80% of samples)* *2000 (95% of samples)* *Where limits for faecal coliform are exceeded and there is reason to believe that the organisms may be of non-faecal origin, test for* Escherichia coli *should be conducted. Recommended limits for E. coli is the same as for faecal coliform.*

At the time it was noted that faecal coliform as an indicator has shortcomings for assessing risk of infection associated with seawater. Additional tests were, therefore considered desirable when inspection of the environment suggested that there may be a health risk. These additional tests could include enterococci, human viruses and coliphages. Furthermore, the revised methods proposed that, as a guide, surf zone of bathing beaches should be tested at least once every two weeks.

Reasons for changes in the microbiological target values included (CSIR, 1992):

Specification of the maximum count at three percentile levels was considered to be confusing and created unnecessary complication in the application;

The 99 percentile criteria were considered too strict and rather unstable.

In 1995 the Department of Water Affairs and Forestry (DWAF) embarked on a project to update Water Quality Guidelines in South Africa, both fresh and coastal marine waters. The 1992 document (DWAF, 1992) was used as a basis for the update on coastal marine waters, transforming this into a similar format as was used in the updated freshwater documents, including extensive background information to better inform application of the guidelines. This led to the publication of a series of documents on coastal marine water quality guidelines one of which was the *South African Water Quality Guidelines for Coastal Marine Waters Volume 2: Recreational Use* (DWAF, 1995). In essence, the target values presented in the updated version (DWAF, 1995) were the same as in the 1992 version (DWAF, 1992). The updated document merely contained the additional background information. Different sections in the updated document addressed the following (DWAF, 1995):

Section 1: Introduction

Section 2: Characterisation of recreational use in South Africa (full contact recreation, intermediate contact recreation and non-contact recreation)

Section 3: Typical water quality problems associated with recreational use (i.e. human health and safety, aesthetics and nuisance factors, mechanical interferences)

Section 4: Water quality properties/constituents relevant to recreational use (i.e. phys ico-chemical properties, inorganic constituents, organic constituents and microbiological indicator organisms, human pathogens)

Section 5: Effects of change in water quality (and target values) related to recreational use.

Parameters and target values that were adopted for recreational use in the 1995 version are listed in Table A.2.

TABLE A.2: Parameters and target values that were adopted for recreational use in the 1995 version (DWAF, 1992)

PARAMETER	FULL CONTACT	INTERMEDIATE CONTACT	NON-CONTACT
Floating matter, including oil and grease	*Water should not contain floating particulate matter, debris, oil, grease, wax, scum, foam or any similar floating materials and residues from land-based sources in concentrations that may cause nuisance* *Water should not contain materials from non-natural land-based sources which will settle to form putrescence* *Water should not contain submerged objects and other subsurface hazards which arise from non-natural origins and which would be a danger, cause nuisance or interfere with any designated/recognized use*		
Colour/turbidity/clarity	*Should not be more than 35 Hazen units above ambient concentrations (colour)* *Should not reduce the depth of the euphotic zone by more than 10 % of ambient levels measured at a suitable control site (turbidity)*		
Suspended solids	*Should not be increased by more than 10 % of ambient concentrations*		
Faecal coliform (including E. coli)	*Maximum acceptable count per 100 ml:* *100 in 80 % of the samples* *2 000 in 95 % of the samples*		-

More recently, the eThekwini Municipality (Durban) has been implementing other classification systems; a classification system that was developed by the CSIR (Livingstone, 1991, as modified in CSIR, 2003) which is applied in the annual microbiological surveillance programme for the monitoring of their beaches and estuaries (CSIR, 2008) and a classification system that was developed by the eThekwini Municipality for assessing beach water quality on a weekly basis.

The CSIR's classification is based on a process of adverse scoring where the microbiological target ranges for full contact recreation, as presented in the Freshwater water quality guidelines series (DWAF, 1996) is applied (Table A.3), forms an integral part. The freshwater guidelines were used instead of the South Africa Water quality guidelines for coastal marine waters (DWAF, 1995) as the latter did not have target ranges for enterococci and the assumption was made that the risk of the number of cases of illness per organism count would be the similar (Liz Simpson, CSIR, Durban, pers. comm.). Risk ranges associated with these enterococci ranges are presented in Table A. 4 (DWAF, 1996).

TABLE A. 3: Scoring system for microbiological indicators used in the eThekwini municipality microbiological surveillance programme (CSIR, 2003)

INDICATOR	DEGREE	VALUE
Escherichia coli per 100 ml	*0 – 130*	*1*
	130 – 200	*2*
	200 - 400	*3*
	> 400	*4*
Faecal streptococci (enterococci) per 100ml	*0 – 30*	*1*
	30 – 60	*2*
	60 – 100	*3*
	> 100	*4*
Parasite units per 250 ml	*1 – 7*	*4*
	> 7	*8*
Staphylococcus aureus per 50 ml	*Present (+)*	*4*
Salmonella spp. per 250 ml	*Present (+)*	*4*

TABLE A.4: Risk exposure associated with enterococci ranges in the CSIR classification system (as per South Africa's freshwater guidelines– DWAF, 1996)

ENTEROCOCCI (counts /100ml)	ESTIMATED RISK
0 – 30	*Low risk of gastrointestinal illness indicated. to exceed a risk of typically < 8 cases/1 000 swimmers*
30 – 60	*Slight risk of gastrointestinal effects expected. Negligible effects expected if isolated instances only*
60 – 100	*Some risk of gastrointestinal effects, particularly if this occurs frequently. Risk is minimal if only isolated samples fall in this range.*
> 100	*Risks of health effects increase as enterococci levels increase. The volume of water which needs to be ingested in order to cause ill effects decreases as the enterococci density increases*

The system allocates values 1 – 4 to counts in their ascending order of magnitude. The presence or absence of selected pathogens and parasites is included in the grading system, since their isolation points to a potential health hazard regardless of the numbers that may be present. Their detection is regarded as being of special significance, and hence they are given greater weight by being allocated higher values in the scaling system. The total indicator scores realised are then used to assign the water to one of four grades, each of which is colour - coded (Table A.5). In this way the acceptability/unacceptability of results can be visually and therefore more meaningfully presented.

TABLE A.5: Beach water quality classification systems used in the eThekwini municipality microbiological surveillance programme (CSIR, 2003)

INDICATOR VALUE	CLASS	COLOUR CODE	GRADE DESCRIPTION
1 – 3	*I*	*Blue*	*Excellent*
4 – 5	*II*	*Green*	*Acceptable*
6 - 11	*III*	*Orange*	*Unacceptable/Poor*
≥ 12	*IV*	*Red*	*Very Poor*

The classification is done per sampling survey and is not based on any statistical analysis of a series of data points over time (e.g. as is the case with the WHO [2003] classification system).

The classification system developed by the eThekwini Municipality (Durban) for the evaluation of beach water quality along their coast on a weekly basis (http://www.durban.gov.za/durban) is presented in Table A.6.

TABLE A.6: eThekwini microbiological target values recommended for recreational waters representing different categories (http://www.durban.gov.za/durban)

CATEGORY	ESTIMATED RISK PER EXPOSURE	E. coli per 100 ml	ENTEROCOCCI per 100 ml
Excellent	*Not provided*	*< 100*	*< 100*
Good	*Not provided*	*101 – 300*	*101 – 300*
Moderate	*Not provided*	*301 – 2000*	*301 – 2000*
Poor	*Not provided*	*> 2000*	*> 2001*

It is not clear how the cut-off for the categories were selected other than the lower range (< 100) corresponding to the 80th percentile of samples cut-off specified for *E. coli* in the existing *South Africa Water quality guidelines for coastal marine waters* and the upper range (> 2000) to the 95th percentile of samples cut-off (DWAF, 1995). The system applies similar target ranges for *E. coli* and enterococci. Other sources (e.g. WHO, 2001 and CEC, 2002) have suggested that the equal risk ratio between *E. coli* to intestinal enterococci range from 2 to 3. However, it was also noted that this equivalence is not exact and where possible, local managers should define the relationship that exists in their own waters (NZME, 2003).

APPENDIX B

INTERNATIONAL REVIEW OF WATER QUALITY GUIDELINES FOR RECREATIONAL USE OF COASTAL MARINE WATERS

Recreational use of coastal waters fits into different categories, based on the degree of water contact, and is typically sub-divided into (WHO, 2003; ANZECC, 2000a; DWAF, 1995):

Whole-body (or primary) contact: recreational activity in which the whole body or the face and trunk are frequently immersed or the face is frequently wetted by spray, and where it is likely that some water will be swallowed, e.g., swimming, diving.

Incidental (or secondary) contact recreational activity in which only the limbs are regularly wetted and in which greater contact (including swallowing water) is unusual, e.g. boating, fishing, wading.

No contact: recreational activity in which there is normally no contact with water (e.g. angling from shore), or where water is incidental to enjoyment of the activity (such as sunbathing on a beach).

In terms of water quality, the following key aspects are important in relation to recreational use of coastal waters:

Aesthetics;

Protection of human health relating to microbiological contaminants and

Protection of human health relating to toxic substances and in some cases, physico- chemical variables (e.g. pH and temperature).

Target values (or water quality guidelines) related to aesthetics typically apply to all three categories of recreational use, while target values linked to human health (microbiological contaminants and toxic substances) mainly apply to primary and secondary contact recreation.

Water quality guidelines linked to recreational use of coastal waters have received much attention worldwide. For the purpose of this review, criteria and guidelines from the following countries and organisations are reviewed:

European Union;

World Health Organisation;

New Zealand;

Australia;

Canada;

United States of America (US-EPA and Hawaii);

Blue Flag Campaign; and

eThekwini Municipality (Durban).

B.1 European Union

i. Approach and methodologies

In the European Union, the management of bathing water quality is addressed in European environmental legislation, namely the Council Directive concerning the management of bathing water quality (CEC, 2006) that repeals the previous directive (CEC, 1976).

The EU does not distinguish between different recreational categories and focuses mainly on the protection of human health in terms of *microbiological contaminants*. The 2006 Directive lays down two parameters for analysis; intestinal enterococci and *Escherichia coli* (*E. coli*) (instead of nineteen in the 1976 Directive). Other parameters that may possibly be taken into account include the presence of cyanobacteria or microalgae (see note box below)

NOTE: Requirement regarding other parameters in bathing waters (CEC, 2006)

The EC directive (CEC, 2006) specifies the following additional parameters (in to other than microbiological) that could be taken into account:

When the bathing water profile indicates a potential for cyanobacterial proliferation, appropriate monitoring shall be carried out to enable timely identification of health risks.

When cyanobacterial proliferation occurs and a health risk has been identified or presumed, adequate management measures shall be taken immediately to prevent exposure, including information to the public.

When the bathing water profile indicates a tendency for proliferation of macro-algae and/or marine phytoplankton, investigations shall be undertaken to determine their acceptability and health risks and adequate management measures shall be taken, including information to the public.

Bathing waters shall be inspected visually for pollution such as tarry residues, glass, plastic, rubber or any other waste. When such pollution is found, adequate management measures shall be taken, including, if necessary, information to the public.

Different categories of water quality are identified, each with a corresponding target values for intestinal enterococci and *E. coli* (CEC, 2006) (Table B.1).

Table B.1: Target values for microbiological parameters in EU bathing waters (CEC, 2006)

PARAMETER	WATER QUALITY CATEGORY (cfu per 100 ml)		
	Excellent	Good	Sufficient
Intestinal Enterococci	*100**	*200**	*185***
E. coli	*250**	*500**	*500***

* *Based upon a 95 percentile evaluation;* ** *Based upon a 90 percentile evaluation*

Using the WHO risk assessment approach (WHO, 2003) the implied health risks of EU water quality categories are estimated as follows (Kay, 2008):

CATEGORY	ESTIMATED RISK PER EXPOSURE	ENTEROCOCCI per 100 ml
Excellent	*2.9 % gastrointestinal (GI) illness risk*	*100 (95 percentile)*
Good	*5.4% GI illness risk*	*200 (95 percentile)*
Sufficient	*8.5% GI illness risk*	*185 (90 percentile)*

ii. Implementation practice

The EU requires member states to conduct a bathing water quality assessment comprising (CEC, 2006):

- Comparison to microbiological target values (Table B.1); and
- Bathing beach profile (reviewed at regular intervals as specified in the Directive).

The bathing water quality assessment should be done at the end of every season on the basis of the information gathered during that season and the three preceding ones in principle. Following the assessment, bathing waters are classified in one of four quality levels: poor, sufficient, good or excellent according to specific criteria (Table B.2). The category "sufficient" is the minimum quality threshold to be attained by the end of the 2015 season at the latest.

NOTE: Bathing water profile (CEC, 2006)

The bathing water profile is to consist of:

A description of the physical, geographical and hydrological characteristics of the bathing water, and of other surface waters in the catchment area of the bathing water concerned, that could be a source of pollution

An identification and assessment of causes of pollution that might affect bathing waters and impair bathers' health;

An assessment of the potential for proliferation of cyanobacteria;

An assessment of the potential for proliferation of macro-algae and/or phytoplankton;

If there is a risk of short-term pollution, the following information should be provided:

- **the anticipated nature, frequency and duration of expected short-term pollution,**
- **details of any remaining causes of pollution, including management measures taken and the time schedule for their elimination,**
- **management measures taken during short-term pollution and the identity and contact details of bodies responsible for taking such action,**

Location of the monitoring point.

TABLE B.2: Bathing water classification system of the European Union (CEC, 2006)

QUALITY LEVEL	*SPECIFICATION*
Excellent	*If in the set of bathing water quality data for the last assessment period, the percentile values for microbiological enumerations are equal to or better than the 'excellent' values (Table B.1)* *If the bathing water is subject to short-term pollution, on condition that:* *adequate management measures are being taken, including surveillance, early warning systems and monitoring, with a view to preventing bathers' exposure by means of a warning or, where necessary, a bathing prohibition;* *adequate management measures are being taken to prevent, reduce or eliminate the causes of pollution; an d* *the number of samples disregarded because of short-term pollution during the last assessment period represented no more than 15 % of the total number of samples provided for in the monitoring calendars established for that period, or no more than one sample per bathing season, whichever is the greater.*
Good	*If in the set of bathing water quality data for the last assessment period, the percentile values for microbiological enumerations are equal to or better than the 'good' values (Table B.1)* *If the bathing water is subject to short-term pollution, on condition that:* *adequate management measures are being taken, including surveillance, early warning systems and monitoring, with a view to preventing bathers' exposure by means of a warning or, where necessa ry, a bathing prohibition;* *adequate management measures are being taken to prevent, reduce or eliminate the causes of pollution; and* *the number of samples disregarded because of short-term pollution during the last assessment period represented no more than 15 % of the total number of samples provided for in the monitoring calendars established for that period, or no more than one sample per bathing season, whichever is the greater.*
Sufficient	*If in the set of bathing water quality data for the last assessment period, the percentile values for microbiological enumerations are equal to or better than the 'sufficient' values (Table B.1)* *If the bathing water is subject to short-term pollution, on condition that:* *adequate management measures are being taken, including surveillance, early warning systems and monitoring, with a view to preventing bathers' exposure by means of a warning or, where necessary, a bathing prohibition;* *adequate management measures are being taken to prevent, reduce or eliminate the causes of pollution; and* *the number of samples disregarded because of short-term pollution during the last assessment period represented no more than 15 % of the total number of samples provided for in the monitoring calendars established for that period, or no more than one sample per bathing season, whichever is the greater.*
Poor	*If in the set of bathing water quality data for the last assessment period), the percentile values for microbiological enumerations are worse than the 'sufficient' values set (Table B.1).*

iii. Monitoring frequency and analysis

The 2006 Directive requires that member states determine the duration of the bathing season and draw up a monitoring calendar for bathing waters that provides for at least four samples to be taken per season. The sampling interval should not be longer than one month. In the event of temporary pollution, a sample should be taken to confirm such an occurrence, but it may be excluded from the samples provided for in the calendar. In such cases, an additional sample should be taken after the pollution has ended, replacing the excluded sample.

The 2006 Directive specifies that where possible, samples be taken 30 centimetres below the water's surface and in water that is at least one metre deep. The monitoring point must be at a point where most bathers are expected or where the greatest risk of pollution is expected. Reference methods of analysis are also specified for both intestinal enterococci (ISO 7899-1 or ISO 7899-2) and *E. coli* (ISO 9308-3 or ISO 9308-1), based on the methods of the International Organisation for Standardization (ISO).

NOTE: Calculation of Percentile values for microbiological parameters (CEC, 2006)

Based upon percentile evaluation of the $\log_{10}$ normal probability density function of microbiological data acquired from the particular bathing water, the percentile value is derived as follows:

Take the $\log_{10}$ value of all bacterial enumerations in the data sequence to be evaluated. (If a zero value is obtained, take the $\log_{10}$ value of the minimum detection limit of the analytical method used instead)

Calculate the arithmetic mean of the $\log_{10}$ values (μ)

Calculate the standard deviation of the $\log_{10}$ values (σ)

The upper 90 percentile point of the data probability density function is derived from the following equation: upper 90 percentile = antilog (μ + 1,282 σ)

The upper 95 percentile point of the data probability density function is derived from the following equation: upper 95 percentile = antilog (μ + 1,65 σ)

B.2 World Health Organisation

i. Approach and methodologies

The World Health Organisation (WHO) published a document entitled *Guidelines for Safe Recreational Water Environments* (WHO, 2003) intended to be used as the basis for the development of international and national approaches (including standards and regulations) to manage recreational water environments. The information provided is generally applicable to any coastal area, but the preferred approaches adopted by national or local authorities towards implementation, including guideline values, may vary depending on social, cultural, environmental and economic characteristics, as well as knowledge of routes of exposure, the nature and severity of hazards, and the effectiveness of control measures (WHO, 2003). The WHO assessed the safety of recreational water environments in a broad context, including aspects such as (aspects specifically related to water quality are highlighted in italics):

Aesthetic issues;

Faecal pollution and water quality;

Chemical and physical agents (e.g. toxic substances);

Presence of toxic algae and cyanobacteria;

Microbiological aspects of beach sand quality;

Drowning and injury prevention;

Sun, heat and cold; and

Free-living microorganisms and dangerous aquatic organisms.

Aesthetic value of recreational waters implies freedom from visible materials that will settle to form objectionable deposits, floating debris, oil, scum and other matter, substances producing objectionable colour, odour, taste or turbidity, and substances and conditions that produce undesirable aquatic life. Water in bathing areas should ideally be clear enough for users to estimate depth, to see subsurface hazards easily and to detect the submerged bodies of swimmers or divers who may be in difficulty (WHO, 2003).

The WHO concluded that in marine waters intestinal enterococci (faecal streptococci) were the only *microbiological indicator* that showed a dose–response relationship for both gastrointestinal illness (GI) and acute febrile respiratory illness (AFRI) (WHO, 2003; Kay et al., 2004). Instead of using 'single' target values that classify recreational waters either as 'safe' or 'unsafe', the WHO opted for a range of target values for this microbiological parameter corresponding to different levels of risk, supporting the principle of informed personal choice and also allowing achievable improvement targets to be set for high-risk areas. The target values for different risk levels were derived from a number of key epidemiological studies and are based on exposure of healthy adult bathers swimming in sewage impacted marine waters in a temperate climate with "exposure" as a minimum of ten minutes of swimming involving three head immersions (WHO, 2003) (Table B.3).

The WHO (2003) concluded the following on microbiological aspects of beach sand quality: "Bacteria, fungi, parasites and viruses have all been isolated from beach sand. A number of them are potential pathogens. Factors promoting the survival and dispersion of pathogens include the nature of the beach, tidal phenomena, presence of sewage outlets, the season, the presence of animals and the number of swimmers. Transmission may occur through direct person-to-person contact or by other means, although no route of transmission has been positively demonstrated. Concern has been expressed that beach sand or similar materials may act as reservoirs or vectors of infection. However, the capacity of microorganisms that have been isolated from beach sand to infect bathers and beach users remains undemonstrated, and the real extent of their threat to public health is unknown. There is therefore no evidence to support establishment of a guideline value for index organisms or pathogenic microorganisms on beach sand. The principal microbial risk to human health encountered upon beaches and similar areas is that arising from contact with animal excreta, particularly from dogs. Regulations that restrict access seasonally on frequently used beaches or place an obligation upon the owner to remove animal excreta, increased public awareness and beach cleaning are preventive management actions."

TABLE B.3: The World Health Organisation microbiological target values recommended for recreational waters representing different risk levels (WHO, 2003)

CATEGORY	ESTIMATED RISK PER EXPOSURE	95th PERCENTILE OF ENTEROCOCCI per 100 ml
A	*<1% gastrointestinal (GI) illness risk; <0.3% acute febrile respiratory (AFRI) risk. This relates to an excess illness of less than one incidence in every 100 exposures. The AFRI burden would be negligible. This value is below the no-observed-adverse-effect level [NOAEL] in most epidemiological studies.*	*<40*
B	*1–5% GI illness risk; 0.3–1.9% AFRI risk. The upper 95th percentile value of 200 relates to an average probability of one case of gastroenteritis in 20 exposures. The AFRI illness rate at this water quality would be 19 per 1000 exposures, or approximately 1 in 50 exposures. The 200 enterococci per 100 ml value is above the threshold of illness transmission reported in most epidemiological studies that have attempted to define a NOAEL or lowest observed-adverse-effect level [LOAEL] for GI illness and AFRI.*	*40 – 200*
C	*5–10% GI illness risk; 1.9–3.9% AFRI 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,*	*201 – 500*

CATEGORY	ESTIMATED RISK PER EXPOSURE	95th PERCENTILE OF ENTEROCOCCI per 100 ml
	or a range of approximately 1 in 50 to 1 in 25 exposures. This level represents a substantial elevation in the probability of all adverse health outcomes for which dose–response data is available	
D	*>10% GI illness risk; >3.9% AFRI risk. There is a greater than 10% chance of illness per single exposure. The AFRI illness rate at the 95th percentile point of 500 enterococci per 100 ml would be 39 per 1000 exposures, or approximately 1 in 25 exposures (above this level there may be a significant risk of high levels of minor illness transmission)*	*> 500*

NOTE: Calculation of the 95 percentile (WHO, 2003)

In the microbiological water quality assessment, the sampling programme should be representative of the range of conditions in the recreational water environment while it is being used, and a sufficient number of samples should be collected. The precision of the estimate of the 95th percentile is higher when sample numbers are increased. For example, the number of results available can be increased significantly by pooling data from multiple years, unless there is reason to believe that local (pollution) conditions have changed. For practical purposes, data on at least 100 samples from a 5-year period and a rolling 5-year data set can be used for water quality assessment purposes.

When calculating percentiles it is important to note that there is no one correct way to do the calculation (implying that there is more than one way of calculating percentiles). It is therefore desirable to know what method is being used, as each will give different results There are two main approaches to calculating a percentile (WHO, 2003):

- **Parametric approach - assumes that samples are drawn from a particular distribution (typically the log10 normal distribution for microbiological data) Using the 95th percentile of that distribution one calculates the mean and standard deviation of the logarithms of the data. This method n eeds more data than the second approach.**
- **Non-parametric approach - does not assume any particular distribution and uses data ranking. There are 3 formulae used for this; Weibull - needs at least 19 samples to work - gives the highest results; Hazen - needs 10 samples to work and Excel - needs only 1 sample - gives the lowest results.**

The potential risks from *chemical contamination* of coastal recreational waters, apart from those caused by toxins produced by marine and freshwater cyanobacteria and algae, marine animals or other exceptional circumstances, will be very much smaller than the potential risks from microbiological contaminants (WHO. 2003). In most cases, the concentrations of contaminants were found to be below drinking water target values. The WHO therefore recommends that, as long as care is taken in their application, the WHO Guidelines for Drinking-water Quality (WHO, 2004) can be used as a starting point for preliminary risk assessments. These guideline values relate, in most cases, to lifetime exposure following consumption of 2 litres of drinking -water per day. For recreational water contact, an intake of 200 ml per day (100 ml per recreational session with two sessions per day) is considered a reasonable assumption. This approach may, however, not apply to substances of which the effects are related to direct contact with water, e.g. skin irritations.

ii. Implementation Practice

Where the traditional approach for managing beach water quality is primarily based on microbiological quality, the WHO's new approach is more holistic (WHO, 2003), moving away from the sole use of guideline values of faecal indicator bacteria, and instead using a combination of a qualitative risk grading of the catchment, supported by the direct measurement of appropriate faecal indicators to assess the suitability of a site for recreation. With reference to microbiological quality, classification or ranking is primarily based upon a combination of:

- Sanitary inspection (extent of influence of [human] faecal material;
- Microbiological quality assessment (counts of faecal bacteria).

The aim of the sanitation inspection is to identify all sources of faecal pollution (particularly human faecal pollution). In this regard, the three most important sources of human faecal contamination are:

- sewage (e.g. wastewater discharges, sewage pump station overflow, seepage from septic/conservancy tanks, contaminated storm-water run-off);
- riverine discharges (e.g. where rivers are receiving sewage discharges) ;
- contamination from bathers (e.g. excreta) ; and
- shipping and boating activities (e.g. inappropriate sewage disposal practices).

The Recreational Classification of a beach is based on the Sanitary Inspection Category and Microbiological Quality Assessment Category (using the microbiological guideline values in Table B.3) and is derived as illustrated in Table B.4.

The recreational beach grading process (Table B.4) of the WHO is summarised in Figure A.1. Where it can be shown that users can be effectively discouraged from entering recreational waters following occasional and predictable water quality deteriorations (e.g. linked to rainfall patten s), the beach may be upgraded to reflect the water quality that users are exposed to outside the problem period, but only with the accompanying explanatory material. In essence, this approach is seen to have the benefit of protecting public health, but also of providing the potential both to improve the classification of a location through low-cost measures as well as to enable the safe use of areas for certain periods that might otherwise be considered inappropriate for recreational use.

TABLE B.4: The World Health Organisation Recreational Classification system

		MICROBIOLOGICAL QUALITY ASSESSMENT CATEGORY (95TH PERCENTILE ENTEROCOCCI per 100 ml)				
		A (<40)	B (41-200)	C (201-500)	D (>500)	Exceptional circumstances[3]
SANITARY INSPECTION CATEGORY	Very Low	Very good	Very good	Follow-up[1]	Follow-up[1]	Action
	Low	Very Good	Good	Fair	Follow-up[1]	
	Moderate	Good	Good	Fair	Poor	
	High	Good	Fair	Poor	Very poor	
	Very high	Follow-up[2]	Fair	Poor	Very poor	
	Exceptional circumstances	Action				

1 *Implies non-sewage sources of faecal indicators (e.g. livestock), and this should be verified*

2 *Indicates possible discontinuous/sporadic contamination (often driven by events such as rainfall). This is most commonly associated with Combined Sewer Overflow presence. These results should be investigated further and initial follow-up should include verification of sanitary inspection category and ensuring samples recorded include "event" periods. Confirm analytical results. Review possible analytical errors*

3 *Exceptional circumstances relate to known periods of higher risk, such as during an outbreak with a pathogen that may be waterborne, sewer rupture in the recreational water catchment, etc. Under such circumstances, the classification matrix may not fairly represent risk/safety.*

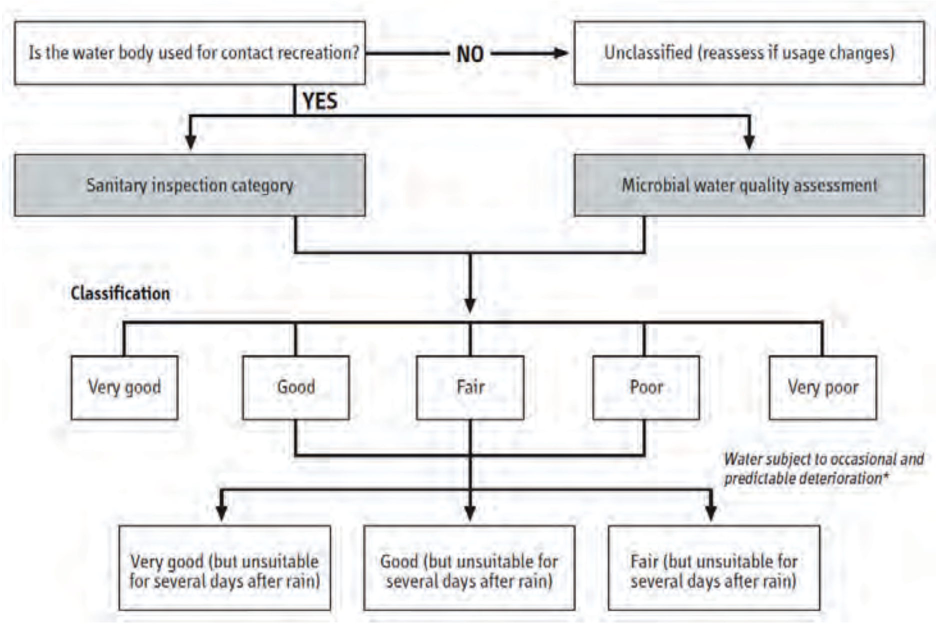


Figure B.1: The recreational beach grading process of the WHO (2003)

iii. Monitoring frequency and analysis

All recreational water environments would be subject to an annual sanitary inspection to determine whether pollution sources have changed. Where the sanitary inspection category was "Very low" or "Low" over several years and the microbiological water quality assessment is stable and based on at least 100 samples, microbiological sampling can be reduced to a minimum of five samples per year to ensure that no major changes go unidentified. A similar situation applies in waters where the sanitary inspection resulted in a "Very high" categorization for susceptibility to faecal contamination (i.e. where swimming would be strongly discouraged). For intermediate-quality recreational water environments (i.e. "Moderate" and "High"), a greater annual microbiological sampling programme is recommended (Table A.5).

TABLE B.5: Monitoring schedule recommended by WHO (2003)

RISK CATEGORY (SANITARY INSPECTION)	MICRIOBIOLOGICAL WATER QUALITY ASSESSMENT	SANITARY INSPECTION
Very low	*Minimum of 5 samples per year*	*Annually*
Low	*Minimum of 5 samples per year*	*Annually*
Moderate	*4 samples x 5 occasions during swimming season* *Annual verification of management effectiveness* *Additional sampling if abnormal results obtained*	*Annually*
High	*4 samples x 5 occasions during swimming season* *Annual verification of management effectiveness* *Additional sampling if abnormal results obtained*	*Annually*
Very high	*Minimum of 5 samples per year*	*Annually*

Data covering at least five years of monitoring (or 100 samples) should be used for classification, preferable the most recent data available.

The WHO (2003) is not prescriptive in terms of the analytical techniques to be applied.

B.3 New Zealand

i. Approach and methodologies

New Zealand updated its microbiological water quality guidelines for recreational areas in 2003 (NZME, 2003). The new approach largely adopts the WHO approach as documented in 'Annapolis Protocol' (WHO, 1999) and the *Guidelines for Safe Recreational Water Environments* (WHO, 2003).

The New Zealand guidelines deal primarily with human health in terms of microbiological contaminants (i.e. they do not provide explicit targets related to aesthetics, physico chemical or toxic substances). Reference to the terms 'beach' means to marine recreational water sites (NZME, 2003)

The New Zealand guidelines apply the same target value ranges for the microbiological assessment category as the WHO (2003) (see Table B.3) (using the Hazen method for calculating the percentiles as it tends to be the 'middle' of all the options).

In addition to the recreational water grading, as proposed by the WHO (2003), the New Zealand guidelines also include alert (140 enterococci per 100 ml) and action (280 enterococci per 100 ml) guideline levels for surveillance (or day-to-day management) throughout the bathing season (NZME, 2003).

NOTE: Derivation of alert and action guidelines for surveillance (New Zealand)

The WHO (2003) guidelines only addressed beach classification (or grading) and not surveillance. As a result New Zealand derived such values from previous uncontrolled epidemiological studies (Cabelli, 1983a). Recognising numerous limitation of their approach, surveillance values were obtained by assuming that enterococci distributions would be lognormal, that the standard deviation of the logarithms of enterococci concentration is 0.7 (a reasonable average of available data) and that enterococci concentration is at a limit of a median of 35 per 100 ml (corresponding to a swimming-associated risk of 19 per 1000 bathing events). The alert and action limits were taken as the 80% and 90% upper one-sided tolerance limits for that distribution, calculated as 136 and 276 enterococci per 100 ml. Acknowledging the uncertainty in estimating the standard deviation (of the logarithms) it was considered appropriate to round these figures to 140 and 280 enterococci per 100 ml.

ii. Implementation Practice

The implementation framework for New Zealand comprises a Suitability of recreation grading system and a Beach surveillance system (NZME, 2003).

Similar to the WHO (2003) their grading system consists of:

Sanitary Inspection Category (SIC), which generates a measure of the susceptibility of a water body to faecal contamination

Historical microbiological results, which generate a Microbiological Assessment Category (MAC), which provides a measurement of the actual water quality over time.

This grade provides an indication of the general condition of a beach. The risk of becoming sick from swimming at a beach increases as the beach grading shifts from Very Good to Very Poor (Table B.6). Ideally there should be 100 data points or greater collected over the previous five years, although it is feasible to consider grading with a minimum of 20 data points collected over one full bathing season (grading should be considered as interim until five years of data have been collected).

TABLE B.6: The New Zealand Suitability for recreation grading system, slightly modified from that of the WHO (2003) (NNZME, 2003)

SUSCEPTIBILITY TO FAECAL INFLUENCE		MICROBIOLOGICAL QUALITY ASSESSMENT CATEGORY (95TH PERCENTILE ENTEROCOCCI per 100 ml)				
		A (<40)	B (41-200)	C (201-500)	D (>500)	Exceptional circumstances[3]
SANITARY INSPECTION CATEGORY	Very Low	Very good	Very good	Follow-up[1]	Follow-up[1]	Action
	Low	Very Good	Good	Fair	Follow-up[1]	
	Moderate	Follow-up[2]	Good	Fair	Poor	
	High	Follow-up[2]	Follow-up[2]	Poor	Very poor	
	Very high	Follow-up[2]	Follow-up[2]	Follow-up[2]	Very poor	
	Exceptional circumstances	Action				

1. *Indicates unexpected results requiring investigation (reassessment). If after reassessment the result is still 'follow up', then assign a conservative grade (i.e. the first grade to the right of the 'follow up' in the same sanitary inspection category row). This follows the precautionary principle applied in public health.*
2. *Implies non-sewage sources of indicators, and this should be verified. If after verification the grading is still 'follow up', then assign a conservative grade (i.e. the first grade after 'follow up' in the same microbiological assessment category).*
3. *Exceptional circumstances: relate to known periods of higher risk for a graded beach, such as during a sewer rupture or an outbreak of a potentially waterborne pathogen in the community of the recreational area catchment. Under such circumstances a grading would not apply until the episode has abated.*

A detailed Catchment Assessment (or Sanitary Survey) checklist is provided in the New Zealand Guideline Document (NZME, 2003).

In addition to grading of beaches, a three-tier management framework (beach surveillance system) is proposed that should be carried out at the middle-range beaches (i.e. good, fair and poor). This framework includes:

Surveillance – involves routine (e.g. weekly) sampling of bacteriological levels

Alert – requires investigation of the causes when alert target values (140 enterococci per 100 ml) are exceeded and increased sampling to enable the risks to bathers to be more accurately assessed

Action – requires the local authority and health authorities to warn the public that the beach is considered unsuitable for recreation (i.e. when action target values – 280 enterococci per 100 ml are exceeded).

Weekly monitoring should be carried out during the bathing season for middle-range beaches. For beaches where routine monitoring will be ongoing during the bathing season, the three-tier system applies, analogous to traffic lights (Figure B.2).

iii. Monitoring frequency and analysis

Samples should be collected during the bathing season, or when the water body is used for contact recreation.

The guidelines recommend a systematic random-sampling regime. Generally this means samples should be collected weekly, regardless of the weather although there may be exceptions if conditions present a health and safety hazard, in which case samples should be collected as soon after the programmed time as possible.

Samples should be collected at approximately 15 cm below the surface at a point where the depth of the water is approximately 0.5 metres.

The New Zealand guidelines are not prescriptive in terms of the analytical techniques.

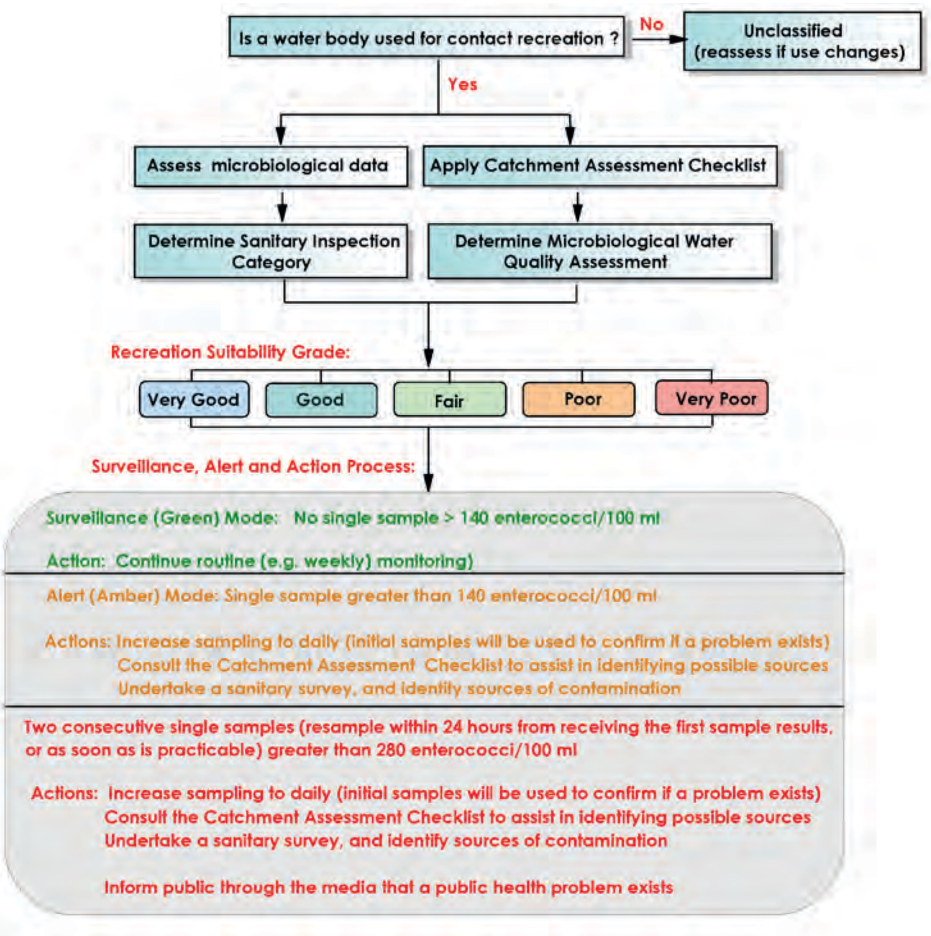


Figure B.2: New Zealand grading and surveillance, alert and action process for the management of recreational use of marine waters (adapted from NZME, 2003)

B.4 Australia

i. Approach and methodologies

Australia is in the process of revising its water quality guidelines for recreation in alignment with recent developments put forward by the WHO (1999, 2003). Until these revised guidelines are endorsed, water quality guidelines in recreational waters will be applied as per ANZECC (2000a).

The guidelines focus primarily on aesthetics and human health in terms of microbiological contamination and physico-chemical parameters and toxic substances (Table B.7).

TABLE B.7: Summary of recommended environmental quality targets for Australian recreational waters (ANZECC, 2000a)

PARAMETER	*RECOMMENDED ENVIRONMENTAL QUALITY TARGETS*
Aesthetics	*Natural visual clarity should not be reduced by more than 20%. Natural hue of the water should not be changed by more than 10 points on the Munsell Scale* *Natural reflectance of the water should not be changed by more than 50%. Horizontal sighting of a 200 mm diameter black disc should exceed 1.6 m.* *Macrophytes, phytoplankton scums, filamentous algal mats, sewage fungus, leeches, etc. should not be*

PARAMETER	RECOMMENDED ENVIRONMENTAL QUALITY TARGETS
	present in excessive amounts. *Direct contact activities should be discouraged if algal levels of 15 000–20 000 cells/mℓ are present, depending on the algal species.* *Oil and petrol should not be noticeable as a visible film on the water nor should they be detectable by odour*
Microbiological indicators	*Primary contact: 35 counts per 100 ml (enterococci) based on the median concentration over bathing season (maximum number in any sample: 60–100 counts per 100 ml), alternatively:* *150 counts/100ml (faecal coliform) based on the median concentration over the bathing season (minimum of 5 samples taken at regular intervals not exceeding 1 month, 4 out of 5 samples containing less than 600 counts per 100 ml)* *Secondary contact: 230 counts per 100 ml (enterococci) based on the median concentration over bathing season (maximum number in any 1 sample: 450–700 counts per 100 ml), alternatively:* *1000 counts/100ml (faecal coliform) based on the median concentration over bathing season should not exceed 1000 counts per 100 ml (minimum of 5 samples taken at regular intervals not exceeding 1 month, 4 out of 5 samples containing less than 4000 counts per 100 ml* *NOTE: Although the Australian guideline also recommends limits for faecal coliform, enterococci is the preferred indicator for marine waters (ANZECC, 2000a)*
Physico-chemical variables	*pH of the water should be within the range 5.0 – 9.0, assuming that the buffering capacity of the water is low near the extremes of the pH limits.* *For prolonged exposure, temperatures should be in the range 15–35°C.*
Toxic substances	*Apply 1987 drinking water guidelines for toxic substances (NHMRC & AWRC, 1987; NHMRC & ARMCANZ, 1996 updated 2001).* *Recreational water should contain no chemicals that can irritate the skin of the human body.*

ii. Implementation Practice

The Australian guidelines do not propose a specific implementation practice, e.g. a recreational water grading system.

iii. Monitoring frequency and analysis

Sampling frequency for microbiological indicators is provided in Table B.7.

The Australian guidelines for water quality monitoring and reporting (ANZECC, 2000b) provide extensive guidance on the design of monitoring programmes in the marine environment, as well as the selection of analytical techniques.

B.5. Canada

i. Approach and methodologies

In preparing the Canadian water quality guidelines for recreational water quality, a working group thoroughly reviewed the existing (international) criteria, current indicators of hygienic quality, water quality data f rom recreational areas in various parts of Canada and pertinent epidemiological studies (CMNHW, 1992).

The guidelines focus primarily on aesthetics and human health in terms of microbiological contamination and physico-chemical parameters and toxic substances (Table B.8).

TABLE B.8: Summary of recommended environmental quality targets for Canadian recreational waters (CMNHW, 1992)

PARAMETER	RECOMMENDED ENVIRONMENTAL QUALITY TARGETS
Aesthetics	*Turbidity and colour should not be so intense as to impede visibility in areas used for swimming e.g. 100 platinum-cobalt (Pt-Co) units or 50 Nephelometric Turbidity Units (NTU).* *Water should be sufficiently clear that a Secchi disc is visible at a minimum depth of 1.2 m.* *Water should be as free as possible from nuisance organisms that could affect swimmers. Nuisance is defined as something that can cause harm or is annoying, unpleasant, or obnoxious* *Water should be free from substances attributable to wastewater or other discharges in amounts that would interfere with the existence of life forms of aesthetic value a) materials that will settle to form objectionable deposits b) floating debris, oil, scum, and other matter c) substances producing objectionable colour, odour, taste, or turbidity d) substances and conditions or combinations thereof in concentrations that produce undesirable aquatic life.* *Oil or petrols should not be present in concentrations that: a) can be detected as a visible film, sheen, or discolouration on the surface b) can be detected by odour c) can form deposits on shorelines and bottom sediments that are detectable by sight or odour.*
Microbiological indicators	*35 counts per 100 ml (enterococci) based on the geometric mean of at least 5 samples, taken during a period not to exceed 30 days. Resample if any sample exceeds 70 counts/100ml.* *If it can be demonstrated that either faecal coliform or E. coli are suitable indicators:* *200 counts/100ml (faecal coliform) based on the geometric mean of at least 5 samples, taken during a period not to exceed 30 days. Resample if any sample exceeds 400 counts per 100 ml*
Toxic substances	*It is recommended that no measurable limits be established for chemicals in recreational water for human exposure risk because of lack of sufficient scientific information. Decisions for use should be based on aesthetic quality (e.g., presence of odour or visible oil and grease) and other factors considered in the environmental health assessment (e.g., proximity to industrial discharge).*

ii. Implementation Practice

In Canada, the determination of the risk of disease or harm from microbiological, physical, or chemical hazards follows a holistic approach that includes the following (CMNHW, 1992):

Environmental health assessments. An annual assessment is carried out prior to the bathing season in order to identify all potential sources of contamination and physical hazards that could affect the recreational area.

Epidemiological evidence. Wherever possible, surveillance for bather illness or injuries is established, which can either be comprehensive epidemiological studies or formal and informal reporting from physicians and hospital emergency departments.

Indicator organism monitoring. Routine microbiological monitoring of a recreational area is carried out, the frequency of which is determined by the usage of the area, the environmental health assessment, and epidemiological evidence.

Presence of pathogens. Tests for pathogenic organisms are carried out when there have been reports of illnesses, when there is suspected illness of undetermined cause, or when levels of an indicator organism demonstrate a continuous suspected hazard (e.g. *Aeromonas* spp., *Pseudomonas aeruginosa*, *Staphylococcus aureus*, *Shigella* spp., *Salmonella* spp., *Campylobacter* spp., *Giardia* spp., human viruses, and toxic phytoplankton).

iii. Monitoring frequency and analysis

The minimum recommended sampling frequency for routine investigations is five samples in not more than 30 days from each sampling location (Table B.6). However, in areas with high bather densities or area s known to have poor water quality or in cases of suspected waterborne diseases associated with bathing, the sampling frequency should be increased.

Sampling locations should be selected on the basis of information gathered during the environmental health assessment. The locations should be representative of the water quality throughout the whole bather exposure area, including points of greatest bather activity as well as peripheral points subject to external faecal pollution. The sampling depth should be 15 to 30 cm below the surface in both deep and shallow waters.

Analytical methods specified for enterococci include:

Membrane filtration (MF) technique described by the US-EPA (1985); and

Multiple Tube Fermentation or Most Probable Number (MPN) method, using azide dextrose broth followed by confirmation with Pfizer selective enterococcus agar (American Public Health Association, 1989) (e.g. in highly turbid waters and waters influenced by chlorinated sewage).

A.6. United States

i. Approach and methodologies

In terms of recreational use, the US -EPA water quality guidelines focus on microbiological parameters, in particular for primary contact recreation (US-EPA, 1986a). The US-EPA also provides an extensive list of target values for toxic substances in ambient waters (US-EPA, 2002, updated 2003).

The most important (and most researched) aspect of water quality guidelines for recreation waters relates to the selection of microbiological indicators that have the most appropriate 'quantifiable relationship between the density of an indicator in the water and the potential human health risks involved in the water's recreational use' (US-EPA, 1986a, 1986b).

The US-EPA is in the process of updating the existing (20 year old) target values for recreational waters (US - EPA, 2007) (Table B.9). High priority research and science to be conducted so as to establish the scientific foundation for the development of new or revised recreational water quality criteria recommendations are described in the Critical Path Science Plan. It is envisaged that the development and publication of new or revised criteria will be completed by the end of 2012.

TABLE B.9: Summary of US-EPA recommended target values for recreational waters (US-EPA, 1986a, 1986b & 2002b)

PARAMETER	RECOMMENDED ENVIRONMENTAL QUALITY TARGETS
Microbiological indicators	*35 counts per 100 ml (enterococci), based on the geometric mean of at least 5 samples, taken during a period not to exceed 30 days. Single sample maximum (SSM) should not exceed:* *104 for designated beach area (75%ile)* *158 for moderate full body recreation (82%ile)* *276 for lightly used full body contact (90%ile)* *501 for infrequent full body contact (95%ile)*
Toxic substances	*Refer to US-EPA (2002, updated 2003)*

NOTE: Derivation of US-EPA Enterococci target values (US-EPA, 1986a, 1986b & 2000)

The enterococci target recommended by the US-EPA was originally based on a series of epidemiological studies conducted by the UP-EPA, based on an ('acceptable') illness ratef d 9 illnesses per 1000 for marine waters (this criterion is primarily aimed at protecting recreational users from acute gastrointestinal illness and may not provide protection against other waterborne diseases, such as eye, ear, skin, and upper respiratory infections, nor illnesses that may be transmitted from swimmer to swimmer). This target value has also been adopted by other countries, e.g. Australia (Table 4.5) .and Canada (Table 4.6) with some modifications.

The potential for indicator microbial survival and regrowth (both *E. coli* and enterococci) in tropical areas has resulted in doubts concerning the interpretation of indicator microbiological concentrations in tropical environments, especially given that the studies used to establish the US-EPA guidelines were conducted in Boston Harbour, New York City and New Orleans which are not representative of tropical regions. In these situations, indicator microbiological concentrations can be elevated beyond that from faecal impacts alone primarily due to the persistence and regrowth of these indicators within the environment (Shibata et al., 2004). Given this problem, the State of Hawaii (USA) currently utilizes *Clostridium perfringens*, a spore-forming obligate anaerobe, as an interim measure to supplement its microbiological monitoring programme. *C. perfringens* is not capable of regrowth in aerobic environments but persists for long periods of time and, its detection may therefore not be an indicator of recent sewage contamination (Hawaii Department of Health, 2000). The additional EQT proposed for *C. perfringens* is: *Geometric mean equal or less than 5 counts per 100 ml.*

ii. Implementation Practice

The US-EPA has published extensive documentation that provides states, territories and authorized tribal a reas with guidance on the implementation of the *Ambient Water Quality Criteria for Bacteria 1986* (US-EPA, 1986) including:

Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health (US-EPA, 2000);

National Beach Guidance and Required Performance Criteria for Grants (US-EPA, 2002b);

Implementation Guidance for Ambient Water Quality Criteria for Bacteria (US-EPA, 2004);

Water Quality Standards for Coastal Recreation Waters: Using Single Sample Maximum Values in State Water Quality Standards (US-EPA, 2006)

In essence, the US-EPA recommends that the protection of recreational waters be assured through (US-EPA, 2004):

Frequent monitoring of known recreation areas to establish a more complete database upon which to determine if the water body is attaining the water quality criteria;

Assuring that where mixing zones for bacteria are authorized, they do not impinge upon known primary contact recreation areas; and

Conducting a sanitary survey when higher than normal levels of bacteria are measured.

iii. Monitoring frequency and analysis

The minimum recommended sampling frequency for routine investigations is five samples in not more than 30 days from each sampling location (Table B.7).

A.7 Blue Flag Campaign

i. Approach and methodologies

The Blue Flag campaign is an international initiative which was started in the mid 1980s to encourage local authorities to provide clean and safe beaches for local populations and tourists (UNEP, 1996). It is a voluntary and non-punitive scheme and is targeted at local authorities, the general public and the tourism industry. The main objectives of the Blue Flag campaignare to improve understanding of the coastal environment and to promote the incorporation of environmental issues in the decision-making processes of local authorities and their partners.

In essence, beaches that meet specific criteria are annually awarded a Blue Flag, which can be used as part of the local tourism marketing strategy (FEE, 2004). Areas for which specific criteria are assigned are:

i) Water quality (typically the area that is addressed in water quality guidelines for recreational waters)

ii) Beach management and safety; and

iii) Environmental information and education.

Although not legally required, South Africa (through its Department of Environmental Affairs) initiated the Blue Flag Campaign to encourage socio economic development and to improve coastal livelihoods through better management of marine and coastal related resources. Detailed criteria differ slightly from one region to another. Specific criteria that currently apply to water quality in South Africa are presented in Table B.10.

TABLE B.10: Summary of water quality criteria for Blue Flag beaches in South Africa

PARAMETER	*ENVIRONMENTAL QUALITY TARGETS*
Microbiological indicators	*Faecal coliform (E. coli) per 100ml: <100 in 80% of samples (guideline)* *Faecal coliform (E. coli) per 100ml: <2000 in 95% of samples (imperative)* *Faecal streptococci (Enterococci) <100/100ml in 80% of samples (imperative)* *Faecal streptococci (Enterococci) <50/100ml at 75% compliance (guide)*
Aesthetics	*Oil: absent in 95% of samples* *"Floatables" – presence should not be noted*
Physico-chemical variables	*pH between 6-9 in 95% of samples*

ii. Implementation Practice

In terms of water quality a beach must comply with the bathing water quality requirements in the previous Blue Flag seasons in order to be eligible for the Blue Flag award (i.e. during the season prior to that for which the application is being submitted, this been changed to the prior four seasons for beaches new to the system).

Where thermotolerant coliform (*E. coli*) counts exceed the 2 000/100ml the Blue Flag must be temporarily withdrawn and a further sample taken immediately. The second (follow-up) sample cannot be considered an additional sample for calculating statistical compliance (i.e. in % of samples). Only the results on this second sample shall be used to assess compliance with the bacteriological standards.

If the compliance with the guideline and imperative values cannot be met during a Blue Flag season, the Flag must immediately be withdrawn. The bacteriological results must be displayed in the Water Quality display on the beach Notice Board (in South Africa icons is used with smiling and frowning faces to indicate water quality), as well as the date of the sampling. The water quality data must be sent through to the National Coordinator as soon as it is available.

iii. Monitoring frequency and analysis

The first sample must be taken within 5-17 days before the beginning of the Blue Flag season. During the season, sampling must be carried out at least once in 28 days. The last sampling of the season must be taken within a fortnight of the last date of the Blue Flag season. Samples should be taken where the daily average density of bathers are highest. If the beach is long and/or there are possible sources of pollution (e.g. storm water outlets), additional samples must be taken at such locations. Samples should be taken 30 cm below the surface of the water on an incoming tide.

An accredited laboratory must undertake all sample analyses. Copies of all laboratory reports must accompany applications for the next season. It is the responsibility of the local authority to ensure that the integrity of the sample is not compromised during transit to the laboratory.

NOTE: Proposed new global standards for Blue Flag *(Alison Kelly, National Blue Flag Coordinator, pers. comm.)*

The Foundation for Environmental Education (FEE) Programme is in the process of revising Blue Flag standards for microbiological indicators. The proposed standards are as follows:

- **Limit values for E. coli – 100 (95 percentile)**
- **Limit value for intestinal enterococci – 50 (95 percentile)**
- **Sampling frequency – 28 days per interval**
- **Sampling history – 3**
- **Bathing water profile – Yes**
- **Sampling calendar - Yes skin, and upper respiratory infections, nor illnesses that may be transmitted from swimmer to swimmer).**

APPENDIX C
BACKGROUND INFORMATION ON WATER QUALITY INDICATORS

Objectionable matter

FLOATING MATTER

Description	Floating matter refers to debris, oil, grease, wax, scum, foam, submerged (just below water surface) objects or any other visible substances.
Natural occurrence	Naturally occurring floating matter is usually limited to macrophytes and algae.
Fate in environment	Objectionable floating matter may end up on beaches or in sheltered areas where it becomes an aesthetic problem. It may also result in smothering or physical injury to marine life, e.g. benthic communities, sea birds and seals.
Interdependence on other constituents	Not relevant to floating matter.
Measurement in seawater	Floating matter is not usually measured quantitatively in marine waters, but is rather 'measured ' in terms of a qualitative description.
Pollution sources	Anthrophogenic sources of objectionable floating matter include: - raw sewage (municipal waste); - stormwater run-off (litter and debris); - accidental oil spills (oil and grease); - paper and pulp waste water (foaming); and - illegal dumping of ship refuse.
Treatability	Treatment is usually limited to the physical removal of objectionable floating matter, either through coarse grid systems or otherwise manually.
Related problems	Typical water quality problems which may be associated with the presence of objectionable floating matter include: - physical injuries; - unpleasant aesthetics; and - clogging and blockage of equipment.
Effects of change	No factual information on specific effects of objectionable floating matter on recreational use could be obtained.

SUSPENDED SOLIDS

Description	Suspended solids refer to particulate inorganic and organic matter that is in suspension in the water column. The presence of suspended solids is usually attributed to a reduction in the clarity of water, i.e. light penetration or visibility. Under calm conditions suspended solids may settle from to water column to form objectionable deposits.
Natural occurrence	Naturally occurring suspended materials include finely divided organic and inorganic matter, plankton and other microscopic organisms. These are usually more evident during stormy conditions, plankton blooms and large river run-off. Suspended solids may also be introduced to the water column through resuspension of natural debris during turbulent conditions, usually cause by strong wind and wave action.
Fate in environment	Suspended solids are usually kept in suspension since their density is similar to that of seawater and turbulence in the water column. Under calmer conditions, solids may settle out from the water column and be deposited onto the sediments.
Interdependence on other constituents	Information on the interdependence of suspended solids on other water quality - constituents or properties could not be obtained.
Measurement in seawater	Suspended solids can be determined by collecting the suspended matter from a a known volume of water (usually one litre) onto GF/C glass fibre filter paper [17]. Units: mg l^{-1}.
Pollution sources	Anthropogenic sources of suspended solids include: - storm water run-off; - sewage discharges; and - industrial waste.
Treatability	Suspended solids with a diameter greater than 60 µm can be removed from seawater by using filters, e.g. sand filters.
Related problems	Typical water quality problems which may be associated with suspended solids include: - physical injuries; - unpleasant aesthetics; and - clogging and blockage of equipment.
Effects of change	No factual information on specific effects of suspended solids on recreational use could be obtained.

COLOUR/TURBIDITY/CLARITY

Description

The turbidity, colour and clarity of water are properties which are usually strongly linked to one another. Turbidity is caused by colloidal suspensions (particle size between 0,001 µm and 0,1 µm) which usually give water a 'murky' appearance, while colour is caused by substances which dissolve in water, and as a result the colour of the water changes. Both turbidity and colour, together with suspended solids, influence the clarity of water, i.e. the depth of light penetration or visibility in water. A constituent which may affect these properties of water is gypsum (calcium sulphate with two waters of hydration [$CaSO_4.2H_2O$]), a waste product of fertilizer industries.

Natural occurrence

Natural turbidity in water is caused by colloidal suspension (particle size between 0,001 µm and 0,1 µm) of, for example, clays and silt, usually introduced through river run-off. Turbidity may also be introduced to the water column through re-suspension of natural debris during turbulent conditions, usually caused by strong wind and wave action. Natural colour in water may result from the presence of natural metallic ions and humic substances, usually introduced through river run-off.

In the natural environment, gypsum only starts to precipitate from seawater at a salinity of 117 (e.g. through evaporation) [55].

Fate in environment

Owing to the high salt content of seawater, natural colloidal suspension (causing turbidity) and humic substances (natural colour) usually coagulate with specific ions and precipitate out.

Interdependence on other constituents

Turbidity and colour may be influenced by the salinity of water - *(see Fate in Environment)*

Measurement in seawater

Turbidity can be measured on a Turbidimeter (Nephelometer) [17].

Units: NTU (Nephelometric Turbidity Units)

'True colour', i.e. the colour in water caused by substances in solution, can be measured through visual comparison methods such as the platinum cobalt method or a Lovibond comparator [17].

Units: Pt-Co mg l^{-1} (defined as the colour being produced by 1 mg Pt l^{-1} in the form of the chloroplatinate ion) or Hazen unit .
(1 Hazen unit = 1 Pt-Co mg l^{-1})

The clarity of water (combined effect of colour, turbidity and suspended solids) can be measured by using a Secchi disc.

Units: metres below water surface.

Pollution sources

Anthropogenic sources of colour/turbidity include:

- industrial waste, e.g. paper and pulp and textile industries;
- raw sewage discharges; and
- waste from fertilizer industries (gypsum).

Treatability

Activated carbon filters can be used to remove turbidity or colour, although, depending on the volume of water, this can be very expensive.

Related problems

Typical water quality problems which may be associated with the presence of objectionable colour/turbidity/clarity include:

- physical injuries;
- unpleasant aesthetics; and
- clogging and blockage of equipment.

Effects of change

Factual information on the effect of different colour/turbidity/clarity on recreational use is provided:

RANGE	MEASURED EFFECT
0 - 2,75 (Secchi disc depth in m)	Perceived to be suitable for swimming, in terms of judging water depth and seeing possible hazards (32) No adverse visual impact (33)
2.75 - 1,5 (Secchi disc depth in m)	Perceived, on average, to be suitable for swimming (32) No adverse visual impact (33)
1,5 - 1,0 (Secchi disc depth in m)	Minimum visibility required for water to be suitable for swimming (34) No visual impact (33)
> 1,0 (Secchi disc depth in m)	Generally considered as unsuitable for swimming unless all subsurface hazards are removed and water depth indication is clearly posted (35) Some visual impact (33)

Physico-chemical Properties

TEMPERATURE

Description

Temperature is a basic property of water. Temperature, or changes in temperature, is important in the regulation or triggering of many physiological processes in marine organisms.

Natural occurrence

The temperature regime for South African marine waters differs from one coastal region to another:

West coast. Generally, the natural temperature regime along the west coast is largely influenced by wind-induced upwelling (south-easterly and southerly winds) which varies seasonally. Seasonality is strongest in the south where south-easterly winds are rare in winter but common in summer. Seasonality diminishes to the north-west where the wind generally comes from the south throughout the year, although velocities are lower in winter [1,2]. Temperatures of the upwelled waters range from 9 °C - 14 °C, depending upon the 'strength' of the upwelling process [1]. These temperatures can increase to 16 °C and higher through sun warming after being upwelled (4). The mixed water is bounded by an oceanic front which lies at or slightly offshore of the shelf break [5]. Temperatures of oceanic water in the area are about 20 °C [1].

South coast. Surface temperatures over most of the south coast are usually between 20-21 °C during summer and 16-17 °C during winter. During summer, thermoclines are formed by the sun heating the surface water, while during winter months the water column is generally well mixed. Upwelling may also influence the temperature regime in the coastal zone, albeit not on the same scale as along the west coast [7].

East coast. The waters of the east coast are of tropical origin with a maximum of 25 °C occurring in February in inshore waters. The difference between summer and winter averages 4 °C with a generally well mixed regime. Further offshore there is also a 4 °C change between summer and winter in the upper 50 m with summer maxima greater than 26 °C. At lower depths, seasonal variation is apparently not evident. However, short-term fluctuations in surface waters may be as high as 8-9 °C, often exceeding seasonal variations. There is evidence of localised upwelling on the inner shore occurs along various areas of the coastline [8].

Although this section gives an indication of the temperature ranges within the different coastal regions, detailed temperature regimes are very site specific. Detailed temperature data sets for a large selection of sites along the South African coast can be obtained from the South African Data Centre for Oceanography (SADCO), CSIR, Stellenbosch.

Fate in environment

Not relevant to temperature.

Interdependence on other constituents

Generally, temperature is not interdependent on any other water quality properties or constituents.

Measurement in seawater

For marine waters, temperature is usually measured in situ, using a Conductivity-Temperature-Depth-Salinity (CTDS) meter. An ordinary thermometer can also be used.

Units: °C.

Pollution sources

Anthropogenic sources which may influence water temperature in the marine environment are usually related to the discharge of cooling water from power stations and certain industries [9].

Treatability

Where seawater is used in enclosed systems, e.g. seawater swimming pools, heat exchangers can be used. The type of metal used in the heat exchanger should be chosen carefully. Generally, titanium is preferred in seawater [10].

Related problems

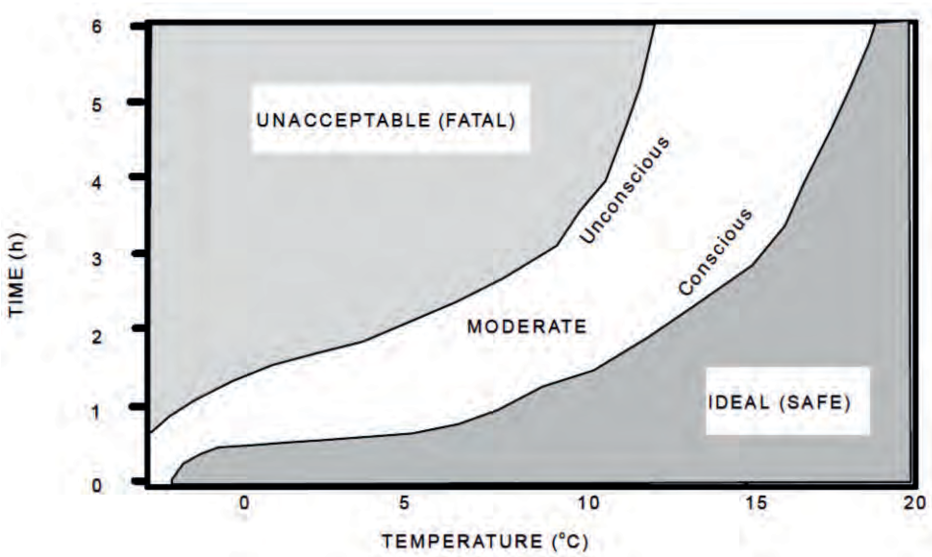
Typical water quality problems which may be associated with tempera ture are hypo- and hyperthermia.

Effects of change

Factual information on the effect of different temperature on recreational use is provided:

TEMPERATURE (°C)	MEASURED EFFECT
< 15	Extended periods of continuous immersion may cause death in some individuals and will be extremely stressful to anyone are not wearing underwater protective clothing [34,36]. The relationship between water temperature and survival time in cold water is illustrated on the next page [36]
15 - 35	No detrimental effect [34]
26 -30	Comfortable for most individuals throughout prolonged periods of moderate physical exertion [35]
> 33	Physiologically, neither adult nor child would experience thermal stress under modest metabolic heat production (normal skin temperature is 33 °C) [34]
> 34 -35	Survival of an individual will depend on tolerance to an elevated internal body temperature, since there is a risk of injury with prolonged exposure [34]. The degree of risk varies with the water temperature, immersion time and the metabolic rate of the individual [35]

The relationship between water temperature and survival time in cold water can be illustrated as follows[36]:



pH

Description

pH is a measure of the concentration of hydrogen ions in solution, according to the expression:

pH = $-\log_{10}[H^+]$, where H^+ is the hydrogen ion concentration.

At a pH less than seven, water is acidic, while at a pH greater than seven, water is alkaline.

Natural occurrence

The pH of seawater usually ranges between 7.9 and 8.2 (15).

Seawater in equilibrium with atmospheric CO_2 is slightly alkaline, with a pH of about 8.1 – 8.3. The pH may rise slightly through the rapid abstraction of CO_2 from surface waters during photosynthesis (14).

Decomposition of organic matter under anaerobic (anoxic) conditions involves the reduction of CO_2 itself, and leads to the formation of hydrocarbons, such as methane. Under these conditions, the pH may rise to values as high as 12 (14).

Fate in environment

Aqueous solutions containing salts of weak acids or bases, such as seawater, show a resistance to pH change (known as buffering), on the addition of acids and bases (16)

Interdependence on other constituents

The pH of seawater can be influenced by certain gases which are soluble in seawater, such as carbon dioxide, ammonia (unionised) and hydrogen sulphide.

For example, carbon dioxide can be abstracted from seawater during phytoplankton blooms, thereby causing an increase in pH.

(In seawater CO_2 [gas] + $H_2O \rightarrow H_2CO_3 \rightarrow H^+ + HCO_3^- \rightarrow 2H^+ + CO_3^{2-}$)

In seawater remote from contaminated or anoxic regions, the pH is mainly controlled by the $CO_2/HCO_3^-/CO_3^{2-}$ system. Other weak electrolytes slightly augment this effect (e.g. borate, phosphate, silicate and arsenate) (16).

Measurement in seawater

pH is measured using a pH meter.

The pH of seawater cannot be measured against the low ionic strength National Bureau of Standards (USA) buffers. Seawater has a high ionic strength resulting in significant errors in measurements. Artificial seawater buffers should be used (10).

Pollution sources

Anthropogenic sources which may influence the pH of water are usually related to highly acidic or alkaline industrial waste waters.

Treatability

In seawater, pH can be decreased by gasing with CO_2.

Related problems

Typical water quality problems which may be associated with pH include skin and eye irritations.

Effects of change

Factual information on the effect of different pH on recreational use is provided:

RANGE	MEASURED EFFECT
< 5.0	Severe eye irritations occur [35] Skin, ear and mucous irritations are likely to occur [35]
5.0 – 6.5	Where the buffering capacity of the water is low, swimming in water with this pH is acceptable . However, in seawater where the buffering capacity can be very high eye, ear, skin and mucous irritations may occur [35]
6.5 – 8.5	No detrimental effects. Minimal eye irritations may occur. The pH is well within the buffering capacity of the lachrymal fluid of the human eye [35]
8.5 – 9.0	Where the buffering capacity of the water is low, swimming in water with this pH is acceptable. However, in seawater where the buffering capacity can be very high eye, ear, skin and mucous irritations may occur [35]
> 9.0	Eye irritations become increasingly severe as pH increases [36] Skin, ear and mucous irritations are likely to occur [36]

Toxic Substances

ALGAL TOXINS

Description

Some natural inhabitants of the sea, e.g. marine algae, produce toxins which pose a health risk to humans and other marine organisms (the latter will not be addressed in this document). Although these are not typical water quality properties/constituents, it is important to be aware of these toxins, especially in areas where people are in contact with seawater or where seafood is cultured or collected for human consumption.

The most well-known toxins include [29]:

- paralytic shellfish poison (PSP) caused by the toxin known as saxitoxin in shellfish which have fed on toxic dinoflagellate plankton (red tide) of the genus *Gonyaulax;*
- diarrhetic shellfish poisoning (DSP); and
- neurotoxic shellfish poisoning (NSP) (aerosol toxins), *Ptychodiscus breve*, being the most widely studied organism causing NSP.

Human intoxication related to PSP has only been associated with the consumption of contaminated shellfish, and rarely, if ever, with recreation in seawater [29].

NPS toxins differ from PSP and DPS in that the toxic effects do not result from ingestion of affected shellfish. Algal physiological processes and/or cell lysis results in the release of these toxins in the water where they act as contact poisons. [29].

Natural occurrence

Algal blooms off the South African west and south coasts occur naturally throughout the year, but are most abundant during late summer and autumn. Some of these, for example, certain red tide species, do produce algal toxins [29].

Blooms of the algae *Gonyaulax polygramma* and *Gymnodinium* sp. have also been reported in False Bay [29].

Fate in environment

Information on the fate of algal toxins in the marine environment could not be obtained.

Interdependence on other constituents

The occurrence of algal blooms, including those producing algal toxins, is usually dependent on factors such as water temperature and nutrient availability [29].

Measurement in seawater

Methods for analysing algal toxins in seawater could not be obtained. However, chromatographic techniques have been used to analyse for these toxins in mussel tissue [30].

Pollution sources

Nutrient enrichment of the sea may stimulate algal blooms, including those producing algal toxins. Anthropogenic sources of nutrients include [9]:

- sewage discharges;
- run-off from agricultural areas, especially where fertilizers are applied;
- septic tank seepage.

Treatability

Practical methods of removing algal toxins from seawater could not be obtained.

Related problems

Typical problems associated with algal toxins, and which are discussed in this document, include gastrointestinal problems and skin, eye, ear and respiratory irritations.

Effects of change

No factual information could be obtained on specific concentration ranges of algal toxins in seawater and associated effects on recreational users.

HYDROGEN SULPHIDE

Description

Hydrogen sulphide is a poisonous gas which readily dissolves in water. No heterotrophic life can exist in water containing hydrogen sulphide, and such affected areas are therefore transformed into oceanic 'deserts' [18].

The speciation of H_2S in seawater at 25 °C, a pH of 8.1 and a salinity of 35 is H_2S (3.07 %), HS^- (96,93 %) and S^{2-} (1.9×10^{-4} %) [21].

Natural occurrence

Hydrogen sulphide is a frequent component of anoxic waters, attaining concentrations as high as 70 mg l^{-1} under extreme conditions [20].

Fate in environment

Dissolved oxygen in seawater is utilised by bacteria for oxidising organic matter to carbon dioxide, water and inorganic ions. In deep water of stagnant basins and in sea areas with a very slow water exchange or a high load of organic matter, all the dissolved oxygen may be utilised, leading to anoxic conditions [16].

Hydrogen sulphide behaves as a weak acid, and is present in natural waters as both the undissociated compound and the HS^- ion (below a pH of 12 the concentration of S^{2-} ion is negligible). Hydrogen sulphide is very volatile and reacts rapidly with oxygen [16].

Hydrogen sulphide is produced in anaerobic environments by the activities of sulphate-reducing bacteria, which derive energy from a process of anaerobic respiration.

$$2\ CH_2O + SO_4^{2-}\ \underline{\text{desulfovibrio}}\ 2\ HCO_3^- + H_2S$$

Probably only a small fraction of H_2S is released to the atmosphere. In many environments, it reacts instead with iron to form insoluble iron sulphide, an abundant constituent of anaerobic organic rich sediments. Much of the sulphide that is not immobilised in this fashion is oxidised by bacteria that derives energy from the following reaction as soon as it reaches the aerobic level of the water profile [20]:

$$H_2S + 2\ O_2 \rightarrow SO_4^{2-} + 2\ H^+$$

Therefore, H_2S is slowly oxidised to sulphate in seawater. Evidence of this is that molecular sulphur does not accumulate in sediments in natural stagnant sea basins e.g. the Black Sea [20].

Interdependence on other constituents

The solubility of hydrogen sulphide decreases with increasing temperature and salinity, e.g. the solubility of H_2S in acidified seawater (pH 2.8 – 3.0) expressed as mg l^{-1} at 1 atm pressure is as follows [22]:

TEMPERATURE (°C)	SALINITY		
	30	35	40
0	6 730.8	6 672.9	6 611.5
10	4 975.7	4 945.0	4 910.9
15	4 338.4	4 314.5	4 287.3
20	3 817.0	3 796.5	3 776.1
25	3 380.7	3 367.1	3 350.1
30	3 019.5	3 005.9	2 992.2

In contact with oxygen, hydrogen sulphide is *rapidly* oxidised to sulphur in an *acid* medium, but *slowly* to sulphate in more neutral solutions like seawater [18].

Measurement in seawater

Hydrogen sulphide in seawater can be analysed photometrically or titrimetrically. The photometric method is more sensitive and accurate[3].

Pollution sources	Although hydrogen sulphide is usually not directly introduced to the marine environment through anthropogenic sources, those with high oxygen demand (reflected in high organic content, high biochemical oxygen demand or chemical oxygen demand) can favour conditions for the formation of hydrogen sulphide.
Treatability	Where seawater is used in enclosed systems, e.g. seawater swimming pools aeration is probably the most practical way of reducing hydrogen sulphide levels.
Related problems	Typical water quality problems which may be associated with hydrogen sulphide include health risks and unpleasant aesthetics.
Effects of change	No factual information on specific effects of hydrogen sulphide on recreational use could be obtained.

Microbiological indicators

THERMOTOLERANT COLIFORM (including *Escherichia coli*)

Description

Thermotolerant coliform refers to a group of total coliform which are more closely related to faecal contamination, and which generally do not readily replicate in the water environment. *Escherichia coli* (*E. coli*) is a member of the group of thermotolerant coliform bacteria. It has the important feature of being highly specific to the faeces of warm-blooded animals and for all practical purposes these bacteria cannot multiply in any natural water environment (27).

These bacteria were selected as indicators of faecal pollution because they typically occur in the faeces of man and warm-blooded animals.

However, some human diseases associated with polluted seawater are caused by viruses. Certain shortcomings of thermotolerant coliform to indicate virological quality have been shown which might be attributed to the following (27):

- viruses are only excreted by infected individuals and coliform bacteria by almost all humans and warm-blooded animals;
- viruses are excreted for relatively short periods, while coliform bacteria is excreted fairly consistently;
- the structure, composition, morphology and size of viruses differ fundamentally from that of bacteria, which implies that behaviour and survival in water differ extensively.

Natural occurrence

Although thermotolerant coliform is not a natural water quality property/constituent of marine waters, they are fairly consistently excreted by humans and other warm-blooded animals.

Fate in environment

The survival of thermotolerant coliform in the marine environment is dependent on a variety of variables including temperature, exposure to ultraviolet light irradiation in sunlight, salinity, osmotic shock, microbiological antagonism, adsorption to solids and sediments and ingestion by molluscs.

The rate of bacterial die-off in the marine environment is usually expressed in T_{90} values, which is the time required for the bacterial density to decrease by 90 %. The T_{90} values are usually greater during day time compared to night time, primarily as a result of higher ultraviolet light irradiation during the day (28).

Interdependence on other constituents

Refer to *Fate in the Environment*

Measurement

In routine monitoring, thermotolerant coliform in seawater is usually measured according to the membrane filter (17) or MPN techniques.

Results are expressed as:

Thermotolerant coliform (*E. coli*) counts per 100 ml

Pollution sources

Major sources of faecal contamination to marine waters include (9):

- sewage discharges;
- bathers themselves, especially at densely populated beaches;
- septic tank seepage;
- stormwater run-off; and
- contaminated river run-off.

Treatability

Treatment should be focused on the microbiological organisms that pose the actual health risk, i.e. the human pathogens.

Related problems

Typical problems associated with the presence of microbiological indicators in seawater used for recreational purposes are usually related to human health, for example gastrointestinal problems and skin, eye, ear and respiratory irritations.

Effects of change

A number of large epidemiological studies have been conducted across the world to determine risk exposure ranges for microbiological indicator organism [37,-45,47].

As an estimate WHO studies (as well as studies conducted at German fresh water bathing sites) suggest *E. coli* to intestinal Enterococci ratios ranging from 2 to 3 would be appropriate to reflect equal risk [48] (*see Effects of change for Intestinal Enterococci*) (CEC, 2002). However, this equivalence is not exact and where possible, local managers should define the relationship that exists in their own waters [49].

INTESTINAL ENTEROCOCCI

Description

Enterococci and faecal streptococci refer to vaguely defined groups of Gram-positive spherical bacteria, some of which are of human and/or animal faecal origin, and some of which are members of the natural flora of various environments. Because of the limited specificity of tests commonly used in these groups, they can, for all practical purposes, be considered the same[27].

Enterococci has been shown to be a valuable indicator for determining the extent of faecal contamination in marine waters [17].

Natural occurrence

Although enterococci are not a natural water quality property/constituent of marine waters, it is fairly consistently excreted by warm-blooded animals [17].

Fate in environment

The survival of enterococci in the marine environment is dependent on a variety of variables including temperature, exposure to ultraviolet light irradiation in sunlight, salinity, osmotic shock, microbiological antagonism, adsorption to solids and sediments and ingestion by molluscs.

The rate of bacterial die-off in the marine environment is usually expressed in T_{90} values, which is the time required for the bacterial density to decrease by 90%. The T_{90} values are usually greater during day time compared to night time, primarily as a result of higher ultraviolet light irradiation during the day [28].

Interdependence on other constituents

Refer to *Fate in the Environment* above.

Measurement

In routine monitoring, enterococci in seawater is usually measured according to the membrane filter [17] or most probable number (MPN) techniques.

Results are expressed as:

Enterococci counts per 100 ml

Pollution sources

Major sources of faecal contamination to marine waters include [9]:

- sewage discharges;
- bathers themselves, especially at densely populated beaches;
- septic tank seepage;
- stormwater run-off;
- contaminated river run-off.

Treatability

Treatment should be focused on the microbiological organisms that pose the actual health risk, i.e. the huma n pathogens.

Related problems

Typical problems associated with the presence of microbiological indicators include gastrointestinal problems and skin, eye, ear and respiratory irritations.

Effects of change

A number of large epidemiological studies have been conducted across the world to determine risk exposure ranges for microbiological indicator organism [37,-45,47]:

ENTEROCOCCI (Count per 100 ml)	EFFECT (ESTIMATED RISK PER EXPOSURE)
40 (95 percentile)	<1% gastrointestinal (GI) illness risk; <0.3% acute febrile respiratory (AFRI) risk. This relates to an excess illness of less than one incidence in every 100 exposures. The AFRI burden would be negligible (this value is below the no-observed-adverse-effect level [NOAEL] in most epidemiological studies).
200	5% GI illness risk; 1.9% AFRI risk. This level relates to an

ENTEROCOCCI (Count per 100 ml)	EFFECT (ESTIMATED RISK PER EXPOSURE)
(95percentile)	average probability of one case of gastroenteritis in 20 exposures. The AFRI illness rate would be 19 per 1000 exposures, or approximately 1 in 50 exposures (This level is above the threshold of illness transmission reported in most epidemiological studies that have attempted to define a NOAEL or lowest observed-adverse-effect level [LOAEL[for GI illness and AFRI).
500 (95percentile)	10% GI illness risk; 3.9% AFRI risk. This level 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 39 per 1000 exposures, or approximately 1 in 25 exposures (this level represents a substantial elevation in the probability of all adverse health outcomes for which dose–response data is available)
>500 (95percentile)	>10% GI illness risk; >3.9% AFRI risk. There is a greater than 10% chance of illness per single exposure. The AFRI illn ess rate would be greater than 39 per 1000 exposures (above this level there may be a significant risk of high levels of minor illness transmission)

Clostridium perfringens

Description

Clostridium perfringens is a spore-forming, obligate anaerobic bac terium.

Natural occurrence

Although *C. perfringens* is not a natural water quality constituent/property of marine waters this species is ubiquitous in nature, including soil and marine sediments [50]. Type A strains form part of the microflora of both soil and the intestinal tracts of humans, while Types B, C, D and E are obligate parasites of warm -blooded animals and occasionally are found in man [51].

Fate in environment

In the absence of fermentable carbohydrates *C. perfringens* has a tendency to form spores, a highly resistant resting phase whereby it can survive in a dormant state through long periods of starvation or other adverse environmental conditions [52]. In this state the organism can remain viable for many years.

Interdependence on other constituents

When external conditions become favourable for growth, i.e. access to moisture, nutrients and anaerobic growth conditions (*C. perfringens* is an obligate anaerobe), germination of the spores occurs and the organism reverts to a vegetative state.

Measurement

In routine monitoring, *C. perfringens* in seawater are enumerated by the membrane filtration method using mCP agar and incubation under anaerobic conditions.

Pollution sources

This bacteria is associated with sources of faecal contamination to marine waters which include [9]:

- sewage discharges;
- bathers themselves, especially at densely populated beaches;
- septic tank seepage;
- stormwater run-off; and
- contaminated river run-off.
- contaminated marine sediments;

Treatability

C. Although *perfringens* can be a pathogen in its own right (see Related Problems below), and since in its spore form it will not succumb to chemical treatments, where seawater is used in enclosed systems such a seawater swimming pools treatment should be focused on the elimination of other human pathogens that pose a health risk through ingestion or by skin, eye, ear and respiratory irritation.

Related problems

Sub-cutaneous invasion by *C. perfringens* through existing deep tissue wounds can result in gas gangrene and septicaemia. Direct oral ingestion of seawater contaminated with the spore form of the organism does not have a detrimental effect.

Effect of change

Detection of *C. perfringens* is being used by the State of Hawaii (USA) as an interim measure to supplement its microbiological monitoring programme in the face of the potential for indicator survival and re-growth in tropical areas. Its use is based on the fact that it acts as an indicator of potential sewage pollution without being capable of re-growth in aerobic environments. Epidemiological studies to determine risk exposure ranges for this indicator organism are currently not well documented in the literature.

HUMAN PATHOGENS

Description

This document will deal with ***human*** pathogens, in particular. Human pathogens refer to microbiological organisms which may cause disease or other health problems in humans. In terms of marine waters, this can either be through contact or ingestion of water containing these organisms or through the consumption of seafood which has been cultured in contaminated waters.

Generally, human pathogens can be divided into three broad groups, i.e.:

- *Bacteria*, including organisms such as *Salmonella*, *Shigella, Klebsiella pneumoniae, Pseudomonas aeruginosa*, *Staphylococcus aureus*, species of *Streptococcus* and *Micrococcus*, *Vibrio parahaemolyticus, Vibrio cholerae, Vibrio vulnificus* and *Listeria monocytogenes* [25,27,31];
- *Viruses*, including enteroviruses, gastroenteric viruses and adenoviruses [25];
- *Protozoan parasites*, including *Giardia lambia*, *Cryptosporidium parvum* and *Entamoeba histolytica* [27,31].

Natural occurrence

Some human pathogens which are known to cause infections in humans, such as *Vibrio parahaemolyticus* and *Vibrio cholerae*, may be natural inhabitants of the marine environment.

Fate in environment

Not much detail is known on the fate of human pathogens in marine waters. Generally, the survival of human pathogens in the marine environment is dependent on a variety of variables including temperature, exposure to ultraviolet light irradiation in sunlight, salinity, osmotic shock, microbiological antagonism, adsorption to solids and sediments and ingestion by molluscs. Obviously, survival is extensively prolonged in environments which protect against antimicrobial agents. Because of their small size, simple structure and resistant outer shell (capsid), viruses generally survive longer than bacteria.

Interdependence on other constituents

Refer to *Fate in the Environment* above.

Measurement in seawater

Methods for testing for human pathogens in seawater vary and largely depend on the type of organism. Because indicator organisms are usually measured in routine monitoring for pathogenic contaminants, methods of testing for human pathogens will not be discussed in detail in this document. These methods can, however, be obtained from a variety of publications [17,26,27].

Pollution sources

Major sources of faecal contamination to marine waters include [9]:

- sewage discharges;
- bathers themselves, especially at densely populated beaches;
- septic tank seepage;
- stormwater run-off;
- contaminated river run-off.

Treatability

Where seawater is used in enclosed systems or where it is extracted before use, UV-irradiation and ozonation can possibly be used to treat the water. This should, however, be done with great care since certain marine organisms are sensitive to such treatments.

In seawater, the effectiveness of chlorine as a disinfectant, e.g. in tidal pools, is doubtful. When chlorine is added to water the following reactions occur:

$$Cl_2 + H_2O \rightarrow H^+ + Cl^- + HOCl$$
$$HOCl \rightarrow H^+ + OCl^-$$

The disinfecting ability of the hypochlorous acid (HOCl) greatly exceeds that of the hypochlorite ion (OCl^-) and the equilibrium between the two is pH-dependent. At pH 5 available chlorine is almost entirely present as hypochlorous acid, but at pH 10 as hypochlorite. At the pH of seawater (i.e. about 8.2), it can therefore be expected that the disinfectant rate of chlorine will be much reduced [(6)].

Related problems

Typical problems associated with human pathogens inc lude gastrointestinal problems and skin, eye, ear and repiratory irritations.

Effects of change

The minimum infectional dose for a number of faecal pathogens may be as follows [(46)]:

Vibrio cholerae	10^9
Escherichia coli	10^4 - 10^5
Salmonella sp.	10^5 - 10^9
Salmonella typhi	10^2 - 10^3

References related to Appendix C

1. SHANNON, L.V. 1985. The Benguela Ecosystem. Part 1. Evolution of the Benguela, physical features and processes. *Oceanogr. Mar. Biol. Ann. Rev.* **23**: 105-182.

2. NELSON, G. and HUTCHINGS, L. 1983. The Benguela upwelling area. *Prog. Oceanogr.* **12**: 333-356.

3. GRASSHOFF, K., EHRHARDT, M. and KREMLING, K. (Eds.). 1983. *Methods of Seawater Analysis*. Verlag Chemie, Weinheim.

4. BROWN, P.C. 1992. Spatial and seasonal variation in chlorophyll distribution in the upper 30 m of the photic zone in the southern Benguela/Agulhas ecosystem. *S. Afr. J. mar. Sci.* **12**: 515-526.

5. ANDREW, W.R.H. and HUTCHINGS, L. 1980. Upwelling in the southern Benguela system. *Prog. Oceanog.* **9**: 1-18.

6. WATER RESEARCH CENTRE. 1979. Disinfection of sewage by chlorination. *Notes on Water Research* No **23**. Published by Water Research Centre. Printed in England by Clarendon Printers Ltd., Beaconfields, Buckinghamshire.

7. SHANNON, L. V. 1989. The physical environment. In: *Oceans of life*. Payne, A.I.L and Crawford, R.J.M. (Eds.) Vlaeberg Publishers, Cape Town.

8. SCHUMANN, E.H., 1988. Physical oceanography off Natal. In : *Coastal Ocean Studies off Natal*. Schumann, E.K. (Ed). Springer - Verlag. p 101 - 130

9. WORLD HEALTH ORGANIZATION. 1982. *Waste discharge into the marine environment.* Principles and guidelines for the Mediterranean action plan. Published under the joint sponsorship of the World Health Organization and the United Nations Environment Programme. Pergamon Press. 422 pp.

10. HAWKINS, A D. 1981. *Aquarium systems*. Academic Press.

11. MILLERO, F.J. and SOHN M.L. 1992. *Chemical oceanography*. CrC Press, Florida, USA. ISBN 0-8439-8840-6. 531 pp.

12. SHANNON, L.V. and STANDER, G.H 1977. Physical and chemical characteristics of water in Saldanha Bay and Langebaan Lagoon. *Trans. roy. Soc. S. Afr.* **42:** 441-459.

13. EAGLE, G.A. and ORREN, M.J. 1985. A seasonal investigation of the nutrients and dissolved oxygen in the water column along tow lines of stations south and west of South Africa. *CSIR Research Report* **567**. 52 pp plus figures and tables.

14. OPEN UNIVERSITY. 1989. *Seawater: Its composition, properties and behaviours*, S 330, Volume 2. Published in association with Pergamon Press.

15. HUGUENIN, J.E. and COLT, J. 1989. Design and operating guide for aquaculture seawater systems. In: *Developments in Aquaculture and Fisheries Science*, Volume 20. Elsevier.

16. RILEY, J.P. and SKIRROW, G. 1975. *Chemical Oceanography*, 2nd edition, Volume 3. Academic Press, London.

17. STANDARD METHODS FOR THE EXAMINATION OF WATER AND WASTEWATER. 1989. 17th edition. Lenore, S.C., Greenberg, A.E. and Trussel, R.R. (Eds.). ISBN 0-87553-161-X.

18. GRASSHOFF, K., EHRHARDT, M. and KREMLING, K. (Eds.). 1976. *Methods of Seawater Analysis*. Verlag Chemie, Weinheim.

19. RILEY, J.P. and CHESTER, R. 1983. *Chemical Oceanography*, Volume 8. Academic Press, London.

20. HUTZINGER, O. (Ed.) 1980. *The handbook of environmental chemistry*. Volume 1, Part A. Springer Verslag, Berlin.

21. MILLERO, F.J. 1976. The thermodynamics and kinetics of the hydrogen sulphide system in natural waters. *Marine Chemistry* **18**: 121-147.

22. DOUABUL, A.A. and RILEY, J.P. 1979. The solubility of gases in distilled water and seawater. Hydrogen sulphide. *Deep Sea Research* **26** (A): 259-268. Pergamon Press.

23. RILEY, J.P. and CHESTER, R.C. 1976. *Chemical oceanography*. 2nd edition. Volume 5. Academic Press, London.

24. RILEY, J.P. and SKIRROW, G. 1975. *Chemical Oceanography*. 2nd edition. Volume 4. Academic Press , London.

25. GRABOW, W.O.K. 1991. Human viruses in water. *Water Sewage and Effluent* **11**(4): 16-21.

26. STANDARD METHODS FOR THE EXAMINATION OF WATER AND WASTEWATER. 1992. 18th edition. ISBN 8755-3546.

27. GRABOW, W.O.K . in prep. Waterborne diseases: Update on quality assessment. Department of Virology, University of Pretoria.

28. BELLAIR, J.T., PARR -SMITH, G.A. and WALLIS, I.G. 1977. Significance of diurnal variations in faecal coliform die-off rates in the design of ocean outfalls. *Journal WPCF*. September. pp 2022-2030.

29. HORSTMAN, D.A., McGIBBON, S., PITCHER, G.C., CALDER, D., HUTCHINGS, L. and WILLIAMS, P. 1991. Red tides in False Bay, 1959 -1989, with particular reference to recent blooms of *Gymnodimium* sp. *Trans Roy. Soc. S. Afr.* **47**(4&5): 611-628.

30. HOVE, H.T. and GRAHL -NEILSEN, O. 1989. Assay for dinoflagellate toxins in mussels by gas chromatography and principal components analysis. *Analytica Chimica Acta* **222**: 35-42.

31. BARSKY, S.M. 1990. *Diving in high risk environments*. Published by Dive Rescue Inc./International, Colorado. 118pp.

32. SMITH, D.G, CRAGG, A. M. and CROKER, G. F. 1991. Water clarity criteria based on user perception. *Journal of Environmental Management* **33**, 285-299.

33. DEPARTMENT OF WATER AFFAIRS AND FORESTRY. 1993. South African Water Quality Guidelines. Volume 1: Recreational Use

34. CANADIAN WATER QUALITY GUIDELINES. 1992. Updated version of Canadian water quality guidelines, 1987. Prepared by the Task Force on Water Quality Guidelines of the Canadian Council of Resource and Environmental Ministers. Canada.

35. NAS/NAE, 1973. *Water Quality Criteria 1972*. EPA-R3-73-033. A report of the committee on water quality criteria. Prepared by the National Academy of Science and the National Academy of Engineering. Prepared for the US Environmental Protection Agency, Washington DC, USA.

36. HEALTH AND WELFARE, CANADA. 1983. Guidelines for Canadian Recreational Waters. Federal-Provincial working group on recreational water quality of the Federal-Provincial advisory committee on Environmental and occupational health, Ottawa.

37. VON SCHIRNDING, Y.E.R., KFIR, R., CABELLI, V., FRANKLIN, L. and JOUBERT, G. 1992. Morbidity among bathers exposed to polluted seawater. *South African Medical Journal* **81**(11): 543-546.

38. FATAL, B., PELEG -OLEVSKY, E., YOSH PE-PURER, Y. and SHUVAL, H.I. 1986. The association between morbidity among bathers and microbial quality of seawater. *Wat. Sci. Tech.* **18** (11): 59-65.

39. CHEUNG, W.H.S., CHANG, K.C.K., HUNG, R.P.S. 1990. Health effects of beach pollution in Hong Kong. *Epidemiol. Infect.* **105**: 139-162.

40. CHEUNG, W.H.S., CHANG, K.C.K., HUNG, R.P.S. 1991. Variations in microbial indicator densities in beach waters and health-related assessment of bathing quality. *Epidemiol. Infect.* **106**: 329-344.

41. CHEUNG, W.H.S., HUNG, R.P.S., CHANG, K.C.K. and KLEEVENS, J.W.L. 1991. Epidemiological study of beach water pollution and health-related bathing water standards in Hong Kong. *Wat. Sci. Tech.* **23** (1-3): 243-252.

42. CORBETT, S.J., RUBIN, G.L., CURRY, G.K., KLEINBAUM, D.G. and th e SIDNEY BEACH USERS ASSOCIATION. 1993. The health effects of swimming at Sidney beaches. *American Journal of Public Health* **83**(12): 1701-1706.

43. 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.

44. FLEISCHER, J.M. 1991. A reanalysis of data supporting US federal bacteriological water quality criteria governing marine recreational waters. *Research Journal WPCF* **63**(3): 259-265.

45. ALEXANDER, L.M., HEAVEN, A., TENNANT, A. and MORRIS, R. 1992. Symptomatology of children in contact with seawater contaminated with sewage. *Journal of Epidemiological and Community Health* **46**: 340-344.

46. HUISMAN, J. 1982. Water and ziekte. *H_2O* **15**(19): 512-517.

47. WORLD HEALTH ORGANISATION (WHO) 2003. Guidelines for Safe Recreational Water Environments. Volume 1: coastal and freshwaters. Geneva. ISBN 92 4 154580 1. (www.who.int/water_sanitation_health/bathing/srwe1/en/).

48. COUNCIL OF EUROPEAN COMMUNITY (CEC) 2002. Proposal for a Directive of the European Parliament and of the Council concerning the quality of bathing water. COM (2002) 581 final.

49. NEW ZEALAND, MINISTRY OF ENVIRONMENT (NZME) 2003. Microbiological water quality guidelines for marine and freshwater recreational area. ISBN: 0-478-24091-0. ME number: 474. Wellington, New Zealand (www.mfe.govt.nz/publications/water/microbiological-quality-jun03/).

50. BUTLER, J.P., VAUGHN, V.M. and NOLLEY, C.S. (Eds.) 1986. Bergey's Manual of Systematic Bacteriology. Volume 2. ISBN 0 -683-07893-3.

51. SMITH, L.D.S. 1975. Common mesophilic anaerobes, including *Clostridium botulinum* and *C. tetani*, in 21 soil samples. *Appl. Microbiol*. **29**: 590-594.

52. CRUICKSHANK, R. (Ed). 1969. Medical Microbiology. E & S Livingstone Limited, Edinburgh and London.

APPENDIX D
PROPOSED SANITARY INSPECTION CHECKLIST

SITE NAME					
LOCATION					
MAP POSITION	**Latitude**		**Longitude**		
PERSON COMPLETING CHECKLIST					

INFORMATION ABOUT AREA

Key features of area	
Total annual rainfall (mm)	
Seasonal rainfall pattern	
Water use activities	
Seasonal loading patterns	

LAND USE OR HUMAN ACTIVITIES SURROUNDING RECREATION SITE (Tick all that apply and note key findings)

Natural vegetation		Cultivated land		Road/rail	
Urban area		Residential		Land-fill/dump sites	
Sand dunes		Commercial		Other potential polluting activities (specify)	
Pastures		Industry (specify)			

NOTES:

	EFFLUENT/WASTEWATER/STORMWATER DIRECT TO RECREATIONAL WATER	**Present?**	**Likely to cause effect?**
1	Discharge of untreated human effluent onto or adjacent to a recreational area		
2	Storm water outlet with potential sewage contamination onto or adjacent to recreational area		
3	Urban stormwater outlet protected from sewage ingress		
4	On-site or other private sewage disposal systems (e.g. septic tank /conservancy tanks/package plant)		
5	Sewage discharge: untreated, primary or secondary treatment		
6	Sewage discharge: tertiary treatment		
7	Intensive agricultural use in immediate catchment and potential for run-off from untreated animal effluent (e.g. dairy farms, livestock)		
8	Incidence and density of bird life (particularly lagoons/estuaries)		
9	Water craft mooring or use (for boats, proximity, densities and pump-outs).		
	QUALITY OF RIVER/STREAM INFLOWS TO RECREATIONAL AREA (if present)	**Present?**	**Likely to cause effect?**
10	Discharge of untreated human effluent, primary or secondary wastewater treatment plant discharge, on-site or other private sewage disposal systems (e.g. septic tank /conservancy tanks/package plant)		
11	Storm water outlets with potential sewage contamination		
12	Sewage discharge after tertiary treatment		
13	High-intensity agricultural/rural activities, incidence and density of feral animal/bird population		
14	Focal points of drainage, as run-off from low-intensity agriculture/urban/rural catchment		
15	Potential for run-off from feral animals (e.g. forest or bush)		
	OTHER INFLUENCES	**Present?**	**Likely to cause effect?**
16	Tidal movements or onshore winds likely to carry water polluted by untreated/primary/secondary treated effluent or onsite waste treatment systems into recreational area		
17	Tidal movements or onshore winds that are likely to carry water polluted by tertiary treated wastewater into recreational area		

Note: If the box is ticked indicating the presence of any of the above, the answer as to whether it is causing an effect may be obvious (e.g. discharge of human or animal effluent onto or adjacent to a recreational area). If it is unclear whether it is causing an effect, a more detailed investigation may be required to establish relative importance and magnitude of the effect.

OTHER CONSIDERATIONS	**Yes**	**No**
Does rainfall trigger contamination events?		
Does microbiological water quality data exceed single sample guideline (280 counts per 100 ml) on any occasion?		
Is there additional information implying risk (such as notified illness related to recreational water activities)?		

APPENDIX E
EXAMPLE: SAMPLING LOG SHEET

SITE NAME				
SAMPLING LOCATION				
MAP POSITION	Latitude	Longitude		
PERSON COLLECTING SAMPLE				
DATE & TIME	Date	Time		
RELATED INFORMATION COLLECTED AT SAMPLING LOCATION				
Climatic conditions (e.g. rainy, sunny, cloudy)				
Wind direction				
Surface current direction				
Water temperature (°C)				
Salinity				
			Yes	**No**
Presence of objectionable matter?				
	If yes, contact responsible authority for further action (Contact & Tel: ……………….)			
Presence of potentially harmful algal blooms?				
	If yes, contact responsible authority for further action (Contact & Tel: ……………….)			
Indication of potential presence of toxic chemical substances (including chlorine)?				
	If yes, contact responsible authority for further action (Contact & Tel: ……………….)			

COMMENTS:

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