SOUTH AFRICAN

WATER QUALITY GUIDELINES

VOLUME 2

RECREATIONAL USE

Department of Water Affairs and Forestry

Second Edition 1996

SOUTH AFRICAN WATER QUALITY GUIDELINES

Volume 2: Recreational Water Use

Second Edition, 1996

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South African Water Quality Guidelines

Volume 2 Recreational Use

Department of Water Affairs and Forestry

Second edition 1996

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This volume is the second in a series of eight volumes comprising the South African Water Quality Guidelines.

Volume 1: South African Water Quality Guidelines - Domestic Water Use

Volume 2: South African Water Quality Guidelines - Recreational Water Use

Volume 3: South African Water Quality Guidelines - Industrial Water Use

Volume 4: South African Water Quality Guidelines - Agricultural Water Use: Irrigation

Volume 5: South African Water Quality Guidelines - Agricultural Water Use: Livestock Watering

Volume 6: South African Water Quality Guidelines - Agricultural Water Use: Aquaculture

Volume 7: South African Water Quality Guidelines - Aquatic Ecosystems

Volume 8: South African Water Quality Guidelines - Field Guide

Foreword

The Department of Water Affairs and Forestry is the custodian of South Africa's water resources. Part of its mission is to ensure that the quality of water resources remains fit for recognised water uses and that the viability of aquatic ecosystems are maintained and protected. These goals are achieved through complex water quality management systems which involve role players from several tiers of government, from the private sector and from civil society.

A common basis from which to derive water quality objectives is an essential requirement that enables all role players involved in such a complex system to act in harmony in order to achieve the overarching goal of maintaining the fitness of water for specific uses and to protect the health of aquatic ecosystems. For these reasons the Department initiated the development of the *South African Water Quality Guidelines*, of which this is the second edition. The *South African Water Quality Guidelines* serve as the primary source of information for determining the water quality requirements of different water uses and for the protection and maintenance of the health of aquatic ecosystems.

The process that followed and the wide variety of organizations and individuals involved in the development of these guidelines ensured the acceptance and use of these guidelines by all significant role players, as the ***South African*** *Water Quality Guidelines*. These guidelines are technical documents aimed at users with a basic level of expertise concerning water quality management. However, the role players involved in the different water use sectors are expected to use these guidelines as a basis for developing material to inform water users in specific sectors about water quality and to empower them to effectively participate in processes aimed at determining and meeting their water quality requirements.

The Department recognises that water quality guidelines are not static and will therefore update and modify the guidelines on a regular basis, as determined by ongoing research and review of local and international information on the effects of water quality on water uses and aquatic ecosystems. The process of developing water quality guidelines, and the involvement of key role players, is a contining one. The second edition is published in a loose leaf, ring binder format to facilitate the regular updating of the guidelines. All those who want to comment on and make suggestions concerning the *South African Water Quality Guidelines* are invited to do so at any time by contacting the Director: Water Quality Management, Department of Water Affairs and Forestry, Private Bag X313, Pretoria 0001.

Finally I wish to express my sincere appreciation to all those who have been involved in the development of these guidelines. I also look forward to their continued involvement in maintaining one of the corner-stones of the water quality management system in South Africa.

Kader Asmal

Professor Kader Asmal **MP**
Minister Of Water Affairs and Forestry May 1996

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Chapter 1

Introduction

Introduction

Scope and Purpose of the Water Quality Guidelines

Scope

The *South African Water Quality Guidelines for Recreational Water Use* is essentially a user needs specification of the quality of water required for different recreational uses. It is intended to provide information required to make judgements as to the fitness of water used for recreational purposes.

The guidelines are applicable to any inland water that is used for recreational purposes, namely rivers, streams, canals, dams, ponds and other impoundments.

Purpose

The *South African Water Quality Guidelines* are used by the Department of Water Affairs and Forestry as its primary source of information and decision-support to judge the fitness for use of water and for other water quality management purposes.

The South African Water Quality Guidelines contains information similar to that which is available in the international literature. However, the information provided in these guidelines is more detailed, and not only provides information on the ideal water quality for water uses but in addition provides background information to help users of the guidelines make informed judgements about the fitness of water for use.

Users of the Guidelines

The *South African Water Quality Guidelines* are being developed as an important information resource, primarily for water quality managers. Nevertheless, educators and other interested and affected members of the general public are likely to find them a valuable source of information for many aspects of water quality and its management.

Ongoing Review

The *South African Water Quality Guidelines* will be periodically reviewed. The purpose of the reviews is to:

Add guidelines for constituents not yet included in the guidelines;

Update the guidelines for constituents currently included in the guidelines as relevant new information from international and local sources becomes available on the water quality or support information for water quality constituents.

The loose leaf / ring binder format of the guidelines, as well as the footnotes at the bottom of each page, clearly indicating the exact version of a guideline, have been designed to facilitate regular updating of the guidelines.

Overview

The South African Water Quality Guidelines for Recreational Use is divided into six chapters:

Chapters 1 - 4 provide an introduction to the guidelines, define some important water quality concepts, explain how water used for recreational purposes was characterised for the purpose of developing these guidelines, describe how the guidelines were developed and provide some guidance on how they should be used.

Chapter 5 provides the guidelines for the different water quality constituents.

Chapter 6 consists of appendices which provide additional support information.

Water Quality

Introduction

To use the *South African Water Quality Guidelines* correctly it is important for users to understand how water quality and some related concepts were defined for the purpose of developing the guidelines.

Definition

The term *water quality* describes the physical, chemical, biological and aesthetic properties of water that determine its fitness for a variety of uses and for the protection of aquatic ecosystems. Many of these properties are controlled or influenced by constituents which are either dissolved or suspended in water.

Constituents

The term *constituent* is used generically in this edition of the *South African Water Quality Guidelines* for any of the properties of water and/or the substances suspended or dissolved in it. In the international and local literature, several other terms are also used to define the properties of water or for the substances dissolved or suspended in it, for example *water quality variable; characteristic;* and *determinand*.

Examples of constituents which are used to describe water quality are:

The temperature of the water is 20 °C.
The colour of the water is green.
The concentration of calcium is 60 mg/L.
Thirty percent of the surface of the water body is covered with water hyacinth.

Note that none of the statements of water quality states anything about how desirable or acceptable it is for water to have the properties listed.

Therefore, in addition to such statements, one also needs to make a judgement about how desirable or acceptable water of such a quality would be for a particular water use or for maintaining the health of aquatic ecosystems before the fitness of water for use can be determined.

Criteria

Water quality criteria are scientific and technical information provided for a particular water quality constituent in the form of numerical data and/or narrative descriptions of its effects on the fitness of water for a particular use or on the health of ecosystems.

No Effect Range

For each water quality constituent there is a No Effect Range. This is the range of concentrations or levels at which the presence of a particular constituent would have no known or anticipated adverse effects on the fitness of water for a particular use or on the protection and maintenance of the health of aquatic ecosystems. These ranges were determined by assuming long-term continuous use (lifelong exposure) and incorporate a margin of safety.

Target Water Quality Range

One of the goals of the Department of Water Affairs and Forestry (DWAF) is to strive to maintain the quality of South Africa's water resources such that they remain within the 'No Effect Range'. The DWAF encourages all stakeholders concerned with the quality of South

Africa's water resources to join forces and aim to maintain water quality within the No Effect Range, where and whenever possible.

For this reason, the No Effect Range in the *South African Water Quality Guidelines* is referred to as the Target Water Quality Range (TWQR). It is included and highlighted as such in the water quality criteria provided for each of the constituents in the guidelines.

Users of the *South African Water Quality Guidelines* should note that an important implication of setting the Target Water Quality Range equal to the No Effect Range is that it specifies good or ideal water quality, instead of water quality which is merely acceptable.

Water Quality Guidelines

A water quality guideline is a set of information provided for a specific water quality constituent. It consists of the water quality criteria, the Target Water Quality Range, and support information, such as the occurrence of the constituent in the aquatic environment, the norms used to assess its effects on water uses, how these effects may be mitigated and possible treatment options.

The South African Water Quality Guidelines consists of the guidelines for domestic, recreational, industrial, agricultural (irrigation, livestock watering and aquaculture) uses, as well as guidelines for the protection of the health and integrity of aquatic ecosystems and guidelines for the protection of the marine environment.

Fitness for use

Introduction

The Department of Water Affairs and Forestry is the custodian of South Africa's water resources. Part of its mission is to maintain the fitness-for-use of water on a sustained basis. The concept of fitness for use is therefore central to water quality management in South Africa and to the development and use of these guidelines.

Water Use

Four broad categories of water use are recognised in the South African Water Act, namely the use of water for:

domestic purposes;
industrial purposes;
agricultural purposes; and
recreational purposes.

The DWAF's mandate also requires that the health of aquatic ecosystems be protected. The water quality requirements of these water uses and those for the protection of aquatic ecosystems, form the basis on which the fitness for use of water is judged.

Characterisation of Water Uses

The broad water use categories listed above can each be subdivided into a number of subcategories, such as the use of water for drinking, cooking, bathing, washing of clothes and gardening. The subcategories of a particular water use can have quite different water quality requirements. Hence the need to characterise water uses into subcategories or components and to specify water quality requirements at a subuse level.

The characterisation of water uses involves determining and describing those characteristics which will help determine its significance as well as those which dictate its water quality requirements, for example :

The significance of each water use is determined by considering issues such as the volume of water used, the socio-economic benefits and costs associated with the use; and the nature of the use, i.e. whether it is consumptive or not or whether it is abstractive or not.

The water quality requirements of a water use are determined by considering:

- Typical water quality problems associated with a particular water use or the role that water quality plays in sustaining the use;
- The nature of the effects of poor water quality on the use;
- The norms which are commonly used as yardsticks to measure the effect of water quality on a particular water use;
- The water quality constituents which are generally of concern;
- Any other site- or case-specific characteristics of the water use which may influence its water quality requirements.

Fitness for Use

The fitness for use of water, is a judgement of how suitable the quality of water is for its intended use or for protecting of the health of aquatic ecosystems.

To be able to make judgements about fitness for use one needs to:

Characterise the water uses and/or particular aquatic ecosystems from a water quality perspective;
Determine the quality requirements of the intended uses and/or that of aquatic ecosystems;
Obtain information on the key constituents which determine the fitness of water for its intended uses and/or that affect the health of aquatic ecosystems;
Establish how, and how much, the intended use of an aquatic ecosystem will be affected by the prevailing water quality;
Determine whether the undesirable effects of water quality on a particular use can be mitigated against.

The fitness for use of water can range from being completely unfit for use to being 100 % or ideally fit for a specific use. Descriptions commonly used to express judgements about the fitness of water for use are:

ideal; 100 % fit for use; desirable water quality; target water quality range;
acceptable;
tolerable, usually for a limited time period only;
unacceptable for use;
completely unfit for use.

Effects and norms

Water quality can affect water uses or the health of aquatic ecosystems in many different ways. For example, it can affect the

health of an individual drinking the water or swimming in it;
productivity or yield of a crop being irrigated;
cost of treating water before it can be used in an industrial process;
sophistication of technology required to treat water to adequate quality;
biodiversity of aquatic ecosystems.

It is therefore necessary to use different norms, such as health effects, crop quality, cost of treatment; type and level of treatment technology and the effects on biodiversity as yardsticks for making judgements about the fitness for use of water.

Sustained use It is generally an important objective for development, and therefore for the associated water uses, to be sustainable. The long-term sustainability of water uses was an important consideration in the development of the guidelines. For example, the water quality criteria for recreational use are based on the assumptions of lifelong and continuous exposure to water of a given quality.

The assumptions underlying the development of the guidelines must be taken into account, particularly when making judgments about the fitness of water which needs to be used for a short duration only.

Chapter 2

Approach to Guideline Development

Approach to Guideline Development

Rationale, Approach and Methodology

Rationale

Many different water quality criteria and guidelines have been published in the international and local literature. Different approaches and methodologies have often been used to derive criteria and guidelines, for example, some guidelines specify maximum concentrations for constituents fit for use, whereas others attempt to define the ideal concentration of a constituent, often with the inclusion of safety factors. Therefore, depending on which guidelines or criteria are used to establish water quality requirements, one can arrive at answers which sometimes differ by a factor of a hundred or more.

The rationale for developing the *South African Water Quality Guidelines* was to:

Develop a single set of guidelines and criteria that are appropriate for South Africa, and that are based on a consensus of South African expertise and other role players in water quality. One of the intentions of this approach was to limit the confusion that often arises from the use of different criteria and guidelines to establish the water quality requirements for a particular water use by the stakeholders of water supply and utilisation in South Africa;

Modify international guidelines in the light of local research and experience.

Approach

The approach used to develop the *South African Water Quality Guidelines for Recreational Use* was that the guidelines should as far as practically possible serve as a standalone source of information and support base for decisions. Using this, water resource managers could make judgements about the fitness for use of water for different recreational purposes. It is accepted that, in many cases, the user will also have to consult different sources or obtain expert opinion before reaching a final conclusion as to the fitness of water for use. However, in these cases the guidelines should at least indicate to the users what kind of information to look for.

The guidelines consist not only of the water quality criteria for a specific constituent but also include a substantial amount of information to support the user of the guidelines in making judgements about the fitness of water for recreational use.

In order to decide on the type of information to be included in the *South African Water Quality Guidelines*, an analysis was done of the DWAF's different water quality management processes. Those that required the guidelines to be used as a source of information and/or decision support were identified and their typical information needs determined.

The product specification of the *South African Water Quality Guidelines*, delineating the information requirements of the guidelines, was provided to technical teams responsible for guideline development.

Methodology

The methods used to develop the recreational water quality guidelines for South Africa consisted of:

Listing the various purposes for which water is used for recreational purposes.

Describing, for each water use, the water quality-related problems or issues typically experienced in South Africa.

Determining for each water quality problem or issue the appropriate norm to be used as a yardstick for assessing the effects of water quality on the purpose the water is used for.

Determining, for each norm, which water quality constituents in South Africa typically affect the fitness of water for use, and from this information, developing a list of constituents for the recreational water use guidelines.

Accessing international and local sources of information and expertise to develop draft guidelines for each constituent selected.

Through a process of technical review and stakeholder participation, finalising the guidelines to be published.

Tentative guidelines

The information available on the effects of some constituents on water uses is either very limited and/or unresolved differences in opinion exist on the effects these constituents may have on water uses. In these cases the guidelines have been included in the *South African Water Quality Guidelines* as tentative guidelines, and are clearly indicated as such.

During the ongoing review of the guidelines, it is intended that the status of the tentative guidelines eventually be changed to guidelines, when either sufficient information becomes available or sufficient consensus is reached among experts concerning the effects of these constituents on water uses.

Sources of Information

Introduction

Because the *South African Water Quality Guidelines* are primarily aimed at South African water resources managers and water users, a greater emphasis was given to South African source documents. Opinions of a wide range of South African experts in water quality for recreational purposes were used to supplement published sources. For some constituents, international literature was also used as background and reference material.

Sources of Information

South African experts in water quality were consulted during the development of the guidelines. The following criteria and guidelines published in the international literature were used as background and supplementary information in the development of the *South African Water Quality Guidelines for Recreational Use*:

World Health Organization Drinking Water Guidelines (WHO, 1984);

Australian Water Quality Guidelines for Domestic Supplies (Hart, 1974; Hart *et al.*, 1992).

European Community (EC) Drinking Water Standards (Joint Research Centre, 1989) and *Standards for Water Abstraction to Potable Supply* (Gardiner and Zabel, 1989). (The European Community is referred to as the EC when discussed as an economical/political entity. It is referred to as the European Economic Community (EEC) when directly citing a Directive promulgated before the formal 1992 change from EEC to EC). (Now EUROPEAN UNION (EU));

Canadian Drinking Water Guidelines (Canadian Guidelines, 1987);

USA Quality Criteria for Recreational Water Supplies (NAS/NAE, 1973; US EPA, 1986).

The following criteria and guidelines published in the South African literature were used in the development of the *South African Water Quality Guidelines for Domestic Use:*

South African Bureau of Standards Specification for Water for Domestic Supplies (SABS, 1984);

National Institute for Water Research (now Division of Water Technology) Proposed Drinking Water Criteria (Kempster and Smith, 1985) and Department of National Health and Population Development Criteria for Drinking Water Quality (Aucamp and Vivier, 1990);

Department of Water Affairs and Forestry Internal Discussion Document on Draft Fitness-for-use Curves for Domestic Water Use (Kempster and Van Vliet, 1991).

Chapter 3

Characterisation of Recreational Water Use

Characterisation of Recreational Water Use

Background Information

Introduction

The use of water for recreational purposes is common to all consumers. The term *recreational water*, as used in these guidelines, refers to all inland water which is used for recreational purposes.

As *recreational water* is used for a wide variety of activities, it follows that the type of quality requirements for such water represents a synthesis of the needs for various activities, and that a wide spectrum of problems may be encountered where water does not meet requirements.

Sources of Water

Water supplies to recreational users can originate from impoundments such as dams, from rivers and streams, or from ground water via boreholes. Recreational water in South Africa spans a wide range, including conventionally-treated water of high quality through to ground water. Both water quantity and quality may be affected by seasonal droughts or floods.

Water Quality Problems

Recreational water users may experience a range of impacts as a result of changes in water quality. These have been categorised as follows:

health impacts (short term and long term)
- waterborne diseases (gastroenteric diseases)
- skin and ear infections
- carcinogenic risk

human safety
- poor visibility
- profuse plant growth
- benthic microbial and/or algal growth

aesthetic impacts
- changes in water taste, odour or colour
- discolouration and staining
- objectional floating matter
- nuisance plants

economic impacts
- damage to equipment
- increased cost of treatment
- increased costs due to scaling, corrosion or deposition of sediments in the distributing system

Constituents

The water quality problems and issues listed above can often be identified with the constituents that cause them. Frequently, water quality problems are associated not only with the presence of a constituent, but with the interactions between constituents.

Some constituents are often used to characterise a water source, such as those which play a role in causing water quality-related problems, whereas other constituents are associated with site-specific water quality problems.

Subuser Groups Three subuser groups, namely full-contact, intermediate-contact and non-contact recreation, have been defined as follows:

Full contact recreation (swimming)

This involves full-body water contact, and includes activities such as swimming and diving. It differs from other categories in the extent of water contact (immersion is common and hence a greater probability of ingestion of water exists), the age group of users (swimmers often include large numbers of children, who are more susceptible to a number of health effects, particularly infectious diseases) and the health status of users (people are inclined to swim even when they are not completely healthy, making them more susceptible to health effects).

Intermediate-contact recreation

This encompasses all forms of contact recreation excluding activities described for full contact recreation. It is a broad class and includes activities which involve a high degree of water contact, such as waterskiing, canoeing and angling and those which involve relatively little water contact, such as paddling and wading. Angling is a common and popular recreational use of inland waters, often involving direct exposure to water and indirect exposure through the handling of fishing lines and fish. Since most fishing is practised from the shoreline, the risk of exposure to bilharzia is of special importance.

The range of activities requires that some discretion is used in applying the guideline. A more stringent approach is necessary where water contact is frequent and relatively extensive, whereas a less stringent approach can be adopted if water contact is infrequent and minimal. The major factors distinguishing high contact activities in this class from full contact recreation are the degree of water contact (full immersion is likely to occur only occasionally and among novices of a water sport), the age of users (water sports such as waterskiing and windsurfing are usually practised by adults rather than by young children, and health status of users (strenuous water sports are generally practised by water users in a fairly good state of health).

Non-contact recreation

Non-contact recreation encompasses all forms of recreation which do not involve direct contact with water. It includes activities such as picnicking and hiking alongside water bodies and scenic appreciation of water by those residing or holidaying on the shores of a water body. These activities concern themselves predominantly with the scenic and aesthetic appreciation of water. The economic value of recreational water bodies is often closely related to scenic appreciation since this is a major factor in determining the value of waterfront properties. Since no water contact occurs, public health effects associated with water contact are of little relevance here. The extent to which water bodies in South Africa are used exclusively for non-contact recreation is not clear.

Norms The following norms were considered: human health, human safety and aesthetics.

Effects **Human health**

Waterborne diseases:

- The water body used for full contact recreational activities may be the source of infectious diseases as a result of microbial contamination. Such diseases may be contracted either by ingestion of contaminated water or through contact with the skin, especially mucous membranes.

- The effects of microbially contaminated water may be chronic if the source of contamination persists, but may be acute as a result of a sudden contamination of the water body with pathogenic organisms.

- Depending on the type of waterborne disease and on the physical health of the person infected through full contact recreational activities, the person may either recover completely from the disease, or suffer permanent harm or damage from the disease, or if severe enough may die as a result of it.

- Remedial measures, such as removing or controlling the source of contamination, may either eliminate or mitigate the effects of infectious diseases. Banning any form of full contact recreation in a contaminated water body will have an immediate mitigatory effect on contracting waterborne diseases from the affected water body.

Skin and ear infections:

- Through contact with the skin or penetration of the ear, microbially or chemically contaminated water may cause skin and ear infections and irritations.

- Such infections may be chronic or acute, depending on the nature and source of the contamination.

- Depending on the nature of the infection and the organ affected, the effects of such infections may be permanent or a person suffering from such an infection may recover completely.

- The use of ear plugs by participants in full contact recreational activities may prevent or reduce infections of the outer and/or middle ear.

Gastroenteric diseases:

- Waterborne gastroenteric diseases may be contracted from the ingestion of water contaminated with pathogenic faecal organisms or polluted by algal toxins or other chemical pollutants.

- Depending on the nature of the contaminants and the mode of contamination, the effects of waterborne gastroenteric diseases are chronic or acute.

- Participants in full contact recreational activities suffering from gastroenteric disorders as a result of contact with contaminated water usually recover fully from the effects of such diseases following treatment.

- The effects of waterborne gastro-enteric diseases may be ameliorated or prevented by regular medical checkups, particularly if the water is known to be contaminated or polluted.

Carcinogenic risk:

- Long-term exposure to water contaminated or polluted with known or potential carcinogens can give rise to carcinogenic problems for participants of full contact recreational activities.

- The effects of exposure to such contaminants is chronic.

- The effects of carcinogenic diseases are irreversible, and may be fatal in some cases. In other cases, the effects may be controlled, although causing undesirable chronic disorders.

- Identification of the sources of carcinogenic pollutants and remedial steps to eliminate these sources may remove the problem, and therefore eliminate the effects. Early diagnosis and appropriate medical treatment may alleviate or ameliorate carcinogenic effects in affected participants.

Human safety

Poor visibility

- High suspended solids loads derived from silt and/or organic debris, as well as dense algal blooms may reduce visibility within the water body to such an extent that underwater hazards may not be visible, creating dangerous situations for swimmers and divers.

- The effects of poor visibility are usually acute. Some rivers and impoundments have permanently low visibility due to the nature of the substrates they drain, or because of the source of their feed water and turbulence in the impoundment. In other cases, visibility in a body of water may be drastically reduced temporarily as a result of flash floods carrying with them high silt loads.

- In naturally turbid impoundments and rivers, or water bodies where visibility is temporarily adversely affected, the effects of poor visibility are usually irreversible. In terms of human safety, accidents arising from diving into invisible, submerged objects or shallow waters very often end tragically in irrecoverable paralysis of limbs, viz. paraplaegia or quadraplaegia.

- Little can be done to mitigate poor visibility in naturally turbid waters. However, in waters with usually good visibility, diversion weirs to bypass turbid water past specific recreational sites may help to retain high visibility levels until the turbid slug has passed. Local warnings of dangers that may be encountered in a particular water body may help to prevent costly accidents.

Profuse plant growth:

- Profuse macrophytic plant growth in impoundments or along river banks, while possibly aesthetically pleasing, may provide hazardous situations for participants of full contact recreational activities as a result of snagging and entanglement.

- Application of herbicides to eradicate or control macrophytic plant growth in impoundments or along river or stream margins will eliminate or ameliorate hazardous situations for full contact recreational water users. However, the use of herbicides may cause skin irritations, or the release of toxins from the decaying plants causing gastroenteric diseases.

Benthic microbial and/or algal growths:

- As a result of heavy microbial, fungal or algal growths, especially those organisms secreting abundant gelatinous matrices, submerged substrates (e.g. rocks, concrete, wood) may become very slippery, posing a threat to human safety.

- While the conditions giving rise to benthic microbial, fungal or algal growths are usually chronic, the effects of these growths are usually acute.

- Participants in full contact recreational activities who have suffered mishaps as a result of such growths usually recover fully.

- The effects of benthic microbial, fungal and/or algal growths may be mitigated to a certain extent in impoundments through mechanical or biocidal treatment programmes. Such biocidal treatment programmes may not be effective in flowing waters.

  Caution, however, should be exercised when biocides are used as these may give rise to skin irritations or to the release of toxins from the dying organisms.

Aesthetics

Undesirable or bad odours:

- Unpleasant or bad odours can arise from a number of sources, such as rotting of dead vegetation, contamination of the water bodies by domestic sewage and other industrial effluents containing substances such as phenolic compounds and other volatile organic pollutants, and/or microbial action that releases hydrogen sulphide.

- The effects of undesirable or bad odours can be chronic if the conditions producing them last for a long period of time, or may be acute if due to a sudden occurrence or accident.

- The effects of bad odours can be eliminated or ameliorated by locating and identifying the source, and implementing measures to treat the offending condition or chemical substances emitting the odour.

Discolouration and staining:

- Both naturally-occurring and industrially-produced inorganic and organic compounds can discolour water bodies, producing aesthetically displeasing conditions and/or staining of equipment and clothing worn in the pursuit of full contact recreational activities.

- The effects of naturally-occurring substances causing discolouration and/or staining are generally chronic, while the effects of industrially-produced substances are often acute.

- Once stained or discoloured, the effects on equipment or clothing are irreversible. Damaged articles may be recovered, repainted or redyed to improve their aesthetic appearance.

- Undesirable discolouration of a water body or staining of equipment arising from industrially-produced colouring substances may be eliminated by identifying the source of the offending compound/s and instituting measures. Little can be done to mitigate staining or discolouration by naturally-coloured waters.

Objectionable floating matter:

- The presence of floating and shoreline litter and other floating matter of human and natural origin detracts from the aesthetic enjoyment of water bodies. Submerged refuse also presents a danger to full contact recreational water users. Such floating matter consists of waste oil and grease, plastic containers and bags, bottles, cans, metal containers and domestic refuse. Some objectionable floating matter may also be generated naturally through decaying vegetation.

- Although it may be difficult to achieve in some instances, education in environmental awareness may result in the decrease of dumping of litter in or near water bodies. Organised campaigns to clean up the environment, both terrestrial and aquatic, may reduce the amount of objectionable floating matter.

Nuisance plants:

- Nuisance plants are those that render water bodies aesthetically displeasing or give rise to discomfort for full contact recreational water users. Such plants may give rise to unsightly or odorous substances, and if present in large numbers, may constitute a hazard to human health and safety. For example heavy blooms of *Microcystis aeruginosa* are not only a health hazard due to the phytotoxins they produce when they decay, but give rise to foul odours and unsightly masses of decaying vegetation, which can form a thick crust covering the water surface, thereby eliminating any light penetration.

- The effects of nuisance plants are usually seasonal, often persisting for a long time after the growth period of the nuisance plant.

- The effects of nuisance plants are reversible and may be achieved naturally through seasonal variations, or by means of mechanical, chemical or biological control programmes.

- The effects of nuisance plants may be mitigated by either exploiting environmental factors to change growth conditions, making them unsuitable for the growth of the nuisance plant, or by mechanical, chemical or biological control programmes to reduce or severely limit the growth of these plants.

Damage to equipment

Poor visibility:

- High suspended solids loads derived from silt and/or organic debris, as well as dense algal blooms, may reduce visibility within the water body to such an extent that underwater hazards may not be visible, creating dangerous situations leading to damage of equipment of participants in intermediate contact recreational activities.

- The effects of poor visibility are usually acute. Some rivers and impoundments have permanently low visibility due to the nature of the substrates they drain, or because of the source of their feed water and turbulence in the impoundment. In other cases visibility in a body of water can be drastically reduced temporarily as a result of flash floods carrying with them high silt loads.

- In naturally turbid impoundments and rivers, or water bodies where visibility is temporarily adversely affected, damage to equipment can occur. Damaged parts or equipment will need to be repaired or replaced.

- Little can be done to mitigate poor visibility in naturally turbid waters. However, diversion weirs bypassing specific recreational sites may help to retain high visibility levels in such sites until the turbid slug has passed. Local warnings of hidden dangers that may be encountered in a particular water body, may help to prevent costly accidents or damage.

Chapter 4

Information Contained in the Guidelines

Information Contained in the Guidelines

Introduction

The information contained in a guideline for a particular constituent is organised in three sections.

Background information. This section contains most of the support information required to make judgements about the fitness of water for use.

Information on the effects of the constituent, the criteria, and the conditions for modification of the criteria.

Information on additional sources of information.

The information in each section of a guideline for a constituent is organised under a series of labels in the left hand margin that identifies the type of information, and can assist users of the guidelines to quickly locate the information they require.

Background Information

Introduction The introduction to the guideline for each constituent includes a brief description of the constituent as well as a brief statement of its significance for recreational water uses.

Occurrence Information on the fate and occurrence of a constituent in the aquatic environment, as well as the natural and manmade sources thereof are provided as background to help the user identify how widely, in what form and under what circumstances the constituent is likely to occur.

Interactions The effects of a water quality constituent on the fitness of water for use can sometimes be significantly modified by synergistic or antagonistic effects caused by the presence or absence of other constituents in the water. These effects, if any, are described in the guideline and should be considered when making judgements about the fitness of water for use.

Measurement The effects of many constituents on water uses depends on the state (dissolved or particulate) and the chemical species (such as oxidised or reduced; inorganic or organic, etc.) in which they occur. It is important for users of the guidelines to understand how measurements of the concentrations of constituents in water are obtained and which methods to use.

Data Interpretation The effects of water quality constituents on water uses vary from acute to chronic. In order to make judgements about the fitness of water for use, it is important that the appropriate statistics, depending on the types of effects that is likely, be estimated from data sets.

For example, if the type of effect is acute, then statistics which estimate extreme values, such as the maximal values or the 95th percentile, should be used to compare with the water quality criteria provided. However, if the effects are mostly chronic then estimates of the average situation, such as the mean or median value, should be used.

Treatment Options

There is a large variety of options or combinations of options, to

Improve, with the use of various treatments, the quality of raw water supplied to water users;

Improve, with the use of various treatments, the quality of water on site by the users themselves. For example, the filtering of raw water drawn from a river before drinking it.

The information provided in the guidelines on treatment is very general and is simply provided to give a first indication of whether management intervention in the form of treatment is possible. It is expected that if that option is to be pursued that the user would obtain expert advice on water treatment.

The cost of and the ease with which management interventions can be implemented are important factors which can influence judgements about the fitness of water for use. The feasibility of such interventions depends on the

availability of technological solutions;
social acceptance;
scale of the intervention required;
institutional capacity to implement and sustain interventions;
availability of suitably qualified people to implement and maintain the intervention;
capital and operating costs of implementing the intervention.

Effects and Criteria

Norms

The norms that were used as yardsticks for assessing the effects of a particular water quality constituent on the fitness for use are described in this section of the guideline.

Effects

Water quality has different types of effects on specific water uses. These effects can range from:

acute to chronic;
reversible to irreversible;
recoverable to irrecoverable.

In order to make informed judgements of the fitness of water for use, it is important that users of the guidelines take into account the information provided on the types of effects.

Differences in the hydrological characteristics of South African rivers can make the water quality highly variable. The effects of water quality on water uses often depends on the duration of exposure to water of a given quality. Therefore, users of the guidelines must also consider information on the likely duration of the exposure to water of particular quality when judging the fitness of water for use.

when judging the fitness of water for use.

Users of the guidelines need to take into account the information provided on environmental factors and interactions with other constituents when deciding on the fitness of water for use.

Mitigation

The undesirable effects of water quality on its fitness for a specific use can often be prevented or mitigated against by management interventions during use, or at the point of use.

The information on mitigation provided in the guidelines is very general and is simply provided to give the user of the guidelines a first indication of whether management intervention is possible. It is expected that if, any options are to be pursued, the user would obtain expert advice.

Criteria

The water quality criteria for most of the constituents is provided in the form of a table, describing the effects of increasing concentrations of the constituents. The No Effect Range, designated in the *South African Water Quality Guidelines* as the Target Water Quality Range, is highlighted. It must be remembered that the Target Water Quality Range describes essentially what is considered good or ideal water quality and therefore that water quality outside of this range may, under certain circumstances, still be acceptable.

Modifications

There are many site- and case-specific factors which modify the effects of water quality on specific water uses.

The information on modifications provided in the guidelines is very general and is simply provided to give the user of the guidelines a first indication of whether the criteria for a constituent may in certain cases be modified. It is expected that if it appears that the criteria should be modified, the user of the guidelines would obtain expert advice.

Sources of Information

It was not possible to either include all the constituents which may possibly affect the fitness of water for recreational use, or to include all the relevant information on the constituents for which guidelines were developed in this document.

The user is therefore referred to additional sources of information for each constituent. These same sources of information may in some cases also provide information on constituents which are not yet included in the *South African Water Quality Guidelines*.

Should the user of these guidelines require additional information it must be remembered that, beside the publications referenced in the guidelines, there is also a wealth of unpublished information available from a number of organisations and individuals in SA. The list of acknowledgements of people and organisations who participated in the development of these guidelines is provided in the front of this document and is a good starting point for accessing this information.

Chapter 5

Water Quality Constituents

Algae

Background Information

Introduction

Algae is a collective term referring to a wide range of pigmented, oxygen-producing, photosynthetic organisms usually present in surface waters. Virtually all aquatic vegetation without true roots, stems and leaves are regarded as algae. Algae range from microscopically small unicellular forms, the size of bacteria, to larger filamentous forms which may be metres in length. Like other plants, algae are primary producers requiring light, carbon dioxide, water, nutrients such as nitrate and phosphate, and trace elements for growth. Algae are common inhabitants of surface water exposed to sunlight.

Algae play an important role in the natural purification of surface waters through the assimilation of nitrogen species (ammonia and nitrate) during photosynthesis. Algal photosynthesis also releases oxygen as a byproduct into the aquatic environment. Algae also often form the basis for aquatic food webs. Excess algae or undesirable algal types can, however, become a nuisance and interfere with the desirable uses of a water body. This can be a natural phenomenon, but is often the result of accelerated eutrophication (increasing nutrient concentrations) caused by human activities.

Attached filamentous or colonial algae grow on substrates such as rocks, but may become detached and form floating masses. This may obscure the view of, and entangle, swimmers and boats. Dense algal growth or dry and decaying algal masses are visually displeasing and can cause unpleasant odours. Algae are ubiquitous in aquatic environments, but when excessive algae growth or undesirable algal types are present they may become a nuisance and/or cause skin irritations.

Occurrence

Algae can loosely be grouped into three types, *free floating algae* (phytoplankton), *attached filamentous algae* and *algae that coat rocks, plants and sediments* (periphyton).

The classification of algae is extremely complex. However, for the purposes of this guideline, the following classes are important:

> **Cyanophyta**: These are more commonly known as the blue-green algae, but are sometimes referred to as cyanobacteria. These typically dominate in highly nutrient-enriched waters.
> **Chlorophyta:** These are commonly referred to as green algae, and are common summer residents of less enriched water bodies.
> **Euglenophyta**: These are flagellate unicellular algae, typical of organically- enriched water
> **Cryptophyta:** These are also flagellate unicellular algae.
> **Bacillophyta**: This group is commonly referred to as the diatoms, and are unicellular algae surrounded by a silica frustule (coating). This group often dominates winter algal populations.

Two types of algae are known to produce toxins which can be lethal to man and other aquatic life. In marine waters some dinoflagellates, a subgroup of the Cryptophyta, are responsible for toxic red tides. In fresh waters, the blue-green algae or Cyanophyta are often responsible for the occurrence of toxic algal blooms. In South Africa the most common bloom forming toxic species are *Microcystis spp* and *Anabaena spp*, although a number of other species may also produce toxins on occasion.

Blue-green algae are known to produce a variety of neuro-, hepato- and lipopolysaccaride toxins. These toxins have been associated with a number of livestock and game deaths, and skin irritations in swimmers. Accidental ingestion of large amounts of blue-green algae by people who have fallen into or swum in affected water bodies has also led to severe gastroenteritis and other health-related problems.

The amount of algae in water is normally assessed by determining the chlorophyll *a* (which is present in all algae) concentration in the water. Chlorophyll *a* concentrations vary from less than one µg/L in clear waters, to well over 50 µg/L in severe nuisance conditions. In extreme cases concentrations in excess of 1 000 µg/L have been recorded. The amount of algae in water can also be enumerated by means of cell or colony counts. Cell counts may range from less than 50 cells/L in very clear waters to many thousands of cells/mL in the case of algal blooms. The amount or density of attached filamentous algae is best qualitatively assessed, but can be assessed by measuring dry biomass per unit area.

Interactions

The amount of algae in surface waters is usually a function of the concentration of nutrients, in particular nitrogen and phosphorus in the water. In turbid waters light availability and other physical conditions may influence the growth of algae. Photosynthetic uptake of CO_2 by day and release of CO_2 by night may cause pH fluctuations in poorly buffered water. Heavy algal growth and the resultant collapse of algal populations can lead to oxygen depletion, often responsible for fish kills and the death of other aquatic organisms. Algae and their extracellular products constitute a major part of the organic matter that provides precursors for the formation of trihalomethanes (THMs) during chlorination.

Attached filamentous algae can also serve as a habitat for the waterborne vectors of diseases like bilharzia.

Measurement

Measurement of algal biomass is usually by means of the chlorophyll *a* concentration in water, even though the percentage of chlorophyll *a* varies between species or during the lifecycle of a species. Concentrations are expressed as µg/L chlorophyll *a*. Chlorophyll *a*, which is present in all algae (except the so-called colourless algae), constitutes approximately one to two percent of the dry weight of organic material in all planktonic algae and is the preferred indicator for algal biomass estimates. All available analytical methods require pigment extraction as a preliminary step.

The amount of algae in water can also be measured in terms of algal cell or colony counts. This method, while more labour intensive, can provide a more accurate measure of the amount of algae present, as well as providing an indication of the species of algae present. Counting is usually preceded by preserving and staining of the cells, and counting is normally done using an inverted microscope fitted with a micrometer grating. Counting may be preceded by disruption of the colonial forms. Blue-green algae, particularly the colonial or filamentous forms, can be enumerated by counting the number of blue-green units (a single colony or filament) detected in a two-minute scan of 0.5 mL of water under x200 magnification. This is the simplest method of assessing the amount of blue-green algae present, and hence the risk of toxicity, but has the disadvantage of not accounting for different sized colonies.

Data Interpretation

Fluctuations in algal and the chlorophyll concentrations over the year are considerable, and are not always accurately represented by a single sample or median value. Infrequent algal blooms may lead to occasional high concentrations, which may result in impairment of the recreational use of the water body. Annual mean values can therefore be used as these bias the result toward these occasional very high values.

Analysis of the distribution of algal cell counts or chlorophyll concentrations from regular samples can provide an indication of the incidence of problems that may be experienced.

Algal cell counts provide information on the numbers of individual species present. Waters experiencing algal blooms are typically dominated by one or two species. The species present can also provide an indication of the problems likely to be experienced. For example, large numbers of blue-green algae should be associated with an increased risk of toxicity and contact with floating scums of algae. Scums of algae serve to concentrate the toxins in the surface layers, where recreational users come into contact with the water.

Treatment Options

Usually water used for recreational purposes is not treated for algal growth. However, copper sulphate and other algicides have been used to control the growth of algae in open waters. Treatment with algicides, which lyse the cells, releases the toxins into the water, whereafter they can be mixed into the whole water column. This can reduce the risk of recreational contact with the toxins, but makes them more difficult to remove if the water is to be treated for drinking purposes. Nuisance filamentous algal species can be removed by mechanical harvesting.

The Effects of Algae

Norms

The norms used in the guideline for algae are human health and aesthetic effects.

Effects

All forms of excess algal growth may interfere with the use of a water body for recreational purposes. Dense growth of free floating algae or dry and decaying algal masses are visually unappealing, can cause unpleasant odours or may obscure the swimmer's visibility. Attached filamentous or colonial algae which grow on rocks may become detached and form floating masses that can obscure underwater hazards, create a danger of entanglement or obstruct boats.

Blooms of blue-green algae can be toxic if accidentally ingested and may cause skin irritations on contact with water. Ingestion of toxic blue-green algae can cause vomiting, acute gastroenteritis and impaired liver function. Although no human deaths have been associated with the ingestion of these algae, severe illness and near death have been noted. Livestock deaths associated with consumption of algal-contaminated water are common. The algal toxins appear to be more toxic when adsorbed via the nasal route. Skiing in water affected by blooms of blue-green algae and the associated algal aerosol, may increase the risk of health problems.

(Chronic effects associated with the ingestion of these algae are not considered to be important for recreational users.)

Mitigation

Treatment of persons suffering from blue-green algal toxicosis should be symptomatic.

Criteria

The criteria distinguish between free and attached algae, which may be associated with aesthetic effects in the water body and blue-green algae, which may lead to health effects associated with full contact recreation.

Full-contact Recreation: Effects of Free Floating Algae on Aesthetics

Algae Range (µg/L chl *a*)	Effects
Target Water Quality Range 0 - 15	***Nuisance conditions negligible for lower end of range, but at a mean concentration of 15 µg/L, severe nuisance conditions encountered for < 12 % of a year. No health effects***
15 - 30	Nuisance conditions may be encountered. Occasional algal scums likely to occur. The water may take on a green colouration with reduced light penetration
> 30	Severe nuisance conditions may be encountered. Aesthetically unacceptable surface algal scums evident for much of the time. (The composition and health of the fish population may be affected, depending on species)

Note:

The effects given for the above criteria are based on mean annual concentrations of chlorophyll *a* and indicate an increasing risk of nuisance conditions occurring with any algal species.

Full-contact Recreation: Effects of Blue-green Algae on Human Health

Algae Range (blue-green units[1])	Effects
Target Water Quality Range 0 - 6	***No health effects expected. No blue-green "bloom" expected to occur***
> 6	Blue-green algae present in significant numbers and scum formation likely. Recreational users should increase their vigilance for algal scums and avoid all contact with scums. Notices warning users to avoid algal scums should be posted. Health effects likely with accidental ingestion of the scums and skin irritations likely with contact with the scums

Note:

[1] This refers to the number of blue-green units (colonies and filaments) counted in a two-minute scan of 0.5 mL of water at x200 magnification.

An algal scum can be considered to be any visible accumulation of algae on the shoreline or on the surface of the water.

Full-contact Recreation: Effects of Attached Filamentous Algae

Filamentous algal mats should be absent from areas intended for contact recreational use. Algal growth should not impede the swimmer's visibility, obscure underwater hazards or create a danger of entanglement.

Intermediate Contact Recreation: Effects of Free-floating and Attached Filamentous Algae

Since activities in this class involve direct contact with water, including occasional possible full-body immersion, the same guideline as for full-contact recreation (swimming) applies for free-floating and attached algae, as well as for the health effects associated with the blue-green algae. However, the extent of water contact should be taken into account and where water contact is slight or infrequent, the criteria may be applied less stringently.

' **Non-contact Recreation: Effects of Free-floating Algae on Aesthetics**

Algae Range (µg/L chl *a*)	**Effects**
Target Water Quality Range 0 - 20	***Algal scums may be evident at the higher end of the range (10 - 20 µg/L) but do not impair non-contact use. Severe nuisance conditions encountered for < 18 % of the year. No health effects should result from rare, accidental exposure***
20 - 30	Nuisance to severe nuisance conditions may occur. Surface algal blooms evident. Oxygen depletion and fish kills may occur at high chlorophyll *a* concentrations. Unsightly mats of rotting algae washed into embayments may cause severe odour problems when drying. No health effects expected
> 30	Severe nuisance algal blooms (scums) as well as other symptoms of eutrophication. Rotting algae may cause severe odour problems. No health effects expected

Note:

The effects given for the above criteria are based on mean annual concentrations of chlorophyll *a* and indicate an increasing risk of nuisance conditions occurring with any algal species. No health-associated effects are likely with non-contact recreation.

Non-contact Recreation: Effects of Attached Filamentous Algae

Filamentous algal growth should be limited such that no interference with activities such as boating and fishing occurs and the aesthetic appreciation of the water body is not limited. If a water body is used for both contact and non-contact recreation, the more stringent criteria for contact recreation should be applied.

Sources of Information

APHA 1989. *Standard Methods for the Examination of Water and Waste Water*, 17th Edition. American Public Health Association, American Water Works Association, Water Pollution Control Federation. Published by the American Public Health Association, Washington DC, USA.

CANADIAN GUIDELINES 1992. *Update, Canadian Water Quality Guidelines*. Chapter 2, Update: Recreational Water Quality and Aesthetics. Prepared by the Task Force on Water Quality Guidelines of the Canadian Council of Resource and Environmental Ministers. Canada.

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SCOTT W.E. 1991. Occurrence and Significance of Toxic Cyanobacteria in Southern Africa. *Water Science and Technology* 23, 175-180.

TRUTER E. 1987. *An Aid to the Identification of the Dominant and Commonly Occurring Genera of Algae Observed in some South African Impoundments*. Technical Report TR 135, Department of Water Affairs, Pretoria, South Africa.

WHO 1984. *Guidelines for Drinking Water Quality*, Volume 2: Health Criteria and Other Supporting Information. World Health Organization, Geneva.

Chemical Irritants

Background Information

Introduction

Chemical compounds that exert toxic or irritant effects occur in water mainly as a result of human activities. Some irritants and toxicants may be secondary metabolites of natural origin, for example from blue-green algae (*Cyanobacteria*). Chemicals present in recreational water, at concentrations which may cause irritant effects in humans, interfere with all forms of recreational water use that involve full or intermediate water contact.

Occurrence

Industrial discharge outlets, mine tailing dams and waters affected by leaching from dumps are likely to be unsafe for contact recreational use. Biocides incorporated into anti-fouling paints used to inhibit the growth of attached filamentous algae on boats are also possible chemical irritants in recreational waters in South Africa.

The fate of chemical irritants in a water body is dependent on the specific identities and properties of the chemical irritant. Generally, most chemicals, such as organics, biodegrade and some may become incorporated into aquatic plants or accumulate in sediments, especially in the case of recalcitrant chemicals.

Interactions

The action of chemical irritants is governed by factors such as the pH, the dissolved oxygen concentration (DOC) and the presence of other chemicals in the water.

Measurement

No single method of measurement is recommended. This constituent represents a wide range of chemicals and the method of measurement depends on chemical type.

Data Interpretation

Few specific recommendations on the general chemical characteristics of recreational waters are available and where they are, the full range of possible irritants and toxicants cannot practicably be addressed. Chemical irritants, or similar aggregated constituents, appear in guidelines from several sources. The criteria given are based on qualitative recommendations and good judgement is required in the interpretation thereof.

Treatment Options

Recreational waters are usually not treated for chemical irritants. The quality of the inflow and receiving water should be monitored and regulated so as to prevent chemical contamination.

The Effects of Chemical Irritants

Norms

The norm used in the guideline for chemical irritants is based primarily on human health. Unless chemicals are coloured or odorous, aesthetic effects need not be considered.

Effects

Persons engaged in contact recreation may swallow small amounts of water or absorb toxic chemicals through the skin. The amount of water accidentally swallowed varies considerably, but probably does not exceed 100 mL for any individual per recreational event. The human body can tolerate greater concentrations of most chemicals upon occasional contact with, or ingestion of, small quantities of water than can most forms of aquatic life.

Chemical irritants may affect any of the skin, eyes, ears or mucous membranes of the nose and mouth, and may be toxic by skin absorption or ingestion of small amounts of water.

Mitigation

The mitigatory measures to alleviate irritations will depend on the specific characteristics of the irritant and symptoms experienced. Washing or taking a shower with clean water after contact is an appropriate first measure**.**

Criteria

The criteria are qualitative, no specific irritants and quantitative measures are given and adherence to the following general principles is recommended:

' **Full-contact recreation (swimming)**

Recreational waters should not contain chemicals in such concentrations as to be toxic to humans if small quantities of water are ingested or absorbed through the skin. Water should be free of chemicals which are irritating to the skin, ears, eyes or mucous membranes. If this cannot be achieved, warning notices should be posted around the water body.

' **Intermediate-contact recreation**

Since activities involving intermediate-contact may include occasional full-body immersion, the criteria for full-contact recreation as given above are suggested. However, the extent of water contact should be taken into account and where contact is slight or infrequent, the criteria may be less stringently applied.

' **Non-contact recreation**

No criteria are necessary if the water body is used exclusively for non-contact recreation. However, volatile toxicants, such as hydrogen cyanide, hydrogen sulphide, or volatile organics may be toxic by inhalation after volatilisation or evaporation from the water surface.

Sources of Information

AUSTRALIAN GUIDELINES 1990. *Australian Guidelines for Recreational Use of Water.* Prepared by the National Health and Medical Research Council. Australian Government Publishing Services, Canberra, Australia.

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HART *et al*. 1992. *Australian Water Quality Guidelines*, Draft for Public Comment. Australian and New Zealand Environment and Conservation Council, Australia.

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 Sciences and the National Academy of Engineering. Prepared for the US Environmental Protection Agency, Washington DC, USA.

Clarity

Background Information

Introduction

The clarity of a water body refers to the depth to which light can penetrate. Hence, lack of clarity is frequently associated with turbidity. Ideally, recreational water should have high clarity (low turbidity and low colour). There is also a possible health risk associated with turbid water due to micro-organisms which may be associated with suspended particulate matter.

Occurrence

Clarity, expressed as Secchi disk visibility, may vary from as much as 20 m in very transparent waters, to as little as 0.002 m in very turbid waters. Clays, organic particles from decomposing plant and animal matter, fibrous particles and suspended soils and sediments constitute most of the particulate matter that contributes to high turbidity and low clarity. Further, sewage and other wastes may contribute significantly to reduced water clarity.

Water clarity expressed as Secchi disk visibility is related to turbidity (see Measurement). Recreational waters in many dams in the interior of the country, particularly in the Orange Free State, have high turbidities in summer, for example as much as 2 000 NTU (Secchi disk visibility ca., 0.0025 m), with lower turbidities occurring in winter, for example 100 NTU (Secchi disk visibility ca., 0.05 m).

The fine clay particles usually responsible for turbidity can remain in suspension for very long periods, unless a flocculant is added to the water.

Interactions

Lack of clarity is associated with water turbidity and with the possible presence of microbiological pollution.

Measurement

Clarity is measured as the Secchi disk visibility in metres. A standard Secchi disk, 0.25 m, with alternating black and white quadrants, is lowered into the water and the depth at which it just disappears, or reappears on raising, is measured. Water clarity as measured by the Secchi disk, is related to turbidity as follows:

Secchi depth (m) = 5.07/Turbidity (NTU).

The above relationship only applies to intermediate turbidity levels and not to very high or low turbidities. It is also affected by the nature of the suspended matter and is only applicable to typical clay particles.

It may be impossible to obtain Secchi disc readings in clear shallow water of less than 2 m.

Data Interpretation

A fair amount of judgement is required in the interpretation of the criteria given. Discretion and good judgement for each individual case should be used to compare with the criteria.

Treatment Options

Water used for recreational purposes is usually not treated. The quality of the inflow and receiving water should be monitored and regulated so as to avoid conditions of low clarity.

The Effects of Clarity

Norms

The norms used in the guideline for clarity are based on aesthetic effects as well as indirect health effects associated with a lack of clarity, that is, turbidity.

Effects

Lack of clarity (presence of turbidity and/or colour) poses a danger for swimmers since potentially hazardous objects and evidence of shallow waters may be obscured. In turbid waters, micro-organisms associated with particulate matter may pose a health risk. If water has a low turbidity, the occurrence of infectious microorganisms may be reduced, but cannot be excluded solely on the basis of clarity.

Mitigation

No direct effects will accrue from contact with unclear water, thus mitigatory measures are not applicable. Persons contracting bacterial inflections should seek medical attention.

Criteria ' **Full-contact Recreation: Effects of Water Clarity on Aesthetics and Human Health**

Clarity Range (Secchi disc depth, metres)	**Effects**
Water Quality Target Range ***≥ 3.0***	***Most users will perceive water as suitable for swimming. This allows water depth to be judged and possible hazards will be visible. Risk of disease transmission by organisms associated with particulate matter is minimal but cannot be excluded on the basis of clarity or turbidity measures alone. No adverse effects on aesthetic appreciation***
3.0 - 1.5	Most users will perceive water as suitable for swimming. Risk of disease transmission by organisms associated with particulate matter is very low but cannot be excluded on the basis of clarity or turbidity measures alone. No adverse effects on aesthetic appreciation expected
1.5 - 1.0	Minimum depth of visibility for water to be suitable for swimming. Risks associated with disease transmission by organisms associated with particulate matter are low. No effects on aesthetic appreciation expected
< 1.0	Unsuitable for swimming. However, if lack of clarity (or turbidity) is the only consideration preventing the use of a water body for swimming, then it may be allowed, provided all subsurface, potential hazards are removed and signs indicating water depth are clearly posted. Risk of disease transmission by organisms associated with particulate matter increases but this cannot solely be determined on the basis of clarity measurements. May be some depreciation in aesthetic quality and enjoyment of the water body

Note:

Conversion of clarity to turbidity data for the above criteria gives a range of 1.84 - 5.07 NTU for Secchi disc depths of 2.75 m - 1.2 m respectively. This range for turbidity measures is far below the range commonly found in South African water bodies and is also at the lower limit of sensitivity for turbidity measurements.

The turbidity of the water should not increase by more than 5 NTU above natural background turbidity when that turbidity is low (less than 50 NTU).

Intermediate Contact Recreation

Since intermediate contact recreation may include activities which require reasonable to good visibility in water and may on occasion involve full-body immersion, the same criteria as given for full-contact recreation (swimming) should be applied. However, the extent of water contact should be taken into account and where contact is slight or infrequent, less stringent criteria may be used.

Recreational waters in some regions of South Africa, for example the Orange Free State, have very low levels of clarity (high turbidities) for most of the year and there are practically no alternative water bodies available for recreational use. In such cases, clear signposts indicating water depth are recommended as a safety precaution. In practice, most resorts exercise some form of control over boating clubs and waterskiing, and are usually familiar with the dam basin. These precautionary measures serve to protect water users.

Non-contact recreation

If a water body is used exclusively for non-contact recreation, then water clarity and turbidity should be such that there are minimal adverse impacts on the aesthetic appreciation of the water body.

Sources of Information

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Floating Matter and Refuse

Background Information

Introduction

The presence of floating and shoreline litter and other floating matter of human and natural origin detracts from the aesthetic appreciation of water bodies and is unlikely to attract many water users. Submerged refuse can also be a danger to recreational water users. Floating algae and aquatic plants, although not strictly identifiable as floating refuse, can also be considered undesirable.

Occurrence

Human activities frequently result in the presence of floating matter and refuse in the aquatic environment. Waste oil, plastic containers and bags, sanitary waste, condoms, discarded vehicle tyres, bottles, cans and domestic refuse lead to aesthetically unattractive recreational waters. Natural processes can also contribute to this phenomenon. Dead vegetation (terrestrial or aquatic) in an advanced state of decomposition in water, releases fatty and oily byproducts which produce an oily sheen on the water and often result in objectionable odours.

Solid refuse will persist for a long time and accumulate if not removed. Most plastics and rubbers disintegrate and biodegrade very slowly if at all; some types of cans (modern aluminium beverage cans) corrode very slowly, while glass persists.

Interactions

Floating matter and refuse are frequently associated with objectionable odours as a result of decay. Water temperature, pH and colour may also be affected.

Measurement

The presence, amount and type of floating matter and refuse is determined qualitatively and no empirical methods of measurement exist.

Data Interpretation

Only qualitative criteria are given and interpretation thereof should involve discretion and good judgement.

Treatment Options

Solid floating matter and refuse may be removed from a water body either manually or mechanically. Oil and grease, if present in large quantities, can be removed using special skimmers or with methods that absorb oil from the water surface. Large amounts of oil may require treatment with dispersants. Refuse that occurs on the bottom of a water body is removed by dredging or dragging the bottom.

Often these methods fail to retrieve all offending refuse and costs are frequently a limitation.

The Effects of Floating Matter and Refuse

Norms

The norm used in the guideline for floating matter and refuse is primarily based on aesthetic effects, although the safety and health of water users is also considered.

Effects

Floating refuse is unaesthetic. Submerged refuse such as broken bottles may pose a safety risk and decomposing refuse may provide a suitable habitat for vectors of disease.

Mitigation Removal of the offending materials and legislation prohibiting pollution are mitigatory measures that should be taken.

Criteria The criteria given are qualitative and the following are recommended*:*

- **Full-contact recreation (swimming)**

  Water should be free of floating or submerged debris which may injure, entangle or obstruct water users. Shorelines should be free of litter.

  Recreational water should also be free of wastewater or other discharges and substances which could cause an adverse visual impact or affect aquatic life forms. This includes oil, scum, foam and substances which can settle out to form objectionable deposits. Oil and petrochemicals should not be present in concentrations which form a visible film on, or discolouration of, the water surface, which can be detected by odour or which can form noticeable deposits on rocks, the water basin and shorelines.

- **Intermediate and non-contact recreation**

  The presence of floating matter and refuse affects the aesthetic appeal of all forms of recreational water use, therefore the criteria for full-contact recreation (swimming) are recommended.

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Indicator Organisms

Background Information

Introduction

A wide variety of pathogenic viruses, protozoa and bacteria may be transmitted by water. These micro-organisms cause diseases such as gastroenteritis, giardiasis, hepatitis, typhoid fever, cholera, salmonellosis, dysentery, and eye, ear, nose and skin infections, which worldwide are associated with polluted water. Infections are generally contracted by drinking contaminated water, recreational exposure to contaminated water, inhaling contaminated aerosols or the consumption of raw food (that is, irrigated vegetables and shellfish) exposed to polluted water.

Most waterborne diseases are caused by pathogens typically transmitted by the faecal-oral route. However, pathogens excreted into water from healthy skin or hair, wounds, pustules, urine, mucus, saliva and sputum can also be transmitted, particularly by recreational body-exposure and inhalation of aerosols. Some waterborne pathogens are excreted by healthy carriers or infected persons, in many cases children, who show no clinical symptoms of disease.

Recreational exposure to water also offers opportunities to micro-organisms which are members of the normal human microbial flora to cause secondary infections in wounds, exposed tissue or individuals with reduced resistance. Infections may even be caused by micro-organisms which naturally occur in water environments, including *Vibrio* species, *Pseudomonas aeruginosa, Aeromonas hydrophila* and various mycobacteria. The minimal infectious dose of intestinal bacteria tends to be relatively high, about 10 - 1 000 or more, while that of intestinal protozoa and viruses may be as low as a single viable unit.

Assessment of the safety of water by tests for the many pathogens which may be present would be impractical for technical and economic reasons. Indicator organisms are, therefore, generally used for routine monitoring of the potential presence of pathogens in water. Indicator organisms should ideally fulfil the following criteria:

- be suitable for all types of water;
- be present in sewage and polluted waters whenever pathogens are present;
- be present in numbers that correlate with the degree of pollution;
- be present in numbers higher than those of pathogens;
- not multiply in the aquatic environment;
- survive in the environment for at least as long as pathogens;
- be absent from unpolluted water;
- be detectable by practical and reliable methods;
- not be pathogenic and be safe to work with in the laboratory.

There is no single indicator organism that meets all these requirements. The wide variety of indicators used all have their own advantages and disadvantages. It is, therefore, generally recommended that routine quality surveillance programmes include appropriate combinations of indicators and, as far as possible, tests for at least those pathogens of major importance, in order to obtain the most reliable indication of potential risks of infection.

There are no universal guidelines for combinations of indicators and the frequency of testing. Each situation has to be considered in its own right.

The selection of individual indicators, combination of indicators, inclusion of tests for pathogens and sampling frequency has to be formulated on the basis of considerations that include risks of infection as indicated by sanitary surveys, potential sources of pollution and bather densities, as well as financial resources and the availability of laboratory facilities and expertise. Sanitary surveys are a fundamental component of safety monitoring programmes and are particularly important when microbiological testing is restricted and infrequent.

Since the waterborne diseases of prime importance are those caused by enteric pathogens transmitted by the faecal-oral route, indicators of faecal pollution are generally included in water quality monitoring programmes, particularly those for drinking water. However, in the case of recreational water there is also merit in tests for indicators or pathogens representing organisms which are not typically of faecal origin but may cause primary skin, eye, ear or respiratory infections, secondary infections and even intestinal infections.
These would include organisms such as *Staphylococcus aureus, Pseudomonas aeruginosa, Streptococcus pyogenes, Aeromonas hydrophila* and *Mycobacterium marinum*. Recreation in water has also been associated with fungal infections by, for instance, *Aspergillus, Microsporum, Trichophyton* and *Epidermophyton* species and *Candida albicans* has been suggested as indicator for these potential pathogens.

Indicators generally recommended for assessment of the microbiological safety of recreational water include:

Total coliform bacteria: Primarily used as a practical indicator of the general hygienic quality of water; mainly used in routine monitoring of drinking water supplies.

Faecal coliform bacteria: Primarily used as a practical indicator of faecal pollution; it is more specific for faecal pollution than total coliforms; mainly used for assessment of faecal pollution of wastewater, raw water supplies and natural water environments used for recreational purposes.

***Escherichia coli*:** Highly specific indicator of faecal pollution which originates from humans and warm-blooded animals.

Enterococci (faecal streptococci): Relatively specific indicators of faecal pollution which tend to survive longer in water environments than coliform bacteria.

Bacteriophages: The survival and incidence of bacterial viruses (phages) in water environments resembles that of human viruses more closely than most other indicators commonly used. The application of coliphages (bacteriophages which infect *E. coli* and certain related species) in water quality assessment is rapidly gaining ground. Somatic coliphages occur in large numbers in sewage and polluted water environments and are easy to detect, but they may be replicated by host bacteria in certain water environments. Male-specific (F-RNA) coliphages are highly specific for sewage pollution and cannot be replicated in water environments, but detection methods are more complicated.

Occurrence

Commonly used indicators are excreted or released consistently by virtually all humans because they are members of the normal microbial flora of humans. Some of the indicators are also consistently excreted by warm-blooded animals. Faecal indicators are, therefore, always present in sewage-polluted water and their numbers are in relatively close correlation with levels of faecal pollution and the time since pollution has taken place. Incidentally, this valuable feature also represents one of the shortcomings of indicators because pathogens are not excreted by all individuals and their numbers in water environments are highly variable depending on factors such as disease outbreaks.

Several natural processes in aquatic systems such as sedimentation, adsorption, coagulation and flocculation may remove micro-organisms from water without inactivation and may even protect the organisms against inactivation. These processes are significant since subsequent release may cause an apparent increase in numbers of the organisms.

Interactions

Many physical, chemical, biological and biochemical factors play a role in the survival and removal of micro-organisms in water environments. These factors include exposure to sunlight, temperature, pH, turbidity, nutrients, toxic substances, predation and competition. Some indicators may even multiply in waters with sufficient nutrients and suitable temperature. Increased survival of micro-organisms in sediments may be due to protection against predation, sunlight and other causes of inactivation.

Data Interpretation

Application

Strictly speaking, faecal indicators (bacteria or phages) only indicate faecal pollution, which implies the potential presence of waterborne pathogens. Faecal pollution does, of course, also have aesthetic implications for drinking and recreational waters. Despite shortcomings, commonly used faecal indicators have proved to be of major value in water quality assessment and control.

Bacterial indicators of faecal pollution recommended in this guideline (coliforms and enterococci) have shortcomings particularly with regard to protozoan parasites and viruses. Although somatic and F-RNA phages overcome some of the shortcomings regarding viruses, these indicators are not yet widely used by laboratories in South Africa. There is a need for more information on the value of phage indicators, and transfer of the technology.

A logarithmic distribution is commonly used in determining the measure of central tendency of bacterial counts. For such a distribution the median is, in principle, the same as the log or geometric mean, although random differences can be expected in practice, depending on the number of samples and the sampling frequency. Organisations concerned with water quality management and research in South Africa tend to use either the median or the geometric mean as the measure of central tendency in microbial data sets.

Sample frequencies

It is not possible to recommend universal sampling frequencies or indicator organisms for monitoring the microbiological safety of recreational water. As mentioned earlier, too many variables are involved. Monitoring programmes have to be formulated for each situation in its own right. The minimum sampling frequency recommended for recreational waters is fortnightly. This would be in agreement with, for instance, specifications of the European Union. Fortnightly testing is considered sufficient to detect seasonal variations and long-term trends to allow for predictions of water quality and to detect unexpected departures from known trends within reasonable time.

When results for any sample exceed recommended limits, it is general policy to immediately examine a second sample from the same site, preferably in more detail. If the second sample also indicates unacceptable quality, steps should be taken to rectify the situation. This approach would seem to be in accordance with many sampling programmes currently applied in South Africa. Under certain circumstances considerably higher sampling frequencies may be justified. For instance, a minimum of five samples taken at regular intervals over a period not exceeding 30 days has been recommended.

Treatment Options

Environmental bodies of water used for recreation are usually not treated. The quality of these waters primarily depends on pollution control. The objectives of monitoring the quality of the water are primarily to caution users about risks of infection, to locate sources of pollution, and to take steps for control of the pollution.

Criteria Recommended Indicator Bacteria, Their Detection and Uses in Water Quality Management

Indicator	Detection and use in water quality management
Total coliform bacteria (total coliforms)	Refers to all bacteria which produce colonies with a typical metallic sheen within 20 - 24 hours of incubation at 35°C on m-Endo agar. Gives an indication of the general sanitary quality of water since this group includes bacteria of faecal origin. However, many of the bacteria in this group may originate from growth in the aquatic environment. Used to evaluate the general sanitary quality of drinking water and related waters, for example swimming pool water
Faecal coliform bacteria (faecal coliforms)	Refers to all bacteria which produce typical blue colonies on m-FC agar within 20 - 24 hours of incubation at 44.5°C and comprises members of the total coliform group which are capable of growth at elevated temperature. Indicator of probable faecal pollution of water since this group is much more closely associated with faecal pollution than the broader total coliform group. Some faecal coliforms may not be of faecal origin. Used to evaluate the quality of waste water effluents, river water, seawater at bathing beaches, raw water for drinking water supply, recreational waters as well as water used for irrigation, livestock watering and aquaculture
Escherichia coli (*E. coli*)	Refers to faecal coliforms which test indole-positive at 44.5°C, and generally consists only of *E. coli* which is almost definitely of faecal origin. Used to evaluate the possible faecal origin of total and faecal coliforms, usually when these are isolated from drinking water
Enterococci (faecal streptococci)	Refers to bacteria which produce typical reddish colonies on m-Enterococcus agar after 48 hours incubation at 35°C. These bacteria always appear in human and animal faeces, but in lower numbers than total or faecal coliforms and are more resistant than coliform bacteria. Not all faecal streptococci are of faecal origin, resulting in taxonomic regrouping of this group in recent years. Enterococci comprise a subgroup of faecal streptococci, and include predominantly faecal streptococci of proven faecal origin. Used in evaluation of treatment processes and recreational waters
Somatic coliphages	A diverse group of phages which infect *E. coli* and certain closely-related bacteria. These phages occur in large numbers in sewage, and are detectable by relatively simple, economic and rapid techniques. Their numbers may increase in certain water environments suitable for the growth of host bacteria. Somatic coliphages indicate faecal pollution, and their incidence and survival in water environments would seem to more closely resemble that of human viruses than faecal bacteria
F-RNA coliphages	A restricted group of coliphages (also known as male-specific coliphages) which only infect *E. coli* and related hosts which produce fertility fimbriae during the logarithmic growth phase at temperatures > 30 °C. These phages can therefore not be replicated in natural water environments, which implies that they are highly specific indicators of faecal pollution. Their numbers in sewage are generally lower than those of somatic coliphages, and their behaviour and incidence in water environments would seem to resemble that of human viruses even closer than somatic coliphages. Detection methods for F-RNA phages are more complicated than those for somatic coliphages

The guidelines include information on the following indicator organisms:

Faecal Coliforms
Escherichia coli
Enterococci (faecal streptococci)
Coliphages

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Indicator Organisms
Faecal Coliforms

Background Information

Introduction

Faecal coliforms are one of the most commonly used bacterial indicators of faecal pollution and indicate the possible presence of pathogens responsible for the transmission of infectious diseases such as gastroenteritis, salmonellosis, dysentery, cholera and typhoid fever. The faecal coliform group is used to evaluate the quality of wastewater effluents, river water, sea water at bathing beaches, raw water for drinking water supply, treated drinking water, water used for irrigation and aquaculture and recreational waters.

Occurrence

Faecal coliforms have been shown to represent 93 % - 99 % of coliform bacteria in faeces from humans, poultry, cats, dogs and rodents. Some faecal coliform tests also enumerate *Klebsiella spp*., which can originate from non-faecal sources, and a few other bacterial strains also of non-faecal origin. *E. coli* may comprise up to 97 % of coliform bacteria in human faeces. Other *Escherichia spp*., *Klebsiella spp*., *Enterobacter spp.* and *Citrobacter spp*. may also be present.

Soil contaminated by animal faecal pollution has been shown to contribute significantly to pollution of storm water runoff and hence, that of receiving water bodies. Runoff from residential areas may also be contaminated with faecal bacteria and pathogens. These, together with discharge of treated or untreated wastewater, are the major sources of total coliforms, faecal coliforms, faecal streptococci and *E.coli* in the aquatic environment.

Interactions

See **indicator organisms**.

Measurement

Faecal coliforms are usually enumerated as counts (number of colonies)/100 mL. Water samples must be refrigerated immediately after collection and should be analysed within 24 hours. Analysis may be by membrane filtration (0.45 μm diameter pore size), pour plates or multiple tube fermentation techniques.

Faecal coliform bacteria are all bacteria which produce typical blue colonies on m-FC agar within 20 - 24 hours of incubation at 44.5 °C.

Data Interpretation

See **indicator organisms.**

Treatment Options

See **indicator organisms.**

The Effects of Faecal Coliforms

Norms

The norm used in the guideline for faecal coliforms is human health.

Effects

Faecal coliforms are primarily used to indicate the presence of bacterial pathogens such as *Salmonella spp*., *Shigella spp., Vibrio cholerae, Campylobacter jejuni, C. coli, Yersinia enterocolitica* and pathogenic *E.coli.* These bacteria can cause gastrointestinal diseases such as gastroenteritis, salmonellosis, dysentery, cholera and typhoid fever after ingestion of contaminated water.

The risk of being infected by microbial pathogens is correlated with the level of contamination of the water and the volume of water ingested during recreational activities.

Mitigation

A person who is suspected of having contracted a water-related infectious disease should receive medical attention.

Criteria

While it is recognised that *E. coli* and not faecal coliforms are the preferred indicator of faecal pollution and health risk associated with recreational water bodies, it is probable that many smaller water laboratories in South Africa may have facilities for analysis of faecal coliforms but not for confirmation of *E. coli*. In these instances, criteria based solely on *E. coli* would be impractical. For this reason, criteria for faecal coliforms are given.

' **Full-contact recreation (swimming)**

Faecal coliform range (counts/ 100 mL)	**Effects**
Target Water Quality Range 0 - 130	***Risk of gastrointestinal effects expected. The presence of faecal coliforms indicate a possible risk to health, but the absence of indicators does not guarantee no risk***
130 - 600	Risk of gastrointestinal illness indicated at faecal coliforms levels which occasionally fall in this range. Risk increases if the geometric mean or median levels are consistently in this range
600 - 2 000	Noticeable gastrointestinal health effects expected in the swimmer and bather population. Some health risk, if single samples fall in this range, particularly if such events occur frequently. Four out of five samples should contain < 600 faecal coliforms/100 mL, or 95 % of faecal coliform analyses should be < 2 000/100 mL
> 2 000	As the faecal coliform count increases above this limit, the risk of contracting gastrointestinal illness increases. The volume of water ingested in order to cause adverse effects decreases as the faecal coliform density increases

Note:

The TWQR should not be exceeded by the geometric mean or median of fortnightly samples collected over a three-month period. The criteria used assume an average intake of water not exceeding 100 mL/recreational event.

' **Intermediate contact recreation**

Faecal coliform range (counts/ 100 mL)	**Effects**
Target Water Quality Range 0 - 1 000	***Health effects are indicated for intermediate contact with recreational water. If water contact is extensive, such as may occur for novice waterskiing or novice windsurfing and if full-body immersion is likely to occur, the more stringent criteria proposed for full-contact recreation may be more appropriate***
1 000 - 4 000	It may be expected that limited contact with water of this quality is associated with a risk of gastrointestinal illness. The upper limit of this range corresponds to the limit recommended by the Australian guidelines for at least four out of five samples collected over 30 days
> 4 000	Intermediate recreational contact with water can be expected to carry an increasing risk of gastrointestinal illness as faecal coliform levels increase

Note:

The TWQR should not be exceeded by the geometric mean or median of fortnightly samples collected over a three-month period, preferably selected to coincide with seasons. Justification for the recommended sampling regime is discussed for faecal coliforms for full-contact recreation, given above.

' **Non-contact recreation**

Provided no contact with water occurs, public health risk due to possible disease transmission, as indicated by faecal coliform concentrations, is not of concern.

Sources of Information

See **Indicator Organisms**.

Indicator Organisms
Escherichia coli

Background Information

Introduction

Faecal coliforms, and more specifically *Escherichia coli,* can be used as a bacterial indicator of faecal pollution by warm-blooded animals (often interpreted as human faecal pollution). *E. coli* is used to evaluate the quality of wastewater effluents, river water, sea water at bathing beaches, raw water for drinking water supply, treated drinking water, water used for irrigation and aquaculture and recreational waters. The presence of faecal pollution by warm-blooded animals may indicate the presence of pathogens responsible for infectious diseases such as gastroenteritis, salmonellosis, dysentery, cholera and typhoid fever. Further, certain types of *E. coli* bacteria are also pathogenic.

E. coli are often used as an indicator of the potential presence of all microbial pathogens, including viruses and parasites, as well as bacteria which cause external infections and respiratory illness, rather than gastrointestinal disease. This usage is not entirely correct since the survival of *E. coli* in water is not necessarily indicative of the behaviour of these organisms.

Occurrence

E. coli may comprise up to 97 % of coliform bacteria in human faeces. Other *Escherichia spp*., *Klebsiella spp., Enterobacter spp.* and *Citrobacter spp*. may also be present.

Interactions

The activity of micro-organisms is dependent on all physico-chemical interactions that determine their growth rate and survival in aquatic environments. See **indicator organisms.**

Measurement

E. coli are usually enumerated as counts (number of colonies)/100 mL and the criteria for *E. coli* are based on geometric mean or median counts.

Water samples must be refrigerated immediately after collection and should be analysed within 24 hours. Analysis may be by membrane filtration (0.45 μm diameter pore size), pour plates or by multiple tube fermentation techniques.

Faecal coliform bacteria are all bacteria which produce typical blue colonies on m-FC agar within 20 - 24 hours of incubation at 44.5 °C. *Escherichia coli* are considered to be all the faecal coliforms which test indole-positive at 44.5 °C.

Data Interpretation

The criteria given should be interpreted as non-exceedance maximal values.

Treatment Options

See **indicator organisms.**

The Effects of *E. coli*

Norms

The norm used in the guideline for *E. coli* is human health.

Effects

E. coli is the preferred indicator of faecal pollution by warm-blooded animals. It is primarily used to indicate the potential presence of bacterial pathogens such as *Salmonella spp.*, *Shigella spp.*, *Vibrio cholerae, Campylobacter jejuni, Campylobacter coli, Yersinia enterocolitica* and pathogenic *E. coli.* These bacteria can cause gastrointestinal diseases such as gastroenteritis, salmonellosis, dysentery, cholera and typhoid fever after ingestion of contaminated water.

Epidemiological studies conducted by the United States Environmental Protection Agency (US EPA) indicate that levels of *E. coli* in fresh water show a high correlation with the occurrence of swimming-related gastric illness. The same correlation has not been observed for faecal coliforms in comparative epidemiological studies.

Mitigation

A person who is suspected of having contracted a water-related infectious disease should receive medical attention.

Criteria

' **Full-contact recreation (swimming): effects of E. coli on human health**

***E. coli* range (counts/ 100mL)**	**Effects**
Target Water Quality Range 0 - 130	***A low risk of gastrointestinal illness is indicated for contact recreational water use. This is not expected to exceed a risk of typically < 8 illnesses/1 000 swimmers***
130 - 200	A slight risk of gastrointestinal effects among swimmers and bathers may be expected. Negligible effects are expected if these levels occur in isolated instances only
200 - 400	Some risk of gastrointestinal effects exists if geometric mean or median *E. coli* levels are in this range, particularly if this occurs frequently. The risk is minimal if only isolated samples fall in this range. Resampling should be conducted if individual results > 400/100 mL are recorded
> 400	Risks of health effects associated with contact recreational water use increase as *E. coli* levels increase. The volume of water which needs to be ingested in order to cause ill effects decreases as the *E. coli* density increases. Gastrointestinal illness can be expected to increase approximately in accordance with the following relationship, based on US EPA epidemiological studies: $y = -150.5 + 423.5(\log x)$ where y = illness rate/100 000 persons, x = number of *E. coli*/100 mL ($x \geq 3$)

Note:

The TWQR should not be exceeded by the geometric mean or median of fortnightly samples over a three-month period, preferably selected to coincide with seasons.

These criteria assume an average intake of water during full contact recreation of more than 100 mL/recreational event.

' **Intermediate contact recreation**

Currently there is insufficient information for the development of criteria for *E. coli* in water used for intermediate contact recreation purposes.

' **Non-contact recreation**

Provided no contact with water occurs and this restriction is clearly signposted, public health risks due to possible disease transmission, as indicated by *E. coli* levels, are not of concern. Health effects should not result from rare accidental water contact, nor should bacterial populations indicated by the above micro-organisms cause adverse impacts on other aquatic organisms.

Modifications The US EPA has recommended criteria based on single sample maximum levels. Application of these US EPA acceptable risk levels under local conditions in South Africa is a research need for future guideline development.

Sources of Information

See **indicator organisms.**

Indicator Organisms
Enterococci: *Faecal Streptococci*

Background Information

Introduction

Enterococci (faecal streptococci) are used to indicate the presence of faecal pollution by warm-blooded animals which could contain pathogens responsible for infectious diseases such as gastroenteritis, salmonellosis, dysentery, cholera and typhoid fever. They are used as preferred indicators of faecal pollution in recreational water bodies, especially in the marine environment as they can survive longer than coliform bacteria in water and sediments.

Occurrence

Faecal streptococci refers to those streptococci generally present in the faeces of humans and animals which possess the Lancefield group D antigen. They mostly include bacteria from the genus *Enterococcus* and two species from the genus *Streptococcus*. Some species, however, occur primarily on plant material.

Soil contaminated by animal faecal pollution has been shown to contribute significantly to pollution in storm water runoff and hence, receiving water bodies. Runoff from residential areas is also usually contaminated with faecal bacteria and pathogens. These, together with discharge of treated or untreated wastewater, are the major sources of total coliforms, faecal coliforms, faecal streptococci and *E. coli* in the aquatic environment.

Interactions

See **indicator organisms.**

Measurement

Faecal streptococci are usually enumerated as counts (number of colonies)/100 mL. The criteria used for faecal streptococci are based on geometric mean or median counts.

Samples must be refrigerated immediately after collection and should be analysed within 24 hours. Analysis may be by membrane filtration (0.45 μm diameter pore size), pour plates or multiple tube fermentation techniques.

Faecal streptococci are all bacteria which produce typical reddish colonies on m-Enterococcus agar after 48 hours incubation at 35 °C.

Data Interpretation

See **indicator organisms.**

Treatment Options

See **indicator organisms.**

The Effects of Faecal Streptococci

Norms

The norm used in the guideline for faecal streptococci is human health.

Effects

Faecal streptococci are primarily used to indicate the potential presence of bacterial pathogens such as *Salmonella spp*., *Shigella spp*., *Vibrio cholerae, Campylobacter jejuni,*

Yersinia enterocolitica and pathogenic *E. coli.* These bacteria can cause gastrointestinal diseases such as gastroenteritis, salmonellosis, dysentery, cholera and typhoid fever after ingestion of contaminated water.

Epidemiological studies conducted by the US Environmental Protection Agency indicate that levels of enterococci in fresh water show a high correlation with the occurrence of swimming-related gastric illness. However, the same correlation has not been observed for faecal coliforms in comparative epidemiological studies.

Mitigation

A person who is suspected of having contracted a water-related infectious disease should receive medical attention.

Criteria

' **Full-contact recreation (swimming): effects of faecal streptococci on human health**

Faecal Streptococci Range (counts/100mL)	Effects
Target Water Quality Range 0 - 30	***Low risk of gastrointestinal illness indicated. Not expected 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. Resampling should be conducted if individual results > 100/100 mL are recorded
>100	Risks of health effects increase as faecal streptococci levels increase. The volume of water which needs to be ingested in order to cause ill effects decreases as the faecal streptococci density increases

Note:

The TWQR should not be exceeded by the geometric mean or median of fortnightly samples over a three-month period, preferably selected to coincide with seasons.

These criteria assume an average intake of water during full contact recreation of less than 100 mL/recreational event.

' **Intermediate contact recreation**

Faecal Streptococci Range (counts/100mL)	Effects
Target Water Quality Range 0 - 230	***Health effects indicated. If water contact is extensive, such as may occur for novice waterskiing or novice windsurfing and if full-body immersion is likely to occur, refer to the more stringent criteria proposed for full-contact recreation***
230 - 700	Limited contact associated with a risk of gastrointestinal illness
> 700	Expected increasing risk of gastrointestinal illness as faecal streptococci levels increase

Note:

The TWQR should not be exceeded by the geometric mean or median of fortnightly samples collected over a three-month period, preferably selected to coincide with seasons. Justification for the recommended sampling regime is discussed for faecal coliforms for full-contact recreation.

' **Non-contact recreation**

Provided no contact with water occurs and this restriction is clearly signposted, public health risks due to possible disease transmission, as indicated by faecal streptococci levels, are not of concern. Health effects should not result from rare accidental water contact.

Modifications The US EPA recommends criteria for faecal streptococci based on single sample maxima. Applicability of these US EPA acceptable risk levels under local conditions in South Africa is a research need for future guideline development.

Sources of Information

See **indicator organisms.**

Indicator Organisms
Coliphages

Background Information

Introduction

Coliphages are bacterial viruses which infect and replicate in *E. coli*. They may also infect related coliform bacteria. The presence of coliphages, therefore, probably indicates the presence of their bacterial hosts, *E. coli.* Coliphages are shed in large numbers in the faeces of warm-blooded animals, including humans. Their presence in faecal matter means that they can serve as indicators of faecal pollution and may indicate the concurrent presence of pathogenic viruses.

Coliphages are broadly divided into two groups, somatic coliphages and male-specific coliphages. Somatic coliphages infect *E. coli* by adsorbing to viral receptors in the cell wall (somatic receptors). Male-specific coliphages infect *E. coli* by adsorbing to threadlike appendages (sex fimbriae or sex pili) which are produced only under specific conditions and elevated temperature, similar to that found in the gastrointestinal tract of humans and other warm-blooded animals. Hence, multiplication of male-specific coliphages is unlikely to take place in the aquatic environment. This makes them highly specific indicators for faecal pollution by warm-blooded animals, including humans.

Male-specific phages are also very similar in structure, composition and morphology to several important human viruses. However, they are not as readily detected as somatic coliphages, for which simple, rapid and cost-effective methods are available. Hence most studies, including these guidelines, use somatic phages even though replication of somatic coliphages in the aquatic environment has been demonstrated.

Occurrence

Somatic **coliphage** counts in the faeces of man and animals may vary from less than 10 plaque-forming units (pfu)/g to 10^8 pfu/g, although in human faeces counts rarely exceed 10^3 pfu/g and may often be undetectable. Phages are often found in faeces of patients suffering from systemic diseases. Somatic coliphage counts in sewage range from 10^3 pfu/mL to 10^4 pfu/mL. In natural waters, coliphages may also be detected in high numbers, primarily due to pollution from sewage. Inactivation of coliphages is affected by similar conditions to those which determine inactivation of bacteria. The most significant factors are temperature, suspended solids, biological activity and sunlight.

Interactions

A constituent or parameter that affects the growth rate of coliphage bacterial hosts, for example *E.coli*, should be considered.

Measurement

Coliphage counts (number of plaque-forming units) are usually reported /10 mL. In this guideline, counts/100 mL are presented for easy comparison to counts of other indicator organisms, particularly faecal coliforms.

Coliphages are usually detected in water by their ability to form visible plaques in a plaque assay using an *E. coli* host under conditions of 16 hours incubation at 35 °C. However, standard methods of analysis have not been defined.

Generally, a particular strain of *E. coli*, known as *E. coli* C, in which viral defence mechanisms have been eliminated, is used. This makes it susceptible to a wide range of coliphages.

Coliphages occurring at concentrations too low to be detected by direct analysis may be detected by either enrichment or concentration of phages.

Note: Guidelines are generally specified for somatic coliphages, which may be capable of multiplying in the aquatic environment in the absence of the above specified *E. coli* host strain.

Data Interpretation

The criteria should be interpreted as non-exceedance maximum values.

Treatment Options

See **indicator organisms.**

The Effects of Coliphages

Norms

The norm used in the guideline for coliphages is human health.

Effects

Coliphages are used as indicators of the potential presence and fate of human viruses in water, particularly the enteric viruses. Viruses are important causative agents of waterborne disease and can cause illnesses such as gastroenteritis, hepatitis, poliomyelitis and respiratory illness.

The risk of being infected by pathogens correlates with the level of contamination of the water and the amount of contaminated water consumed. Viruses have a considerably lower minimum infectious dose than bacteria, i.e. 1 - 10 viral particles, as compared to 10 - 1 000 bacteria, respectively. This means that even at low levels of viral pollution, a high risk of infection exists.

Mitigation

A person who has contracted a suspected waterborne disease caused by a virus should receive medical attention.

Criteria

The criteria are based on findings which indicate that coliphage concentrations frequently outnumber enteric virus levels by a factor of at least 10^6 and the assumption that accidental water ingestion during recreation is unlikely to exceed 100 mL/recreational event.

' **Full-contact recreation: effects of coliphages on human health**

Coliphage Range (counts/100 mL)	Effects
Target Water Quality Range 0 - 20	***Risks of faecal pollution and of enteric virus infection indicated. Note: the absence of the indicator does not necessarily guarantee the absence of indicated pathogens***
20 - 100	Some risk of virus infection indicated. Risk is increased if the geometric mean or median levels frequently fall in this range, but is probably minimal if only isolated instances are recorded. Some criteria give a coliphage level of 20/100 mL for degraded water; this is not universally accepted
> 100	Significant health risks expected if geometric mean or median coliphage levels commonly exceed this limit. Risks increase as occurrences of high coliphage levels increase in frequency and extent

Note:

The TWQR should not be exceeded by the geometric mean or median of fortnightly samples collected over a three-month period, preferably selected to coincide with seasons.

Justification for the recommended sampling regime is discussed for faecal coliforms and should be used to assist in the interpretation of the criteria given above.

' **Intermediate contact recreation**

The criteria proposed for full-contact recreation are recommended for intermediate contact. The extent and frequency of water contact should, however, be taken into account. Where limited or infrequent contact occurs, less stringent application of the criteria may be justified.

' **Non-contact recreation**

If a water body is used exclusively for non-contact recreation, then the level of microbiological pollution, including coliphages, is of little relevance to the recreational amenity.

Sources of Information

See **indicator organisms.**

Indicator Organisms

Enteric Viruses

Background Information

Introduction

Viruses are submicroscopic inert particles of protein and nucleic acid which are unable to replicate or adapt to environmental conditions outside a living host. Human enteric viruses require man as their specific host and are associated with the digestive tract. Enteric viruses are primarily transmitted by the faecal-oral route, that is, from the ingestion of faecally-contaminated water or food. The enteric virus group includes enteroviruses (polio, coxsackie A and B, and echo viruses) enteric adenoviruses, reoviruses, rotaviruses, hepatitis A and E viruses, calciviruses (that is, Norwalk virus) and astroviruses. Possible health effects associated with the presence of such viruses in water include paralysis, meningitis, hepatitis, respiratory illness and diarrhoea.

Occurrence

Recreational exposure to polluted water has often been linked to viral infections. Enteric viruses are excreted in faecal matter and may occur in recreational water as a result of storm water discharge, runoff, sewer overflows or sewage discharge. Quantitative data on the occurrence of enteric viruses in the environment are limited due to the complexity of virus recovery and detection methods. Viruses are excreted by infected individuals in numbers up to 10^{11}/g faeces. Compared with most pathogens, the minimal infectious dose is extremely low. In many cases, a single virus may cause infection.

Since viruses cannot multiply outside a living host and are exceptionally resistant to unfavourable conditions, virus levels tend to decrease gradually after discharge into the aquatic environment and may, therefore, be present in water for a long period.

Interactions

A number of physical, chemical and biological factors govern the survival of enteric viruses in water, the most significant of which are temperature, biological activity and sunlight.

Measurement

For the detection of enteric viruses, water samples must be refrigerated immediately after collection and should be analysed within six hours. The volume of water tested is significant since the presence of viral particles, even very low numbers, poses a high risk of infection. Risk assessment studies recommend an optimal sample volume of 100 Q to be concentrated. Samples are concentrated by a variety of procedures, including adsorption-elution and ultrafiltration techniques. After concentration, the sample is inoculated into tissue culture, where, if present, viruses cause damage to cells (cytopathic effects). In this guideline, levels of enteric viruses in water are expressed as $TCID_{50}$ (tissue culture infectious dose required to cause 50 % infection)/10L. Since many enteric viruses do not cause cytopathic effects in cell cultures, other methods, such as molecular (PCR) and immunological techniques, are required for their detection.

Generally, cheaper, more rapid and more sensitive detection methods need to be developed. Single-sample maximal values should be used to compare with the criteria which should be interpreted as non-exceedance limits.

Data Interpretation

The detection of viruses is relatively expensive and most microbiological laboratories in South Africa do not possess the necessary facilities and expertise for routine virological monitoring. Assessment of virological safety will, therefore, generally have to rely on regular testing for appropriate indicator organisms and sanitary surveys. Virological analysis is recommended only for situations in which there is reason to suspect the presence of viruses, such as outbreaks of enteric viral disease or high density bathing, and in support of indicator monitoring when advisable. The latter would primarily refer to full and intermediate contact recreation, particularly during peak recreational season, when one or two test runs per season in combination with appropriate indicator and sanitary surveillance programmes may be sufficient.

Treatment Options

Water used for recreational purposes is usually not treated, but the quality of the inflow and receiving water should be monitored and regulated so as to avoid contamination by enteric viruses. Enteric virus levels in source water are influenced by treatment, but are not necessarily reduced consistently since they display relatively high resistance to environmental stress and to treatment. Several processes including sedimentation, adsorption, coagulation and flocculation may remove viruses from water, but not necessarily inactivate them.

In natural water environments viruses are inactivated by exposure to sunlight, physico-chemical damage (that is, heavy metals and oxidising agents), antagonism by predator organisms and enzymes which degrade proteins and nucleic acids. Pollution of recreational waters can be restricted by disinfection of wastewater discharges using chlorine, other oxidising agents or ultraviolet light. However, these processes require efficient control because viruses are exceptionally resistant and commonly used faecal bacteria are not reliable indicators of viral inactivation.

The Effects of Enteric Viruses

Norms

The norm used in the guideline for enteric viruses is human health.

Effects

Recreational exposure to polluted water has been linked to viral infections and diseases such as gastroenteritis, pneumonia, meningitis and viral hepatitis. Compared with most pathogens, the minimal infectious dose of viruses is extremely low. In many cases, a single virus may cause infection. This implies that even at low levels of viral pollution, a meaningful risk of infection exists.

Mitigation

A person who has contracted a suspected waterborne disease caused by an enteric virus should receive immediate medical attention.

Criteria

The criteria are based largely on the opinion of South African experts and extrapolations from recommendations from international guidelines.

' **Full-contact recreation: effects of enteric viruses on human health**

Enteric Viruses ($TCID_{50}$/10 L)	**Effects**
Target Water Quality Range* *0	***Negligible risk of enteric virus infection expected for single samples***
1 - 10	Meaningful risk of infection may exist, particularly if virus counts in this range are recorded for consecutive samples. Minimal risk expected if occasional/isolated samples yield counts in this range
> 10	Significant risk of infection expected, particularly if virus counts in this range are obtained for consecutive samples or > 50 % of the samples tested. Risk of infection increases as the number of viruses increases

Note:

The criteria are based on the low infective dose of viruses (theoretically, as little as one virus may be infective), and on the assumption that ingestion during recreational water contact is unlikely to exceed 100 mL/recreational exposure.

The criteria only refer to cytopathogenic viruses, that is viruses detectable by cell culture propagation. These viruses may cause infections themselves, but in the guideline they serve as a group of restricted indicators for a wide variety of non-cytopathogenic viruses, primarily involved in waterborne diseases, notably hepatitis A and E viruses and a host of gastroenteric viruses.

' **Intermediate contact recreation**

The same criteria as those for full-contact recreation are recommended for intermediate contact recreation. However, the extent and frequency of water contact differs from full-contact recreational use and should be taken into account. Where limited or infrequent contact occurs, less stringent application of the criteria may be justified.

' **Non-contact recreation**

If a water body is used exclusively for non-contact recreation the level of viral pollution is of little relevance to the recreational amenity.

Sources of Information

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Indicator Organisms

Schistosoma/Bilharzia

Background Information

Introduction

Schistosomiasis, more commonly referred to as bilharzia, is a disease of humans and animals caused by parasitic worms known as schistosomes. The worms have a complex life cycle. The larval stages develop in aquatic snails and the adults live in mammals. The adult worms lay eggs in the veins of several organs. These eggs are passed out in the excreta of infected persons or animals and hatch in water where the miracidia (lifecycle stage that infects the intermediate host) infect certain species of aquatic snails. The snails later discharge cercariae (lifecycle stage that infects the final mammalian host), which infect man and animals. Thus an intermediate host is required and infection cannot pass directly from man to man or from snail to snail. Although water is not essential for all lifecycle stages, the absence of a suitable aquatic environment supporting intermediate host snails would make it impossible for the parasite to survive.

Occurrence

Two forms of bilharzia occur in South Africa:

- bladder and urinary bilharzia of humans, characterised by blood in the urine, caused by the parasite *Schistosoma haematobium*, the larval stages of which develop in the aquatic snail *Bulinus africanus*;
- intestinal bilharzia in humans, characterised by diarrhoea with blood and mucus, caused by the parasite *Schistosoma mansoni*, the larval stages of which develop in the aquatic snail *Biomphalaria pfeifferi*.

Schistosoma mattheei, the larval stages of which develop in the aquatic snail *Bulinus africanus*, causes intestinal bilharzia of sheep and goats and very rarely infects humans, and so rarely occurs in South Africa. **Only very rarely have cases of Schistosoma which infect animals (i.e. *S. mattheei*, *S. bovis* and others) been reported in humans**.

Bilharzia is a health risk only in the northern and eastern parts of South Africa encompassing parts of the northern and eastern Transvaal, northern KwaZulu-Natal and the KwaZulu-Natal north coast.

The major constituent determining the survival and transmission of bilharzia parasites is the existence of a suitable environment for the snail host. This includes the availability of suitable reed beds along the shorelines of water bodies.

Interactions

Any physical, chemical and biological conditions that impinge on the survival of the snail host will also affect the parasite.

Measurement

Due to difficulties associated with the recovery of bilharzia parasites from large water bodies, routine monitoring of bilharzia parasites is not practical. However, routine monitoring of recreational water bodies for the presence of host snails can provide sufficient information to implement control measures.

Data Interpretation

Bilharzia or schistosomiasis is very rarely included in guidelines because of the impracticality of monitoring the lifecycle stages of the bilharzia parasite in water. For this reason, no numeric criteria for risk assessments are given and only control measures for the intermediate host snail are recommended.

Treatment Options

Treatment of water for bilharzia is principally aimed at eradication of the host snail and can be achieved by

application of molluscicides to the water to reduce snail population levels such that transmission of the parasite no longer occurs; and

removal and control of reeds which serve as a habitat for the snails.

The Effects of Bilharzia (Schistosomiasis)

Norms

The norm used in the guideline for bilharzia is human health.

Effects

The presence of bilharzia parasites in water bodies poses a health risk to recreational water users due to infection by schistosome cercariae entering the body through the skin during contact with contaminated water. Contact may occur during activities such as swimming, bathing, angling or paddling in water infested with snails which are shedding cercariae. *The belief that cercariae enter only through damaged skin or by ingestion of water is erroneous because they can penetrate intact skin.* Permanent organ damage can result from infection.

Mitigation

Bilharzia can be cured by proper treatment prescribed by a medical practitioner. Repeated courses may be necessary in exceptional cases.

Criteria

The following recommendations are given:

' **Full-contact recreation**

No snails capable of acting as the intermediate host of the bilharzia parasite should be present in waters used for full contact recreation.

' **Intermediate-contact recreation**

The possibility of infection exists whenever water contact occurs. Hence no snails capable of acting as the intermediate host of the bilharzia parasite should be present.

' **Non-contact recreation**

No recommendations are necessary, provided that the water body is used exclusively for non-contact recreation.

Sources of Information

WHO 1993. *Guidelines for Drinking Water Quality*, 2nd Edition, Volume 1: Recommendations. World Health Organization.

WHO 1995. *Guidelines for Drinking Water Quality*, 2nd Edition, Volume 2: Health Criteria and Other Supporting Information. World Health Organization, Geneva (in press).

Nuisance Plants

Background Information

Introduction

Nuisance plants endanger the safety of and impinge on the physical comfort of recreational water users, and tend to render water aesthetically objectionable or unusable as a result of excessive growth or objectionable odours.

Excessive plant growth can obstruct the view of swimmers and obscure underwater hazards. It can entangle swimmers and induce panic, especially if encountered unexpectedly. Boating, waterskiing, boardsailing and angling may be restricted or impossible if the growth is very dense. Floating or attached plants that become dislodged from the substrate may drift into swimming areas. Dead and decaying aquatic plants are unsightly, cause objectionable odours and provide a breeding ground for a variety of invertebrates, bacteria and fungi. When not present in large amounts, aquatic plants can enhance the habitat for certain fish species, thereby benefiting angling.

Occurrence

In addition to algae, macrophytes (rooted and non-rooted vascular plants) may occur in water bodies. Plant growth can be extremely dense and may form large, free-floating mats.

Increased plant growth may be caused by the introduction of exotic species, such as water hyacinth, and by the presence of excess nutrients, for example from wastewater discharges or runoff from agricultural land. Increased silt loads and changes in shorelines or land uses can also contribute to changes in the aquatic habitat which may promote plant growth.

Nuisance plants will continue to flourish unless removed or deprived of nutrients. This can lead ultimately to the complete choking up of a river or dam. However, aquatic plants can also be highly beneficial in a catchment area. Certain species accumulate nutrients, heavy metals and other pollutants and may form the basis for the conservation and development of wetland areas.

Interactions

Many physical, chemical and biological properties govern aquatic plant growth in water bodies. Inflow of excessive nutrients should be avoided, since this is one of the key factors contributing to excessive plant growth.

Measurement

Evaluation of the nuisance value of aquatic plant growth is essentially qualitative and subjective and no methods of measurement are applicable.

Data Interpretation

The criteria given are qualitative; discretion and good judgement is required in the interpretation thereof.

Treatment Options

The removal of plants from water bodies may constitute a major undertaking. For example, aerial spraying of herbicides being a notable case to remove water hyacinth from the Hartbeespoort Dam (Pretoria). Normally plants are removed manually and mechanically since the use of herbicides may not be practicable, safe or economical. In the case of uncontrolled plant proliferation, herbicide control measures by aerial spraying have proved effective.

Limitations to the effective removal of excessive plant growth from water bodies may involve difficulties with mechanical removal, the lowering of dissolved oxygen levels through the use of herbicides and consequently adverse affects on aquatic life. Adequate follow-up operations are always required if herbicides are used.

The Effects of Nuisance Plants

Norms

The norms used in the guideline for nuisance plants are based on the health and safety of water users and aesthetic effects.

Effects

Plant growth can pose a physical hazard in recreational water by entangling swimmers, waterskiers and boardsailors. In addition it can be a nuisance to anglers through snagging of tackle. In extreme cases water bodies can become unusable for recreation.

The inevitable decay of dead plants can give rise to odours and render the water unaesthetic if excessive amounts are present.

A water body choked up with prolific plant growth, for example water hyacinth, is less aesthetically enjoyable than one that is free from such growth.

Mitigation

Mitigatory measures are inapplicable.

Criteria

' **Full-contact recreation (swimming)**

The growth of aquatic vascular plants in water bodies used for full-contact recreation should be limited to ensure that entanglement of swimmers does not occur and that plants do not obscure visibility. Excessive plant growth should not occur in full-contact recreational areas. The presence of floating masses of detached plants which may obstruct water users are aesthetically objectionable and provide a habitat for the growth of nuisance and vector organisms (for example insects, fungi and bacteria) and should be limited as far as possible.

' **Intermediate-contact recreation**

Since activities involving intermediate-contact recreation may include occasional full-body immersion, the criteria given above should be used and the extent of contact should be taken into account. Where water contact is slight or infrequent, the criteria may be applied less stringently. Plant growth should also be limited to prevent possible entanglement of boats, waterskiers and boardsailors.

Non-contact recreation

Aquatic plant growth should not detract from the aesthetic aspects of water bodies used for non-contact recreation. Hence, water should not be completely covered, plant growth should not be unsightly or cause unpleasant odours, and there should be no adverse effects on other aquatic organisms.

Sources of Information

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Odour

Background Information

Introduction Odours associated with recreational water detract from aesthetic appreciation of water bodies and are perceived by potential users to indicate the presence of pollutants as demonstrated in case studies conducted at Hartbeespoort Dam (Pretoria) and Zandvlei (Cape Town). Complaints concerning the odour of a water body are often useful in evaluating suitability for recreational use.

Occurrence Some odours from surface water originate from the decomposition of algae and other aquatic plants. Several species of algae produce offensive odours while actively growing. Drying and decaying aquatic plants are both unsightly and cause objectionable odours. Other odours may result from domestic and industrial discharges into recreational water bodies. Organic chemicals such as phenolics, oils or petrochemicals may be associated with water odours.

Interactions Odour can indicate varied instances of pollution or imbalances in natural ecosystems, and can therefore be linked to a wide range of factors. These include the presence of excess algae or aquatic plants, excess nutrients, low dissolved oxygen, extremes of pH or temperature, discharges of sewage or other wastes, chemical discharges and refuse.

Measurement Odour in recreational water is usually assessed qualitatively. A quantitative measurement of odour is generally not necessary, as is the case with water used for domestic purposes.

Data Interpretation The criteria for water odour are qualitative and should be interpreted with good judgement and discretion.

Treatment Options Recreational water bodies are usually not treated directly for odours and the quality of the inflow and receiving water should be monitored and regulated to avoid odour-associated problems.

The Effects of Odour

Norms The norm used in the guideline for odour is primarily based on aesthetic effects. Some odours may be associated with substances which have health implications, but most odours do not pose a direct health hazard.

Effects The main effects of odours are aesthetic unless the substances causing the odour are associated with health-threatening pollutants.

Mitigation Removal of the source of the odour(s) is a mitigatory measure, but depends on the nature of the pollutant.

Criteria *Qualitative descriptions of the impact of odour are given.*

- **Full-contact recreation (swimming)**

  Recreational waters should be free of any substances which cause noticeably unpleasant or objectionable odours. Odours detract from the aesthetic appreciation of water bodies and are considered by water users as indicative of pollution.

- **Intermediate and non-contact recreation**

  Odour affects the aesthetic aspects of all forms of recreational water use, hence the criteria given for full-contact recreation is recommended. There should be no adverse impact on aquatic life forms.

Sources of Information

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pH

Background Information

Introduction

The pH of a solution is the negative logarithm to the base ten of the hydrogen ion concentration, given by the expression:

$pH = -\log_{10}[H^+]$

where $[H^+]$ is the hydrogen ion concentration.

At pH less than 7 water is acidic, while at pH greater than 7 water is alkaline.

The pH of natural waters is a measure of the acid-base equilibrium of various dissolved compounds and is a result of the carbon dioxide-bicarbonate-carbonate equilibrium which involves various constituent equilibria, all of which are affected by temperature. Conditions which favour production of hydrogen ions result in a lowering of pH, referred to as an acidification process. Alternatively, conditions which favour neutralisation of hydrogen ions result in an increase in pH, referred to as an alkalinisation process. **It should be noted** that the pH of water does not indicate the ability to neutralise additions of acids or bases without appreciable change. This characteristic, termed buffering capacity, is controlled by the amounts of acidity and alkalinity present.

The pH of a water does not have direct health consequences except at extremes. Rather, the effects of pH arise as a result of the solubilisation of toxic heavy metals and the protonation or deprotonation of other ions.

Contact with water of extreme pH can cause discomfort and irritation to the eyes, ears, skin and mucous membranes of the nose and mouth.

Occurrence

The geology and geochemistry of the rocks and soils of a catchment area affect the pH and alkalinity of the aquatic system. The pH of most raw waters lies in the range of 6.5 - 9.5. Biological and anthropogenic activities such as nutrient cycling and industrial effluent discharge respectively, can give rise to pH fluctuations. Acid mine drainage, in particular, can have a marked effect on the pH. Further, acid-forming substances released into the atmosphere such as oxides of sulphur and nitrogen, may ultimately alter the acid-base equilibria in natural waters and result in a reduced acid-neutralising capacity and hence a lower pH.

Interactions

The pH of natural waters is influenced by various factors and processes, including temperature, discharge of effluents, algal growth, acid mine drainage, acidic precipitation, runoff, microbial activity and decay processes.

Measurement

Water pH is usually measured electrometrically using a pH meter. The pH meter should be calibrated against standard buffer solutions on known pH, prior to measurement of a sample.

Fresh samples should be used to determine pH. The temperature at which measurements are made should always be reported, since pH measurement is influenced by temperature. Errors may be caused by the presence of sodium at pH values higher than 10.

Data Interpretation The pH should be interpreted in relation to the full analysis of the water sample and its use. Mean or single-sample maximal values may be used depending on the application.

Treatment Options Recreational water bodies are not treated for pH. The quality of the inflow water should be monitored and regulated to avoid excessively high or low pH.

The Effects of pH

Norms The norm used in the guideline for pH is human health.

Effects Water pH values outside a fairly narrow range of circum-neutral pH cause irritation of eyes, skin, ears and mucous membranes of the nose, mouth and throat of swimmers and other contact recreational water users.

The lachrymal fluid (tears) of the eye has a normal pH of close to 7.4, which is maintained within a narrow range by physiological buffering agents. A pH change of as little as 0.1 in the lachrymal fluid can cause irritation, and greater change can cause severe discomfort and pain. Ideally, water used for contact recreation should be as close to pH 7.4 as possible.

Discomfort of the eyes and other susceptible parts of the body is not permanent and usually disappears rapidly if contact is discontinued.

Mitigation Eye irritation can be alleviated using over the counter or prescription eye-drops. In most cases taking a shower in clean water is sufficient to alleviate the irritation to other body parts.

Criteria

- **Full-contact recreation: effects for pH of water for full-contact recreation (swimming)**

pH Range (pH units)	Effects
0 - 5.0	Severe eye irritation occurs. Skin, ear and mucous membrane irritation likely. Adverse aesthetic taste effects expected, if water accidentally swallowed.
5.0 - 6.5	Swimming in water of this pH is generally acceptable. Some eye irritation occurs. Skin, ear and mucous membrane irritation unlikely.
Target Water Quality Range 6.5 - 8.5	***Minimal eye irritation occurs. The pH of water is well within the buffering capacity of the lachrymal fluid of the human eye. Skin, ear and mucous membrane irritation absent***
8.5 - 9.0	Swimming is acceptable. Some eye irritation expected. Skin, ear and mucous membrane irritation may occur. Adverse aesthetic taste effects expected if water swallowed accidentally
> 9.0	Eye irritation becomes increasingly severe as pH values become more extreme. Skin, ear and mucous membrane irritation occurs. Adverse aesthetic taste effects expected, if water accidentally swallowed

- **Intermediate-contact recreation (waterskiing, boardsailing, canoeing)**

Since intermediate contact recreation may involve some degree of direct contact with water, including occasional full-body immersion, the same criteria as those given for full contact recreation are recommended. However, the extent of water contact should be taken into account and where contact is only slight or infrequent, the criteria may be less stringently applied.

- **Non-contact recreation**

If the water body is used exclusively for non-contact recreation, the effect of pH on human health is not relevant.

Sources of Information

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Chapter 6

Glossaries

Glossary of Terminology

acclimation: short-term adaptation of individuals to specific environmental conditions

adsorption/elution: the attachment of molecules or ions to, and their removal from, a substrate by manipulation of electrical charge or pH

aerobic: of organisms requiring molecular oxygen for respiration conditions *or* conditions where oxygen is available

aetiological: causative, as in causing disease

agglomeration: the coalescing of particles in water to form flocs; or promoted by gentle stirring or by adding chemicals

amphoteric: the capability of a substance to react as an acid or a base, hence of dissolving under basic or acidic conditions

anaerobic: conditions lacking oxygen or of organisms not requiring oxygen for respiration

anionic: characteristic behaviour or property of an ion that has a negative charge. Anions move to the anode in electrolysis

anions: negatively charged ions

ascariasis: a disease caused by helminthic parasites of the genus *Ascaris*, in man *A. lumbricoides*

biochemical oxygen demand (BOD): the amount of dissolved oxygen consumed by organisms in in water rich inorganic matter

buffering capacity: a measure of the relative sensitivity of a solution to pH changes on addition of acids or bases

carcinogenic: capable of causing, promoting or giving rise to the development of cancer

cationic: the characteristic behaviour or property of an ion with a positive charge. Cations move to the cathode in electrolysis

cations: positively charged ions

cercariae: the final free-swimming larval stage of the life cycle of a trematode parasite, for example, *Schistosoma*. This is the stage which infests humans and animals

chemical oxygen demand (COD): the amount of oxygen required to oxidise all the organic matter in a sample that is susceptible to oxidation by a strong chemical oxidant

chlorophyll:	the green pigment in plants and algae that during photosynthesis, captures sunlight energy and converts it into chemical energy in the form of carbohydrates. Chlorophyll *a*, *b and c* are three forms of chlorophyll. Chlorophyll *a* is used as a measure of the quantity of algae in water
clarity:	the depth to which light can penetrate in a water body and is measured by the depth to which a Secchi disk (a 20 cm-diameter disk printed with black and white quadrants) is visible
coagulation:	the separation or precipitation of particles in a dispersed state from a suspension resulting from their growth. This may result from the addition of an electrolyte (coagulant), prolonged heating or from a condensation reaction between a solvent and solute
cytopathogenic or *cytopathic*:	damage caused to cells
dissolution:	the process of dissolving
epidemiology:	the science or study of diseases in the community
eutrophic:	water, particularly in lakes and dams, which is high in nutrients and hence has excessive plant and algal growth
flocculation:	the addition of chemical reagents (flocculants) to bring small particles together in flocs through the process of *coagulation*, aggregation or biochemical reaction of fine suspended particles
full-contact recreation:	one of the categories used in recreational water that involves full-body water contact such as swimming and diving
giardiasis:	a disease caused by protozoan parasites of the genus *Giardia*, in man *G.lamblia*
intermediate-contact: recreation:	one of the categories used for recreational water. It includes activities with a high degree of water contact such as waterskiing and canoeing, as well as those involving relatively little water contact, such as paddling or wading
macrophyte:	any macroscopic form of aquatic vegetation; encompasses certain species of algae, mosses and ferns as well as aquatic vascular plants
mesotrophic:	a term applied to freshwater bodies that contain moderate quantities of plant nutrients and are therefore moderately productive
microbes:	microscopic organisms such as bacteria or viruses
miracidia:	free-swimming larvae of a trematode, e.g., *Schistosoma*. This is the stage which infests humans and animals

mucilaginous:	the tacky or slimy property of extracellular substances secreted by certain groups of bacteria, such as the slime-producing bacteria
mutagenic:	the capability of inducing mutations
non-contact recreation:	one of the categories for recreational water use in which there is no direct contact with water, such as when picnicking or hiking. Scenic and aesthetic aspects are the important features for this category
organoleptic:	characteristics of water that affect the sense organs, e.g. taste and odour
pathogenic:	an agent that causes a disease
photosynthesis:	the trapping of solar energy and its conversion to chemical energy by plants and algae, that use the energy to manufacture food molecules from carbon dioxide and water
physico-chemical:	the physical (e.g. temperature, electrical conductivity) and chemical (e.g. concentrations of nitrate, mercury) characteristics of water
raw water:	source water in its untreated state
redox potential:	an expression of the oxidising or reducing power of a solution relative to a reference potential. This potential is dependent on the nature of the substances dissolved in the water, as well as on the proportion of their oxidised and reduced components
reducing conditions:	conditions prevailing within an aquatic environment in which the redox potential is such that substances become reduced
salinity:	a measure of the salt content of soil or water
schistosome:	members of the genus *Schistosoma*
schistosomiasis:	a disease, typically chronic, caused by a tropical parasite of the genus *Schistosoma*. It is frequently referred to by the older term, bilharzia
threshold odour number (TON):	defined as the greatest dilution of a sample with odour-free water that yields a final odour which is just detectable by a panel of judges under carefully controlled conditions
trihalomethanes:	organic molecules containing a single carbon atom on which hydrogen atoms have been replaced by halogens, generally either chlorine or bromine. Frequently formed during disinfection by chlorination or bromination

valency:	the number of electrons required to be gained or lost by an atom to reach a state where the outermost electron shell is full
vascular plants:	plants with woody conducting vessels

Glossary of Abbreviations / Acronyms

ADI acceptable daily intake. Refers to a concentration of a chemical or substance which can be tolerated as a daily dose over a long exposure period, usually a lifetime. This is usually applied to toxic chemicals which do not have carcinogenic effects

APHA American Public Health Association

ASCE American Society of Civil Engineers

AWWA American Water Works Association

BOD biological oxygen demand

COD chemical oxygen demand

CSIR Council for Scientific and Industrial Research

DOC dissolved organic carbon

EC electrical conductivity

EC European Community - in this document, the European Community (EC) is referred to as such when discussing it as an economic/political entity. It is referred to the European Economic Community (EEC) when directly citing a Directive promulgated prior to the change from EEC to EC, formally in 1992. Now EUROPEAN UNION (EU)

EEC European Economic Community

EDTA ethylenediamine tetra-acetic acid

HPLC high performance liquid chromatography

IAWPRC International Association for Water Pollution Research and Control. Now International Association for Water Quality (IAWQ)

NAS/NAE National Academy of Sciences/National Academy of Engineering (USA)

NOAEL no observed adverse effect level. Refers to that test concentration of a toxicant in a toxicological experiment at which no adverse effect on the test organism is observed or measured

NTU nephelometric turbidity units

PFU plaque-forming units

PVA polyvinyl alcohols

SD Secchi disk depth in metres

$TCID_{50}$	dose of virus required to cause 50% infection in tissue culture
TDS	total dissolved solids
THMs	trihalomethanes
TOC	total organic carbon
TON	threshold odour number
TWQR	Target Water Quality Range
US EPA	United States Environmental Protection Agency
WHO	World Health Organization

Glossary of Units of Measure

µg/L	micrograms per litre
mg/L	milligrams per litre
mM/L	millimoles per litre
ng/L	nanograms per litre
NTU	nephelometric turbidity units
$TCID_{50}$	Dose of virus required to cause 50 % infection in tissue culture
°C	degrees centigrade

Statement regarding this version of the document on 2017-09-04

The South African Water Quality Guidelines are available from http://www.dwa.gov.za/iwqs/wq_guide/index.asp as individual volumes in PDF format. This is not the official source for these documents, which is http://www.dwa.gov.za/Dir_WQM/docsFrame.htm (Enter the following in the search box: water quality guidelines, which will return the link to South African Water Quality Guidelines, with all the guideline PDF files in a single 10Mb ZIP file.)

The original documents were written in WordPerfect 6.0, using non-standard WordPerfect symbol fonts. These are now rarely installed on users' computers, and even when they are present some PDF readers (e.g. Adobe) do not detect them. A "font not found" warning occurs, and even installing the non-copyright version of the WP font set WPFONTS.EXE does not work in all circumstances. Using an alternative PDF reader is sometimes successful.

For these reasons, Marc de Fontaine and Mike Silberbauer have produced this document by converting the PDF files to MS Word, then replacing the special characters with standard characters, where possible. For example, the curly litre sign is replaced with a capital L.

The new document has certain formatting differences from the original, for example some bullet points are missing, and the typeface is not exactly the same.

The document was then converted back to PDF for distribution.

The printed copies remain the definitive version of these documents.