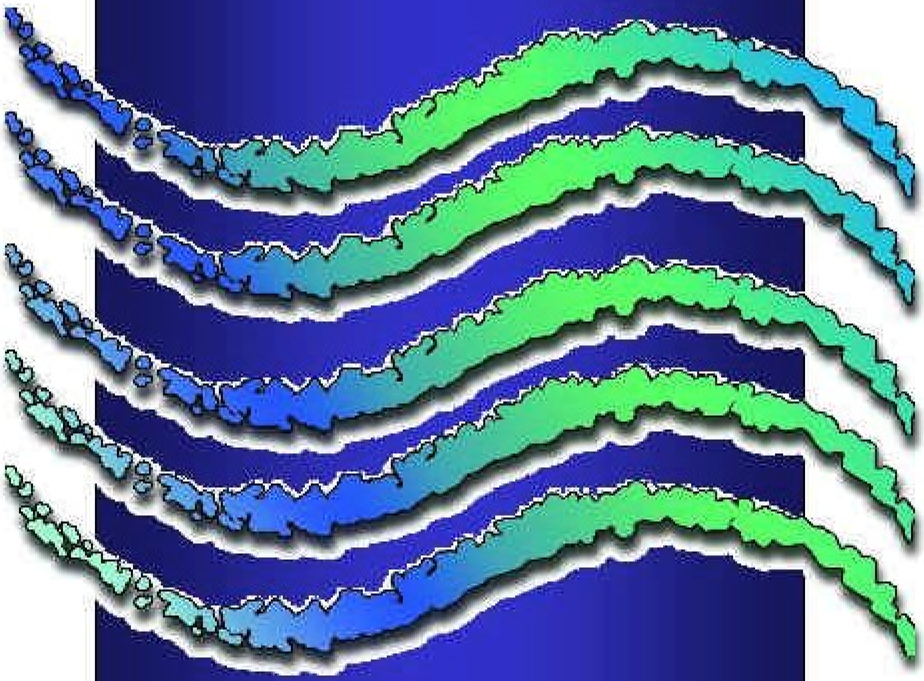
SOUTH AFRICAN

WATER QUALITY GUIDELINES

VOLUME 3

INDUSTRIAL USE



Department of Water Affairs and Forestry
Second Edition 1996

SOUTH AFRICAN WATER QUALITY GUIDELINES
Volume 3: Industrial Water Use
Second Edition, 1996

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South African Water Quality Guidelines

Volume 3
Industrial Use

Department of Water Affairs
and Forestry

Second edition
1996

Published by

Department of Water Affairs and Forestry
Private Bag X313
PRETORIA
0001

Republic of South Africa
Tel: (012) 299-9111

Printed and bound by
The Government Printer, Pretoria

ISBN 0-7988-5338-7 (Set)
ISBN 0-7988-5341-7 (Volume)

This report should be cited as:

Department of Water Affairs and Forestry, 1996. South African Water Quality Guidelines (second edition), Volume 3: Industrial Use.

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Produced by:

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This volume is the third 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 continuing 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

Contents

Page

Acknowledgements

The following individuals and organisations are thanked for their contributions to these guidelines.

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Draft documents were distributed to the following stakeholders, and all comments received have been incorporated.

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Mr J R Muller, S.A. Abattoir Corporation
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Mr B Southworth, David Whitehead and Sons
Mr T Spencer, Eskom
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Mr B Swart, Sasol 3
Mr G Swart, Dairybelle
Mrs T Taljaard, Chamber of Commerce
Mr J Uys, Natref
Mr G van der Vyver, Iscor Ltd
Mr P van Schalkwyk, Edison Electroplating Group
Mr G van Tonder, Iscor Ltd
Mr H C van Zyl, Amcoal
Mr N Viljoen, Dairybelle
Mr R Youldon, Sapref

We also wish to thank the many people who provided administrative, secretarial and financial support services during the development and production of this handbook.

Chapter 1

Introduction

Introduction

Scope and Purpose of the Water Quality Guidelines

Scope

The South African Water Quality Guidelines for Industrial Water Use is essentially a user needs specification of the quality of water required for different industrial uses. It provides the information needed to make judgements as to the fitness of water to be used for industrial purposes.

The guidelines are applicable to any water that is used for industrial purposes, irrespective of its source (municipal supply, borehole, river, etc.) or whether or not it has been treated.

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 similar information 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 for Industrial Water Use 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 which clearly indicate the exact version of a guideline, have been designed to facilitate regular updating of the guidelines.

Overview

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

Chapters 1 - 4 provide an introduction to the guidelines, define some important water quality concepts, explain how industrial water use was characterised for the purpose of developing these guidelines, describe how the guidelines were developed and provide 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 for Industrial Water Use* correctly it is important to understand how water quality and some related concepts were defined for the purpose of developing the guidelines.

Definition

The term *water quality* is used to describe 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 Industrial Water Use* 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 that 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 Ca/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.

Water Quality 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 for the maintenance of the health of aquatic ecosystems.

Desired Water Quality Range

For most water uses and irrigation, it is possible to define 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 use. The purpose of defining such a range is for water resource managers to use it as guidance for setting water quality management objectives.

However, some industrial processes, e.g. steam generation, have such unique water quality requirements that it would not even be attempted to manage the quality of a water resource to meet such requirements. Instead, for such processes pretreatment of intake water is a standard requirement.

Therefore, in the case of industrial water use, it serves no purpose, from a water resource management perspective, to define a No Effect Range. Instead, a Desired Water Quality Range is defined which is the range of concentrations or levels at which the presence of that particular constituent would not result in any extraordinary requirements, in terms of cost or any other requirements, in order to use water from a particular resource for a particular industrial process category.

Target Water Quality Range

One of the goals of the Department of Water Affairs and Forestry (DWAF) is to maintain the quality of South Africa's water resources such that water quality remains within the Desired Water Quality Range for a particular industrial process category; this includes pretreatment. 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 Desired Water Quality Range, where and whenever possible.

For this reason, the Desired Water Quality 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 dealt with 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 Desired Water Quality 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* consist of the guidelines for domestic, recreational, industrial and agricultural (irrigation, livestock watering and aquaculture) water 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 protecting aquatic ecosystems form the basis on which the fitness for use of water is judged.

Characterisation of Water Uses

In the case of water for industrial purposes, its use can be subdivided into a number of subcategories such as water used for steam generation, cooling, lubrication, humidification, etc. The subcategories of a particular water use can each 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 indicate 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; and
- 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 purpose or for protecting aquatic ecosystems. Fitness for use may range from being completely unfit for use to 100 % or ideally fit for a specific use.

The concept of fitness for use of water in industrial applications differs in a number of aspects from other water uses. Most industries are comprised of a collection of water-using processes, each with its own specific water quality requirements. Some processes are highly sensitive to water quality changes, while others may be unaffected. Consequently, in a single industry, water that is ideally fit for one process may be totally unfit for another.

Furthermore, with progress in modern treatment technology nearly any quality water can be used for a specific purpose provided it can be treated to the required specifications. Therefore, how fit a particular water source is for use depends also on the design specifications for the process and how much the user is prepared to invest in treating the water to comply with these specifications.

Bearing these considerations in mind, the guidelines give some guidance with respect to judgements of how suitable or how fit for use a water may be. However, site-specific investigation is essential to establish the true situation for any particular industry.

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 the aquatic ecosystem.

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

The sustained use of water is generally an important objective for structural and economic growth, and has therefore received special consideration in the development of the guidelines. In industry, however, the degree to which water use is sustainable is dependent largely on the user and what the user is prepared to do to treat the water to the desired quality. For example, the cost of treating water for its sustained use must be considered against the cost of maintenance of equipment or machinery if water of inferior quality is used.

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, whereas others attempt to define ideal concentrations for constituents, 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 may differ by a factor of a hundred or more.

The rationale for developing the *South African Water Quality Guidelines for Industrial Water Use* 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 difficulty in developing water quality guidelines for industrial use is the inherent difference between industries, even between those manufacturing similar products. For example, tanneries may differ in the types and conditions of hides they receive, the steps included in the tanning process, and in varied ways of finishing leather. Thus the water quality requirements for different tanneries may differ, and a similar range of variations is seen in most industries.

In the first edition (1993) of the *South African Water Quality Guidelines for Industrial Water Use* the differences were acknowledged and a site-specific routine provided to determine the water quality requirements for a particular example of the industry. A second difficulty was to provide water quality guidelines for a comprehensive range of industries. The possible list of industries is long and increasing all the time, as uses are found for new products and new technologies emerge. The first edition provided water quality guidelines for only seven industries with the intention of extending these in future editions.

In this second edition, the approach has been revised. It is recognised that all industries have water-using processes in common, so that the water requirements of any industry can be described as a progression of general and specific processes. Each process has definable water quality requirements, so that by defining water quality guidelines for different processes, the water quality requirements for any industry can be defined using a building block approach.

Methodology

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

Defining norms for measuring fitness for use:

- Determining the norms by which the fitness of the water for industrial use can be measured;

Assigning industrial processes to categories:

- Listing different uses of water in industries under major process types, such as cooling water, steam generation, process water, production water and utility water.
- Defining four categories of processes according to the degree of water purity or tightness of specification for the required water quality.
- Assigning each of the water uses to one of these process categories determined by the quality of water they require.

Identifying water-related problems:

- Identifying the water quality-related problems associated with the water uses in each process type.

Identifying constituents involved with problems:

- Identifying the water quality constituents playing a role in these problems.

Producing water quality criteria:

- Defining, through primarily South African experience, and assessing international literature, the TWQR for each water quality constituent.
- Delimiting further concentration ranges for each water quality constituent that would result in increasingly deleterious potential or actual effects on the norms.
- Developing from the above information water quality guidelines as numerical values and narratives describing the effects of the water quality constituent at different concentration ranges in each of the four process categories.
- Finalising, through a process of technical and stakeholder review, the guidelines as published in the *South African Water Quality Guidelines*.

Sources of Information Used to Develop the Guidelines

Introduction

Because the *South African Water Quality Guidelines* are primarily aimed at South African water resource managers and water users, greater weight was given to South African sources of information. Opinions of a wide range of South African experts in water quality, water treatment, water supply as well as users were used to supplement published information. For some constituents, international literature was also used as background and reference material.

Sources of Information

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 Industrial Water Use*:

Standard Methods for the Examination of Water and Waste Water (APHA, 1985);

Australian Water Quality Guidelines (Australian Guidelines, 1992), a Draft for Public Comment;

Water Quality and Treatment. A Handbook of Public Water Supplies, 3rd Edition. (AWWA, 1971);

Canadian Water Quality Guidelines (Canadian Guidelines, 1987);

Water Quality Criteria in Environmental Management. Commission of the European Communities (Chaudini & Premazzi, 1988);

A Compilation of Australian Water Quality Criteria (Hart, 1974);

Water Quality Criteria, 2nd Edition (McKee & Wolf, 1963);

Report of the National Technical Advisory Committee on Water Quality Criteria (NCWQ, 1968);

Water Quality Criteria 1972 (United States Environmental Protection Agency, 1973);

Quality Criteria for Water (Train, 1979);

Criteria for Water Quality Criteria (United States Environmental Protection Agency, 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 Industrial Water Use:*

Water Quality Management Policies and Strategies in the RSA (Department of Water Affairs & Forestry);

CSIR Technical Guide K11 on Industrial Water and Effluent Management in the Textile Industry (Funcke, 1969);

Summarised Water Quality Criteria (Kempster, Hattingh & Van Vliet, 1980);

Water Quality Fitness for Use Curves for Domestic Water (Kempster & Van Vliet, 1991);

Waste Water Treatment and Pollution Control (Murray, 1987);

NATSURV Series of documents on *Water and Waste Water Management* in various South African Industries (published by the Water Research Commission);

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

South African Water Quality Guidelines, 1st Edition. Volume 3: Industrial Use (DWAF, 1993).

Chapter 3

Characterisation Of Industrial Water Use

Characterisation of Industrial Water Use

Background Information

This chapter sets out to show how the guidelines have been developed in accordance with the methodology outlined in Chapter 2.

Define norms for fitness for use

In these guidelines, industries are defined as systems of water-using processes, in which fitness for use of the water is assessed in terms of the norms listed below:

- its potential for causing damage to equipment (for example, corrosion, abrasion)
- problems it may cause in the manufacturing process (for example, precipitates, colour changes)
- impairment of product quality (for example, taste, discolouration)
- complexity of waste handling as a result of using water of the quality available.

Assign industrial water using processes to categories

Process types include cooling, steam production, process water (solvent, diluent, carrier), product water (as in beverages), utilities (domestic, fire protection) and wash water. Four categories of processes have been defined according to the degree of water purity or *tightness* of specification for the required water quality, as outlined in the table below.

Category 1	Processes that require a high quality water with relatively tight to stringent specifications of limits for most or all the relevant water quality constituents. Standard or specialised technology is essential to provide water conforming to the required quality specifications Consequently, costs of inhouse treatment to provide such water are a major consideration in the economy of the process
Category 2	Processes that require water of a quality intermediate between the high quality required for Category 1 processes and domestic water quality (Category 3 processes). Specifications for some water quality constituents are somewhat tighter or more stringent than required for domestic water quality. Standard technology is usually sufficient to reach the required water quality criteria. Cost for such additional water treatment begins to be significant in the economy of the process
Category 3	Processes for which domestic water quality is the baseline minimum standard. Water of this quality may be used in the process without further treatment, or minimum treatment using low to standard technology may be necessary to reach the specifications laid down for a desired water quality. Costs of further inhouse treatment are not significant in the economy of the process
Category 4	Processes that within certain limitations can use water of more or less any quality for their purposes without creating any problems. No additional treatment is usually required and there is therefore no further cost

Industrial processes requiring particular water quality types are given in the table below.

Process	Process type	Water use
Category 1	Cooling water	Evaporative cooling (high recycle)
	Steam generation	High pressure (HP) boiler: demineralisation of feed water
	Process water	Phase separation
		Petrochemicals
	Product water	Pharmaceuticals
	Wash water	No residual washing (electronic parts)
Category 2	Cooling water	Evaporative cooling (high recycle)
		Solution cooling
		Water heating
	Steam generation	HP boiler: demineralisation feed
	Process waters	Solvent
		Heat transfer medium
		Humidification
		Lubrication
		Gas cleaning
	Product water	Beverages
		Dairy products
		Petrochemicals
	Wash water	Reaction vessel washing
Category 3	Cooling water	Evaporative cooling: (once through)
		Bearing cooling
		Mould cooling
	Steam generation	Low pressure (LP) boiler: (softener feed)
	Process waters	Solvent
		Dilution agent
		Transport agent
		Gland seal
		Vacuum seal
		Lubrication
		Descaling (iron and steel)
		Gas scrubbing
	Product water	Beverages
		Food products
		Baking
		Confectionery
		Chemicals
		Surface washing (table tops, walls)
	Utility water	Domestic use
		Fire fighting

Process	Process type	Water use
Category 4	Cooling water	Ash quenching
	Process waters	Transport agent
	Utility water	Dust suppression
		Fire fighting
		Irrigation
	Wash water	Rough washing (floors, rough apparatus, trucks, raw materials)

- **Identify water-related problems**

Potential water-related problems associated with various industrial processes are given in the table below.

Process	Equipment damage	Process problems	Product problems	Waste disposal
Cooling water	• corrosion • scaling • fouling • blockages	• foaming • sediments • gas production • odours • HE impairment		• pH • TDS • COD • SS
Water for steam generation	• resin film • resin poison • corrosion • scaling	• resin impairment • competition	• inadequate treatment	• pH • TDS
Process water	• corrosion • scaling • fouling • blockages • abrasion • embrittlement • discolouration	• precipitates • foaming • colour effects • gas production • interference	• sediment • foam • colour • taste/odour • tarnish	• SS • Fe/Mn • TDS
Product water	• corrosion • scaling • fouling • blockages	• precipitates • foaming • gas production • interference	• sediment • turbidity • foam • colour • taste/odour • coagulation	
Utility water	• corrosion • scaling • fouling • blockages • abrasion		• sediment • turbidity • foam • colour • taste/odour • intestinal irritation • health hazards	• pH • TDS • SS • Fe/Mn • COD
Wash water	• corrosion • scaling • fouling • blockages • abrasion	• contamination	• contamination • blemishes • sediment • process solutions	• pH • TDS • SS • Fe/Mn • COD

Identify constituents that contribute to problems

The water quality problems listed in the table above can be identified with constituents which contribute to them. Frequently, water quality problems are associated not only with the presence of a variable but with the interaction between variables, as is the case with corrosion and scaling. The table below indicates the constituents which may be associated with water-related problems in industrial processes.

Problem	**pH**	**Cond**	**TH***	**Fe**	**Mn**	**Alk**	**SO_4**	**Cl**	**SiO_2**	**SS**	**COD**
Corrosion	▨	▨	▨	▨		▨	▨	▨		▨	▨
Scaling	▨	▨	▨	▨		▨	▨		▨	▨	
Fouling				▨	▨					▨	▨
Blockages	▨	▨	▨	▨	▨	▨	▨		▨	▨	▨
Abrasion							▨			▨	
Embrittlement	▨	▨						▨			
Discolouration	▨			▨	▨						▨
Resin blinding	▨	▨	▨	▨	▨	▨	▨		▨	▨	
Foaming	▨					▨					▨
Sediment	▨		▨	▨	▨		▨			▨	
Gas production	▨					▨	▨				▨
Taste/odours	▨	▨		▨	▨			▨			
Precipitates	▨	▨	▨	▨	▨	▨	▨				
Turbidity	▨			▨			▨			▨	▨
Colour	▨			▨	▨						▨
Biological growth	▨		▨	▨	▨	▨	▨			▨	▨

Note: Although it is the calcium component of the total hardness (mainly Ca^{2+} plus Mg^{2+}) which is commonly implicated in scaling and corrosion problems, a guideline for total hardness is given since softening procedures usually remove total hardness rather than calcium alone.

Produce water quality guidelines

Water quality guidelines for the four categories of industrial processes have been compiled in terms of the constituents listed above. Clearly there are many other constituents such as heavy metals, phenols and organic substances which can adversely affect the fitness for use of the water. These are not commonly present in significant concentrations and guidelines are therefore not provided. In the unusual situation where such constituents may be significant they would need to be considered on a site-specific basis.

Chapter 4

Information Contained in the Guidelines

Information Contained in the Guidelines

Overview

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 in industrial water use.

Occurrence Information on the fate and occurrence of a constituent in the aquatic environment, as well as natural and manmade sources thereof are provided as background to help the user determine 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. Where interactions involve constituents included in these guidelines, they are highlighted in bold print.

Measurement The effect 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 methodologies to use. A reference method has been indicated for most constituents. Should other methods be used their characteristics relative to the reference method should be known.

Data Interpretation The effects of water quality constituents on water uses vary from reversible, partially reversible and irreversible. This is often dependent on whether the adverse effects have arisen due to long-term or short-term exposure and hence the occurrence of accumulative or sporadic effects respectively. 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 are likely, be estimated from data sets.

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

Treatment Options

There are 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; and

Improve, with the use of various treatments, the quality of water on site. This can be done by the users themselves. For example, softening of hard water before using it to generate steam.

The information provided 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 options are to be pursued, the user will obtain expert advice.

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

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

The Effects of a Constituent

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 constituents have 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 to be expected.

As a result of differences in the hydrological characteristics of South African rivers, water quality can be 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 a particular quality when judging the fitness of water for use.

The effect of a given water quality on its fitness for use can be significantly enhanced or suppressed by other factors such as

temperature
storage time

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.

Criteria

In the guidelines for industrial water use, the water quality criteria for most of the constituents are provided in the form of a table in which the effects of increasing concentrations of the constituent are described using the appropriate norms. The No Effect Range, designated 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. However, water quality outside of this range may, under certain circumstances, still be acceptable.

Modifications

The water quality guidelines in this document are intended to provide the water quality manager with a preliminary indication of the problems that an industry may face as a result of a change in the quality of the water supply.

The wide diversity of supposedly similar industries has been mentioned in Chapter 2, and any detailed assessment of the water quality requirements of a particular industry will therefore need to be made on a site-specific basis.

A site-specific evaluation will require a visit to the factory to determine the proportion of water needed for each process category as indicated in the table below. This breakdown will show which process category requires the major portion of the water supply, and provide a basis for assessing the cost to that industry of not providing the quality of water it needs. An example of a site-specific assessment of water use for a particular industrial water process category is given in the table below.

Process	**Fraction of Water use by Process Category (%)**			
	1	**2**	**3**	**4**
Cooling	-	-	-	-
Steam generation	-	< 5	-	
Process water	-	< 5	< 10	25
Product water	-	-	-	-
Utilities	-	-	5	-
Washing	-	-	60	-
TOTAL	**nil**	**< 10**	**65 - 70**	**25**

In the example shown in the above table, a water quality suitable for Category 3 processes would satisfy 65 % - 70 % of the water requirements of a factory.

Sources of Information

It is simply not possible either to include all the constituents which may affect the fitness of water for industrial use, or to include all the relevant information on the constituents for which criteria were developed.

The user is therefore referred to additional sources of information for each constituent. These same sources of information can 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, besides the publications referenced in the guidelines, there is also a wealth of unpublished information. This is available from various industry-specific associations or institutes, the industries themselves or individuals with long-standing experience in specific industries or industrial applications. The list of acknowledgements of people and organisations who participated in the development of these guidelines provided in the front of the document is a good starting point for accessing this information.

Chapter 5

Water Quality Constituents

Alkalinity

Background Information

Introduction

Alkalinity is a measure of the acid-neutralising capacity of water and as such, it is also an indication of the base content. Ions which commonly contribute to the alkalinity of water are bicarbonate (HCO_3^-) and carbonate (CO_3^{-2}), and at high pH values, hydroxide (OH^-). The total alkalinity is the sum of these three ions. Other ions which can also contribute to the alkalinity are borates, silicates, phosphates and some organic substances.

Occurrence

The geological nature of the rocks and soils in a particular catchment area strongly influences the natural alkaline content of water. Alkalinity of natural water can range from zero to several hundred mg $CaCO_3$/L. Alkalinity can be neutralised in rivers, dams and ground waters by acid inputs from mining or industrial activities.

The alkalinity of water is governed by the concentration of the conjugate base ions, of which bicarbonate is the most common. At pH values less than 8.3 the bicarbonate ion concentration is the predominant form of alkalinity whereas at pH values above 8.3 and 9.6, the concentrations of the carbonate and hydroxide ions respectively are of consequence. Bicarbonate alkalinity is neutralised above about pH 4. Waters with pH values higher than four will contain increasing amounts of alkalinity. Alkalinity can be readily neutralised in water by acid inflows. Where acid inputs predominate and neutralise the total alkalinity of water, the pH will fall to below a pH value of four and net amounts of acidity will appear. Where alkalis are added to a water, the alkalinity and hence the pH will increase.

Interactions

Alkalinity is dependent on the concentrations of all acidic and basic species present, and as such is governed by the full chemical composition of the water as well as physical parameters, such as the temperature and electrical conductivity (see **total dissolved solids**). The concentration of the dissolved carbon dioxide in water is closely related to the alkalinity.

Measurement

The criteria are given in terms of the total alkalinity concentration, expressed as mg $CaCO_3$/L. The reference method for the determination of total alkalinity is by titration of the sample with a strong acid (usually hydrochloric acid), of known concentration, to the methyl orange end-point. Other methods of determining the total alkalinity, such as potentiometric titration and titration using a suitable mixed indicator are also acceptable. The characteristics of other methods relative to the reference method should be known.

Data Interpretation

Mean values should be used to compare with the criteria given. Alkalinity measurements should also be interpreted in conjunction with the **pH**, as well as related water properties such as **total hardness** and the relative concentrations of cations and anions present. Alkalinity is an important property in evaluating the corrosivity of water and should also be interpreted in relation to the various corrosion and scaling indices.

Treatment Options

Treatment of industrial water may involve the removal or addition of alkalinity according to the requirements of the user.

Alkalinity may be added to water by dosing it with a solution of an alkaline reagent. This is usually sodium carbonate, although sodium bicarbonate or calcium carbonate can be used for small increases in alkalinity. Addition would be by means of a dosing pump controlled by a pH meter. Calcium carbonate, however, is sparingly soluble in water and can be simply dosed by passing the stream of water over a bed of marble chips. This may be done to reduce the aggressive nature of the water by increasing its tendency to form scale.

Removal of alkalinity is most commonly achieved by

dosing the water with a weak acid solution (hydrochloric or sulphuric acid), controlled by a pH controller;

a dealkalisation ion exchange process, in which the alkalinity is liberated as carbon dioxide which is then removed from the water in a stripping tower.

Adjustment of alkalinity requires instrumental control to be consistently effective. The dosing of acid solutions may be hazardous to unskilled operators.

The ion exchange process will produce a waste stream which may present disposal difficulties.

The Effects of Alkalinity

Norms

The norms used to measure the suitability of the water supply in terms of the presence of alkalinity are

the extent of damage caused to equipment and structures as a result of the alkalinity;
the extent to which the alkalinity in the water supply interferes with industrial processes;
the extent of impairment of product quality caused by the presence of alkalinity; and
the degree of complexity involved in the treatment and/or disposal of wastes generated as a result of the concentration of the alkalinity.

Effects

The effects of changes in the concentration of alkalinity in a water source are discussed below in terms of the norms to measure fitness for use.

' **Damage to equipment and structures**

Scaling is chiefly the deposition of insoluble calcium carbonate and is a major problem wherever heating of water or heat exchange takes place. Elevated concentrations of alkalinity and hardness are conducive to scaling. Scale accumulates on heat exchange surfaces, insulating them, and reduces heat exchange efficiency. Scaling of internal passageways of heat exchangers and pipelines decreases working volume and restricts flow.

Scaling may also lead to problems in other items of industrial equipment, such as screens, vacuum pumps, heating baths, steam-heated drying drums and tanks. Scale can also form on paper machine wires and felts, necessitating special cleaning procedures that can reduce their active life.

Uneven distribution of scale in boilers can lead to localised overheating with subsequent boiler failure due to distortion and fatigue. High alkalinity in boiler feed water may affect surface tension properties promoting foaming and the carryover of undesirable dissolved salts with the steam. Excessive bicarbonates and carbonates in boiler water gives rise to carbon dioxide in the steam, which promotes corrosion in condensate and steam pipelines.

Low alkalinity water may also be undesirable, since the lack of pH buffering capacity associated with low alkalinity may be conducive to corrosion. A certain degree of alkalinity may act as a corrosion inhibitor.

' **Interference with processes**

High alkalinity concentrations promote precipitation of calcium carbonate especially in hard waters or in alkaline processes. Such precipitates may interfere with a number of processes in the manufacture of textiles or finishing of leather, since they may react with certain dyestuffs.

Highly alkaline water is particularly detrimental in the food processing and beverage industries. Use thereof may result in the neutralisation of natural taste-producing substances, rendering them more susceptible to bacterial activity. Alkalinity concentrations should therefore be kept uniformly low to prevent reaction with the acidifying agents of flavouring.

' **Product quality**

Undesirably high concentrations of alkalinity result in the impairment of product quality due to loss of flavour and flat-tasting drinks.

Uneven deposition of calcium carbonate precipitates in cloth and on hides may result in patchiness of dyeing or blemishes in colour and hue.

' **Complexity of waste handling**

Generally, the handling of effluents with high alkalinity concentrations does not present serious problems, and no limits to alkalinity are specified in the General Standards for discharges. However, some water treatment processes to remove or reduce alkalinity can result in raised TDS or chloride concentrations in the effluents of a specific facility, and may require special treatment before discharge.

Criteria The tables below describe the effects of alkalinity on industrial equipment and processes for each of the four categories of industrial processes.

Table 1: Effects of Alkalinity on Category 1 Industrial Processes

Range of concentration (mg $CaCO_3$/L)	**Damage to equipment and structures**	**Interference with processes**	**Product quality**	**Complexity of waste handling**
0 - 50 ***Target Water Quality Range***	***No or negligible damage due to scaling. Water may be corrosive***	***No or negligible interference with processes***	***No or negligible effect on product quality***	***No problems except for disposal of highly saline effluents from low frequency regeneration of demineralisation plant***
50 - 120	Mild to moderate damage due to scaling or precipitation	Mild to moderate interference with processes	Little to minor impairment of product quality	No problems except for disposal of highly saline effluents from low to moderate frequency regeneration of demineralisation plant
120 - 300	Moderate to significant damage due to scaling or precipitation	Moderate to significant interference with processes	Moderate to significant impairment of product quality	No problems except for disposal of highly saline effluents from moderate frequency regeneration of de-mineralisation plant
> 300	Significant to major damage due to heavy scaling or precipitation	Significant to major interference with processes	Significant to major impairment of product quality	Treatment may be required to reduce TDS levels to meet local or General Standards

Examples of Category 1 Industrial Processes

Cooling Water	**Steam Generation**	**Process Water**	**Wash Water**
Evaporative cooling (high recycle)	High pressure boilers (demineralisation - plant feed water)	Phase separation Petrochemicals Pharmaceuticals (demineralisation - feed water)	Washing with no residuals (electronic parts) (demineralisation - feed water)

Table 2: Effects of Alkalinity on Category 2 Industrial Processes

Range of concentration (mg $CaCO_3$/L)	**Damage to equipment and structures**	**Interference with processes**	**Product quality**	**Complexity of waste handling**
0 - 120 ***Target Water Quality Range***	***No or negligible damage due to scaling. Water may be corrosive***	***No or negligible interference with processes***	***No or negligible effect on product quality***	***No problems except for disposal of highly saline effluents from low frequency regeneration of demineralisation plant***
120 - 250	Mild to moderate damage due to scaling or precipitation	Mild to moderate interference with processes	Little to minor impairment of product quality	No problems except for disposal of highly saline effluents from low to moderate frequency regeneration of demineralisation plant
250 - 600	Moderate to significant damage due to scaling or precipitation	Moderate to significant interference with processes	Moderate to significant impairment of product quality	No problems except for disposal of highly saline effluents from moderate frequency regeneration of demineralisation plant
> 600	Significant to major damage due to heavy scaling or precipitation	Significant to major interference with processes	Significant to major impairment of product quality	Treatment may be required to reduce TDS levels to meet General standards or local requirements

Examples of Category 2 Industrial Processes

Heat Exchange	**Steam Generation**	**Process Water**	**Product Water**
Evaporative cooling (high recycle)	High pressure boilers (demineralisation - plant feed water)	Solvent agent	Beverages
Solution cooling		Heat transfer medium	Dairy
Water heating		Humidification	Petrochemical
		Lubrication	
		Gas cleaning	

Table 3: Effects of Alkalinity on Category 3 Industrial Processes

Range of concentration (mg $CaCO_3$/L)	Damage to equipment and structures	Interference with processes	Product quality	Complexity of waste handling
0 - 300 Target Water Quality Range	***No to minor damage due to scaling. Water may be corrosive***	***No to minor interference with processes***	***No to minor impairment of product quality***	***No problems except for disposal of highly saline effluents from low to moderate frequency regeneration of demineralisation plant***
300 - 600	Moderate to significant damage due to scaling or precipitation	Moderate to significant interference with processes	Moderate to significant impairment of product quality	No problems except for disposal of highly saline effluents from moderate frequency regeneration of demineralisation plant
> 600	Significant to major damage due to heavy scaling or precipitation	Significant to major interference with processes	Significant to major impairment of product quality	Treatment may be required to reduce TDS levels to meet local or General Standards

Examples of Category 3 Industrial Processes

Cooling Water	Steam Generation	Process Water	Product Water	Utility Water
Evaporative cooling (once through) Bearing cooling Mould cooling	Low pressure boilers:softening process feed water	Solvent Dilution agent Transport agent Gland seal Vacuum seal Lubrication Descaling (iron and steel industry) Gas scrubbing	Beverages Food products Baking and confectionery Chemicals	Surface washing (table tops, walls) Domestic use Fire fighting

Table 4: Effects of Alkalinity on Category 4 Industrial Processes

Range of concentration (mg $CaCO_3$/L)	Damage to equipment and structures	Interference with processes	Product quality	Complexity of waste handling
0 - 1 200 Target Water Quality Range)	***No or negligible damage expected, particularly in acidic environments***	***No interference with processes***	***No or negligible effect on product quality***	***No problems in waste handling***
> 1 200	Slight damage due to scaling or precipitation can be expected	No or minor interference with processes	Minor impairment of product quality due to precipitation can be expected	Treatment may be required to reduce TDS concentrations to meet General Standards or local requirements for discharges

Examples of Category 4 Industrial Processes

Cooling Water	**Process Water**	**Utility Water**	**Wash Water**
Ash quenching	Transport agent	Dust suppression Fire fighting Irrigation	Rough washing (floors, rough apparatus, trucks, raw materials)

Sources of Information

APHA 1985. *Standard Methods for the Examination of Water and Waste Water*, 16th Edition. American Public Health Association, American Water Works Association, Water Pollution Control Federation. Published by the American Public Health Association, Washington DC, USA.

AWWA 1971. *Water Quality and Treatment. A Handbook of Public Water Supplies*, 3rd Edition. The American Water Works Association. McGraw-Hill Book Company, New York.

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Chemical Oxygen Demand

Background Information

Introduction Chemical oxygen demand (COD) is defined as *a measure of the oxygen equivalent of the organic matter content of a sample that is susceptible to oxidation by a strong chemical oxidant.* Most organic compounds can be oxidised to between 95 % - 100 % of their theoretical value. The COD therefore gives an estimate of the organic matter present in a water body.

Occurrence In the aquatic environment, two forms of organic matter exist, autochthonous organic matter, which arises within the water body itself through the growth and death of aquatic organisms and allochthonous organic matter, which originates outside a water body. Human activities such as agricultural and stock farming and the production of industrial and domestic wastes are significant sources of organic matter in the aquatic environment. The organic matter can be present either in dissolved form or as particulate organic matter. The former may be associated with undesirable tastes and odours, while the particulate organic matter contributes to the suspended solids load of a water body.

Interactions The dissolved oxygen concentration of water is strongly affected by the presence of oxidisable matter and as such is affected by the dissolved organic carbon (DOC), biological oxygen demand (BOD) and organic nitrogen concentrations. Other factors that affect the dissolved organic oxygen concentration are temperature and pressure.

Measurement Chemical oxygen demand refers to the oxygen equivalent of the oxidisable matter in a sample following oxidation with a strong chemical oxidant. Concentrations are expressed as mg O_2/L. The COD test is non-specific and does not distinguish between the organic and inorganic matter in a sample. There is, however, a direct empirical relationship between the COD, the BOD and the total organic carbon (TOC) for samples from a specific source. Therefore, once a correlation has been established, the COD test is useful for monitoring and control purposes.

Data Interpretation Mean values should be used to compare with the criteria given. The COD concentration should also be interpreted in relation to **turbidity** measurements.

Treatment Options Removal of organic carbon from industrial water supplies can be achieved by a number of techniques. Assuming the residual concentrations are only marginally above acceptable levels, the treatment methods include:

Filtration of the water through a slow sand filter. In time, the filter develops a biologically active surface layer which metabolises the organic carbonaceous material in the water, effecting measurable purification.

Some forms of organic carbon are amenable to removal by coagulation, flocculation, clarification (by settlement or flotation) and filtration. An activated carbon filtration step may be beneficial.

Organic carbon is readily oxidised by strong oxidising agents such as combinations of hydrogen peroxide, ozone or peroxone and UV light.

Membrane processes.

In many cases, a combination of treatment processes will be needed to achieve the water quality required. The strong oxidising agents mentioned above are hazardous if handled carelessly.

The Effects of the Chemical Oxygen Demand

Norms

The norms used to measure the suitability of the water supply in terms of the chemical oxygen demand are

the extent of damage caused to equipment and structures as a result of the chemical oxygen demand;
the extent to which the chemical oxygen demand in the water supply interferes with industrial processes;
the extent of impairment of product quality caused by the chemical oxygen demand;
the degree of complexity involved in the treatment and/or disposal of wastes generated as a result of the chemical oxygen demand concentration.

Effects

The effects of changes in the chemical oxygen demand concentration in a water source are discussed below in terms of the norms to measure fitness for use.

- **Damage to equipment and structures**

Organic matter adhering to or absorbed by mucilaginous biofilms augments material fouling in heat exchanger and cooling systems. It also promotes the formation of microbial slimes, acting as a nutrient source for bacterial growth. Such microbial slimes often contain sulphate-reducing bacteria (SRB), which are responsible for extensive damage to heat exchange and cooling systems through microbially-influenced / induced corrosion (MIC).

Organic matter can also foul ion exchange resins and electrodialysis and pressure membrane processes, thereby curtailing operational cycles before regeneration, and causing loss of exchange capacity due to irreversible exchanges. Products of degraded organic compounds passing through ion exchange beds can cause problems in steam generation systems by promoting corrosion/erosion in steam and condensate return lines.

- **Interference with processes**

Some organic acids of humic origin or soil-derived material interfere with the colour of dyes used in the finishing of leather and in the production of paper and textiles. The additional oxygen demand exerted by excessive organic matter in oxidative bleaching operations and cooling systems leads to the use of surplus bleaching agent or increased quantities of oxidising biocides respectively.

The presence of organic matter in feedwater promotes foaming in boilers as a result of changed surface tension characteristics. Similarly, carbonation difficulties may be experienced in the bottling of beverages.

- **Product quality**

  Some organic acids of humic origin stain leather or textiles. Certain organic compounds create undesirable tastes or unpleasant odours even at low concentrations. Chlorinated water used for beverages may contain possible carcinogens.

  Pyrogens in pharmaceutical water can induce fevers. Microbial slimes, promoted by organic nutrients, can impair paper quality by forming slick spots or slime inclusions in the paper.

- **Complexity of waste handling**

  The complexity of waste handling depends on the nature of the organic matter constituting the COD. Particulate organics may be reasonably simply removed through filtration or flocculation and sedimentation. More sophisticated techniques or methods may be required to remove dissolved organic substances. The General Standard for discharges allows a concentration of less than 75 mg O_2/L in an effluent.

Criteria The tables below describe the effects of the COD on industrial equipment and processes for each of the four categories of industrial processes.

Table 1: Effects of the COD on Category 1 Industrial Processes

Range of concentration (mg O_2/L)	**Damage to equipment and structures**	**Interference with processes**	**Product quality**	**Complexity of waste handling**
0 - 10 Target Water Quality Range	***No damage due to fouling***	***No interference with processes***	***No effect on product quality***	***No problems in waste handling***
10 - 30	Minor to moderate damage due to fouling and/or MIC	Slight to minor interference with processes	Negligible to minor impairment of product quality	No problems in waste handling
30 - 50	Moderate to significant damage due to fouling and/or MIC	Moderate to significant interference with processes	Moderate to significant impairment of product quality	No problems in waste handling
> 50	Significant to major damage due to fouling and/or MIC may be expected	Significant to major interference with processes may be expected	Significant to major impairment of product quality may be expected	Reduction in COD may be required to meet General Standard or local requirement

Examples of Category 1 Industrial Processes

Cooling Water	**Steam Generation**	**Process Water**	**Wash Water**
Evaporative cooling (high recycle)	High pressure boilers (demineralisation - plant feed water)	Phase separation Petrochemicals Pharmaceuticals	Washing with no residuals (electronic parts)

Table 2: Effects of the COD on Category 2 Industrial Processes

Range of concentration (mg O_2/L)	**Damage to equipment and structures**	**Interference with processes**	**Product quality**	**Complexity of waste handling**
0 - 15 ***Target Water Quality Range***	***No damage due to fouling and/or MIC***	***No interference with processes***	***No effect on product quality***	***No problems in waste handling***
15 - 40	Minor to moderate damage due to fouling and/or MIC	Slight to minor interference with processes	Negligible to minor impairment of product quality	No problems in waste handling
40 - 70	Moderate to significant damage due to fouling and/or MIC	Moderate to significant interference with processes	Moderate to significant impairment of product quality	No problems in waste handling
> 70	Significant to major damage due to fouling and/or MIC may be expected	Significant to major interference with processes may be expected	Significant to major impairment of product quality may be expected	Reduction in COD may be required to meet General Standard or local requirement

Examples of Category 2 Industrial Processes

Heat Exchange	**Steam Generation**	**Process Water**	**Product Water**
Evaporative cooling (high recycle)	High pressure boilers (demineralisation - plant feed water)	Solvent agent	Beverages
Solution cooling		Heat transfer medium	Dairy
Water heating		Humidification	Petrochemical
		Lubrication	
		Gas cleaning	

Table 3: Effects of the COD on Category 3 Industrial Processes

Range of concentration (mg O_2/L)	**Damage to equipment and structures**	**Interference with processes**	**Product quality**	**Complexity of waste handling**
0 - 30 Target Water Quality Range	***No damage due to fouling and/or MIC***	***No interference with processes***	***No effect on product quality***	***No problems in waste handling***
30 - 50	Minor to moderate damage due to fouling and/or MICs	Slight to minor interference with processes	Negligible to minor impairment of product quality	No problems in waste handling
50 - 100	Moderate to significant damage due to fouling and/or MIC	Moderate to significant interference with processes	Moderate to significant impairment of product quality	Reduction in COD may be required to meet General Standard or local requirement
> 100	Significant to major damage due to fouling and/or MIC may be expected	Significant to major interference with processes may be expected	Significant to major impairment of product quality may be expected	Reduction in COD required to meet General Standard or local requirement

Examples of Category 3 Industrial Processes

Cooling Water	**Steam Generation**	**Process Water**	**Product Water**	**Utility Water**
Evaporative cooling (once through) Bearing cooling Mould cooling	Low pressure boilers: softening process feed water	Solvent Dilution agent Transport agent Gland seal Vacuum seal Lubrication Descaling (Iron and steel industry) Gas scrubbing	Beverages Food products Baking and confectionery Chemicals	Surface washing (table tops, walls) Domestic use Fire fighting

Table 4: Effects of the COD on Category 4 Industrial Processes

Range of concentration (mg O_2/L)	Damage to equipment and structures	Interference with processes	Product quality	Complexity of waste handling
0 - 75 ***Target Water Quality Range***	***No to minor damage due to fouling and/or MIC***	***No interference with processes***	***No effect on product quality***	***No problems in waste handling***
> 75	Moderate to major damage due to fouling and/or MIC may be expected	Negligible to minor interference with processes may be expected	No or minor impairment of product quality may be expected	Reduction in COD required to meet General Standard or local requirement

Examples of Category 4 Processes

Cooling Water	**Process Water**	**Utility Water**	**Wash Water**
Ash quenching	Transport agent	Dust suppression Fire fighting Irrigation	Rough washing (floors, rough apparatus, trucks, raw materials)

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.

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Chloride

Background Information

Introduction

Chloride is the anion of the element chlorine, which does not occur in nature but is found only as chloride. The chlorides of sodium, potassium, calcium and magnesium are all highly soluble in water.

Chloride is of concern in water supplies because elevated concentrations accelerate the corrosion rate of metals and shorten the lifetime of equipment and structures.

Occurrence

Chloride is a common constituent of water, is highly soluble and once in solution tends to accumulate. Typically, the concentrations of chloride in fresh water range from a few to several hundred mg/L. In sea water the concentration is approximately 19 800 mg/L. Chloride inputs to surface water can arise from irrigation return flows, sewage effluent discharges and various industrial processes.

Interactions

The taste threshold and the corrosion acceleration threshold of chloride are dependent on the action of other water quality constituents such as the associated cations, the pH and the calcium carbonate concentration.

Measurement

The criteria are given in terms of the dissolved chloride concentration, in units of mg Cl/L. The reference method for the determination of dissolved chloride is usually by means of the ferricyanide method and colorimetry. If other methods are used, their characteristics relative to the reference method should be known.

Data Interpretation

Mean values should be used to compare with the criteria given. Chloride concentrations should also be interpreted in conjunction with the concentrations of the major cations and anions present.

Treatment Options

Chlorides are highly soluble in water and cannot be precipitated at concentrations normally present. Chloride can be removed from water by **electrolysis** to form chlorine gas liberated at the anode. Electrolysis is not effective where the conductivity and the chloride concentration are low.

More commonly, chloride is removed together with other ions using

anion exchange resin beds, in which all significant anions will be removed; and

desalination techniques such as reverse osmosis and electrodialysis.

The concentrated waste streams generated from ion exchange and desalination processes can cause disposal difficulties. Desalination techniques require skilled operation, control and maintenance. Capital and operating costs are typically high.

The Effects of Chloride

Norms

The norms used to measure the suitability of the water supply in terms of the presence of chloride are:

the extent of damage caused to equipment and structures as a result of chlorides;
the extent to which chlorides in the water supply interfere with industrial processes;
the extent of impairment of product quality caused by the presence of chlorides; and
the degree of complexity involved in the treatment and/or disposal of wastes generated as a result of the concentration of the chlorides.

Effects

The effects of changes in the concentration of chloride in a water source are discussed below in terms of the norms to measure fitness for use.

- **Damage to equipment and structures**

  High, but unspecified chloride concentrations enhance corrosion and its effect is synergistic when pH values are low. Chlorides are particularly aggressive to stainless steel, causing localised (pitting), stress and cracking corrosion. Chlorides may also form rough iridescent and crystalline deposits in cadmium, copper, silver and tin plating tanks.

- **Interference with processes**

  It appears that chlorides cause little interference with industrial processes and, if necessary, can be removed by any demineralising process.

  In the dairy industry, chlorides can displace calcium from casein resulting in greater water uptake and soft curds.

- **Product quality**

  At concentrations above 20 mg Cl/L, chlorides in rinse water may give rise to speckled rust in some finished steel products. The quality of some paper grades required for plastic impregnation or for dielectric purposes may be affected by undesirably high chloride concentrations. Concentrations of up to 60 - 100 mg Cl/L chlorides have a mellowing effect on beer, but above this concentration, chlorides may be harmful to the product.

- **Complexity of waste handling**

  There are no specific removal methods for chlorides and their concentrations are usually controlled by the use of demineralising techniques. Removal of chlorides usually results in an increase in the TDS concentration of the effluents generated by a facility. Although the General Standards for the discharge of effluents do not specify limits for chloride, the chloride concentration should not be greater than that which would result in the electrical conductivity of an effluent exceeding the limit for conductivity in the General Standards.

Criteria The tables below describe the effects of chlorides on industrial equipment and processes for each of the four categories of industrial processes.

Table 1: Effects of Chlorides on Category 1 Industrial Processes

Range of concentration (mg Cl/L)	Damage to equipment and structures	Interference with processes	Product quality	Complexity of waste handling
0 - 20 Target Water Quality Range	***No or negligible damage due to corrosion***	***No process interference expected***	***No effect on product quality***	***No problems except for disposal of highly saline effluents from low frequency regeneration of demineralisation plant***
20 - 50	Minor damage due to corrosion particularly if pH is low and temperature elevated	No or negligible interference with processes may be expected	No to minor impairment of product quality	No problems except for disposal of highly saline effluents from low frequency regeneration of demineralisation plant
50 - 120	Moderate damage due to corrosion particularly if pH is low and temperature elevated	Slight to moderate interference with processes possible	Minor to moderate impairment of product quality may occur	No problems except for disposal of highly saline effluents from low to moderate frequency regeneration of demineralisation plant
> 120	Major damage likely due to corrosion particularly if pH is low and temperature elevated	Moderate to major interference with processes may be expected	Moderate to major impairment of product quality may be expected	Major reduction in chloride content of effluents may be required to comply with local or General Standards for discharges

Examples of Category 1 Industrial Processes

Cooling Water	**Steam Generation**	**Process Water**	**Wash Water**
Evaporative cooling (high recycle)	High pressure boilers- (demineralisation - plant feed water)	Phase separation Petrochemicals Pharmaceuticals	Washing with no residuals (electronic parts)

Table 2: Effects of Chlorides on Category 2 Industrial Processes

Range of concentration (mg Cl/L)	**Damage to equipment and structures**	**Interference with processes**	**Product quality**	**Complexity of waste handling**
0 - 40 Target Water Quality Range	***No or negligible damage due to corrosion***	***No process interference expected***	***Generally no effect on product quality, but speckled rust may be expected***	***No problems except for disposal of highly saline effluents from low frequency re-generation of demineralisation plant***
40 - 80	Minor damage due to corrosion, particularly if pH is low and temperature elevated	Negligible to minor interference with processes may be expected	Slight to minor impairment of product quality may be expected	No problems except for disposal of highly saline effluents from low to moderate frequency regeneration of demineralisation plant
80 - 200	Moderate damage due to corrosion particularly if pH is low and temperature elevated	Moderate to significant interference with processes may be expected	Moderate impairment of product quality may be expected	No problems except for disposal of highly saline effluents from moderate frequency regeneration of demineralisation plant
> 200	Moderate to major damage due to corrosion particularly if pH is low and temperature elevated	Significant to major interference with processes expected	Moderate to major impairment of product quality expected	Major reduction in chloride content may be required to comply with local or General Standards

Examples of Category 2 Industrial Processes

Heat Exchange

Evaporative cooling (high recycle)
Solution cooling
Water heating

Steam Generation

High pressure boilers (demineralisation-plant feed water)

Process Water

Solvent agent
Heat transfer medium
Humidification
Lubrication
Gas cleaning

Product Water

Beverages
Dairy
Petrochemical

Table 3: Effects of Chlorides on Category 3 Industrial Processes

Range of concentration (mg Cl/L)	Damage to equipment and structures	Interference with processes	Product quality	Complexity of waste handling
0 - 100 Target Water Quality Range	***No or minor damage due to corrosion particularly if pH low and temperature elevated***	***No or little interference with processes expected***	***Generally no effect on product quality, but speckled rust may be expected***	***No problems in waste handling***
100 - 200	Minor to moderate damage due to corrosion particularly if pH low and temperature elevated	Mild to moderate interference with processes possible	Mild to moderate impairment of product quality may be expected	No problems in waste handling
> 200	Moderate to major damage likely due to corrosion particularly if pH is low and temperature elevated	Significant to major interference with processes expected	Moderate to major impairment of product quality expected	Moderate to major reduction in chloride content of effluents to comply with local or General Standards for discharges

Examples of Category 3 Industrial Processes

Cooling Water

Evaporative cooling (once through)
Bearing cooling
Mould cooling

Steam Generation

Low pressure boilers: softening process feed water

Process Water

Solvent
Dilution agent
Transport agent
Gland seal
Vacuum seal
Lubrication
Descaling (iron and steel industry)
Gas scrubbing

Product Water

Beverages
Food products
Baking and confectionery
Chemicals

Utility Water

Surface washing (table tops, walls)
Domestic use
Fire fighting

Table 4: Effects of Chlorides on Category 4 Industrial Processes

Range of concentration (mg Cl/L)	Damage to equipment and structures	Interference with processes	Product quality	Complexity of waste handling
0 - 500 Target Water Quality Range	***No or negligible damage expected provided exposure not excessive***	***No process interference expected***	***No effect on product quality***	***No problems in waste handling***
> 500	Minor to major damage due to corrosion may be expected	No or little process interference expected	Minor impairment of product quality may be expected	Minor to major reduction in salt content of effluents required to comply with local or General Standards for discharges

Examples of Category 4 Industrial Processes

Cooling Water	**Process Water**	**Utility Water**	**Wash Water**
Ash quenching	Transport agent	Dust suppression Fire fighting Irrigation	Rough washing (floors, rough apparatus, trucks, raw materials)

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Iron

Background Information

Introduction

Pure iron is silvery in colour but usually appears as greyish-black or brown deposits as a result of oxidation. Iron is found in three oxidation states, namely 0, II and III of which the III oxidation state is the most common. In water, iron can be present as dissolved ferric iron, Fe(III), as ferrous iron, Fe(II) or as suspended iron hydroxides. Biologically, iron is an essential micronutrient required by all living organisms.

Occurrence

Iron is the fourth most abundant element and constitutes five percent of the earth's crust. It is found in many minerals, the most common of which is haematite (Fe_2O_3), widely used as an iron ore for metallurgical purposes. Other important iron minerals are pyrite (FeS_2), siderite ($FeCO_3$), magnetite (Fe_3O_4), goethite ($Fe_2O_3 \cdot H_2O$) and limonite ($2Fe_2O_3 \cdot 3H_2O$), as well as a number of mixed ores, such as chalcopyrite ($CuFeS_2$) and arsenopyrite (FeAsS). Pyrite is often associated with coal formations and iron may also occasionally be found in its elemental form, either as terrestrial iron or as meteoric iron. The reddish colour of soil is due to iron, the median concentration in soil being 4.0 % (m/m). Typically, the concentration of dissolved iron in

unpolluted surface water is between 1 and 500 µg Fe/L, and
sea water is approximately 2 µg Fe/L.

The speciation of iron is strongly related to the pH and the redox potential of the water. At neutral or alkaline pH values, under oxidising conditions, the concentration of dissolved iron is usually in the low µg/L range, but under reducing conditions, soluble ferrous iron can be formed and substantially higher concentrations in the mg/L range may be encountered. Where marked acidification of the water occurs, for example acid mine drainage, and the pH is less than 3.5, the dissolved iron concentrations can be in the range of several hundreds of mg/L.

Micro-organisms, particularly iron bacteria such as *Gallionella spp*., play a significant role in the natural cycling of iron between the dissolved and precipitated phases. This activity occurs predominantly at the water sediment interface.

Interactions

The dissolved iron concentration in water is dependent on the **pH**, redox potential turbidity, suspended matter, the aluminium concentration and the occurrence of several heavy metals, notably **manganese**. The natural cycling of iron can also result in the coprecipitation of trace metals such as arsenic, copper, cadmium and lead.

Measurement

The criteria are given in terms of the total iron concentrations, expressed in units of mg Fe/L. The reference method for the determination of iron is by atomic absorption spectrometry (AAS) using an air acetylene flame. Filtration followed by acidification of the sample prior to AAS analysis is required. However, measurement of the total iron concentration requires acidification followed by filtration prior to AAS analysis. Where other methods of analysis are used, their characteristics relative to the reference method should be known.

Data Interpretation

Mean values should be used to compare with the criteria given. Turbidity and pH must be taken into account in the interpretation of iron concentrations.

Treatment Options

Iron is commonly removed from water using an oxidising process which converts the iron into an insoluble oxide removable by filtration. The following treatment approaches are used:

> The water can be **aerated** by devices such as fountains, cascades or mechanical aeration.
>
> The water can be **chemically oxidised** by dosing with chlorine, hydrogen peroxide, ozone or other strong oxidants. On an industrial scale, chlorine is commonly used as the chemical oxidant. Post-treatment high levels of residual chlorine should be avoided since this can interfere with the quality of the water.

Removal of iron using aeration techniques, followed by settlement of iron oxide particles, usually needs to be closely controlled and monitored because the consequences of incomplete treatment may be severe.

For the optimisation of treatment processes it is important to determine both the total and dissolved iron species and their relative concentrations.

The Effects of Iron

Norms

The norms used to measure the suitability of the water supply in terms of the presence of iron are:

> the extent of damage caused to equipment and structures as a result of iron;
> the extent to which iron in the water supply interferes with industrial processes;
> the extent of impairment of product quality caused by the presence of iron; and
> the degree of complexity involved in the treatment and/or disposal of wastes generated as a result of the concentration of iron.

Effects

The effects of changes in the concentration of iron in a water source are discussed below in terms of the norms to measure fitness for use.

' **Damage to equipment and structures**

> Iron may cause damage to equipment and structures in a number of ways. On precipitation it contributes to the sediment deposits which foul boilers, heat exchangers and pipelines. Localised hot spots occurring under such iron precipitates in boilers or heat exchangers may cause overheating and subsequent structural damage.
>
> Oxidised iron deep within the resin structure of ion exchange columns can destroy the resin exchange capacity.
>
> In acidic industrial environments, protective leather clothing may be damaged through the effect of iron on the ageing properties of leather.

- **Interference with processes**

  Iron can interfere with the efficient and effective operation of processes in various ways. It can form dark-coloured precipitates during tanning, which subsequently reduce tanning efficiency.

  In dyeing operations, iron may form complexes with acid dyes, rendering them inactive and resulting in discolouration, colour changes and dulling of shades. The presence of iron in concentrations above 1.0 mg/L during bleaching operations produces a yellowing effect.

  In the production of pulp for paper making, iron complexes with lignin hinder the removal of lignin during washing of the crude pulp.

  Iron precipitates may foul ion exchange resins, thereby reducing their ion exchange efficiency.

- **Product quality**

  In the beverage and food processing industries, the presence of undesirably high concentrations of iron in the water supply may give rise to taste, odour and discolouration problems in the products. Its ability to catalyse the oxidation of fatty matter and the hydrolysis of milk constituents may cause rancidity in dairy products. Beer may take on a bad flavour and iron can contribute to the oxidation of beer tannins, resulting in the discolouration of the beer.

  The tendency of iron to be absorbed by cellulose fibres results in discolouration of pulp and paper products. The presence of precipitated iron discolours water and causes black or brown stains in newly-produced fabrics as well as in laundry. In hydrogen peroxide bleaching operations, iron can catalyse the degradation of cellulose fibres, thus impairing the fabric with small holes. Hides may be discoloured and stained due to the formation of dark precipitates during tanning.

- **Complexity of waste handling**

  Removal of iron from solution is generally achieved either through oxidation precipitation and filtration, or ion exchange methods. The techniques involved in these methods are relatively simple to reasonably sophisticated. Depending on the method used, the iron removed is a waste material either in the form of a sludge or in solution. No concentration limits have been specified in the General Standards for the discharge of iron in effluents.

Criteria The tables below describe the effects of iron concentration on industrial equipment and processes for each of the four categories of industrial processes.

Table 1: Effects of Iron on Category 1 Industrial Processes

Range of concentration (mg Fe/L)	Damage to equipment and structures	Interference with processes	Product quality	Complexity of waste handling
0.0 - 0.1 Target Water Quality Range	***No damage due to precipitation of iron compounds***	***No interference with processes***	***No effect on product quality***	***No problems in waste handling***
0.1 - 0.3	Minor to moderate damage due to precipitation of iron compounds	Negligible to minor interference with processes	Negligible to minor impairment of product quality	No problems in waste handling
0.3 - 1.0	Moderate to significant damage due to precipitation of iron compounds	Moderate to significant interference with processes	Moderate to significant impairment of product quality	No problems in waste handling
> 1.0	Significant to major damage due to precipitation of iron compounds	Significant to major interference with processes	Significant to major impairment of product quality	Treatment may be required to precipitate excessive iron in effluents

Examples of Category 1 Processes

Cooling Water	**Steam Generation**	**Process Water**	**Wash Water**
Evaporative cooling (high recycle)	High pressure boilers (Demineralisation - plant feed water)	Phase separation Petrochemicals Pharmaceuticals	Washing with no residuals (electronic parts)

Table 2: Effects of Iron on Category 2 Industrial Processes

Range of concentration (mg Fe/L)	Damage to equipment and structures	Interference with processes	Product quality	Complexity of waste handling
0.0 - 0.2 Target Water Quality Range	***No damage due to precipitation of iron compounds***	***No interference with processes***	***No effect on product quality***	***No problems in waste handling***
0.2 - 0.5	Minor to moderate damage due to precipitation of iron compounds	Negligible to minor interference with processes	Negligible to minor impairment of product quality	No problems in waste handling
0.5 - 2.0	Moderate to significant damage due to precipitation of iron compounds	Moderate to significant interference with processes	Moderate to significant impairment of product quality	Treatment may be required to precipitate excessive iron in effluents
> 2.0	Significant to major damage due to precipitation of iron compounds	Significant to major interference with processes	Significant to major impairment of product quality	Treatment may be required to precipitate excessive iron in effluents

Examples of Category 2 Industrial Processes

Heat Exchange

Evaporative cooling (high recycle)
Solution cooling
Water heating

Steam Generation

High pressure boilers (Demineralisation-plant feed water)

Process Water

Solvent agent
Heat transfer medium
Humidification
Lubrication
Gas cleaning

Product Water

Beverages
Dairy
Petrochemical

Table 3: Effects of Iron on Category 3 Industrial Processes

Range of concentration (mg Fe/L)	Damage to equipment and structures	Interference with processes	Product quality	Complexity of waste handling
0.0 - 0.3 Target Water Quality Range	***No damage due to precipitation of iron compounds***	***No interference with processes***	***No effect on product quality***	***No problems in waste handling***
0.3 - 1.0	Minor to moderate damage due to small to precipitation of iron compounds	Negligible to minor interference with processes	Negligible to minor impairment of product quality	No problems in waste handling
1.0 - 10.0	Moderate to significant damage due to precipitation of iron compounds	Moderate to significant interference with processes	Moderate to significant impairment of product quality	Treatment may be required to precipitate excessive iron in effluents
> 10.0	Significant to major damage due to precipitation of iron compounds	Significant to major interference with processes	Significant to major impairment of product quality	Treatment may be required to precipitate excessive iron in effluents

Examples of Category 3 Processes

Cooling Water

Evaporative cooling (once through)
Bearing cooling
Mould cooling

Steam Generation

Low pressure boilers:softening process feed water

Process Water

Solvent
Dilution agent
Transport agent
Gland seal
Vacuum seal
Lubrication
Descaling (iron and steel industry)
Gas scrubbing

Product Water

Beverages
Food products
Baking and confectionery
Chemicals

Utility Water

Surface washing (table tops, walls)
Domestic use
Fire fighting

Table 4: Effects of Iron on Category 4 Industrial Processes

Range of concentration (mg Fe/L)	**Damage to equipment and structures**	**Interference with processes**	**Product quality**	**Complexity of waste handling**
0.0 - 10.0 Target Water Quality Range	***No or little damage due to precipitation of iron compounds***	***No interference with processes***	***No effect on product quality***	***No problems in waste handling***
> 10.0	No serious damage arising from precipitation of iron compounds	Little interference with processes, but precipitation of iron compounds may cause blockages in pipes and nozzles	Little effect on product quality	Treatment may be required to precipitate excessive iron in effluents

Examples of Category 4 Industrial Processes

Cooling Water	**Process Water**	**Utility Water**	**Wash Water**
Ash quenching	Transport agent	Dust suppression Fire fighting Irrigation	Rough washing (floors, rough apparatus, trucks, raw materials)

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Manganese

Background Information

Introduction

Manganese is a grey-white brittle metal found in several oxidation states. It is an essential element for humans and animals, but is neurotoxic in excessive amounts. At typical concentrations encountered in water, manganese has aesthetic rather than toxic effects.

Occurrence

Manganese is a relatively abundant element, constituting about 0.1 % of the earth's crust. Commonly-occurring minerals containing manganese include pyrolusite (MnO_2), manganite ($Mn_2O_3.H_2O$), rhodochrosite ($MnCO_3$) and rhodonite ($MnSiO_3$). Manganese is found in solution predominantly as the manganous ion, (Mn II$^+$), which may be stabilised by complexation with humic acids. On oxidation to the manganic ion, (Mn IV$^+$), manganese tends to precipitate out of solution to form a black hydrated oxide, which causes staining problems often associated with manganese-bearing waters.

Typically, the median concentration of manganese in

freshwater is 8 µg Mn/L with a range of 0.02 - 130 µg Mn/L;
soils is 1 000 mg Mn/kg; and
sea water, is approximately 0.2 µg Mn/L.

Manganese concentrations in the mg Mn/L range can be found in anaerobic bottom level waters, where manganese has been mobilised from the sediments.

Industrial uses of manganese include:

the manufacture of steel and manganese alloys;
the salts of manganese as drying compounds in varnishes and oils;
manganese chloride in dry cell batteries;
manganese carbonate as the pigment, "manganese white"; and
manganese dioxide in the making amethyst glass and decorative porcelain.

Interactions

The aquatic chemistry of manganese is closely associated with that of **iron** and the two elements tend to behave synergistically in their dissolution from sediments under anaerobic conditions and re-precipitation under aerobic conditions. Manganese, once in solution, is more readily stabilised by complexation than iron and is often difficult to remove from the solution, except at high pH values where it precipitates as the hydroxide. Like iron, manganese can be utilised by metallophyllic bacteria.

Other water constituents and properties that govern the action of manganese in water are **pH**, redox potential, turbidity, suspended matter and the concentration of aluminium.

Measurement

The criteria are given as the total manganese concentration, in units of mg Mn/L. The reference method for the determination of manganese in water is by atomic absorption spectrometry, using an air-acetylene flame. Samples should be acidified prior to analysis to dissolve manganese adsorbed to suspended matter. Where other methods are used, their characteristics relative to the reference method should be known.

Data Interpretation

Mean values should be used to compare with the criteria given. The occurrence of elevated manganese concentrations in surface waters are typically cyclic unless directly due to pollution by manganese bearing effluents. Transient episodes of elevated manganese concentrations in distribution systems can result in a long standing manganese problem through precipitation in reservoirs or in the distribution system, followed by gradual release. In the investigation of consumer complaints of manganese staining, point of use analyses should be done in conjunction with that of the source water.

Treatment Options

Manganese is commonly removed from water using an oxidizing process which converts the manganese into an insoluble oxide removable by filtration. The reaction is considerably more difficult to achieve than with iron and normally requires the use of a **strong oxidizing agent**. Agents commonly used include:

Chlorine
Hydrogen peroxide
Potassium permanganate
Ozone

Where the oxidant used leaves a residual, as is the case with chlorine, the residual should be removed before the water is supplied for use.

On an industrial scale, the process needs to be closely controlled and monitored because the consequences of incomplete treatment may be severe.

The Effects of Manganese

Norms

The norms used to measure the suitability of the water supply in terms of the presence of manganese are:

the extent of damage caused to equipment and structures as a result of manganese;
the extent to which manganese in the water supply interferes with industrial processes;
the extent of impairment of product quality caused by the presence of manganese; and
the degree of complexity involved in the treatment and/or disposal of wastes generated as a result of the concentration of manganese.

Effects

The effects of changes in the concentration of manganese are discussed below in terms of the norms to measure fitness for use.

- **Damage to equipment and structures**

  Precipitation of manganese contributes to the accumulation of sediments which foul boilers, heat exchange surfaces and pipelines. Localised hot spots under such deposits in boilers or heat exchangers may cause overheating and subsequent structural damage.

  The resin exchange capacity of ion exchange columns may be destroyed by the accumulation of manganese precipitates within the resin structure.

- **Interference with processes**

  High concentrations of manganese may interfere with the prechlorination of raw water supplies by creating an excessive chlorine demand on the system.

  Dark-coloured precipitates formed during the tanning process may reduce the efficiency of tanning.

  Manganese interferes with bleaching operations in both textile and pulp and paper manufacture through the oxidation of manganese to pink permanganate, which causes discolouration and dulling of the product.

  The formation of manganese complexes with dyes renders the dyes inactive. In the pulp and paper industry, manganese can form complexes with lignin and additives used in paper manufacture, hindering removal of lignin from crude pulp during washing and interfering with the proper function of the additives.

- **Product quality**

  Excessive concentrations of manganese in the water supply discolours the water. Similarly, hides, fabrics, pulp and paper may be discoloured, principally due to the tendency of manganese to be absorbed by cellulose fibres. Dark-coloured manganese precipitates stain hides and produce black or brown stains in fabrics and laundry at concentrations as low as 0.2 mg Mn/L. Due to complexing with dyes, colours of fabrics may be changed and shades dulled.

  In the beverage and food processing industry, manganese can impair tastes, and promote chemical deterioration of products.

- **Complexity of waste handling**

  The General Standard for discharge allows a maximum concentration of 0.4 mg Mn/L in effluents released into a receiving water. Waste streams from industrial processes exceeding this limit will have to be treated before discharge.

Criteria The tables below describe the effects of manganese concentration on industrial equipment and processes for each of the four categories of industrial processes.

Table 1: Effects of Manganese on Category 1 Industrial Processes

Range of concentration (mg Mn/L)	Damage to equipment and structures	Interference with processes	Product quality	Complexity of waste handling
0.0 - 0.05 Target Water Quality Range	***No damage due to precipitation of manganese compounds***	***No interference with processes***	***No effect on product quality***	***No problems in waste handling***
0.05 - 0.2	Minor to moderate damage due to precipitation of manganese compounds	Negligible to minor interference with processes	Negligible to moderate impairment of product quality	No problems in waste handling
0.2 - 1.0	Moderate to significant damage due to precipitation of manganese compounds	Moderate to significant interference with processes	Moderate to significant impairment of product quality	Treatment may be required to reduce manganese concentrations to conform with local and General Standards for discharges
> 1.0	Significant to major damage due to precipitation of manganese compounds	Significant to major interference with processes	Significant to major impairment of product quality	Treatment required to reduce manganese concentrations to conform with local and General Standards for discharges

Example of Category 1 Industrial Processes

Cooling Water	Steam Generation	Process Water	Wash Water
Evaporative cooling (high recycle)	High pressure boilers (demineralisation - plant feed water)	Phase separation Petrochemicals Pharmaceuticals	Washing with no residuals (electronic parts)

Table 2: Effects of Manganese on Category 2 Industrial Processes

Range of concentration (mg Mn/L)	Damage to equipment and structures	Interference with processes	Product quality	Complexity of waste handling
0.0 - 0.1 Target Water Quality Range	***No damage due to precipitation of manganese compounds***	***No interference with processes***	***No effect on product quality***	***No problems in waste handling***
0.1 - 0.5	Minor to moderate damage due to precipitation of manganese compounds	Negligible to minor interference with processes	Negligible to moderate impairment of product quality	Treatment may be required to reduce manganese concentrations to conform with local and General Standards for discharges
0.5 - 2.0	Moderate to significant damage due to precipitation of manganese compounds	Moderate to significant interference with processes	Moderate to significant impairment of product quality	Treatment required to reduce manganese concentrations to conform with local and General Standards for discharges
> 2.0	Significant to major damage due to precipitation of manganese compounds	Significant to major interference with processes	Significant to major impairment of product quality	Treatment required to reduce manganese concentrations to conform with local and General Standards for discharges

Examples of Category 2 Processes

Heat Exchange

- Evaporative cooling (high recycle)
- Solution cooling
- Water heating

Steam Generation

- High pressure boilers (demineralisation - plant feed water)

Process Water

- Solvent agent
- Heat transfer medium
- Humidification
- Lubrication
- Gas cleaning

Product Water

- Beverages
- Dairy
- Petrochemical

Table 3: Effects of Manganese on Category 3 Industrial Processes

Range of concentration (mg Mn/L)	Damage to equipment and structures	Interference with processes	Product quality	Complexity of waste handling
0.0 - 0.2 Target Water Quality Range	***No damage due to precipitation of manganese compounds***	***No interference with processes***	***No effect on product quality***	***No problems in waste handling***
0.2 - 1.0	Minor to moderate damage due to precipitation of manganese compounds	Negligible to minor interference with processes	Minor to moderate impairment of product quality	Treatment may be required to reduce manganese concentrations to conform with local and General Standards for discharges
1.0 - 10.0	Moderate to significant damage due to precipitation of manganese compounds	Moderate to significant interference with processes	Moderate to significant impairment of product quality	Treatment required to reduce manganese concentrations to conform with local and General Standards for discharges
> 10.0	Significant to major damage due to precipitation of manganese compounds	Significant to major interference with processes	Significant to major impairment of product quality	Treatment required to reduce manganese concentrations to conform with local and General Standards for discharges

Examples of Category 3 Industrial Processes

Cooling Water	**Steam Generation**	**Process Water**	**Product Water**	**Utility Water**
Evaporative cooling (once through) Bearing cooling Mould cooling	Low pressure boilers: softening process feed water	Solvent Dilution agent Transport agent Gland seal Vacuum seal Lubrication Descaling (iron and steel industry) Gas scrubbing	Beverages Food products Baking and confectionery Chemicals	Surface washing (table tops, walls) Domestic use Fire fighting

Table 4: Effects of Manganese on Category 4 Industrial Processes

Range of concentration (mg Mn/L)	Damage to equipment and structures	Interference with processes	Product quality	Complexity of waste handling
0.0 - 10.0 Target Water Quality Range	***No or little damage due to precipitation of manganese compounds***	***No interference with processes***	***No effect on product quality***	***Treatment to conform to General Standard only required when manganese concentrations in effluent > 0.4 mg/L***
> 10.0	No serious damage arising from precipitation of manganese compounds	Little interference with processes, but precipitation of manganese compounds may cause blockages in pipes and nozzles	Little effect on product quality	Treatment required to reduce manganese concentrations to conform with local and General Standards for discharges

Examples of Category 4 Industrial Processes

Cooling Water	**Process Water**	**Utility Water**	**Wash Water**
Ash quenching	Transport agent	Dust suppression Fire fighting Irrigation	Rough washing (floors, rough apparatus, trucks, raw materials)

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pH

Background Information

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

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

where $\{H^+\}$ is the hydrogen ion activity.

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

The pH of natural waters is a measure of the acid-base equilibrium achieved by 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. 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.

Occurrence The geology and geochemistry of the rocks and soils in a particular catchment area affects the pH and alkalinity of the water. The pH of most raw waters lies in the range of 6.5 - 9.5. Biological activities and anthropogenic sources such as nutrient cycling and industrial effluent discharge, respectively, can give rise to pH fluctuations. Acid mine drainage 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 lowering of the pH.

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

Measurement Water pH is measured electrometrically using a pH meter. The pH meter should be calibrated against standard buffer solutions of 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 greater than 10.

Data Interpretation Use of individual or mean sample values depends on the purpose for which the water is being used. Usually single-sample values are used. The pH should also be interpreted in relation to the full analysis of the water sample and its use. For example, if the pH is acidic, the water should be analysed for metal constituents which may have dissolved from the distribution system.

Treatment Options

The main significance of pH in industrial water supplies relates to its effects on water treatment processes. The pH of water can be adjusted up or down by the addition of an alkali or an acid respectively.

Commonly used alkaline reagents are lime sodium carbonate or sodium hydroxide. Acidic reagents commonly used are carbon dioxide (a gas which forms carbonic acid in water), hydrochloric acid or sulphuric acid. The reagent is usually added in dilute form using a dosing pump controlled by a pH monitor.

The adjustment of pH in water will inevitably increase the salinity of the water through the addition of ions such as sodium, carbonate, hydroxyl, sulphate or chloride. Reagents should be chosen to minimise secondary effects. For certain purposes, the pH of the water will need to be stabilised to within a chosen range by the addition of buffering reagents.

The handling of acids and alkalis is often hazardous requiring special precautions in the form of protective clothing and in materials used in the manufacture of the dosing equipment.

The Effects of pH

Norms

The norms used to measure the suitability of a water supply in terms of the pH are:

the extent of damage caused to equipment and structures;
the extent to which the pH of the water supply interferes with industrial processes,
the extent of impairment of product quality;
the degree of complexity required to treat or dispose of wastes generated as a result of the water supply quality.

Effects

The effects of changes in the pH value of a water source are discussed below in terms of the norms to measure fitness for use.

- **Damage to equipment and structures**

  pH strongly influences corrosion and scaling processes which may cause considerable damage to industrial equipment and structures. At the TWQR (pH 6.5 - 8.0) few problems in this regard occur. However, at pH values on either side of this range, damage due to corrosion or scaling may be mild to severe and extensive. At pH values below 5, waters may be highly corrosive and may enhance the disintegration of concrete. On the other hand, waters with pH values between 8.0 - 10.0 exhibit a mild to moderate tendency for scaling, while hard waters with a pH greater than 10.0 have an extremely high tendency for severe scaling.

  Corrosion effects are usually chronic and irreversible and severely damaged equipment or structures may have to be replaced. Scaling is responsible to a large degree for the narrowing and blockage of pipes and for coating surfaces of heat exchangers, thereby reducing their efficiency. The effects of scaling may be acute, but reversible through mechanical or chemical means, although this may be difficult to achieve completely.

- **Interference with processes**

  A generalised description of the effects of pH on industrial processes is practically impossible, since pH requirements of processes differ from industry to industry and from one process to another in a particular industry. Nevertheless, industrial processes usually function optimally in well-defined pH ranges, with most having an optimum working range around neutral point (pH 7). Others require either acidic or alkaline environments for proper and efficient functioning. Industries therefore include, as an integral part of these processes, appropriate techniques or means to achieve and maintain the correct pH working level. As long as the pH of the water supply remains constant, the pH can be maintained within the correct range for the relevant process. On the other hand, changes in the pH of the water supply may have profound effects on the efficient operation or functioning of pH-sensitive processes. While such changes may be acute, the effects are usually temporary and relatively easily reversible by taking appropriate action to adjust the pH.

- **Product quality**

pH has no direct effect on product quality, but its influence on physico-chemical relationships in industrial processes may result in severe impairment of the product quality. When processes operate within their recommended optimal ranges, product quality is seldom impaired. However, the further the pH moves away from the optimal range, the greater the potential for impairment to product quality. pH changes may have significant effects on certain dyes and colourants resulting in colour or shade aberrations. Similarly, the taste of beverages and foodstuffs may be affected by changes in the pH of the water supply and proteins may become denatured by extremes of pH.

Under highly acidic conditions, corrosion or corrosion products may damage product quality. Lower pH values may also influence the solubility or ionic equilibrium of some substances, resulting in the contamination of products by elements or compounds with undesirable effects in the products. On the other hand, highly alkaline conditions may impair product quality through scaling or precipitation of salts on or within products. At high pH levels, hard waters may prevent the effective use of some products, such as soaps and detergents.

- **Complexity of waste handling**

Waste handling problems as a result of waste streams with pH levels below or exceeding the TWQR are relatively easily overcome. pH adjustment through the addition of acid or alkali is generally sufficient to bring such effluents into line with the General Standard for effluents or to conform with local requirements. The permissible range for pH of an effluent to be discharged is given in the General Standards as 5.5 -9.5.

Criteria The tables below describe the effects of the pH of a water supply on industrial equipment and processes for each of the four categories of industrial processes.

Table 1: Effects of pH on Category 1 Industrial Processes

Range of pH (pH units)	Damage to equipment and structures	Interference with processes	Product quality	Complexity of waste handling
< 6.0	Major to moderate and extensive damage due to highly corrosive environment	No effect on highly acidic processes; major pH adjustment required for alkaline processes	Potential for product impairment due to corrosion or corrosion products high	Major to minor pH adjustment required before disposal
6.0 - 7.0	Moderate to minor damage due to tendency for corrosion	Little interference with acidic or neutral processes; moderate pH adjustment required for alkaline processes	Potential for product impairment due to corrosion or corrosion products mild to moderate	No problems in waste handling
7.0 - 8.0 ***Target Water Quality Range***	***No or little damage due to corrosion or scaling***	***No effect on most industrial processes. Minor to major adjustment necessary for both highly acidic and alkaline processes***	***No or little impairment of product quality due to corrosion, scaling or deposits***	***No problems in waste handling***
8.0 - 9.5	Minor to moderate damage due to scaling possible	Mild effect on alkaline and neutral processes; moderate to major pH adjustment for highly acidic processes	Potential for product impairment due to scaling or deposits mild to moderate	No problems in waste handling
> 9.5	Moderate to major and extensive damage due to very high scaling tendency	No effect on highly alkaline processes; mild to major pH adjustment required for acidic processes	Potential for product quality impairment due to scaling or deposits high	Minor to major pH adjustment required before disposal

Examples of Category 1 Industrial Processes

Cooling Water	**Steam Generation**	**Process Water**	**Wash Water**
Evaporative cooling (high recycle)	High pressure boilers (Demineralisation-plant feed water)	Phase separation Petrochemicals Pharmaceuticals	Washing with no residuals (electronic parts)

Table 2: Effects of pH for Category 2 Industrial Processes

Range of pH (pH units)	Damage to equipment and structures	Interference with processes	Product quality	Complexity of waste handling
< 5.0	Major to minor and extensive damage due to highly corrosive environment	No effect on highly acidic processes; major pH adjustment required for alkaline processes	Potential for product impairment due to corrosion or corrosion products high	Major to minor pH adjustment required before disposal
5.0 - 6.5	Moderate to minor damage due to tendency for corrosion	Little interference with acidic or neutral processes; moderate pH adjustment required for alkaline processes	Potential for product impairment due to corrosion or corrosion products mild to moderate	pH adjustment may be required before disposal
6.5 - 8.0 Target Water Quality Range	***No or little damage due to corrosion or scaling***	***No effect on most industrial processes; minor to major adjustment necessary for both highly acidic or alkaline processes***	***No or little impairment of product quality due to corrosion, scaling or deposits***	***No problems in waste handling***
8.0 - 10.0	Minor to moderate damage due to scaling possible	Mild effect on alkaline and neutral processes; moderate to major pH adjustment for highly acidic processes	Potential for product impairment due to scaling or deposits mild to moderate	pH adjustment may be required before disposal
> 10.0	Major and extensive damage due to very high scaling tendency	No effect on highly alkaline processes; mild to major adjustment required for acidic processes	Potential for product impairment due to scaling or deposits high	Minor to major pH adjustment required before disposal

Examples of Category 2 Processes

Heat Exchange

Evaporative cooling (high recycle)
Solution cooling
Water heating

Steam Generation

High pressure boilers (demineralisation - plant feed water)

Process Water

Solvent agent
Heat transfer medium
Humidification
Lubrication
Gas cleaning

Product Water

Beverages
Dairy
Petrochemical

Table 3: Effects of pH on Category 3 Industrial Processes

Range of pH (pH units)	Damage to equipment and structures	Interference with processes	Product quality	Complexity of waste handling
< 5.0	Major to minor and extensive damage due to highly corrosive environment	No effect on highly acidic processes; major pH adjustment required for alkaline processes	Potential for product impairment due to corrosion or corrosion products high	Major to minor pH adjustment required before disposal
5.0 - 6.5	Major and extensive damage due to highly corrosive environment	Little interference with acidic or neutral processes; moderate pH adjustment required for alkaline	Potential for product impairment due to corrosion or corrosion products mild to moderate	pH adjustment may be required before disposal
6.5 - 8.0 Target Water Quality Range	***No or little damage due to corrosion or scaling***	***No effect on most industrial processes; minor to major adjustment necessary for both highly acidic or alkaline processes***	***No or little impairment of product quality due to corrosion, scaling or deposits***	***No problems in waste handling***
8.0 - 10.0	Minor to moderate damage due to scaling possible	Mild effect on alkaline and neutral processes; moderate to major pH adjustment for highly acidic processes	Potential for product impairment due to scaling or deposits mild to moderate	pH adjustment may be required before disposal
> 10.0	Major and extensive damage due to scaling and/or deposits	No effect on alkaline processes; Mild to major pH adjustment required for acidic processes	Potential for product quality impairment due to scaling or deposits high	Minor to major pH adjustment required before disposal

Examples of Category 3 Industrial Processes

Cooling Water

Evaporative cooling (once through)
Bearing cooling
Mould cooling

Steam Generation

Low pressure boilers (softening process feed water)

Process Water

Solvent
Dilution agent
Transport agent
Gland seal
Vacuum seal
Lubrication
Descaling (iron and steel industry)
Gas scrubbing

Product water

Beverages
Food products
Baking and confectionery
Chemicals

Utility Water

Surface washing (table tops, walls)
Domestic use
Fire fighting

Table 4: Effects of pH on Category 4 Industrial Processes

Range of pH (pH units)	Damage to equipment and structures	Interference with processes	Product quality	Complexity of waste handling
< 5.0	Potential for damage high due to high corrosive tendency	No significant effect on processes	No significant effect on product quality	Major to minor pH adjustment required before disposal
5.0 - 10.0 Target Water Quality Range	***No significant damage under most circumstances but potential for corrosion or scaling at extremes of range***	***No effect on processes***	***No effect on product quality***	***No problems in waste handling***
> 10.0	Potential for damage high due to high scaling tendency	No significant effect on processes	No significant effect on product quality	Minor to major pH adjustment required before disposal

Examples of Category 4 Industrial Processes

Cooling Water	**Process Water**	**Utility Water**	**Wash Water**
Ash quenching	Transport agent	Dust suppression Fire fighting Irrigation	Rough washing (floors, rough apparatus, trucks, raw materials)

Sources of Information

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Silica

Background Information

Introduction Elemental silicon is a steel grey non-metal, and silica (SiO_2) is the dioxide of silicon. Silica, or sand, varies in colour from colourless to many shades of colour, depending on the nature of impurities present in the silica. Silica concentrations in water used for industrial purposes, are of concern since extensive damage can be caused to steam turbines and boilers.

Occurrence Silicon is the second most abundant element in the earth's crust after oxygen and makes up 27.7 % thereof. It occurs predominantly as silica or as various silicates. Silica is found in low concentrations in all natural waters given its universal occurrence. Silica is of relatively low solubility in water, the typical concentration in fresh water being about 7 mg Si/L and in sea water, about 2 mg Si/L.

The solubility of silicates in water depends on the nature of the metal cations present. Most metal silicates are insoluble in water, with the exception of the silicates of sodium and potassium, which are highly soluble in water. Under alkaline conditions, the solubility of silica is enhanced. The solubility of silica is also affected by particle size and temperature. The insolubility of transition metal silicates implies that silica will tend to be reprecipitated onto sediments. Silica may be taken up by diatoms and by plants in small amounts.

Interactions The solubility of silica is governed by **pH** and the concentrations of available cations.

Measurement The criteria are given in terms of the dissolved silica concentration, expressed as silicon, in units of mg Si/L. The molybdosilicate method is the reference method for the determination of dissolved reactive silica. Where other methods are used, their characteristics relative to the reference method should be known.

Data Interpretation Mean values should be used to compare with the criteria given.

Treatment Options Silica is commonly removed from water using a modification of the lime-soda softening process, or alternatively in an anion exchange column.

Precipitation of magnesium hydroxide in the lime-soda softening process will remove silica, which absorbs onto the surface of magnesium hydroxide. If there is insufficient magnesium in the water to effect the required removal of the silica, the process is modified by the use of dolomite lime or magnesium oxide.

The efficiency of the removal is greatly increased by using the hot soda-lime process where the reactions proceed at close to 100 °C. The water is subsequently filtered through an anthracite bed rather than a silica sand bed to avoid adding silica from the sand. This filtration process should be carried out under appropriate back pressure to avoid flashing as pressure is reduced.

A highly basic **anion exchange** unit, regenerated with a sodium hydroxide solution, is used to remove silica from water.

> Where silica removal is required as a pretreatment for high pressure boilers, the process needs to be closely monitored because the consequences of inadequate silica removal can be severe.

On an industrial scale the alternative processes need skilled operation and control. Further, the processes produce a concentrated sludge or brine stream which can cause disposal difficulties.

The Effects of Silica

Norms

The norms used to measure the suitability of the water supply in terms of the presence of silica are:

the extent of damage caused to equipment and structures as a result of silica;
the extent to which silica in the water supply interferes with industrial processes;
the extent of impairment of product quality caused by the presence of silica;
the degree of complexity involved in the treatment and/or disposal of wastes generated as a result of the concentration of silica.

Effects

The effects of changes in the silica concentration of a water source are discussed below in terms of the norms to measure fitness for use.

' **Damage to equipment or structures**

Silica is undesirable in boilers as it may form hard scale in the boilers and boiler tubes. In steam-generation systems, silica can volatilise and pass over with the steam, where it will form hard scale on steam turbine blades, which is difficult to remove. This can be prevented to some extent by maintaining a sufficiently high hydroxide alkalinity level in the boiler water.

Concentrations of silica over 150 mg Si/L may form *silica scale* in cooling water systems.

In the manufacture of pulp and paper, silica may aggravate scaling in evaporators.

' **Interference with processes**

Silica does not appear to interfere significantly with any industrial process. It is undesirable in process waters of the pulp and paper industry, as it tends to be absorbed by pulp, increasing its ash content. Silica may also interfere with the settling of *white liquor*, and may also affect the stability of some solutions.

' **Product quality**

Product quality is not usually affected by silica, although silica may form undesirable deposits in paper making.

- **Complexity of waste handling**

  Several methods for the removal of silica are available. Strongly basic anion-exchange resins are currently favoured.

  There is no General Standard for silica in effluents to be discharged.

Criteria

The tables below describe the effects of silica on industrial equipment and processes for each of the four categories of industrial processes.

Table 1: Effects of Silica for Category 1 Industrial Processes

Range of concentration (mg Si/L)	**Damage to equipment and structures**	**Interference with processes**	**Product quality**	**Complexity of waste handling**
0 - 5 Target Water Quality Range	***No or negligible damage due to scaling***	***No process interference expected***	***No effect on product quality***	***No problems in waste handling***
5 - 10	Minor damage due to scaling	No or negligible interference with processes expected	No to negligible impairment of product quality	No problems in waste handling
10 - 20	Moderate to significant damage due to scaling	Slight to moderate interference with processes may be expected	Minor impairment of product quality may be expected	No problems in waste handling
> 20	Significant to major damage due to scaling may be expected	Moderate to major interference with processes may be expected	Moderate to major impairment of product quality may be expected	No problems in waste handling unless treatment to remove silica has been applied in a process

Examples of Category 1 Industrial Processes

Cooling Water	**Steam Generation**	**Process Water**	**Wash Water**
Evaporative cooling (high recycle)	High pressure boilers (demineralisation-plant feed water)	Phase separation Petrochemicals Pharmaceuticals	Washing with no residuals (electronic parts)

Table 2: Effects of Silica for Category 2 Industrial Processes

Range of concentration (mg Si/L)	Damage to equipment and structures	Interference with processes	Product quality	Complexity of waste handling
0 - 10 Target Water Quality Range	***No or negligible damage due to scaling***	***No process interference expected***	***No effect on product quality***	***No problems in waste handling***
10 - 20	Minor damage due to scaling	No to negligible interference with processes expected	No to negligible impairment of product quality	No problems in waste handling
20 - 40	Moderate to significant damage due to scaling	Minor to moderate interference with processes may be expected	Minor impairment of product quality may be expected	No problems in waste handling
> 40	Significant to major damage due to scaling may be expected	Moderate to major interference with processes may be expected	Moderate to major impairment of product quality expected	No problems in waste handling unless treatment to remove silica has been applied in a process

Examples of Category 2 Industrial Processes

Heat Exchange

- Evaporative cooling (high recycle)
- Solution cooling
- Water heating

Steam Generation

- High pressure boilers (demineralisation - plant feed water)

Process Water

- Solvent agent
- Heat transfer medium
- Humidification
- Lubrication
- Gas cleaning

Product Water

- Beverages
- Dairy
- Petrochemical

Table 3: Effects of Silica for Category 3 Industrial Processes

Range of concentration (mg Si/L)	Damage to equipment and structures	Interference with processes	Product quality	Complexity of waste handling
0 - 20 ***Target Water Quality Range***	***No or negligible damage due to scaling***	***No process interference expected***	***No effect on product quality***	***No problems in waste handling***
20 - 50	Minor damage due to scaling	No or negligible interference with processes expected	No to negligible impairment of product quality	No problems in waste handling
50 - 150	Moderate to significant damage due to scaling	Slight to moderate interference with processes may be expected	Minor impairment of product quality may be expected	No problems in waste handling
> 150	Significant to major damage due to scaling may be expected	Moderate to major interference with processes may be expected	Moderate impairment of product quality may be expected	No problems in waste handling unless treatment to remove silica has been applied in a process

Examples of Category 3 Industrial Processes

Cooling Water

- Evaporative cooling (once through)
- Bearing cooling
- Mould cooling

Steam Generation

- Low pressure boilers: softening process feed water

Process Water

- Solvent
- Dilution agent
- Transport agent
- Gland seal
- Vacuum seal
- Lubrication
- Descaling (iron and steel industry)
- Gas scrubbing

Product water

- Beverages
- Food products
- Baking and confectionery
- Chemicals

Utility Water

- Surface washing (table tops, walls)
- Domestic use
- Fire fighting

Table 4: Effects of Silica for Category 4 Industrial Processes

Range of concentration (mg Si/L)	**Damage to equipment and structures**	**Interference with processes**	**Product quality**	**Complexity of waste handling**
0 - 150 ***Target Water Quality Range***	***No damage expected***	***No process interference expected***	***No effect on product quality***	***No problems in waste handling***
> 150	Some damage due to scaling may be expected	No process interference expected	Minor impairment of product quality may be expected	No problems in waste handling

Examples of Category 4 Industrial Processes are

Cooling Water	**Process Water**	**Utility Water**	**Wash Water**
Ash quenching	Transport agent	Dust suppression Fire fighting Irrigation	Rough washing (floors, rough apparatus, trucks, raw materials)

Sources of Information

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Sulphate

Background Information

Introduction

Sulphate ($SO_4^{=}$) is the oxy-anion of sulphur in the VI oxidation state and forms salts with various cations such as potassium, sodium, calcium, magnesium, barium, lead and ammonium. Potassium, sodium, magnesium and ammonium sulphates are highly soluble whereas calcium sulphate is less soluble and barium and lead sulphates are insoluble.

Occurrence

Sulphate is a common constituent of water and results from the dissolution of mineral sulphates in soil and rock, particularly calcium sulphate (gypsum) and other partially soluble sulphate minerals. Since most sulphates are very soluble in water, and calcium sulphate relatively soluble, sulphates when added to water tend to accumulate and give rise to progressively increasing concentrations. Typically, the concentration of sulphate in

> surface water is 5 mg SO_4/L, although concentrations of several hundred mg SO_4 /L may occur where the dissolution of sulphate minerals or discharge of sulphate rich effluents from acid mine drainage takes place;
> sea water is just over 900 mg SO_4/L.

Sulphates are discharged from acid mine wastes and many other industrial processes, such as tanneries, textile mills and processes using sulphuric acid or sulphates. Ion-exchange processes can remove or add sulphate to water and microbiological reduction or oxidation can interconvert sulphide and sulphate. The microbiological processes tend to be slow and require anaerobic conditions usually only found in sediments and soils. Atmospheric sulphur dioxide, discharged on combustion of fossil fuels, can give rise to sulphuric acid in rainwater (acid rain), which in turn results in the return of sulphate to surface waters in the environment.

Interactions

To a large extent the interactions of sulphate are governed by the nature of the associated cations, of which calcium and sodium are important in terms of industrial uses of water.

Measurement

The criteria are given in terms of the dissolved sulphate concentration, in units of mg SO_4/L. Dissolved sulphate is normally determined turbidimetrically on precipitation as insoluble barium sulphate. This is the reference method. For rain water, or water with low sulphate concentrations, ion-chromatography is preferentially used. If other methods are used, their characteristics relative to the reference methods should be known.

Data Interpretation

Individual sample values should be used to compare with the criteria given. Sulphate concentrations should also be interpreted in conjunction with the major associated cations, as well as the **pH** of the water.

Treatment Options

Sulphate can be removed from water by a variety of processes including:

> **Lime softening**. This reduces sulphate concentrations to 2 000 mg SO_4/L and less and involves precipitation with calcium and sodium (carbonate) followed by settlement and filtration to remove the insoluble calcium. Calcium salts alone will not reduce sulphate concentrations to below 2 000 mg SO_4/L. More commonly the method of choice is ion exchange or membrane treatment.

Ion exchange in an anion exchange column, which will remove all anions.

Any **desalination** technique in which scaling due to insoluble sulphate must be controlled, can be avoided or tolerated. These include:

- **demineralisation** in mixed bed ion exchange columns
- **membrane treatment** by reverse osmosis or electrodialysis
- a range of **evaporative** processes.

All of the processes produce a concentrated waste stream or slurry which can cause disposal difficulties. The industrial-scale processes require high levels of design, operator and maintenance skills.

The Effects of Sulphate

Norms

The norms used to measure the suitability of the water supply in terms of the presence of sulphate are:

the extent of damage caused to equipment and structures as a result of sulphate
the extent to which sulphate in the water supply interferes with industrial processes;
the extent of impairment of product quality caused by sulphate;
the degree of complexity in the treatment and/or disposal of wastes generated as a result of the concentration of the sulphate.

Effects

The effects of changes in the sulphate concentration of a water source are discussed below in terms of the norms to measure fitness for use.

- **Damage to equipment or structures**

  Precipitation of sulphates can cause damage to equipment through the formation of calcium sulphate scale. Solubility of gypsum increases with decreasing pH and decreasing temperature.

  High concentrations of sulphate can promote the growth of sulphate-reducing organisms, which in turn enhances damage through microbially-influenced / induced corrosion (MIC). High concentrations may also promote aggressive degradation of concrete structures.

- **Interference with processes**

  At high concentrations, precipitation of sulphates may interfere with the efficiency of dyeing operations in leather tanning and finishing industries. In contrast, sodium sulphate is added during the dyeing of textiles to enhance penetration and adherence of dyes to the fibres.

  Sulphate may be the source of hydrogen sulphide during the fermentation of beer.

- **Product quality**

  Precipitation of gypsum on the surface of leather during dyeing causes variations in colour; this may impair the quality of the finished product.

Small sulphate deposits remaining on cold rolled steel after rinse water has evaporated can cause speckled rust in finished steel products. This usually occurs when sulphate concentrations are higher than 20 - 30 mg SO_4/L.

High concentrations of sulphate in water used for brewing may give to beer a drier flavour.

- **Complexity of waste handling**

Neither the General nor the Special Standards for the discharge of effluents specify any criteria for sulphates. Nevertheless, since it is a component of the TDS content of the water, an indirect limit for sulphate can be inferred from the standard laid down for electrical conductivity. Excessive sulphate concentrations in effluents, derived from process operation or desalination of the water supply, can result in the corrosion of concrete sewers and must therefore be reduced to acceptable levels. Conventional or standard technology is available for this purpose.

Criteria The tables below describe the effects of sulphate on industrial equipment and processes for each of the four categories of industrial processes.

Table 1: Effects of Sulphate on Category 1 Industrial Processes

Range of concentration ($mg\ SO_4/L$)	**Damage to equipment and structures**	**Interference with processes**	**Product quality**	**Complexity of waste handling**
0 - 30 Target Water Quality Range	***No or negligible damage as a result of corrosion, concrete degradation or scaling***	***No interference with processes expected***	***No impairment of product quality***	***No problems except for disposal of highly saline effluents from low frequency regeneration of demineralisation plant***
30 - 80	Negligible to minor damage as a result of corrosion, scaling	Some interference with processes may be expected	Slight to moderate impairment of product quality	No problems except for disposal of highly saline effluents from low to moderate frequency regeneration of demineralisation plant
80 - 150	Moderate damage as a result of corrosion, scaling	Moderate interference with processes may be expected	Moderate to significant impairment of product quality	No problems except for disposal of highly saline effluents from moderate frequency regeneration of demineralisation plant
> 150	Moderate to major damage as a result of corrosion, scaling	Moderate to major interference with processes may be expected	Significant to severe impairment of product quality may occur	No problems except for disposal of highly saline effluents from moderate to high frequency regeneration of demineralisation plant

Example of Category 1 Industrial Processes

Cooling Water	**Steam Generation**	**Process Water**	**Wash Water**
Evaporative cooling (high recycle)	High pressure boilers (demineralisation - plant feed water)	Phase separation Petrochemicals Pharmaceuticals	Washing with no residuals (electronic parts)

Table 2: Effects of Sulphate on Category 2 Industrial Processes

Range of concentration (mg SO_4/L)	Damage to equipment and structures	Interference with processes	Product quality	Complexity of waste handling
0 - 80 ***Target Water Quality Range***	***No or negligible damage as a result of corrosion, scaling***	***No interference with processes expected***	***No impairment of product quality***	***No problems except for disposal of highly saline effluent from low frequency regeneration of demineralisation plant***
80 - 150	Negligible to minor damage as a result of corrosion, scaling	Some interference with processes may be expected	Slight to moderate impairment of product quality due to precipitation of sulphates	No problems except for disposal of highly saline effluent from low to moderate frequency regeneration of demineralisation plant
150 - 250	Moderate damage as a result of corrosion, scaling	Moderate interference with processes may be expected	Moderate to significant impairment of product quality due to precipitation of sulphates	No problems except for disposal of highly saline effluent from moderate frequency regeneration of demineralisation plant
> 250	Moderate to major damage as a result of corrosion, scaling, or concrete degradation	Moderate to major interference with processes may be expected	Significant to major impairment of product quality may be expected through precipitation	No problems except for disposal of highly saline effluent from moderate to high frequency regeneration of demineralisation plant

Examples of Category 2 Industrial Processes

Heat Exchange	Steam Generation	Process Water	Product Water
Evaporative cooling (high recycle)	High pressure boilers (demineralisation - plant feed water)	Solvent agent	Beverages
Solution cooling		Heat transfer medium	Dairy
Water heating		Humidification	Petrochemical
		Lubrication	
		Gas cleaning	

Table 3: Effects of Sulphate on Category 3 Industrial Processes

Range of concentration (mg SO_4/L)	**Damage to equipment and structures**	**Interference with processes**	**Product quality**	**Complexity of waste handling**
0 - 200 Target Water Quality Range	***No or negligible damage as a result of corrosion, scaling***	***No or little interference with processes may be expected***	***No impairment of product quality***	***No problems in waste handling***
200 - 300	Mild to moderate damage through corrosion, scaling	Mild to moderate interference with processes may be expected	Slight to moderate impairment of product quality	No problems in waste handling
> 300	Significant to major damage as a result of corrosion, scaling or concrete degradation	Significant to major interference with processes may be expected	Significant to major impairment to product quality due to precipitation of sulphates, unpleasant tastes and severe flavour changes may be expected	No problems except for disposal of highly saline effluents from moderate to high frequency regeneration of demineralisation plant

Examples of Category 3 Industrial Processes

Cooling Water	**Steam Generation**	**Process Water**	**Product water**	**Utility Water**
Evaporative cooling (once through) Bearing cooling Mould cooling	Low pressure boilers: softening process feed water	Solvent Dilution agent Transport agent Gland seal Vacuum seal Lubrication Descaling (iron and steel industry) Gas scrubbing	Beverages Food products Baking and confectionery Chemicals	Surface washing (table tops, walls) Domestic use Fire fighting

Table 4: Effects of Sulphate on Category 4 Industrial Processes

Range of concentration (mg SO_4/L)	**Damage to equipment and structures**	**Interference with processes**	**Product quality**	**Complexity of waste handling**
0 - 500 Target Water Quality Range	***No damage to equipment and structures expected, provided exposure to water within this range is not excessive. Longer exposures to concentrations at upper end of range may result in corrosion, scaling or concrete degradation***	***No interference with processes expected***	***No impairment of product quality***	***No problems in waste handling***
> 500	Damage to piping carrying water for Category 4 processes may be experienced due to corrosion and scaling; severe damage to concrete structures due to concrete degradation may be experienced	Little interference with Category 4 processes expected	Quality of products from Category 4 processes little affected, apart from encrustation with salts following evaporation	Major reduction in sulphate content may be required to comply with local or General Standards for discharges

Examples of Category 4 Industrial Processes

Cooling Water	**Process Water**	**Utility Water**	**Wash Water**
Ash quenching	Transport agent	Dust suppression Fire fighting Irrigation	Rough washing (floors, rough apparatus, trucks, raw materials)

Sources of Information

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Suspended Solids

Background Information

Introduction

Suspended solids are the matter retained on a glass fibre filter after filtration of a well-mixed sample and drying of the filter at 103 - 105 °C. The settleable solids fraction is a component of the suspended solids fraction and is that fraction which settles out of solution within a defined period.

Occurrence

Suspended solids in water consist of inorganic and organic matter, such as clay, particles or suspended mineral matter, and a combination of decay products and living organisms respectively. In clear non-turbid waters, like spring water, the amount of suspended matter is low or absent, while in muddy waters the amount of suspended matter is high. The amount of suspended matter found in the rivers draining a catchment area usually reflects the degree of soil erosion. Activities which result in accelerated soil erosion will therefore increase the suspended matter load in the draining rivers.

The settleable fraction of the suspended solids accumulates as sediment in lakes, dams and rivers. Scouring action during high flow periods in rivers can resuspend settled matter and finer particles can remain in suspension for long periods.

Interactions

Suspended solids give rise to turbidity in water. The relationship between the amount of suspended solids and turbidity measurement is, however, dependent on the nature and particle size distribution of the suspended matter. Addition of strongly electropositive ions such as Fe(III) and Al(III) salts to water will neutralise the electrical repulsive charges on the suspended matter and allow coagulation and settling to occur.

Measurement

The criteria for the suspended solids concentration are given in units of mg/L. Suspended solids are measured as the mass of material retained on a glass fibre filter after drying at 103 - 105 °C. Settleable solids are determined by difference after a one-hour settling period followed by determination of the suspended solids in the supernatant.

Data Interpretation

Mean values should be used to compare with the criteria given. Water with elevated suspended solid concentrations may not be microbiologically safe since the efficiency of disinfection processes can be compromised.

Treatment Options

Removal of suspended solids from water used for industrial purposes normally requires an effective coagulation and flocculation process followed by deep-bed or multimedia filtration, since the particles involved are usually colloidal in nature.

Coagulants like aluminium sulphate or ferric chloride are conventionally used, with small doses of polyelectrolytes added to assist in flocculation. With many waters, small doses of polyelectrolytes alone may be sufficient to promote flocculation of the particles for removal by settlement and filtration. Polyelectrolytes are chosen for the application on the basis of jar tests.

Multimedia filters of anthracite, garnet and silica sand are commonly used, although there is a growing tendency to use membrane processes such as microfiltration or ultrafiltration in more critical applications.

The processes involved require careful design and skilled monitoring and control. Filter backwash water may cause disposal difficulties.

The Effects of Suspended Solids

Norms

The norms used to measure the suitability of the water supply in terms of the suspended solids are

the extent of damage caused to equipment and structures as a result of the suspended solids;
the extent to which the suspended solids in the water supply interfere with industrial processes;
the extent of impairment of product quality caused by the presence of suspended solids; and
the degree of complexity involved in the treatment and/or disposal of wastes generated as a result of the concentration of the suspended solids.

Effects

The effects of changes in the concentration of suspended solids in a water source are discussed below in terms of the norms to measure fitness for use.

' **Damage to equipment and structures**

The presence of suspended solids in water supplies is one of the main causes of fouling. Fouling is the accumulation of inorganic and organic solid matter, other than scale, which interferes with the normal operation of a facility and may contribute to its deterioration. Fouling is generally encountered in steam generation and cooling water systems, where it causes blockages, impedes air circulation and can lead to localised overheating in boilers with subsequent metal damage. It is also one of the chief causes of foaming and priming in boilers.

Suspended solids may be abrasive and cause failure of pump seals, bearings or valves and controls.

Suspended solids promote microbial growth and the consequent buildup of slime which acts as a sediment trap. Such microbial slimes often contain sulphate-reducing bacteria (SRB) responsible for microbially-influenced / induced corrosion (MIC), which results in serious damage to pipelines and equipment.

In paper making, suspended solids can cause blockages of fine spray nozzles and edge cutters of paper machines, as well as the clogging of wire screens. Suspended solids foul ion exchange resins, reducing their life span and increasing the cost of regeneration.

' **Interference with processes**

Suspended solids interfere with the finishing of paper products by dulling the brightness of colours and affecting the texture and uniformity of the products.

Suspended solids can interfere with oxidising bleaches by creating an additional oxygen demand. The brightness of bleached fibres is adversely affected, colours are dulled and suspended solids may leave marks on the cloth.

In bottling of carbonated drinks, small quantities of suspended solids may cause foaming, poor carbonation and other bottling problems.

- **Product quality**

  Due to uneven, patchy adherence of suspended solids to products being dyed, the product is impaired. Suspended solids can impair the brightness of paper products and textiles and can cause abrasion in hides. The occurrence of suspended solids in beverages is unacceptable.

- **Complexity of waste handling**

  A maximum concentration of 25 mg/L is permitted by the General Standard to be discharged in effluents. Removal of suspended solids from the water supply may therefore create an additional load on the effluent of a facility.

Criteria

The tables below describe the effects of suspended solids on industrial equipment and processes for each of the four categories of industrial processes.

Table 1: Effects of Suspended Solids on Category 1 Industrial Processes

Range of concentration (mg/L)	**Damage to equipment and structures**	**Interference with processes**	**Product quality**	**Complexity of waste handling**
0 - 3 ***Target Water Quality Range***	***No damage due to fouling***	***No interference with processes***	***No effect on product quality***	***No problems in waste handling***
3 - 10	Minor to moderate damage due to fouling and/or MIC	Slight to minor interference with processes	Negligible to minor impairment of product quality	No problems in waste handling
10 - 25	Moderate to significant damage due to fouling and/or MIC	Moderate to significant interference with processes	Moderate to significant impairment of product quality	No problems in waste handling
> 25	Significant to major damage due to fouling and/or MIC may be expected	Significant to major interference with processes may be expected	Significant to major impairment of product quality may be expected	Minor to major reduction in suspended solids required to meet General Standard or local requirement

Examples of Category 1 Industrial Processes

Cooling Water	**Steam Generation**	**Process Water**	**Wash Water**
Evaporative cooling (high recycle)	High pressure boilers (demineralisation - plant feed water)	Phase separation Petrochemicals Pharmaceuticals	Washing with no residuals (electronic parts)

Table 2: Effects of Suspended Solids on Category 2 Industrial Processes

Range of concentration (mg/L)	Damage to equipment and structures	Interference with processes	Product quality	Complexity of waste handling
0 - 5 ***Target Water Quality Range***	***No damage due to fouling***	***No interference with processes***	***No effect on product quality***	***No problems in waste handling***
5 - 15	Minor to moderate damage due to fouling and/or MIC	Slight to minor interference with processes	Negligible to minor impairment of product quality	No problems in waste handling
15 - 40	Moderate to significant damage due to fouling and/or MIC	Moderate to significant interference with processes	Moderate to significant impairment of product quality	Reduction of suspended solids may be required to meet local and General Standard for discharges
> 40	Significant to major damage due to fouling and/or MIC may be expected	Significant to major interference with processes may be expected	Significant to major impairment of product quality may be expected	Minor to major reduction in suspended solids required to meet local and General Standard for discharges

Examples of Category 2 Industrial Processes

Heat Exchange

- Evaporative cooling (high recycle)
- Solution cooling
- Water heating

Steam Generation

- High pressure boilers (demineralisation - plant feed water)

Process Water

- Solvent agent
- Heat transfer medium
- Humidification
- Lubrication
- Gas cleaning

Product Water

- Beverages
- Dairy
- Petrochemical

Table 3: Effects of Suspended Solids on Category 3 Industrial Processes

Range of concentration (mg/L)	Damage to equipment and structures	Interference with processes	Product quality	Complexity of waste handling
0 - 5 Target Water Quality Range	***No damage due to fouling***	***No interference with processes***	***No effect on product quality***	***No problems in waste handling***
5 - 20	Minor to moderate damage due to fouling and/or MIC s	Slight to minor interference with processes	Negligible to minor impairment of product quality	No problems in waste handling
20 - 50	Moderate to significant damage due to fouling and/or MIC	Moderate to significant interference with processes	Moderate to significant impairment of product quality	Reduction of suspended solids may be required to meet local and General Standard for discharges
> 50	Significant to major damage due to fouling and/or MIC may be expected	Significant to major interference with processes may be expected	Significant to major impairment of product quality may be expected	Minor to major reduction in suspended solids required to meet local and General Standard for discharges

Examples of Category 3 Industrial Processes

Cooling Water	Steam Generation	Process Water	Product water	Utility Water
Evaporative cooling (once through) Bearing cooling Mould cooling	Low pressure boilers: softening process feed water	Solvent Dilution agent Transport agent Gland seal Vacuum seal Lubrication Descaling (iron and steel industry) Gas scrubbing	Beverages Food products Baking and confectionery Chemicals	Surface washing (table tops, walls) Domestic use Fire fighting

Table 4: Effects of Suspended Solids on Category 4 Industrial Processes

Range of concentration (mg/L)	Damage to equipment and structures	Interference with processes	Product quality	Complexity of waste handling
0 - 25 Target Water Quality Range	***No damage due to fouling and/or MIC***	***No interference with processes***	***No effect on product quality***	***No problems in waste handling***
25 - 100	Minor to moderate damage due to fouling and/or MIC	No interference with processes	No impairment of product quality	Reduction of suspended solids required to meet local and General Standard for discharges
> 100	Moderate to major damage due to fouling and/or MIC may be expected	Negligible to minor interference with processes may be expected	No or minor impairment of product quality may be expected	Moderate to major reduction in suspended solids required to meet local and General Standard for discharges

Examples of Category 4 Industrial Processes

Cooling Water	**Process Water**	**Utility Water**	**Wash Water**
Ash quenching	Transport agent	Dust suppression Fire fighting Irrigation	Rough washing (floors, rough apparatus, trucks, raw materials)

Sources of Information

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Total Dissolved Solids

Background Information

Introduction

The total dissolved solids (TDS) concentration is a measure of the quantity of various inorganic salts dissolved in water. The TDS concentration is proportional to the electrical conductivity (EC) of water. Since EC is much easier to measure, it is routinely used as an estimate of the TDS concentration.

Electrical conductivity is a measure of the ability of water to conduct an electrical current. This ability is a result of the presence of ions in water, all of which carry an electrical charge. In most waters nearly all the EC is due to the major cations (calcium, magnesium, sodium, potassium and nitrate) and anions (carbonate, bicarbonate, chloride and sulphate). In acidic or basic waters the proton (H^+) or hydroxyl ion (OH^-) contribute extensively to the EC. Most organic compounds dissolved in water do not dissociate into ions, consequently they do not affect the EC.

Occurrence

Virtually all natural waters contain varying concentrations of TDS as a consequence of the dissolution of minerals in rocks and soils and from decomposing plant material. Therefore the TDS of natural waters often depends on the characteristics of the geological formations the water was, or is, in contact with. The TDS concentration of

- rainwater is low, generally less than 1 mg TDS/L;
- water in contact with granite, siliceous sand and well-leached soils is generally low, less than 30 mg TDS/L;
- water in contact with precambrian shield areas is generally below 65 mg TDS/L;
- water in contact with palaeozoic and mesozoic sedimentary rock formations is in the range of 195 - 1 100 mg TDS/L.

The natural processes causing TDS are enhanced through anthropogenic activities such as domestic and industrial effluent discharges (mine pump water), surface runoff from urban, industrial and cultivated areas, irrigation and other return flows.

High TDS concentrations in surface waters are also caused by evaporation in water bodies which are isolated from natural drainage systems. The saline pans in the central parts of South Africa are examples of such water bodies.

Dissolved solids are likely to accumulate in water as it moves downstream because salts are continuously being added through natural and manmade processes, while very little of it is removed by precipitation or natural processes.

Interactions

Because the TDS concentration in water is a measure of the total amount of inorganic salt dissolved in water, it is also closely related to properties such as the **Total Hardness** of the water and the corrosion and scaling potential.

Measurement

The criteria are given in terms of the TDS concentration (mg/L), as well as the equivalent EC, expressed in milli-Siemens/metre (mS/m), measured at or corrected to a temperature of 25 °C.

The TDS concentration can be measured as

the estimate of the EC value (see below);
the measurement of the dry weight of the salts after evaporation of a known volume of filtered water;
the sum of the concentrations of the constituent cations and anions.

For most natural waters EC is related to the TDS concentration by a conversion factor ranging from 5.5 - 7.5. The average conversion factor for most waters is 6.5. The conversion equation is as follows:

EC (mS/m at 25°C) x 6.5 = mg TDS/L

The exact value of the conversion factor depends on the ionic composition of the water, especially the pH and bicarbonate concentration. Should very accurate measures of the TDS be required, the conversion factor should be determined for specific sites and runoff events.

Data Interpretation

Mean values should be used to compare with the criteria given. The effects of TDS on water used in industry are related to the TDS concentration of the inflow water and water that is continuously recycled for certain processes. The TDS concentrations for inflow water prevailing for long periods of time rather than a few extreme events is important. Therefore one should compare the criteria given for the TDS with annual or seasonal mean TDS concentrations in order to judge the fitness of water for use.

Treatment Options

Although some salts, such as those of calcium, magnesium, sulphate and certain heavy metals can be removed by chemical precipitation, most of the inorganic salts dissolved in water can only be removed by evaporative crystallisation or by highly sophisticated physical-chemical separation technologies. All these technologies are characterised by their high cost and/or their high energy requirements.

Desalination technologies used for reducing the TDS in water are selected for their cost-effectiveness in treating different ranges of TDS. Technologies available include:

Demineralisation in a mixed-bed ion exchange column. This is usually applied where the feed TDS concentration does not exceed 2 000 mg/L. Large banks of ion exchange filter beds, capable of being regenerated, are used on an industrial scale. Ion exchange processes are also used for the production of ultrapure water.

Treatment by membrane processes such as reverse osmosis or electrodialysis is commonly applied where the TDS concentration is in the range of 2 000 - 3 500 mg/L. Large-scale treatment is achieved with banks of membrane modules in parallel.

Distillation becomes cost effective where the TDS concentration exceeds approximately 10 000 mg/L.

All the possible process alternatives are usually fouled by suspended matter in water and may also be impeded by severe scaling from hard waters. All large-scale processes require high levels of design, operator and maintenance skills. Further, all processes produce a concentrated waste stream of salts removed from the water and can cause disposal difficulties.

The choice of an appropriate treatment technology depends on many factors and is a highly technical matter. Expert advice should be sought when selecting a treatment process.

The Effects of Total Dissolved Solids

Norms

The norms used to measure the suitability of the water supply in terms of the presence of TDS are

the extent of damage caused to equipment and structures as a result of the TDS;
the extent to which the TDS in the water supply interfere with industrial processes;
the extent of impairment of product quality caused by the presence of TDS; and
the degree of complexity involved in the treatment and/or disposal of wastes generated as a result of the concentration of the TDS.

Effects

The effects of changes in the TDS or EC of a water supply are discussed below in terms of the norms to measure fitness for use.

' **Damage to equipment and structures**

In conjunction with **pH,** temperature and other water quality properties, such as **total hardness** and **alkalinity**, the TDS play a major role in the determination of the corrosion or scaling potential of a water supply. Depending on the nature of the dominant cations and anions, the water will either have a tendency to scale (carbonates, **sulphates, silica,** calcium and magnesium) or corrode (**chlorides** and **sulphates**).

The effects of corrosion are usually chronic and irreversible; usually damaged equipment or structures have to be replaced. The effects of scaling may be acute but can be completely or partially reversed by mechanical or chemical treatments.

' **Interference with processes**

High levels of TDS can indirectly interfere with the proper functioning of several industrial processes. The higher the TDS level, the greater the potential for precipitation of salts, which may alter working conditions and result in the inefficient and improper operation of processes. Certain ions in solution can also adversely influence some processes, for example if the concentration of ions constituting alkalinity and hardness is high, heat exchange surfaces can become insulated with scale, rendering the heat exchange process inefficient.

' **Product quality**

Precipitation of insoluble salts in or on products may render them unacceptable, for example patchiness in dyeing, deposition of insoluble salts in medical products, and changes in the flavours of beverages.

' **Complexity of waste handling**

In many processes salts are produced as waste products which enter the waste stream. Thus, high TDS concentrations in the water supply place an additional salt load on the effluents derived from processes using that water, for example demineralising processes. The General Standards for the discharge of effluents do not specify any limit for TDS, but the EC of an effluent may not increase beyond 75 mS/m with a maximum of 250 mS/m.

Criteria The tables below describe the effects of TDS and EC on industrial equipment and processes for each of the four categories of industrial processes.

Table 1: Effects of TDS and EC for Category 1 Industrial Processes

Range of TDS (mg/L) EC (mS/m)	**Damage to equipment and structures**	**Interference with processes**	**Product quality**	**Complexity of waste handling**
TDS 0 - 100 EC 0 - 15 Target Water Quality Range	***No or negligible damage as a result of corrosion, scaling or fouling***	***No process interference expected***	***No effect on product quality***	***No problems except for disposal of highly saline effluents from low frequency regeneration of demineralisation plant***
TDS 100 - 200 EC 15 - 30	Minor damage as a result of corrosion, scaling or fouling possible	Little or minor interference with processes as a result of precipitation possible	Slight to minor product impairment as a result of precipitation of salts	No problems except for disposal of highly saline effluents from low to moderate frequency regeneration of demineralisation plant
TDS 200 - 450 EC 30 - 70	Moderate damage through corrosion, scaling or fouling possible	Moderate to significant interference with processes possible	Moderate impairment of product quality as a result of precipitation of salts	No problems except for disposal of highly saline effluents from moderate frequency regeneration of demineralisation plant
TDS > 450 EC > 70	Significant to major damage likely as a result of corrosion, scaling or fouling	Significant to major interference with processes may be expected	Significant to major impairment to products may be expected	No problems except for disposal of highly saline effluents from moderate to high frequency regeneration of demineralisation plant

Examples of Category 1 Industrial Processes are:

Cooling Water	**Steam Generation**	**Process Water**	**Wash Water**
Evaporative cooling (high recycle)	High pressure boilers (Demineralisation - plant feed water)	Phase separation Petro-chemicals Pharmaceuticals	Washing with no residuals (electronic parts)

Table 2: Effects of TDS and EC for Category 2 Industrial Processes

Range of TDS (mg/L) EC (mS/m)	Damage to equipment and structures	Interference with processes	Product quality	Complexity of waste handling
TDS 0 - 200 EC 0 - 30 Target Water Quality Range	***No or negligible damage as a result of corrosion, scaling or fouling***	***No process interference expected***	***No effect on product quality***	***No problems except for disposal of highly saline effluents from low frequency regeneration of demineralisation plant***
TDS 200 - 350 EC 30 - 50	Minor damage as a result of corrosion, scaling or fouling possible	Little or minor interference with processes as a result of precipitation possible	Slight to minor product impairment as a result of salt precipitation possible	No problems except for disposal of highly saline effluents from low to moderate frequency regeneration of demineralisation plant
TDS 350 - 800 EC 50 - 120	Moderate damage through corrosion, scaling and fouling possible	Moderate to significant interference with processes possible	Moderate impairment of product quality due to precipitation possible	No problems except for disposal of highly saline effluents from moderate frequency regeneration of demineralisation plant
TDS > 800 EC > 120	Significant to major damage likely as a result of corrosion, scaling, or fouling	Significant to major interference with processes expected	Significant to major impairment to products expected	Major reduction in salt content required to comply with local or General Standards for discharges

Examples of Category 2 Industrial Processes

Heat Exchange

Evaporative cooling (high recycle)
Solution cooling
Water heating

Steam Generation

High pressure boilers (demineralisation - plant feed water)

Process Water

Solvent agent
Heat transfer medium
Humidification
Lubrication
Gas cleaning

Product Water

Beverages
Dairy
Petrochemical

Table 3: Effects of TDS and EC for Category 3 Industrial Processes

Range of TDS (mg/L) EC (mS/m)	Damage to equipment and structures	Interference with processes	Product quality	Complexity of waste handling
TDS 0 - 450 ***EC 0 - 70*** ***Target Water Quality Range***	***No or negligible damage as a result of corrosion, scaling or fouling***	***No or little interference with processes expected***	***No effect on product quality***	***No problems except for disposal of highly saline effluents from low to moderate frequency regeneration of demineralisation plant***
TDS 450 - 800 EC 70 - 120	Minor to moderate damage through corrosion, scaling or fouling possible	Mild to moderate interference with processes possible	Mild to moderate impairment of product quality due to salt precipitation, taste and flavour changes	No problems except for disposal of highly saline effluents from moderate frequency regeneration of demineralisation plant
TDS 800 - 1 600 EC 120 -250	Moderate to significant damage likely as a result of corrosion, scaling or fouling	Moderate to significant interference with processes expected	Moderate to significant impairment to products expected	Reduction in salt content of effluents may be required to comply with local or General Standards for discharges
TDS > 1 600 EC > 250	Significant to major damage likely as a result of corrosion, scaling or fouling	Significant to major interference with processes expected	Significant to major impairment to product quality expected	Moderate to major reduction in salt content of effluents to comply with local or General Standards for discharges

Examples of Category 3 Industrial Processes

Cooling Water

Evaporative cooling (once through)
Bearing cooling
Mould cooling

Steam Generation

Low pressure boilers: softening process feed water

Process Water

Solvent
Dilution agent
Transport agent
Gland seal
Vacuum seal
Lubrication
Descaling (iron and steel industry)
Gas scrubbing

Product water

Beverages
Food products
Baking and confectionery
Chemicals

Utility Water

Surface washing (table tops, walls)
Domestic use
Fire fighting

Table 4: Effects of TDS and EC for Category 4 Industrial Processes

Range of TDS (mg/L) EC (mS/m)	Damage to equipment and structures	Interference with processes	Product quality	Complexity of waste handling
TDS 0 - 1 600 ***EC 0 - 250*** ***Target Water Quality Range***	***No or negligible damage expected provided exposure not excessive***	***No process interference expected***	***No effect on product quality***	***No problems in waste handling***
TDS > 1 600 EC > 250	Major damage likely due to corrosion, scaling or fouling	No or little process interference expected	Minor impairment to product quality due salt encrustation following evaporation	Minor to major reduction in salt content of effluents required to comply with local or General Standards for discharges

Examples of Category 4 Industrial Processes

Cooling Water	**Process Water**	**Utility Water**	**Wash Water**
Ash quenching	Transport agent	Dust suppression Fire fighting Irrigation	Rough washing (floors, rough apparatus, trucks, raw materials)

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Total Hardness

Background Information

Introduction

Water hardness was originally described as the soap-destroying power of a water, caused by the presence of calcium and magnesium salts, and measured by titration against a standard soap solution. The current definition of total hardness is the sum of the calcium and magnesium concentrations expressed as mg $CaCO_3$/L. Other metals such as strontium, iron, aluminium, zinc and manganese will contribute to the hardness of water if they are present, but the calcium and magnesium hardness usually predominates. *Temporary hardness* is due to the presence of bicarbonates of calcium and magnesium and can be removed by boiling whereas *permanent hardness* is attributed to other salts which cannot be removed by boiling.

Excessive hardness of water can give rise to scaling in hot water systems and heat exchangers and hence has adverse economic implications. Excessive softness, on the other hand, may lead to aggressive and corrosive water characteristics.

Occurrence

The natural hardness of water is influenced by the geology of the catchment area and the presence of soluble calcium and magnesium minerals. The total hardness of raw water varies and may range from 0 - 1 000 mg $CaCO_3$/L. The total hardness in surface waters rarely exceeds concentrations of 100 mg $CaCO_3$/L.

Interactions

Hardness is a complex property of water and is governed by the concentrations of **calcium**, **magnesium** and other polyvalent cations.

Measurement

Total hardness is expressed as mg $CaCO_3$/L. Total hardness is calculated from the concentrations of calcium and magnesium as given below:

$$\text{Total hardness (mg } CaCO_3\text{/L)} = 2.497 \text{ x [mg Ca/L]} + 4.118 \text{ x [mg Mg/L]}$$

Data Interpretation

Mean values should be used to compare with the criteria given.

Hardness of waters is classified as follows by Kunin :

Hardness range (mg	Description of Hardness
0 to 50	Soft
50 to 100	Moderately soft
100 to 150	Slightly hard
150 to 200	Moderately hard
200 to 300	Hard
> 300	Very hard

Treatment Options

Water is commonly softened by using an ion exchange technique, sometimes preceded by a precipitation step if hardness in the feed water is particularly high. The following processes are routinely employed in the treatment of water hardness:

- **Base exchange softening** is used to replace the calcium and magnesium in the water with non-hardness forming sodium in ion exchange columns regenerated with a sodium chloride brine. The process usually needs to be closely monitored because the consequences of incomplete softening can be severe.

  Demineralisation in mixed bed ion exchange columns can be used to remove all hardness-forming ions together with other ions in solution where a particularly low salinity water is required.

The same results can be obtained using a range of desalination techniques such as membrane treatment or distillation. However, problems of scaling may occur due to the hardness-forming salts and impair proper functioning of the equipment

All the processes need skilled operation and control and produce a concentrated waste stream which may cause disposal difficulties.

The Effects of Total Hardness

Norms

The norms used to measure the suitability of the water supply in terms of the total hardness of the water are:

the extent of damage caused to equipment and structures as a result of the total hardness;
the extent to which the total hardness in the water supply interferes with industrial processes;
the extent of impairment of product quality caused by the total hardness ; and
the degree of complexity involved in the treatment and/or disposal of wastes generated as a result of the concentration of the total hardness.

Effects

The effects of changes in the concentration of total hardness in a water source are discussed below in terms of the norms to measure fitness for use.

- **Damage to equipment and structures**

  Scaling is the deposition of insoluble carbonate and sulphate salts of calcium and magnesium, chiefly calcium carbonate, and is a major problem wherever heating of water or heat exchange takes place. Elevated levels of hardness and alkalinity are conducive to scaling. Scale accumulates on heat exchange surfaces and insulates them. Scaling of internal passageways of heat exchangers and pipelines decreases volume and restricts flow. Uneven distribution of scale in boilers may lead to localised overheating of boiler metal with subsequent boiler failure due to distortion and fatigue. Scaling may also cause problems in other items of equipment, such as screens, vacuum pumps, heating baths, steam heated drying drums and tanks. Scale may also form on paper machine wires and felts necessitating special cleaning procedures which may lead to a reduction in the lifespan of the equipment.

In contrast, very soft waters are aggressive towards concrete surfaces and promote corrosion of unprotected metal surfaces.

- **Interference with processes**

Hard waters are undesirable for a number of processes. Collagen softening and deliming in the preparation of hides is hindered, while calcium carbonate precipitates interfere with dyeing. Calcium and magnesium may form insoluble compounds with tannins resulting in incomplete tanning. Similarly, some dyestuffs are sensitive to hardness-forming calcium and magnesium complexes which cause colour changes. Calcium and magnesium may also form leuco-compounds with dyes making them less soluble and decreasing their affinity for fibres.

The formation of insoluble calcium and magnesium resinates interferes with the sizing process in paper making. In highly alkaline environments precipitation of calcium and magnesium salts blocks diffuser jets of textile humidifiers.

In the beverage and food industry too much hardness retards fermentation processes, and may cause toughening of some products as a result of the formation of insoluble pectides during blanching.

- **Product quality**

Precipitation of insoluble calcium or magnesium salts in alkaline processes can cause abrasion of hides or patchiness due to uneven deposition of these salts on fabrics during bleaching, mercerising and dyeing operations. Insoluble calcium and magnesium soaps or curds, which adhere to fabrics, may also occur. Due to the sensitivity of some dyes to hardness, colour changes can occur.

- **Complexity of waste handling**

To prevent problems caused by hardness, hard waters are generally softened either by the lime-soda process or ion exchange. However, softening process residues need to be disposed of; several disposal methods, such as discharge to flowing water courses, sludge beds, lagoons, or to sewers may be employed. Reclamation of softening residues can also be achieved by recalcination.

Criteria The tables below describe the effects of total hardness on industrial equipment and processes for each of the four categories of industrial processes.

Table 1: Effects of Total Hardness on Category 1 Industrial Processes

Range of concentration (mg $CaCO_3$/L)	Damage to equipment and structures	Interference with processes	Product quality	Complexity of waste handling
0 - 50 Target Water Quality Range	***No or negligible damage due to scaling. At low pH water conducive to corrosion and concrete degradation***	***No or negligible interference with processes; some dyes sensitive to hardness > 25 mg/L***	***No or negligible effect on product quality***	***No problems except for disposal of highly saline effluents from low frequency regeneration of demineralisation plant***
50 - 100	Mild to moderate damage due to scaling	Mild to moderate interference with processes	Little to minor impairment of product quality	No problems except for disposal of highly saline effluents from low to moderate frequency regeneration of demineralisation plant
100 - 250	Moderate to significant damage due to scaling	Moderate to significant interference with processes	Moderate to significant impairment of product quality	No problems except for highly saline effluents from moderate frequency regeneration of demineralisation plant
> 250	Significant to major damage due to heavy scaling	Significant to major interference with processes	Significant to major impairment of product quality	Treatment may be required to reduce TDS levels to meet local and General Standards for discharges

Examples of Category 1 Industrial Processes

Cooling Water	**Steam Generation**	**Process Water**	**Wash Water**
Evaporative cooling (high recycle)	High pressure boilers (demineralisation - plant feed water)	Phase separation Petrochemicals Pharmaceuticals	Washing with no residuals (electronic parts)

Table 2: Effects of Total Hardness on Category 2 Industrial Processes

Range of concentration (mg $CaCO_3$/L)	Damage to equipment and structures	Interference with processes	Product quality	Complexity of waste handling
0 - 100 Target Water Quality Range	***No or negligible damage due to scaling. At low pH water conducive to corrosion and concrete degradation***	***No or negligible interference with processes; some dyes sensitive to hardness > 25 mg/L***	***No or negligible effect on product quality***	***No problems except for disposal of highly saline effluents from low frequency regeneration of demineralisation plant***
100 - 200	Mild to moderate damage due to scaling	Mild to moderate interference with processes	Little to minor impairment of product quality	No problems except for disposal of highly saline effluents from low to moderate frequency regeneration of demineralisation plant
200 - 500	Moderate to significant damage due to scaling	Moderate to significant interference with processes	Moderate to significant impairment of product quality	No problems except for disposal of highly saline effluents from moderate frequency regeneration of demineralisation plant
> 500	Significant to major damage due to heavy scaling	Significant to major interference with processes	Significant to major impairment of product quality	Treatment may be required to reduce TDS levels to meet local and General Standards for discharges

Examples of Category 2 Industrial Processes are:

Heat Exchange

Evaporative cooling (high recycle)
Solution cooling
Water heating

Steam Generation

High pressure boilers (demineralisation-plant feed water)

Process Water

Solvent agent
Heat transfer medium
Humidification
Lubrication
Gas cleaning

Product Water

Beverages
Dairy
Petrochemical

Table 3: Effects of Total Hardness on Category 3 Industrial Processes

Range of concentration (mg $CaCO_3$/L)	Damage to equipment and structures	Interference with processes	Product quality	Complexity of waste handling
0 - 250 Target Water Quality Range	***No to minor damage due to scaling. At low pH water conducive to corrosion and concrete degradation***	***No to minor interference with processes; some dyes sensitive to hardness > 25 mg/L***	***No to minor impairment of product quality***	***No problems except for disposal of highly saline effluents from low to moderate frequency regeneration of demineralisation plant***
250 - 500	Moderate to significant damage due to scaling	Moderate to significant interference with processes	Moderate to significant impairment of product quality	No problems except for disposal of highly saline effluents from moderate frequency regeneration of demineralisation plant
> 500	Significant to major damage due to heavy scaling	Significant to major interference with processes	Significant to major impairment of product quality	Treatment may be required to reduce TDS levels to meet local and General Standards for discharges

Examples of Category 3 Industrial Processes

Cooling Water	**Steam Generation**	**Process Water**	**Product water**	**Utility Water**
Evaporative cooling (once through) Bearing cooling Mould cooling	Low pressure boilers: softening process feed water	Solvent Dilution agent Transport agent Gland seal Vacuum seal Lubrication Descaling (iron and steel industry) Gas scrubbing	Beverages Food products Baking and confectionery Chemicals	Surface washing (table tops, walls) Domestic use Fire fighting

Table 4: Effects of Total Hardness on Category 4 Industrial Processes

Range of concentration (mg $CaCO_3$/L)	**Damage to equipment and structures**	**Interference with processes**	**Product quality**	**Complexity of waste handling**
0 - 1 000 Target Water Quality Range	***No or negligible damage expected, particularly in acidic environments***	***No interference with processes***	***No or negligible effect on product quality***	***No problems in waste handling***
> 1 000	Slight damage due to scaling or deposits may be expected	No or minor interference with processes	Minor impairment of product quality due to precipitation may be expected	Treatment may be required to reduce TDS levels to meet local and General Standards for discharges

Examples of Category 4 Industrial Processes

Cooling Water	**Process Water**	**Utility Water**	**Wash Water**
Ash quenching	Transport agent	Dust suppression Fire fighting Irrigation	Rough washing (floors, rough apparatus, trucks, raw materials)

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Chapter 6

Glossaries

Glossary of Terminology

adsorption/elution:	the attachment of molecules or ions to, and their removal from, a substrate by manipulation of electrical charge or pH
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 with a negative charge. Anions move to the anode in electrolysis
anions:	negatively-charged ions
assimilative capacity:	the capacity of a water body to accommodate, through processes such as dilution, dispersion and chemical and biological degradation, a quantity of substance without causing any known impairment of use
biochemical oxygen demand (BOD):	the amount of dissolved oxygen consumed by organisms in water rich inorganic matter
bituminous emulsions:	permanent mixtures of bituminous liquids dispersed as droplets in water
black liquor evaporation:	the process of concentrating the black liquid remaining after digestion of timber in a chemical pulping process. The concentrated chemicals together with its organic solid wastes are burnt in the recovery furnace
buffering capacity:	a measure of the relative sensitivity of a solution to pH changes on addition of acids or bases
carbonising:	a chemical process for eliminating cellulosic matter from a mixture with animal fibres by degrading the cellulosic material to an easily friable condition
cationic:	the characteristic behaviour or property of an ion with a positive charge. Cations move to the cathode in electrolysis
cations:	positively-charged ions
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
chemical pulping:	the defibrisation of timber by the use of chemicals in processes such as the sulphite, soda and sulphate processes
clarified white water:	process water that is recycled in the paper making process after undergoing the process of clarification

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
condensate water:	water obtained through condensing spent steam in heat exchanges
curds:	solid particles formed when *hardness* interferes with soaps used in various washing operations in the textile industry
desizing:	the process of removing size or sizing material from a fabric after they have fulfilled the purpose for which they were added
dissolution:	the process of dissolving
distillation:	the process of producing a gas or vapour from a liquid by heating the liquid in a vessel, and then collecting and condensing the vapours into liquids
effluent standard:	a legally enforceable value or limit of a *water quality constituent/variable* in an effluent being discharged into a water body
electrodialysis:	a process of selective diffusion through a membrane conducted with the aid of an electromotive force
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
fulling:	a process in which wool is washed in a highly caustic solution
General Effluent Standard:	a set of *effluent standards*, published in terms of the Water Act, which are applicable throughout South Africa. An effluent must comply to the whole set unless an *exemption* relaxing one or more standards has been issued by the Department of Water Affairs and Forestry
groundwood pulp:	pulp obtained by the mechanical grinding of logs to separate the bundles of fibres into individual strands
hard water:	water that contains high concentrations of calcium, magnesium, and to a lesser extent other alkaline earth metal ions, in solution. Under highly alkaline conditions, the calcium and magnesium of hard waters may precipitate out as scale or as some other insoluble salt of these two metal ions
hardness:	defined as the sum of the calcium and magnesium concentrations, both expressed as calcium carbonate, in milligrams per litre
hygroscopic:	a substance that absorbs water
incandescent coke:	coke that is so hot from combustion that it emits light radiation

ion exchange:	the interchange of ions of like charge, usually on a solid medium; that occurs in water treatment, such as water softening
kiering:	the process of prolonged boiling of cellulosic or flax materials with alkaline liquors in a large steel container known as a kier, either at or above atmospheric pressure
kraft process:	a chemical pulping process in which pulp is produced by digesting wood chips or other fibrous material heated by steam under pressure with a solution of sodium hydroxide and sodium sulphide
leuco compounds:	compounds of dyes in which the dye is in a reduced form; the original dye may be regenerated by oxidation processes
lignin:	an organic polymer providing strengthening and thickening in plant cell walls. The properties of wood are due to the encrustation of plant cell walls with lignin
limiting concentration:	the concentration of a water quality variable above which damage to the product or the operation of a process or machinery may be done
make-up water:	water used to replenish water lost in a system through evaporation, windage, blowdown and leakage
mechanical pulping:	the mechanical defibrisation of timber, other than for pretreatment, usually without the use of chemicals
mercerising:	the treatment of cellulosic textiles in yarn or fabric form with a concentrated solution of caustic alkali, whereby the fibres are swollen, the strength and dye affinity of the materials are increased, and their handle is modified
mesotrophic:	a term applied to freshwater bodies which contain moderate amounts of plant nutrients and are therefore moderately productive
microbes:	microscopic organisms such as bacteria or viruses
mucilaginous:	the tacky or slimy property of extracellular substances secreted by certain groups of bacteria, such as the slime-producing bacteria
occlusion:	a blockage
open boiling:	a method of scouring cellulosic textiles with alkaline liquors in open-topped vessels at or near to boiling point
organoleptic:	characteristics of water which affect the sense organs, e.g. taste and odour
ozonation:	a disinfection process that uses ozone
permeability:	the condition of allowing the passing of fluid molecules through a particular medium, such as soil, etc.
phenolic jointing compounds:	materials used in the joining of pipes which contain phenolic substances

physico-chemical:	the physical (e.g. temperature, electrical conductivity) and chemical (e.g. concentrations of nitrate, mercury) characteristics of water
point pollutant sources:	discharges of pollutants from known discrete sources, e.g. an effluent discharge from an industry. The volume and quality of the discharge can normally be measured and quantified
point of supply:	that point in an industrial operation where water is obtained for use in various industrial processes
point of use:	the point in an industrial operation where the water is actually used in a process
primary fibre mill:	a pulp mill which uses wood or some other fibrous plant or chemical material as its primary raw material
process water:	that water which can be used in a number of processes in the manufacture of a product, but is not part of the product
production water:	that water which has direct contact with a product and forms a constituent part of the product
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
reverse osmosis:	a technique in the desalination of water in which pressure is applied to the surface of the saline solution, forcing pure water to pass through a semi-permeable membrane which prevents the passage of other ions
salinity:	a measure of the salt content of soil or water
scaling:	the formation of a dense coating of predominantly inorganic material formed from the precipitation of water-soluble constituents. The most common substances forming scale are carbonates and sulphates of calcium and magnesium hydroxide
secondary fibre mill:	a paper mill which uses waste paper as its primary raw material
singeing:	the process of removing unwanted surface hairs or filaments produced in manufacture by means of burning against a hot plate or in a flame. The operation is usually performed as a pretreatment to bleaching or finishing
site-specific:	conditions that are unique or specific to a certain site or locality

size or sizing:	a chemical or mixture of chemicals, in solution or suspension. In the textile industry it is applied to textile fibres prior to weaving to strengthen, lubricate and protect them during weaving. In the paper industry size is added to the paper on the paper machine during the drying process to impart special characteristics to the finished paper
Special Effluent Standard:	a set of effluent standards, published in terms of the Water Act (54 of 1956) which are applicable in certain catchments in South Africa
spontaneous combustion:	combustion that is self-initiated without any external supply of heat energy
steam tracing:	the heating of pipelines by means of steam in ducts parallel to the pipeline in order to keep the product flowing in the pipeline
suint:	an extraction from the sweat glands of sheep, which is deposited on wool fibres
supersaturation:	a solution containing more solute than equilibrium conditions will allow; unstable to the addition of solute crystals
thermomechanical pulping:	a process in which pulp is produced by macerating wood chips in a screw press to a homogeneous slush which is then passed continuously through a steam-heated digester
threshold concentration:	the highest concentration of a water quality variable that can be tolerated before damage is done to the product or operation of a process and the machinery required for the process
treatment breakthrough:	the occurrence of contaminants in final water after treatment as a result of failure of a component of the treatment process. This is usually an isolated event with a clearly definable cause and effect, e.g. appearance of bacteria in treated water as a result of failure of chlorination
treatment overload:	the occurrence of contaminants in final water after treatment because the capacity of the plant to remove the contaminants is exceeded. This may be a long-term effect which often occurs at lower levels than treatment breakthrough
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
viscosity:	the degree of resistance to shear of a fluid. The more viscous a fluid, the less easily will it flow
white water:	clarified process water recycled within the paper making process

Glossary of Abbreviations / Acronyms

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
DWAF	Department of Water Affairs and Forestry
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 formal 1992 change from EEC to European Union (EU).
EEC	European Economic Community
EDTA	ethylene diamine tetra-acetic acid
GAC	granular activated carbon
HP	high pressure
HPLC	high performance liquid chromatography
IAWPRC	International Association for Water Pollution Research and Control
LP	low pressure
MIC	microbially-influenced / induced corrosion
NAS/NAE	National Academy of Sciences / National Academy of Engineering (USA)
NCWQ	National Technical Advisory Committee on Water Quality Criteria
PAC	powdered activated carbon
PVA	polyvinyl alcohols

SA	South African
SRB	sulphate-reducing bacteria
TDS	total dissolved solids
TOC	total organic carbon
TWQR	Target Water Quality Range
US EPA	United States Environmental Protection Agency

Glossary of units of measure

µg/L	micrograms per litre
µS/cm	micro-Siemens per centimetre
meq/L	milli-equivalents per litre
mg/L	milligrams per litre
mM/L	millimoles per litre
mS/m	milli-Siemens per metre
ng/L	nanograms per litre
nm	nanometre
°C	degrees Celsius

Statement regarding this version of the document on 2017-08-21

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.