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Guidelines for performance evaluation of treatment technologies for water reuse systems —

Part 1: General

Lignes directrices pour l'évaluation des performances des techniques de traitement des systèmes de réutilisation de l'eau —
Partie 1: Généralités

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 282, *Water reuse,* Subcommittee SC 3, *Risk and performance evaluation of water reuse systems*.

A list of all parts in the ISO 20468 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

The rapidly growing global market for water reuse technologies inevitably demands standards which are applicable on a world-wide basis be developed. Many regions in the world are facing water shortages, and there is great interest in fit-for-purpose water reuse technologies that can treat and reclaim wastewater to a water quality level that is suitable for a wide range of reuse applications that can satisfy non-potable water demands, thereby conserving precious potable water resources. The implementation of water reuse programs raises public and regulatory concern regarding potential human health, environmental and societal impacts. This has led to an increasing need to specify various aspects of water reuse projects, and regulators, reuse technology suppliers, and users of those technologies have a growing need for international standardization. A great number of opportunities for sustainable water use and development based on water reclamation can be lost without ISO water reuse standards.

Standardization needs to include objective specification and evaluation of levels of service and water reuse system performance dependability including safety, environmental protection, resilience and cost-effectiveness considerations. Hence, appropriate methods are needed to evaluate the performance of treatment technologies for water reuse systems.

The performance of treatment technologies for water reuse, *inter alia*, should be evaluated properly in order to select the most appropriate technologies in an unbiased way to achieve the objectives of water reuse projects. Despite considerable research and development on treatment technologies, such scientific knowledge is largely held within commercial interests. Performance evaluations are also useful for assessing the efficiency of existing wastewater reclamation systems and operations, including the identification of continuous improvement opportunities. To address these challenges, this document provides methods and tools, which can be accepted by most stakeholders, to evaluate the performance of treatment technologies for water reuse systems for a multitude of applications. This document provides treatment technology functional requirements and non-functional requirements, the former based on water quality parameter concentration or removal efficiency and the latter based on performance indicators. A step-by-step procedure for evaluating the functional requirements and examples of non-functional key performance indicators and evaluation methods are provided.

This document is intended for use by planners and managers of water reuse projects, technical advisors, designers, operators of the treatment systems, those involved in monitoring, assessing, regulating and other activities of third-party organizations or relevant authorities, as well as treatment technology manufacturers.

The application of the guidelines for performance evaluation at the stages of procurement, designing and operation of treatment systems can enable, for example:

— designers to identify and evaluate an optimal treatment system design which will meet regulatory performance requirements;

— manufacturers to determine technology performance expectations;

— operators to evaluate and improve the operating efficiency and performance of water reuse treatment systems.

This document is not intended to address the design and integration of specific unit treatment processes or overall treatment system design.

This document can be useful for the application of management system standards, such as ISO 9001, ISO 14001, ISO 22301, ISO 50001, and ISO 55001.

Guidelines for performance evaluation of treatment technologies for water reuse systems —

Part 1:
General

1 Scope

This document gives guidelines on performance evaluation of treatment technologies for water reuse systems. It provides typical parameters of water quality and treatment efficiency that are associated with the performances of treatment technologies. It also includes a comparison of measured and target values, and provides treatment technology functional requirements and non-functional requirements.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated reference, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 20670, *Water reuse — Vocabulary*

3 Terms, definitions and list of abbreviated terms

For the purposes of this document, the terms and definitions given in ISO 20670 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1 Terms and definitions

3.1.1
availability
<performance> ability of a treatment technology to be in a state to perform a required function under given conditions at a given instant of time or over a given time interval, assuming that the required external resources are provided

Note 1 to entry: This ability depends on the combined aspects of the reliability performance, the maintainability performance, and the maintenance support performance.

Note 2 to entry: Required external resources, other than maintenance resources, do not affect the availability performance of the treatment technologies.

[SOURCE: IEC 60050-191:1990, 191-02-05]

3.1.2
benchmarking
tool for performance improvement through systematic search and adaptation of leading practices

[SOURCE: Benchmarking Water Services - *Guiding water utilities to excellence* (2011)]

3.1.3
correction
action to eliminate a detected nonconformity

[SOURCE: ISO 9000:2015, 3.12.3, modified — Notes 1 and 2 to entry have been deleted.]

3.1.4
corrective action
action to eliminate the cause of a nonconformity and to prevent recurrence

[SOURCE: ISO 9000:2015, 3.12.2, modified — Notes 1 to 3 to entry have been deleted.]

3.1.5
dependability
collective term used to describe the availability performance and its influencing factors

EXAMPLE Reliability performance, maintainability performance and maintenance support performance.

[SOURCE: IEC 60050-191:1990, 191-02-03]

3.1.6
downtime
amount of time that a system or a component is not able to operate or meet required functions

3.1.7
failure
state in which a treatment technology does not meet a functional or a non-functional requirement

3.1.8
functional requirement
requirement related to the transformation of water quality by a treatment technology

3.1.9
maintainability
<performance> ability of a treatment technology under given conditions of use, to be retained in, or restored to, a state in which it can perform a required function, when maintenance is performed under given conditions and using stated procedures and resources

[SOURCE: IEC 60050-191:1990, 191-02-07, modified — Notes 1 to entry has been deleted.]

3.1.10
maintenance support performance
ability of a maintenance organisation, under given conditions and maintenance policy, to provide, upon demand, the resources required to maintain the treatment technology

Note 1 to entry: The given conditions are related to the treatment technology and to the conditions under which the treatment technology is used and maintained.

Note 2 to entry: When evaluating the treatment technologies, required maintenance support performance can be used as a given condition to evaluate the maintainability.

[SOURCE: IEC 60050-191:1990, 191-02-08, modified — Note 2 to entry has been added.]

3.1.11
nonconformity
non-fulfilment of a requirement

[SOURCE: ISO 30000:2009, 3.8]

3.1.12
non-functional requirement
requirement that specifies criteria or constraints on the design or implementation of a treatment technology

3.1.13
performance evaluation
overall process to judge whether, or to measure the extent to which the outputs or state of a system, or a component, fulfill the requirements

Note 1 to entry: See ISO 9001:2015, Clause 9.

3.1.14
performance indicator
parameter, or a value derived from parameters, which provides information about the performance of a subject matter with a significance extending beyond that directly associated with a parameter value

Note 1 to entry: See ISO 24511:2007, 2.16.

3.1.15
predictive analysis
practice of extracting information from existing data sets in order to determine patterns and predict future outcomes and trends

3.1.16
removal efficiency
efficiency of removal of a constituent

Note 1 to entry: Removal efficiency and log removal value for some specific constituent are defined by the following Formula (1) and Formula (2):

$$(RE) = 1 - \frac{(C_e)}{(C_i)} \tag{1}$$

$$(\log RV) = -\log_{10}\left[1 - (RE)\right] = -\log_{10}\left[\frac{(C_e)}{(C_i)}\right] \tag{2}$$

where

RE is the removal efficiency;

C_e is the effluent constituent concentration;

C_i is the influent constituent concentration;

RV is the removal value.

Note 2 to entry: Removal efficiency is often expressed as a percentage. A value of indicator for the constituent can be used in place of concentration of the constituent. Log removal value is often used for microbial constituents.

3.1.17
requirement
need or expectation that is stated, generally implied or obligatory

[SOURCE: ISO 9000:2015, 3.6.4, modified — Notes 1 to 6 to entry have been deleted.]

3.1.18
robustness
ability of a structure to withstand adverse and unforeseen events or consequences of human errors without being damaged to an extent disproportionate to the original cause

[SOURCE: ISO 2394:2015, 2.1.46, modified.]

3.1.19
safety
freedom from risk which is not tolerable

[SOURCE: ISO/IEC GUIDE 51:2014, 3.14]

3.2 List of abbreviated terms

BOD	biochemical oxygen demand
COD	chemical oxygen demand
E. coli	*Escherichia coli*
LCA	life cycle assessment
LCC	life cycle cost
LRV	log removal value
MBR	membrane bioreactor
PAA	peracetic acid
QA	quality assurance
QC	quality control
RO	reverse osmosis
TDS	total dissolved solids
TSS	total suspended solids
UV	ultraviolet

4 Concepts of treatment technology for water reuse systems

4.1 General

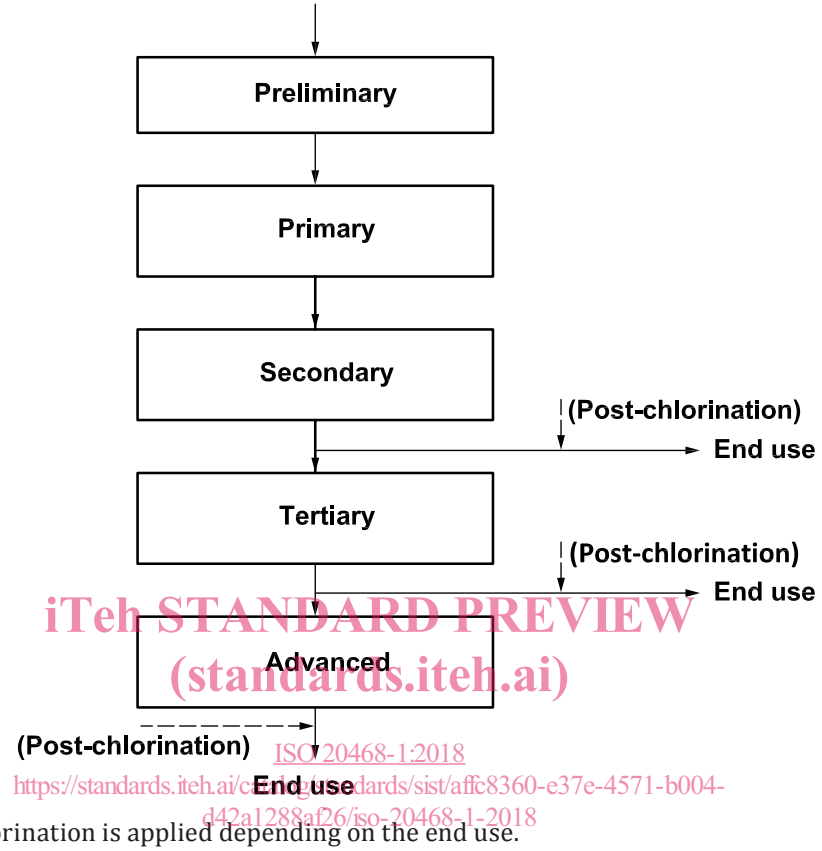
Clause 4 outlines information on treatment technologies including treatment systems and processes.

The constituents found in untreated wastewater are derived from the substances that come into contact with water used for various domestic, commercial, and industrial uses; as well as those carried by stormwater which flows into sanitary system. The focus of this document is on the performance of the processes and systems with respect to constituents of concern for water reuse applications that include suspended solids, colloidal turbidity, dissolved constituents (i.e. dissolved organic and inorganic substances such as sugars and fats, heavy metals, nutrients, etc.), and pathogens (disease causing viruses, bacteria, protozoa and helminths) assessed by indicator microorganisms. Various treatment processes can be used individually or combined to remove a target constituent.

The water quality requirements of a given reuse application governs the type of treatment needed and the degree of treatment reliability. Because health and environmental concerns are primary issues in implementing water reuse, attention should be focused on developing treatment systems to ensure whether water quality requirements are consistently met. With respect to performance of disinfection technologies, a multi-barrier approach is recommended (i.e. two or more different processes including at least one form of disinfection and additional barriers with accepted levels of pathogen reduction).

4.2 Treatment objective

Because of the importance of water quality in water reuse applications, different technologies are often combined to achieve desired levels of constituent removal. Figure 1 shows progressive stages of wastewater treatment processes.



NOTE Post-chlorination is applied depending on the end use.

Figure 1 — Wastewater treatment stages as per reuse applications[20]

One of the primary objectives of treatment technologies for water reuse is to reduce the pathogen content to reduce public health risk associated with exposure to reuse water. While disinfection requirements can vary depending on the specific water reuse application, disinfection is most commonly accomplished by the use of chemical oxidants (e.g. chlorine based oxidants, and ozone), UV, membrane filtration and (more recently) PAA. Disinfection can include treatment strategies that incorporate multiple disinfection technologies or ultrafiltration/reverse osmosis treatments in series as necessary – referred to as a multi-barrier approach to disinfection. The purpose of the multi-barrier approach is, in part, to provide a back-up disinfection mechanism in the event one of the technologies relied upon for disinfection should underperform because of design or equipment failure; however, it is also carried out in recognition that not all pathogens are equally affected by a particular disinfection technology, and that combinations of disinfection/treatment technologies can achieve a more effective and broader range of pathogen reduction. A multi-barrier approach can also include the maintenance of a residual level of disinfectant (e.g. post-chlorination) in water to prevent recontamination.

The general categories of treatment technologies in this document are shown below[20].

— Preliminary treatment

  Preliminary treatment is to remove from the wastewater any constituents which can clog or damage pumps or other equipment, or interfere with the operation or maintenance of the subsequent treatment processes. It consists of removal of large size, suspended or floating materials and also heavy settleble solids such as rags, sticks, grit, and grease.

— Primary treatment

Primary treatment targets the removal of settleable organic and inorganic solids by sedimentation, and the removal of materials that will float (scum) by skimming. Enhanced removal of suspended solids and organic matter from the wastewater can be accomplished by chemical addition or filtration (e.g. fine mesh filtration).

— Secondary treatment

In secondary treatment, biological, chemical and physical processes are used to reduce most of the soluble organic matter and organic and inorganic particulates, measured as BOD or COD and TSS. There is a very wide range of biological processes used for secondary treatment including those that incorporate suspended bacteria, fixed film and hybrid (i.e. suspended and fixed film bacteria) followed by a solid-liquid separation step, typically by sedimentation (e.g. clarifier). Typical biological processes used for secondary treatment include activated sludge, trickling filters, rotating biological contactors and non-conventional treatment processes such as lagoons, wetlands that are capable of achieving secondary treatment water quality criteria. Secondary biological treatment can also remove nutrients. MBR is an alternative biological treatment process for secondary treatment.

— Tertiary treatment

Tertiary treatment follows the secondary treatment of wastewater, and aims at producing higher quality treated wastewater. Effluent from secondary treatment plants typically contains residual dissolved organic constituents, suspended solids and colloidal particulate matter that, in certain jurisdictions, and/or depending on the particular reuse application, can require further reduction. Their removal can be achieved by filtration. Color and odor can also be constituents targeted for removal by tertiary treatment. Tertiary treatment can include additional removal of nitrogen and phosphorus.

— Advanced treatment

Advanced treatment targets the removal of TDS and/or trace constituents as required for specific water reuse applications. This can include, for example, complex and/or toxic organic compounds, heavy metals, color, odor compounds remaining after tertiary treatment and emerging contaminants (e.g. pharmaceuticals, nanotechnology byproducts, etc.). Technologies to achieve advanced treatment can include chemical or physical processes such as ozonation, advanced oxidation, adsorption, or ion exchange, either singly or in combination with membrane technologies.

— Disinfection

Disinfection is enhanced by the upstream removal of particulate matter that often shields pathogenic organisms from the disinfecting agent, and this is especially critical for UV disinfection. Technologies used to remove particulates (e.g. filtration) not only improve the efficacy of disinfection technologies, but can also reduce the number of pathogens present prior to disinfection and form part of a multi-barrier approach to disinfection to ensure public health protection and maximize process reliability. Disinfection can be used after secondary, tertiary, or advanced treatment as necessary (see Figure 1).

— Post-chlorination

Post-chlorination is a method of adding and maintaining a minimum level of chlorine within the reuse water distribution system. It provides the control of chlorine residual for the prevention of regrowth of microorganisms or recontamination in distribution systems. Post-chlorination is typically performed before reuse water is delivered to end users.

4.3 Treatment technologies used in fit-for-purpose water reuse

The required water quality for reuse water depends on the intended non-potable reuse application and the degree of health and environmental risks associated with that application. As a rule, domestic,

