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

Part 4: UV Disinfection

Lignes directrices pour l'évaluation des performances des techniques de traitement des systèmes de réutilisation de l'eau —

Partie 4: Désinfection aux UV

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Contents

Page

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*.

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. Many regions in the world are facing water shortages, and there is great interest in the use of technologies that can treat wastewater and make the reclaimed water available for a wide range of reuse applications that can satisfy non-potable water demands, thereby conserving precious potable water supplies. Simultaneously, the implementation of water reuse schemes is raising public and regulatory concerns regarding potential human health, environmental and societal impacts. This has led to an increasing need to specify various aspects of water reuse projects and there is a growing need on behalf of regulators, reuse technology suppliers, and users of those technologies for international standardization. Without ISO water reuse standards, a great number of opportunities for sustainable development based on water reuse will be lost.

Standardization needs 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 most appropriate technologies in an unbiased way to achieve the objectives of the water reuse project. 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 water reuse 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 from multitude of applications.

Based on the discussion in the meetings of ISO/TC 282/SC 3, ISO 20468-1 titled “Guidelines for performance evaluation of treatment technologies for water reuse systems – Part 1: General” has been developed to establish the standard of generic aspects for performance evaluation which can be applied to a variety of wastewater treatment technologies and their combinations, while descriptions specific to the representative technologies should be included in individual standards being submitted subsequently to ISO 20468-1. In this context, this document stipulating specific ways of performance evaluation of UV treatment technology for water reuse systems, based on ISO 20468-1 as the generic standard is established herein.

In non-potable water reuse systems, UV technology is used mainly for disinfection as indicated in Table A.1 and works well with secondary or tertiary treated water as shown in ISO 20468-1:2018, Figure 1.

This guideline is intended as an integrated part of a framework for UV systems, consistent with other items in the work of TC 282. This framework includes several important aspects such as design, validation and verification (ISO 9000) and evaluation.

Guidelines focused on UV System Design, Validation and Evaluation are found in ISO 16075-5:2021, Clause 7.

Guidelines focused on UV system Design, Verification and Evaluation are found in ISO 20468-4.

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

Part 4: **UV Disinfection**

1 Scope

This document provides guidelines for performance evaluation methods of UV disinfection for full scale water reuse systems. It deals with the methods of measurement of typical parameters which indicate performance of UV disinfection systems.

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 references, 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 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
biodosimetry
procedure of measuring the UV *reduction equivalent dose* (3.1.7) of a specific microorganism in a UV unit and a comparing the results to the known UV dose-response curve of this microorganism determined by bioassay (typically collimated beam methods)

3.1.2
challenge microorganism
microorganism used for a *biodosimetry* (3.1.1)

Note 1 to entry: Common challenge microorganisms include Bacteriophages MS2, Qβ and T1UV as well as *Bacillus subtilis* spores

3.1.3
computational fluid dynamics-intensity
simulation method to model a UV unit by performing a combination of computational fluid dynamics (CFD) and optical analysis

3.1.4
lamp protection component
apparatus for protecting the light source, including a lamp protection sleeve, tube or other component

Note 1 to entry: Lamp protection sleeve – the quartz tube or thimble that surrounds and protects the UV lamp. The exterior is in direct contact with the water being treated

3.1.5
low pressure lamp
mercury-vapour lamp that operates at an internal pressure of 0,13 Pa to 1,3 Pa (2×10^{-5} psi to 2×10^{-4} psi) and electrical input of 0,5 watts per centimetre (W/cm)

Note 1 to entry: This results in essentially monochromatic light output at 253,7 nm.

3.1.6
medium pressure lamp
mercury-vapour lamp that operate at an internal pressure of 13 kPa to 1,300 kPa (2 psi to 200 psi) and electrical output of 50 W/cm to 300 W/cm

Note 1 to entry: This results in a polychromatic (or broad spectrum) light output at multiple wavelengths, generally between 200 nm to 400 nm.

3.1.7
reduction equivalent dose
dose of UV in a given device which is determined by *biodosimetry* (3.1.1)

Note 1 to entry: See "UV dose" and "biodosimetry".

Note 2 to entry: This UV dose is determined by measuring the inactivation of a challenge microorganism after exposure to UV light in a UV unit and comparing the results to the known UV dose response curve of the same challenge organism determined via Bench scale collimated beam testing.

3.1.8
UV dose
UV fluence
amount of UV energy given as the time integral of the fluence rate or irradiance (W/m^2)

Note 1 to entry: This is given in units of mJ/cm^2 or J/m^2.

3.1.9
UV irradiance
UV fluence rate
UV intensity
UV output emitted from a given light source and entering a unit area of the irradiated surface. The value is typically given in W/m^2 or mW/cm^2

Note 1 to entry: The terms UV irradiance, fluence rate or intensity are often used to mean the same thing.

Note 2 to entry: For details, refer to Bolton and Linden 2003.

3.1.10
UV intensity sensor
UV irradiance (3.1.9) meter or radiometer instrument to measure *UV irradiance* (3.1.9)

3.1.11
UV transmittance
fraction of photons in the UV spectrum transmitted through a material such as water or quartz

Note 1 to entry: It is preferable that an online UVT sensor be installed and used to verify UVT.

Note 2 to entry: The wavelength of the UVT (unit %) should be specified, often using a path-length of 1 cm. The measurement is calibrated compared to ultra-pure water (ISO 3696 grade 1 or equivalent).

Note 3 to entry: UVT is related to the UV absorbance (A) by the following equation (for a 1- cm path length): % UVT = 100 × 10^{-A}.

3.2 List of abbreviated terms

AOPs	advanced oxidation processes
BOD	biochemical oxygen demand
CFD-I	computational fluid dynamics-intensity
E. coli	Escherichia coli
LCC	life cycle cost
PCD	pitch circle diameter
POPs	persistent organic pollutants
RED	reduction equivalent dose
TDS	total dissolved solids
TSS	total suspended solids
UV	ultraviolet
UVT	ultraviolet transmittance

4 Purpose and function of UV disinfection

4.1 Purpose

To conduct water reuse, secondary or tertiary treated wastewater requires disinfection and sometimes further treatment by more advanced processes. The treated and disinfected wastewater is then used for various applications such as, urban, agricultural, industrial recreational and environmental uses.

4.2 Function

UV light has been proven effective against microorganisms including bacteria, protozoa and viruses (see Annex A). UV disinfection is achieved mostly by the absorption of photons by the genome of microorganisms, resulting in the formation of damage such as pyrimidine dimers on DNA or RNA. Such lesions hinder the self-replication in the microorganisms and thus deprives the infectivity. Accordingly, UV disinfection does not require chemical addition and results in limited by-product formation.

5 System configuration

5.1 General

A UV disinfection system for water reuse can consist of the following components and systems may have several of each component based on the disinfection application requirements.

— UV unit;

— influent water quality monitoring devices;

— flow meter;

— power control panel.

Each component will be explained in 5.2 to 5.5.

5.2 UV unit

A UV unit has simple components including irradiation chamber, a light source, an automatic cleaning system and a UV intensity sensor. A specific UV unit may need one or more UV intensity sensor and one or more irradiation chamber and light source, depending on the specifics of the application. UV units may be categorized into closed and open systems, based on the configuration of UV units in the irradiation chamber. The closed system has a UV unit, comprised of UV lamps and their sleeves, placed in the closed vessel flow chamber. Meanwhile, the open system has a UV unit immersed in an open channel or chamber with gravity flow and water level control device. UV systems can also consist of non-contact unit designs with UV lamps suspended outside a transparent conduit that carries the wastewater.

— light source

A light source for UV disinfection should have a germicidal emission at wavelengths appropriate to the task, often at the wavelength of 253,7 nm or a combination of wavelengths between 200-385 nm. Options include low-pressure mercury lamps, medium-pressure mercury lamps, excimer lamps, pulsed-Xenon lamps, and ultraviolet light emitting diodes. The light source should be housed in a lamp protection component.

— cleaning system

A cleaning system is the device having a wiper driven by electric power supply, hydraulic power supply or pressurized air, or ultrasonic wave, etc. Options include a mechanical wiper consisting of a brush, ring or a mechanical chemical wiper consisting of a chamber with rings filled with a washing liquid.

— UV intensity sensor

A UV intensity sensor is installed to measure the UV irradiance in the irradiation chamber so that the irradiance can be tracked and it can be determined whether the required dose has been provided.

— ballast

A ballast is installed when using a UV lamp as a light source. Ballasts provide the power that the lamp converts to UV photons (energy).

5.3 Influent water quality monitoring devices

A UV transmittance monitor can be used to feed data to the system controller to adjust the power of the lamp to assure that the required dose is provided. To check whether or not the water quality of the influent has changed from the design conditions, water quality monitors including a UV transmittance monitor, a turbidity meter (optional) etc. are used.

5.4 Flow meter

Generally, each UV unit should have a dedicated flow meter for several reasons, including to confirm that the unit is operating within the validated flow rate range. The measured flow rate data may be sent to control panel and may be utilized for light-source controlling, monitoring and operating in order to achieve system performance. The method of flow rate measurement should be selected according to the variability in plant flow rate and installation conditions.

5.5 Power control panel

The control panel has the following functions: power receiving, power supplying, controlling, monitoring and operating, and other functions for the light source and other apparatuses.

6 Functional requirements

6.1 General

Functional requirements for treatment technologies address the transformation of influent water quality constituents to produce reclaimed water and include both water quality and water quantity parameters.

One of the functional requirements of a given UV treatment system is to secure, at all times, enough UV dose to obtain a target quality of the reclaimed water that is appropriate for application of such water. The UV dose is the time integral of the fluence rate or irradiance. What is necessary to this end includes: use of a UV light source with appropriate irradiance; and retaining the reclaimed water in a UV irradiation chamber for a predetermined time period.

In actual equipment, the irradiation time and UV irradiance in the UV irradiation chamber vary from one portion to another due to the shape of the chamber, as well as the location and number of the light sources, and other similar factors. Water quality determined by, for example, suspended matter and UV absorbing components also reduces UV transmittance, and thereby affects UV dose distribution. By taking these influences into consideration, a predetermined UV dose, or higher dose that is sufficient for the water flow passing through the UV irradiation chamber, shall be secured at all times.

Methods for evaluating the performance of the UV unit in the design stage and for subsequently monitoring the performance of the UV disinfection system in operation are provided below.

6.2 Evaluation of the UV unit performance

Evaluation of the UV unit performance should be done; a number of experimental methods may be used including those described in Annex B, while the method in Annex C is accepted as a second option.

NOTE The amount of upscaling varies from no upscaling permitted to a specific level of upscaling permitted depending on country regulations.

Method I: Annex B (Experimental evaluation method)
- I-1: Experimental testing using a challenge microorganism
  - I-1-1: Preliminary testing
  - I-1-2: Full-scale unit testing
- I-2: Determine the RED

Method II: Annex C (Experimental evaluation method in combination with CFD-I simulations)
- II-1: Experimental testing using a challenge organism for reference unit
- II-2: Intensity measurement test on UV light source
- II-3: Development of the CFD-I simulation models
- II-4: Determine the RED in the unit of interest

6.3 Method of monitoring UV treatment system performance

The UV treatment system can be run automatically, so that its usual operation is generally simple compared to other disinfection processes. What is important for routine maintenance includes: monitoring the amount and the quality of UV treatment target water; and monitoring the UV dose. Figure 1 shows the water flow through the UV treatment system and the monitoring points situated in the system.