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

Part 3: Ozone treatment technology

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

Partie 3: Technique de traitement à l'ozone

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

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. 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 reuse 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 to include objective specification and evaluation of levels of service and water reuse system performance dependability, including safety, environmental protection, and resilience and cost-effectiveness considerations. Hence, appropriate methods are needed to evaluate the performance of 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 the water reuse project. Despite considerable research and development on treatment technologies, such scientific knowledge is largely held within commercial interests. Given less than ideal communication between producers and users of reuse technologies with regards to treatment performance, clear information as to what to measure on the one hand and what level of performance is required on the other is currently missing. 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. In this context, this document stipulating specific ways of performance evaluation of ozone treatment technology, commonly known as ozonation, for water reuse systems, based on ISO 20468-1 as the generic standard, is established herein.

Ozone (O_3) is an allotrope of oxygen (O_2) and is the second strongest oxidiser after fluorine. Its strong oxidative decomposition power makes it effective as a disinfectant and in removal of oxidizable constituents in water. There are cases where ozonation at high doses is used to remove micro-pollutants in wastewater for environmental protection.

In various types of water reuse systems, the disinfection and the removal of colour and odour are essential. Then it can be said that ozone technology plays an important role to improve these water qualities for the purpose of water reuse, working well with secondary or tertiary treated water as shown in Figure 1 of ISO 20468-1:2018 and in Annex A.

In this guideline, the dedicated features to ozone technology for water reuse are described and the requirements for proper and accurate evaluation of ozone system for water reuse are offered.

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

Part 3: Ozone treatment technology

1 Scope

This document specifies performance evaluation methods of treatment technology using ozone for water reuse systems. It deals with how to measure typical parameters which indicate performance of ozone treatment technology.

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 following 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
ambient ozone concentration
concentration of ozone existing in the air or surrounding the ozone treatment apparatus

3.1.2
exhaust residual ozone concentration
ozone concentration (3.1.6) at the outlet of an off-gas ozone treatment unit

3.1.3
generated ozone amount
mass of ozone generated in a unit time

3.1.4
generated ozone concentration
ozone concentration (3.1.6) in the gas phase at the outlet of an ozone generator

3.1.5
off-gas ozone concentration
ozone concentration at the outlet of an ozone contactor

3.1.6
ozone concentration
volume, mass or mole of ozone in a unit volume or mass of gas or liquid

3.1.7
ozone concentration monitor
instrument capable of measuring ozone concentration in samples continuously

3.1.8
ozone demand
amount of ozone consumed to oxidize material in water

3.1.9
ozone dose
mass of ozone injected into a unit volume of water

Note 1 to entry: Ozone dose is expressed in units of mass-per-volume concentration (g/m^3 or mg/l).

3.1.10
residual ozone concentration
dissolved ozone concentration measured after a given contact time

Note 1 to entry: It is expressed in mg/l.

3.1.11
transferred ozone dose
mass of ozone applied into a unit volume of water

Note 1 to entry: Transferred ozone dose is expressed in units of mass-per-volume concentration (g/m^3 or mg/l).

3.2 Abbreviated terms

CT product of residual concentration and time

EPDM ethylene propylene diene monomer

FRP fiber-reinforced plastic

GHG greenhouse gases

LOX liquid oxygen

LRVs log-reduction values

PTFE polytetrafluoroethylene

SS stainless steel

UV ultraviolet

4 System configuration

4.1 General

The ozone system for water treatment consists of:

— a feed gas supply unit

— an ozone generation unit

— an ozone contact unit

— an off-gas ozone treatment unit

Depending on the water treatment efficiency and performance to be achieved, pre-treatment and/or post-treatment can be added to the ozone system. For example, sand filtration as the typical pre-treatment process to remove suspended impurities including ozone scavengers and inorganic matter enhances treated water quality and reduces ineffective ozone consumption. On the other hand, post-treatment such as biological activated carbon process removes residual particles and dissolved matter which are not decomposed and/or are generated as by-products during ozonation. In order to retain bactericidal effects after ozonation, post disinfection such as chlorine disinfection can be added.

4.2 Ozone system for water treatment

4.2.1 Feed gas supply unit

The feed gas supply unit is using either air or oxygen gas to the ozone generation unit. An air-fed ozone system uses compressed air directly from the atmosphere. An oxygen-fed ozone system uses LOX or concentrated oxygen fed by an oxygen concentrator. Typically, the oxygen concentrator increases oxygen concentration by adsorbing nitrogen selectively from air.

4.2.2 Ozone generation unit

The ozone generation unit typically consists of:

— ozone generator(s)

— a power supply

— a cooling system

Corona discharge is currently the most common ozone generation method.

4.2.3 Ozone contact unit

The ozone contact unit typically consists of:

— an ozone dissolution system

— ozone contactor(s)

The ozone contactor is a vessel where ozone is dissolved in water and reacts with target substance(s), followed by the ozone dissolution system which dissolves ozone gas in water. Mass transfer of ozone is a critical aspect of water ozonation. Dissolution devices include bubble diffusion, down flow tube injection, venturi injection, radial diffuser, static mixers and mechanical agitation. These applicable dissolution devices should be selected depending on the space limitation for system installation, electric power charge and ozone transfer efficiency. The method of ozone gas dissolution used also depends on system design and method of ozone generation used.

4.2.4 Off-gas ozone treatment unit

Since ozone is a very strong oxidant, any unreacted ozone in the off-gas can be harmful to the environment and endanger human health. Consequently, it shall be converted to oxygen and neutralized before the off-gas is released to atmosphere.

The off-gas ozone treatment unit typically consists of an off-gas ozone destruction unit and an off-gas ozone suction unit. The off-gas ozone suction unit withdraws off-gas ozone from the ozone contactor and draws it into the off-gas ozone destruction unit. The off-gas ozone destruction unit converts ozone residual exhausted from the ozone contactor to oxygen by using such methods as activated carbon, catalyst media and heat, or combination of heat and catalyst media.

4.2.5 Ozone measuring system

Various types of ozone monitors are available for measuring ozone concentrations. The typical configuration of ozone treatment system as well as the monitoring points of ozone concentration are shown in Figure 1.

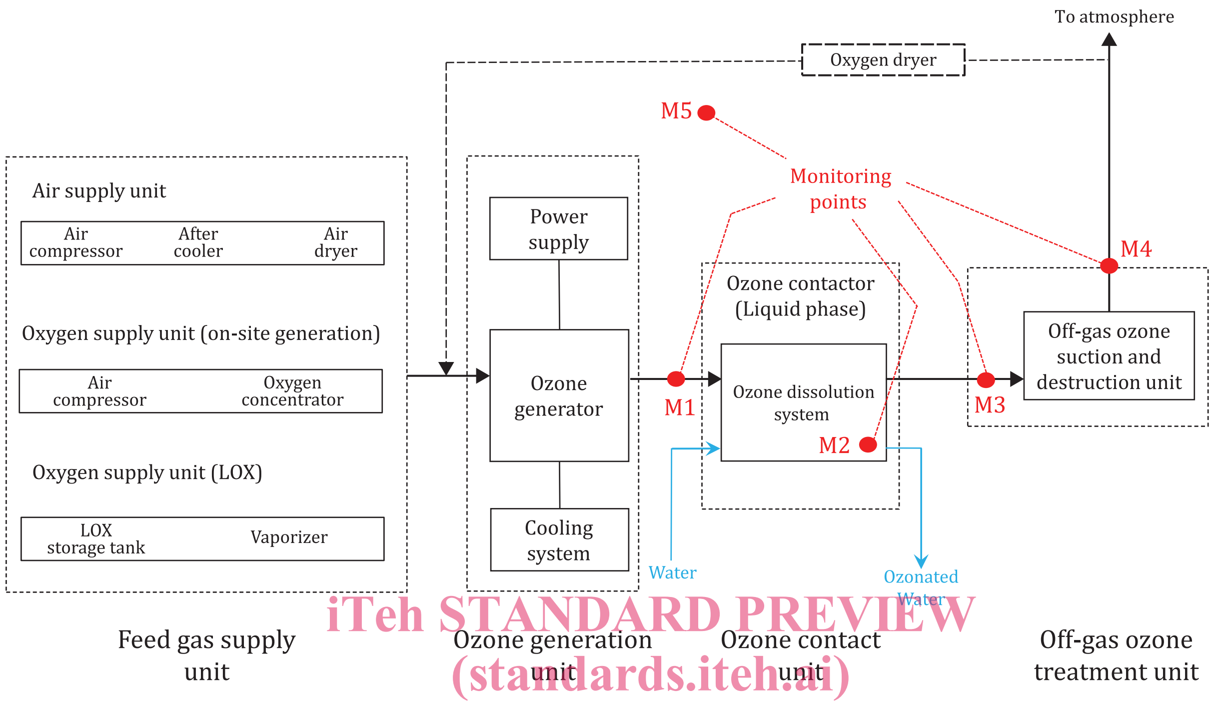

Figure 1 — Typical configuration of ozonation system and ozone concentration monitoring points

The high concentration ozone monitor, residual ozone concentration monitor and off-gas ozone concentration monitor are installed to measure ozone concentration at key locations in the ozonation system for the purpose of controlling ozone generation and dose. Specific descriptions about ozone generation control methods are shown in Annex D.

The exhaust and ambient ozone monitors measure ozone concentrations to verify safe operating conditions. The control system works automatically for system shutdown or stopping ozone production if necessary.

5 Principles and general guidelines for performance evaluation

5.1 General

Based on the principles and general guidelines for performance verification described in ISO 20468-1:2018[1], this document also specifies two kinds of performance requirements:

— functional requirements

— non-functional requirements

5.2 Functional requirements

5.2.1 General

Functional requirements consist of two parts; water quality based performance and process-based performance, both of which strongly influence the conformity of produced water quality to water reuse regulations and related standards.

Water quality based performance for ozone treatment includes the potential reduction of disease causing microorganisms that can be present and the removal of specific constituents such as colour and odour (Annex A). They are generally expressed as a logarithmic-scale reduction and a residual constituent concentration in the treated reuse water, respectively. On the other hand, ultra-violet absorbance and ultra-violet transmission can be used as surrogate indicators to check the removal efficacy of dissolved organic carbon. These water quality parameters and indicators should be in accordance with the water reuse regulations and standards stipulated in respective countries (examples in Annex B).

The reduction in, or residual concentration of, *Escherichia coli*, enterococci bacteria, thermo-tolerant coliform bacteria and total coliform bacteria can be used as potential indicators of microorganisms to assess the effectiveness of ozone disinfection in reducing pathogenic microorganisms that can be present in the source water. Quantification of these microbial indicators can be carried out by using analysis methods stipulated in ISO 6222:1999[2].

The reduction of concentration in pharmaceutical and personal care products and other contaminants of emerging concern, as well as colour and odour, can also be functional requirements for some reuse applications. Colour and odour can be quantified by the methods stipulated in Standard Methods for the Examination of Water and Wastewater[3]. The analytical methods and water quality parameters should be required by the regulations in respective countries.

The CT approach could be used for wastewater ozonation but is much less relevant than in drinking water. It is noted that a sufficient ozone dose to achieve the targeted water quality should be transferred to the effluent resulting in detection of residual ozone concentration.

Ideally, supplied ozone should be used completely in the reactor. However, if the off-gas ozone concentration indicates zero, it is practically impossible to correctly estimate transferred ozone dose. Therefore, the concentration of off-gas ozone before the destruction should be as low as possible by providing just enough amount of ozone for treatment.

On the other hand, process-based performance for ozone treatment is concerned with the functional performance of main units of ozone treatment system such as ozone generators and contactors and is assessed by monitoring the ozone concentration in different points (Annex C and D). The dependability of these units is also important as a part of process-based performance since failure in ozone generators and/or contactors can lead to releasing insufficient transferred ozone into water.

Failure in off-gas ozone treatment units can raise an issue of undestroyed ozone gas leaking to rooms, with the possibility of personnel injury and/or property damage in the worst-case situation. Therefore, the dependability of off-gas ozone treatment units should be included into non-functional requirements.

5.2.2 Performance evaluation procedures

5.2.2.1 STEP1 — Setting performance criteria and objectives

An ozone treatment system is expected to improve water quality parameters such as *E. coli*, thermo-tolerant coliforms, colour and odour. The water quality standards for these parameters as water-quality based performance criteria should be set for the purpose of water reuse.

Those reuse water quality parameters are standardized in some countries for landscape, amenity and other purposes, as illustrated in Annex B.

The values of the reclaimed water quality parameters should be some of the values that presented in Annex A of ISO 20761:2018[4].

In addition, to ensure the functionality and reliability of water reclamation processes for pathogen control in the case of high risk of exposure, the health risk management strategy can also include targets for log-reduction values (LRVs). Other water quality parameters can be relevant for specific non-potable water applications, such as those described in ISO 16075-1, ISO 16075-2, ISO 16075-3:2015, ISO 16075-4:2016[5] for irrigation. Further information on the risk assessment and management approach can be found in ISO 20426:2018[6], ISO 20761:2018 and in Australian Guidelines for Water Recycling[7].

On the other hand, in order to meet the target water quality consistently, the ozone system is required to be operated properly. From this viewpoint, the parameters of operational conditions should be included into process-based performance indicators.

5.2.2.2 STEP 2 — Performance evaluation

Water quality based performance of ozone treatment system for water reuse can be evaluated by periodically measuring residual concentrations of the target constituents. The residual concentrations should be assessed frequently enough to ensure operating parameters and regulatory and aesthetic reuse water quality objectives are consistently met. The monitoring program and sampling frequency should be in accordance with the standards in respective countries.

At the same time, it is important to measure the ozone concentration. Figure 1 shows the typical configuration of ozone treatment system as well as monitoring points of ozone concentration as operating conditions; ozone concentration at M1 and M3 points should be monitored as shown in Annex C to effectively evaluate the treatment system performance. When those concentrations meet the target values, it is confirmed that the appropriate amount of ozone is supplied and consumed in the ozone contactor to achieve the functional requirement on water quality.

Furthermore, the following parameters are also expected to function well as process-based performance indicators:

a) Generated ozone amount

Generated ozone amount is calculated by the following formula.

(Generated ozone amount) = (Generated ozone concentration) × (Ozone gas flow rate)

The value of generated ozone amount should be larger than ozone demand.

b) Ozone dose

Ozone dose is calculated by ozone gas flow rate, water flow rate and generated ozone concentration.

(Ozone dose) = (Ozone gas flow rate) × (Generated ozone concentration) / (Water flow rate)

Ozone dose should be controlled to provide sufficient amount of ozone to achieve targeted water quality.

c) Transferred Ozone dose

Transferred ozone dose is calculated by ozone gas flow rate, water flow rate, generated ozone concentration and off-gas ozone concentration.

(Transferred ozone dose) = (Ozone gas flow rate) × (Generated ozone concentration − Off-gas ozone concentration) / (Water flow rate)

In case that off-gas ozone concentration is sufficiently low, ozone dose would be equal to transferred ozone dose.

d) Mass transfer efficiency

Mass transfer efficiency shows how much ozone is transferred into water out of generated ozone amount. Specifically, it is calculated by generated ozone concentration and off-gas ozone concentration.

(Mass transfer efficiency) = (Generated ozone concentration − Off-gas ozone concentration) / (Generated ozone concentration) × 100

This value is normally between 80 to less than 100 %, depending on dissolution methods.

