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## Wastewater treatment plants

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Part 14: Disinfection

## National foreword

This British Standard is the UK implementation of EN 12255-14:2023. It supersedes BS EN 12255-14:2003, which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee B/505/40, Wastewater Treatment Plants 50 PT.

A list of organizations represented on this committee can be obtained on request to its committee manager.

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Published by BSI Standards Limited 2023

ISBN 978 0 539 14298 3

ICS 13.060.30

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This British Standard was published under the authority of the Standards Policy and Strategy Committee on 31 July 2023.

### Amendments/corrigenda issued since publication

Date	Text affected
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EUROPEAN STANDARD  
NORME EUROPÉENNE  
EUROPÄISCHE NORM

# EN 12255-14

July 2023

ICS 13.060.30

Supersedes EN 12255-14:2003

English Version

## Wastewater treatment plants Part 14: Disinfection

Stations d'épuration - Partie 14: Désinfection

Kläranlagen - Teil 14: Desinfektion

This European Standard was approved by CEN on 28 May 2023.

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## European foreword

This document (EN 12255-14:2023) has been prepared by Technical Committee CEN/TC 165 “Wastewater engineering”, the secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by January 2024, and conflicting national standards shall be withdrawn at the latest by January 2024.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN shall not be held responsible for identifying any or all such patent rights.

This document supersedes EN 12255-14:2003.

It is the 14<sup>th</sup> part prepared by Working Group CEN/TC 165/WG 40 relating to the general requirements and processes for treatment plants for a total number of inhabitants and population equivalents (PT) over 50.

The EN 12255 series with the generic title “Wastewater treatment plants” consists of the following parts:

- *Part 1: General construction principles*
- *Part 2: Storm management systems*
- *Part 3: Preliminary treatment*
- *Part 4: Primary treatment*
- *Part 5: Lagooning processes*
- *Part 6: Activated sludge process*
- *Part 7: Biological fixed-film reactors*
- *Part 8: Sludge treatment and storage*
- *Part 9: Odour control and ventilation*
- *Part 10: Safety principles*
- *Part 11: General data required*
- *Part 12: Control and automation*
- *Part 13: Chemical treatment — Treatment of wastewater by precipitation/flocculation*
- *Part 14: Disinfection*
- *Part 15: Measurement of the oxygen transfer in clean water in aeration tanks of activated sludge plants*
- *Part 16: Physical (mechanical) filtration*

NOTE Part 2 is under preparation.

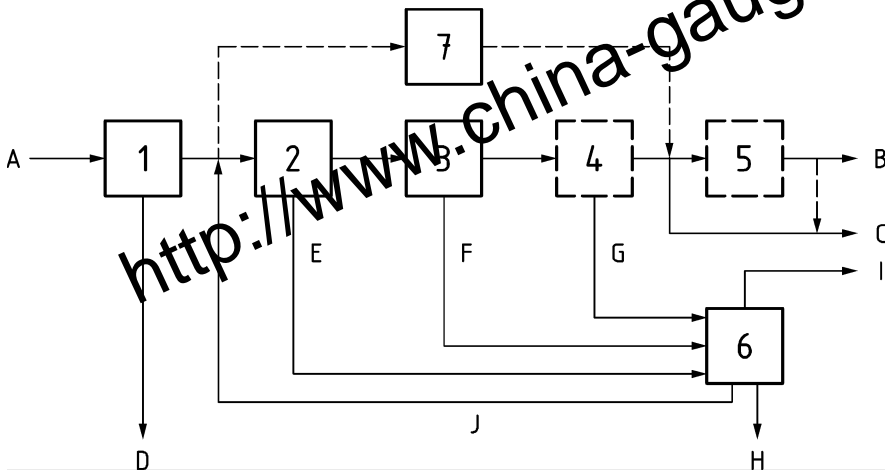
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Introduction

Differences in wastewater treatment throughout Europe have led to a variety of systems being developed. This document gives fundamental information about the systems; this document has not attempted to specify all available systems. A generic arrangement of wastewater treatment plants is illustrated below in Figure 1:



- Key**
- 1 preliminary treatment
  - 2 treatment
  - 3 secondary treatment
  - 4 tertiary treatment
  - 5 additional treatment (e.g. disinfection or removal of micropollutants)
  - 6 sludge treatment
  - 7 lagoons (as an alternative)
  - A raw wastewater
  - B effluent for re-use (e.g. irrigation)
  - C discharged effluent
  - D screenings and grit
  - E primary sludge
  - F secondary sludge
  - G tertiary sludge
  - H stabilized sludge
  - I digester gas
  - J returned water from dewatering

Figure 1 — Schematic diagram of wastewater treatment plants

Detailed information additional to that contained in this document can be obtained by referring to the Bibliography.

The primary application is for wastewater treatment plants designed for the treatment of domestic and municipal wastewater.

NOTE For requirements on pumping installations at wastewater treatment plants see EN 752 and the EN 16932 series:

- *Part 1: General requirements;*
- *Part 2: Positive pressure systems;*
- *Part 3: Vacuum systems.*

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## 1 Scope

This document specifies design principles and performance requirements for disinfection of effluents (excluding sludge) at wastewater treatment plants serving more than 50 PT.

NOTE Sludge disinfection is described in EN 12255-8.

## 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.

EN 12255-1, *Wastewater treatment plants - Part 1: General construction principles*

EN 12255-5, *Wastewater treatment plants - Part 5: Lagooning processes*

EN 12255-10, *Wastewater treatment plants - Part 10: Safety principles*

EN 12255-12, *Wastewater treatment plants - Part 12: Control and automation*

EN 12255-15, *Wastewater treatment plants - Part 15: Measurement of the oxygen transfer in clean water in aeration tanks of activated sludge plants*

EN 16323, *Glossary of wastewater engineering terms*

ISO 15727, *UV-C devices — Measurement of the output of a UV-C lamp*

## 3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 12255-1, EN 16323, and the following apply.

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

- ISO Online browsing platform: available at <https://www.iso.org/obp/>
- IEC Electropedia: available at <https://www.electropedia.org/>

### 3.1

#### **residual concentration**

concentration of a substance in the final effluent of a treatment stage

### 3.2

#### **UV dose**

product of UV irradiance and specific exposure time along the pathway of an infinitesimal small water volume

Note 1 to entry: UV dose is expressed in millijoules per square centimetre (mJ/cm<sup>2</sup>).

### 3.3

#### **UV intensity**

quotient of the energy of the UV radiation received on the surface of an infinitesimal small area divided by the size of the area

Note 1 to entry: The unit of UV intensity is W/m<sup>2</sup>, measured in accordance with ISO 15727.

### 3.4

#### **UV-reactor**

closed vessel or an open channel section with an assembly of UV-lamps irradiating the water passing through

### 3.5

#### **bioassay**

measurement of the concentration or potency of a substance by its effect on living cells or tissues

[SOURCE: EN 16323:2014, 2.3.5.4, modified to remove limitations]

### 3.6

#### **specific ozone demand**

required dissolved ozone concentration in the wastewater to achieve a level of disinfection

Note 1 to entry: The unit of specific ozone demand is typically  $\text{g O}_3/\text{m}^3$  or  $\text{g O}_3/\text{l}$ .

### 3.7

#### **ozone destructor**

device for destruction of residual ozone that has not been consumed in the ozonation process and is accumulated in the gaseous form in an off-gas stream

Note 1 to entry: The destruction takes place in gas-phase by converting ozone ( $\text{O}_3$ ) into oxygen ( $\text{O}_2$ ).

### 3.8

#### **chlorinator**

equipment for dosing chlorine into water

Note 1 to entry: Includes *in situ* generation.

### 3.9

#### **contact tank**

tank for providing the required retention time for certain reactions to take place

### 3.10

#### **contact time**

required retention time at a certain concentration for a specific reaction to occur

### 3.11

#### **membrane**

semipermeable material used as filter media in membrane filtration processes

Note 1 to entry: Membranes normally are flat sheets, tubes or hollow fibres composed of a thin semipermeable layer on a structural material.

### 3.12

#### **permeate** (*noun*)

liquid or gas that diffuses through a permeable membrane

[SOURCE: ISO 3857-4:2012, 2.54]

### 3.13

#### **concentrate** (*noun*)

fluids enriched with substances not passing the membranes in membrane filtration processes

**3.14****membrane flux**

amount of permeate produced per unit area of membrane surface per unit time

**3.15****transmembrane pressure**

mean pressure exerted across the semipermeable membrane

[SOURCE: ISO 8637-3:2018, 3.7]

**3.16****cross flow filtration**

filtration with a significant flow parallel to the membrane surface

Note 1 to entry: This is intended to prevent substances from accumulating on the surface of the membrane.

[SOURCE: EN 16323:2014, 2.3.3.5]

**3.17****perpendicular mixing**

mixing perpendicular to flow direction

**3.18****feed-gas**

gas or gas mixture which is supplied to the ozone generation system

**3.19****normal cubic metre**

<gas> cubic metre of gas, usually dry, referenced to 1 atmosphere (101,325 kPa) and 0 °C

[SOURCE: ISO 20675:2018, 3.41]

Note 1 to entry: The unit is expressed m<sup>3</sup><sub>n</sub>. In other documents the unit Nm<sup>3</sup> is sometimes used.

**4 Symbols and abbreviations**

AOX	halogenated organic compounds
BOD <sub>5</sub>	biochemical oxygen demand in 5 days (expressed as milligrams of oxygen needed to break down the organic matter contained in a litre of water over five days (mg/l))
COD	chemical oxygen demand
<i>CT</i>	product of concentration and contact time
LOX	liquid oxygen
NO <sub>x</sub>	nitrogen oxides
PAA	peracetic acid
PE	polyethylene
PTFE	polytetrafluoroethylene
PVC	polyvinyl chloride
<i>Q</i>	wastewater flow rate

RH	relative humidity, (expressed as a percentage of present state of absolute humidity relative to a maximum humidity given the same temperature)
SS	suspended solids, (expressed as milligrams of small solids contained in a litre of water (mg/l))
$P_{\text{tot}}$	concentrations of total phosphorus compounds expressed in milligrams of phosphorous in a litre of water (mg/l)
$T$	contact time
THM	trihalomethanes
$t_R$	retention time
UV	ultraviolet, electromagnetic radiation with wavelength 100 nm to 400 nm
$V$	active contact volume

## 5 Design requirements

### 5.1 General

Disinfection processes are used to improve the microbiological quality of effluents, if required, e.g. because of sensitive uses of the receiving waters downstream. A disinfection of effluents from wastewater treatment plants can reduce public health risks by preventing contamination by human pathogens in:

- waters used for bathing and other recreational activities involving immersion;
- shellfisheries;
- treated wastewater to be used for irrigation or as process water or other compatible uses;
- sources used for potable water supply.

Disinfection of effluents from wastewater treatment can be attained by two possible mechanisms:

- inactivation of microorganisms rendering microorganisms incapable of reproduction;
- removing the microorganisms from an effluent (e.g. by filtration) but not necessarily inactivating them.

Although other methods exist, the processes most commonly used for disinfecting wastewater by inactivating microorganisms are:

- ultraviolet (UV)-radiation;
- chlorination;
- ozonation;
- peracetic acid.

The processes most commonly used for disinfecting wastewater by removing respectively reducing microorganisms are:

- membrane filtration;
- effluent maturation ponds;

- soil filtration.

Combinations of different processes are possible e.g. flocculation filtration with ozonisation.

## 5.2 Planning

### 5.2.1 General

Disinfection, if required, should be the last stage in the wastewater treatment process. Poor performance by upstream processes will affect the performance of the disinfection process. If an effluent has to be stored prior to discharge – e.g. in case of discharge to final water or irrigation – it should preferably be disinfected after storage directly prior to discharge in order to limit regrowth hazards.

When planning disinfection systems consideration shall be given to the:

- level of disinfection required;
- stability and efficiency of disinfection process;
- technological level of disinfection process;
- operational requirements;
- monitoring of water quality;
- safety hazards;
- environmental impacts, e.g.:
  - effects on the quality of the effluents (reduction of BOD<sub>5</sub>, COD, SS, P<sub>tot</sub>);
  - deleterious effects of residual disinfectants;
  - production of toxic or bioaccumulating by-products;
- power requirements.

### 5.2.2 Level of disinfection

Disinfection processes shall reduce or inactivate human pathogens to a level that the risk of the disinfected wastewater being a source of infections is minimized. Disinfection processes are not intended to remove all micro-organisms, or even remove all human pathogens.

National or local regulations or the relevant authority can specify the required level of disinfection to be achieved.

The specification of the planned level of disinfection shall include procedures for sampling, analysis and evaluation. Statistical criteria for complying with the level of disinfection required shall be named explicitly e.g. for dry weather and storm water conditions. These procedures shall be defined by the customer.

## 5.3 Process design

### 5.3.1 General

With respect to the high required reduction rate no short circuiting, by-passing, or incomplete treatment is permitted. The required treatment shall be applied to all wastewater because the microbiological

quality of disinfected wastewater reacts very sensitively to any wastewater not being disinfected properly.

NOTE This is because the required reduction of indicator organisms is usually in the magnitude of 99,9 % to 99,99 %. A leakage or short circuiting of 0,01 % to 0,1 % of the wastewater or a reduced reduction rate of only 99 % in 1 % to 10 % of the wastewater due to incomplete treatment can cause germ counts that already exceed the effluent standards.

### 5.3.2 UV radiation

UV disinfection is the application of UV radiation artificially generated in UV lamps in UV reactors to the wastewater to be disinfected. An appropriate dose of UV radiation will cause an irreversible inactivation of microorganisms with no other significant effects on the wastewater.

NOTE The disinfection by UV radiation is due to a photochemical effect. UV radiation of germicidal wavelength causes the formation of dimers of neighbouring thymine bases in nucleic acids. These dimers disturb the replication of the nucleic acids and cause an irreversible inactivation of the microorganisms if the formation of dimers is too numerous to be repaired by the cells' repair mechanisms.

UV radiation systems for wastewater disinfection can be classified as follows:

- type of UV reactor (open channel gravity flow systems, closed vessel systems);
- type of UV-lamps (low pressure or medium pressure mercury discharge lamps);
- configuration of UV-lamps (in wastewater immersed lamps housed in quartz glass sleeves, non-contact systems).

Radiation systems can consist of one or more UV reactors. UV reactors can be in series or parallel. Designing and sizing a UV radiation system for wastewater disinfection, the following site specific parameters shall be taken into consideration:

- minimum UV dose;
- peak flow;
- minimal UV transmittance of effluent.

The minimum UV-dose is the UV irradiation required to reduce the concentration of microorganisms in an effluent to the requested level of disinfection. The minimum UV dose is independent of the UV radiation system used for the disinfection. The minimum UV dose is only determined by:

- a) the level of disinfection required specified in terms of
  - relevant indicator and/or pathogen organisms concentrations;
  - sampling and analysis procedures (photo-reactivation);
  - statistical criteria for approval.
- b) characteristics of the wastewater
  - suspended solids concentration;
  - concentrations of microorganisms before disinfection.

The required minimum UV-dose can be estimated on the basis of experimental data determined by collimated beam tests, pilot plant studies, or experience from other installations.

On the basis of the minimum UV dose, peak flow, and minimum UV transmittance a UV radiation system can be designed and sized appropriate to deliver the required minimum UV dose to all wastewater to be disinfected. Design and sizing of UV radiation systems are system specific. The system supplier shall provide a verifiable UV dose calculation based on a bioassay study or on an UV intensity distribution calculation combined with a detention time distribution study (tracer study).

For a safe disinfection and a good efficiency of a UV radiation system the hydraulic design and the efficiency of the UV-lamps are most important. The UV-lamp-ballast-systems provider should provide an expertise on efficiency and out-put drop over time from an independent source. The system shall be such that, if the lamps efficiency drops, leading to a UV-dose lower than the minimum UV-dose, maintenance shall occur for cleaning the sleeves and/or replacing the lamps. As an alternative, the system can be such, that the UV input can be increased-so that the UV dose is higher than the minimum UV-dose.

The hydraulic design of UV radiation system shall ensure that:

- no wastewater to be disinfected can by-pass the UV radiation system at any time;
- all the cross sections of the UV reactors are irradiated (no shadowed areas);
- hydraulic flow is as close to plug flow as practicable;
- hydraulic flow is as close to perfect perpendicular mixing as practicable.

Efficiencies of UV radiation systems claimed by contractors can be verified by:

- bioassay studies (see [15], [24]);
- pilot plant studies;
- full scale experience.

For systems with submerged UV-lamps a cleaning routine for the quartz glass sleeves of the UV-lamps shall be established. For systems with low pressure mercury discharge UV-lamps cleaning frequencies of less than once every two weeks can be expected. For systems using medium pressure mercury discharge UV-lamps cleaning might be required much more frequently. In addition to the existence of automatic cleaning systems it may be necessary to implement manual cleaning routines for the quartz glass sleeves of the UV-lamps. Contractors shall provide information to the operational/maintenance team and a maintenance plan.

UV-lamps should be replaced at intervals recommended by the manufacturers. It is recommended that the minimum lamp lifetime should be greater than one year (8760 h) for continuous disinfection systems.

### 5.3.3 Ozonation

Ozone is typically produced by transforming oxygen ( $O_2$ ) to ozone ( $O_3$ ) from oxygen sources such as:

- a) ambient air, typically 21 % oxygen, 78 % nitrogen and 20 % to 40 % RH;
- b) compressed air, from e.g. a compressor, typically 21 % oxygen, 78 % nitrogen. RH depending on the installation/dryer;
- c) oxygen generated from air at the installation site using an oxygen generator, typically below  $-45^\circ\text{C}$  dew point,  $\geq 85$  % oxygen,  $\leq 15$  % nitrogen;
- d) gaseous oxygen from e.g. pressurized cylinders;
- e) liquid oxygen (LOX) from e.g. pressure tanks.

A feed-gas is considered dry at dew point (humidity) below of  $-45^{\circ}\text{C}$ .

The main objective of an ozone generator is to produce ozone. However, by-product formations of nitrogen oxides ( $\text{NO}_x$ ) and nitric acid/nitric salts are directly correlated to the quality of the feed-gas.

The use of on-site generated oxygen feed-gas also removes potential hazards and manual handling commonly associated with storing pressurized oxygen bottles or liquid oxygen.

The purity requirements for the feed-gas, including requirements of dew-point (humidity in the feed-gas), shall be fulfilled and stated by the manufacturer of the ozone generator.

Ozone generation from supply air inevitably produces by-products in the form of nitrogen oxides ( $\text{NO}_x$ ), mainly  $\text{N}_2\text{O}$  and  $\text{N}_2\text{O}_5$  [47]-[50], which are classified significant greenhouse gases. In addition, depending on the bromide concentration and ozone dose, bromate can be formed in a concentration that is not suitable for drinking water production.

If the feed-gas is insufficiently dried ( $\geq -45^{\circ}\text{C}$  dewpoint),  $\text{N}_2\text{O}_5$  will react with the water (humidity) present in the feed-gas (e.g. air) and form nitric acid ( $\text{HNO}_3$ ). The involved transient nitrogen oxides  $\text{NO}$ ,  $\text{NO}_2$  and  $\text{NO}_3$  react in catalytic processes with the ozone and consequently reduce the ozone yield of the ozone generator [54].

The nitric acid itself can accumulate inside the ozone generator and lead to corrosion or affect components inside the ozone generator as well as downstream components in the overall plant. The formation of nitric acid will be effectively inhibited using dried feed-gas (dew point below  $-45^{\circ}$  at normal temperature and pressure).

However, diluting of the feed-gas with a small amount of nitrogen when generating ozone will improve the ozone yield [51].

Furthermore, by drying the feed-gas, the energy demand for the generation of ozone will be decreased (due to lack of above-mentioned reduction of ozone yield) [52]-[53].

Always follow the ozone generator manufacturer's recommendations for feed-gas regarding purity, dew point, pressure, volumetric flow, etc. An ozonation system shall at least include the following components:

- ozone generator(s);
- oxygen concentrator or oxygen cylinder;
- air compressor with dryer if an oxygen concentrator is used;
- contact tank for mass transfer of ozone from gas to liquid phase;
- contact tank;
- if necessary; process water pump;
- automation components (control cabinet, sensors/gauges, control valves, etc.);
- other process and mechanical equipment used to achieve the required ozone residual concentration in the water;
- ozone destructor for off-gas.

Ozonation systems shall be classified in accordance with Annex A.

Ozone is an oxidizing gas that is produced on site. Exposure to ozone can be hazardous to health so exposure levels may need to be monitored e.g. humans shall not be exposed above 0,1 ppm (0,2  $\text{mg}/\text{m}^3$ )



in gas phase as mean value for a period longer than eight (8) hours. Ozonation can lead to formation of other by-products. In designing an ozonation plant all relevant safety considerations for generating and handling ozone, in accordance with EN 12255-10, shall be respected.

The efficiency of the ozonation process is highly dependent of an effective ozone mass transfer through the contact tank, into the effluent in order to achieve the required  $CT$ -value, as defined in Formula (1) below.

$$CT = C \times T \quad (1)$$

where:

$C$  = ozone residual concentration (mg/l)

$T$  = contact time (expressed in minutes)

NOTE Annex B describes a method used for measuring ozone concentration in water.

The following types of contact tank can be used:

- diffused bubble;
- positive pressure injection;
- negative pressure injection (venturi);
- mechanical agitation;
- packed tower.

A higher ozone concentration ( $\text{g O}_3/\text{m}^3_{\text{n}}$ ) improves the mass transfer efficiency of the contact tank; an ozone concentration of at least  $50 \text{ g}/\text{m}^3_{\text{n}}$  is recommended. The contact tank shall provide sufficient retention time for the disinfection reactions of the ozone to be completed. Short circuiting shall be avoided. The total footprint of the contact tank should be minimized.

With respect to its toxicity any residual ozone in the waste gas shall be destroyed. The volumetric flow rate of waste gas from the contact tank should be minimized. Where possible, the contact tank and waste gas destruction should be integrated. All ozone bearing parts of an ozonation plant shall be a closed vessel system only vented through an ozone destructor. In the case of an elevated ozone concentration ( $> 0,2 \text{ mg}/\text{m}^3$ ) being detected the ozone generators shall shut down automatically. Systems used for ozone destruction in the waste gas include:

- thermal destruction ( $T > 350 \text{ }^\circ\text{C}$ ,  $t_{\text{R}} > 2 \text{ s}$ );
- catalytic destruction (i.e. Palladium/CuO-MnO in accordance with manufacturer's instructions);
- activated carbon (activated carbon is oxidized and consumed by the ozone destruction).

The ozone systems shall be equipped with ambient detectors and safety mechanisms delivered by the ozonation system manufacturer. In confined spaces, ambient ozone sensors shall be placed in areas according to the end-user risk analysis.

Typical residual concentration of ozone in the wastewater is in range of  $0,1 \text{ g}/\text{m}^3$  to  $1 \text{ g}/\text{m}^3$ . For ecological reasons at particularly sensitive sites lower concentrations can be necessary. Important parameters for the design of the ozonation system for water treatment are the following:

- If possible, project specific pilot tests should be carried out to determine the actual specific ozone demand;

- If specific pilot tests cannot be performed a  $CT$  value of 3 (minutes  $\times$  mg  $O_3$ /l), can be used;
- An "Active" volume = Tank volume minus the volume occupied by other equipment and materials in the tank = Net water volume;
- Dissolved ozone residual concentration shall be measured on the wastewater outlet from the contact tank using ozone or ozone equivalent measuring equipment;
- The ozone system should automatically be able to control the  $CT$  determined dissolved ozone residual concentration in the water;
- Contact time,  $T$ , (minutes) is calculated using Formula (2).

$$T = \frac{V}{Q} \quad (2)$$

where:

$Q$  = wastewater flow rate (litres/ minute)

$V$  = active contact volume (litres)

The efficacy of the ozonation system shall be expressed as grams of ozone residual concentration per kWh under nominal test conditions defined in EN 12255-15. The efficacy assessment shall include the total power consumption of all components of the ozonation system (see Annex A).

#### 5.3.4 Chlorination

Chlorination is a well-established disinfection technique, known to present the potential to form disinfection by-products, such as THM's, AOX or PCB's, among others. The toxicity potential associated with chlorination should be assessed through a risk analysis, whenever justified by the characteristics of the receiving water body (e.g. a sensitive water body) and intended use for the treated wastewater [46].

The required dosage of the disinfectant solution depends on the type of disinfectant used and is site specific. The dosage of the disinfectant chemical shall be adjusted to the flow rate and the disinfectant consumption rate of the wastewater with the objective to attain a stable residual concentration in the contact basin effluent and also to prevent by-product formation. The site specific required dosage should be determined by experiments, if possible, before design is undertaken. Residual concentration for chlorination in the contact basin effluent should be approximately 0,2 mg/l of free chlorine. With a lower residual concentration disinfection might not be complete, with a higher residual concentration a severe damage of the bacterial population in the receiving water and excessive concentrations of toxic by-products in the effluent might be the consequence. In order to reduce the negative effects of chlorinated effluents in the receiving water, chlorinated effluents may have to be dechlorinated prior to being discharged.

Chlorinators for the disinfection of wastewater are technologically similar to the systems used for the chlorination of potable water and include appropriate systems for:

- storage of disinfectant chemicals;
- preparation and dosing of disinfectant solutions;
- mixing of wastewater and disinfectant solution;
- disinfection reactions being completed in reaction tanks commonly referred to as contact tanks;
- the dechlorination before discharge.

Disinfecting chemicals are toxic and hazardous. The more commonly used in chlorinators are:

- sodium hypochlorite solution;
- chlorine gas;
- chlorine dioxide.

The systems for the storage, preparation, and dosing of the disinfecting chemicals depend on the type of disinfecting chemicals being used.

Sodium hypochlorite solution can be purchased in concentrations of 5 % to 15 % NaOCl. It can be stored in tanks and dosed with positive displacement pumps. Stored sodium hypochlorite solutions decompose over time. The decomposition rate increases with rising temperature and/or solar exposure.

Chlorine gas can be stored in pressurized gas tanks. Any rooms possibly affected by chlorine gas in case of leakage, rupture or malfunctioning shall be controlled by chlorine gas detectors. Chlorine gas can be dosed with negative pressure injection systems (venturi) into a side stream of the effluent, producing a solution of hypochlorous acid, which then is mixed with the effluent. Such chlorinators shall have the following components:

- a pressure/vacuum regulator;
- a feed rate controller;
- a mixing device (e.g. venturi injector);
- a flow indicator for the dosing substance.

Chlorine dioxide is an unstable gas that can explode if not well managed. It should not be stored prior to use and should be generated on-site as required for disinfection. Storage and use of chlorine dioxide in a solution of approximately 5 % is possible. The manufacturer's instructions shall be considered. There are a number of methods which can be used to generate chlorine dioxide solution on site. These include the following reactions:

- sodium chlorite and chlorine gas;
- sodium chlorite and hydrochloric acid;
- sodium chlorite, hydrochloric acid and sodium hypochlorite.

Chlorine dioxide reactors shall be designed to ensure that there is:

- an efficient generation of chlorine dioxide from the feed chemicals;
- a low concentration of chlorine in the chlorine dioxide solution.

Chlorine dioxide is an effective bactericide over a wide range of pH values and in many circumstances more effective than chlorine. Unlike chlorine, it does not react with ammonia to form chloramines and there seems to be considerably less formation of AOX compounds with chlorine dioxide than with chlorine. It can lead to the formation of other by-products (chlorates, bromates, etc.).

The mixing of the effluent and the disinfectant solution should be very intense and should be completed in a very short time (within a period of seconds). In line mixing systems or vigorously stirred tank reactors with a short detention time are appropriate solutions.

Disinfection reactions are completed in contact tanks. The objective of the contact tanks is to maintain the microorganisms in the effluent stream in intimate contact with the disinfecting chemical for the

required period. A disinfection contact tank shall be designed to avoid short circuiting and should be as near to a plug flow system as is practicable. It will normally be a pipeline or a serpentine chamber.

The required dosage of the disinfectant solution depends on the type of disinfectant used and is site specific. The dosage of the disinfectant chemical shall be adjusted to the flow rate and the disinfectant consumption rate of the wastewater with the objective to attain a stable residual concentration in the contact tank effluent. The site-specific required dosage should be determined by experiments, if possible, before design is undertaken. Residual concentration for chlorination in the contact tank effluent should be approximately 0,2 mg/l of free chlorine. With a lower residual concentration disinfection might not be complete, with a higher residual concentration a severe damage of the bacterial population in the receiving water and excessive concentrations of toxic by-products in the effluent might be the consequence. Negative effects on the receiving water have been reported for chlorine concentrations as low as 0,05 mg/l to 0,1 mg/l. In order to reduce the negative effects of chlorinated effluents in the receiving water chlorinated effluents shall be dechlorinated prior to being discharged.

### 5.3.5 Peracids (Peracetic acid)

Peracetic acid (PAA) is a strong oxidant and disinfectant. The disinfecting action of PAA is through the release of reactive hydroxyl radicals that react with organisms.

PAA produces by-products with little toxic potential for the aquatic environment [38], [42], [43]. However, its mode of action could dictate that PAA may potentially provoke oxidative stress to beneficial organisms in waterbodies receiving PAA-treated wastewater [39][44].

PAA will decompose into hydrogen peroxide and acetic acid. PAA disinfection has the potential to increase the organic content in the treated effluent due to the presence of acetic acid.

Peracetic acid can be used in aqueous solution of 10 % to 18 %. Solutions with more than 18 % of PPA exhibit some degree of explosiveness, instability, and reactivity. Attention shall be paid to the loss of disinfection activity over time. Peracetic acid should be stored at cool temperatures in containers or other recipients of glass, plastics, or stainless steel.

The required dosage and the contact time depend strongly on:

- the quality of the wastewater;
- the target organism; and
- the level of inactivation required.

To achieve best performance the pH of the water to be disinfected, should be below 8,2. Therefore, the site-specific required dosage should be determined by experiments.

### 5.3.6 Membrane filtration

The membrane filtration processes used for wastewater disinfection are ultra- and microfiltration. Both membrane filtration processes use porous membranes as filter media and behave as sieving filters. In membrane filtration the effluent is forced through the membrane pores under pressure. The transmembrane pressure is normally generated by a pressure pump on the effluent side, static height difference or a vacuum pump on the permeate side. Membrane filtration systems include the following elements:

- modules which contain membranes in the form of hollow fibres, tubes, discs or pleated cartridges, flat or spiral wound sheets, and provide adequate systems for distributing the inflowing effluent and for collecting the concentrate and the permeate;
- pressure or vacuum pumps that provide an appropriate transmembrane pressure;

- systems for backwashing and/or chemical cleaning of the membranes.

Membrane filtration processes are characterized e.g. by:

- size of the pores in the membranes (microfiltration or ultrafiltration);
- material of the membranes (organic or inorganic);
- type of the modules (hollow fibres, tubes, discs or pleated cartridges, flat or spiral wound sheets);
- mode of operation (dead end or cross flow filtration);
- type of influent (settled effluent or mixed liquor).

Designing and sizing a membrane filtration system the following additional factors shall be considered:

- membrane flux achievable in operation just before backwashing or cleaning the membrane;
- backwashing and cleaning procedures;
- energy consumption.

Consideration shall also be given to the safe disposal of the concentrate. Design and operation of the secondary treatment process shall then consider any such additional inputs. Care should be exercised to avoid the build-up of solids within such a system which are removed by the membrane filtration process but are not removed by the secondary treatment process. The addition of small amounts of coagulant to the concentrate is one method of avoiding this problem.

A routine for cleaning the membrane shall be established. Cleaning can be accomplished using backwashing, air scouring or chemical cleaning. The interval between cleaning will be dependent on the reduction in membrane flux or alternatively can be based on a fixed time interval. An appropriate cleaning regime shall be established during commissioning. The cleaning regime shall be reviewed periodically.

A method shall be provided to identify and isolate and replace membranes that have failed.

### 5.3.7 Effluent maturation ponds

The basic design requirements for effluent maturation ponds are set out in EN 12255-5. Retention time should be 5 d to 20 d. The design of the ponds shall aim to avoid short circuiting. Flow patterns in effluent maturation ponds can be improved by a high length to width ratio, a meandering design of the ponds or by dividing the volume into several ponds in series.

**NOTE** The efficiency and reliability of maturation ponds is generally far less than for other disinfection processes due to climate influences such as solar radiation and temperature and their variability.

### 5.3.8 Soil filtration

In general soil filtration is not suitable for wastewater treatment plants for over 50 PT.

National or local regulations or the requirements of the relevant authority can apply to the minimum horizontal distance between any soil filter and manmade features and surface waters. Such features will include water supply wells, property boundaries and the foundations of buildings.

**NOTE** National or local regulations or the relevant authority might prohibit the use of soil filtration systems.

### 5.3.9 Hydrogen peroxide

Hydrogen peroxide (HP) is a strong oxidant and disinfectant. The disinfecting action of HP is through the release of reactive hydroxyl radicals that react with organisms.

### 5.4 Process control

The requirements of EN 12255-10 and EN 12255-12 shall apply. In wastewater disinfection process control shall be used for:

- preventing health and safety hazards caused by disinfectants due to uncontrolled leakage;
- preventing negative effects of disinfectants in receiving waters due to overdosing;
- safeguarding a disinfectant dosage sufficient to meet the required level of disinfection at all times;
- optimizing disinfectant and power consumption.

For preventing health and safety hazards caused by disinfectants due to uncontrolled leakage all rooms with installations containing hazardous chemicals shall be equipped with specific detectors ensuring that any toxic concentration of these chemicals (see 5.6) will cause a shut down and an alarm. Also, all waste gas streams from these installations shall be monitored in the same way.

Overdosing of chemical disinfectants is mostly associated with negative effects in receiving waters and can often be avoided by controlling the disinfectant dosage by monitoring the residual disinfectant concentration in the effluent. This method shall be applied in chlorination and ozonation processes. This method reacts to variations in the disinfectant demand no matter if they are due to a change of the flow rate or of the disinfectant consumption in the wastewater. For this control to work properly, the sensors monitoring the residual concentrations shall be maintained and calibrated on a regular basis. If the specific disinfectant demand of the wastewater varies only in a limited range a flow proportional dosage of the disinfectant might be appropriate. If due to pumping also the flow is constant a manual control can be sufficient.

In chemical disinfection processes the same control that prevents overdosing is used for ensuring a sufficient disinfectant dosage for meeting the required level of disinfection at all times. In UV radiation systems the UV intensity shall be monitored at an appropriate reference point in each UV reactor for ensuring a sufficient UV dosage. If the required UV intensity is not reached the sleeves of the UV-lamps shall be cleaned or UV lamps shall be renewed. The UV-C output intensity values shall be provided by the lamp's manufacturer including output drop over time down to 80 % of maximum output. The measurements shall be performed in accordance with ISO 15727.

In membrane filtration systems process control shall ensure that there is no leakage from the effluent side to the permeate side. In some cases, turbidity or particle counters can be appropriate systems for identifying a leakage in a membrane filtration system.

By controlling the dosing of disinfectant in relation to the demand the most economic operation is attained. In UV radiation systems with more than one UV-reactor proportional to the flow UV-reactors can be switched on and off. This is commonly referred to as flow pacing. In flow pacing it shall be taken into consideration that a frequent switching on and off of UV lamps shortens the UV lamps life expectancy. In UV radiation systems with medium pressure mercury discharge UV-lamps the UV-lamps can be dimmed.

For disinfection systems with multiple modules (such as UV lamps, ozone generators, or chlorinators), each module shall be able to operate independently of the other modules, without causing any overall system operational disruptions.

## 5.5 Structures

The requirements of EN 12255-1 shall apply. Structures shall be designed to be corrosion resistant. This particularly applies to disinfection processes when the disinfectant or its by-products are corrosive.

All confined spaces shall be provided with adequate ventilation.

## 5.6 Health and safety

The requirements of EN 12255-10 shall apply. National or local regulations or the relevant authority can require additional safety measures and process controls.

The design and operation of a disinfection system shall ensure that there is no threat posed to the health and safety of the general public or the plant operators. All plant operators shall be trained in the health and safety aspects of the disinfection system in which they are operating.

In some disinfection processes health and safety aspects deserve special consideration due to the involvement of:

- the generation and/or application of chemicals particularly toxic to man;
- high voltage equipment;
- UV radiation;
- submerged fragile electrical equipment.

Chemicals used in disinfection processes and which are particularly toxic to man include:

- chlorine gas;
- chlorine dioxide gas;
- ozone gas;
- peracetic acid.

Risks to health and safety associated with the generation and/or application of toxic chemicals in disinfection processes include:

- exposure to toxic gases;
- exposure to toxic or corrosive liquids;
- explosions caused by storage of gases under pressure;
- fire and explosions caused by the build-up of flammable gases;
- fire and explosions caused by the storage of powerful oxidants or oxygen.

Appropriate safety standards shall be applied in order to minimize the risk of these potential hazards.

Disinfection processes with a generation and/or application of gases particularly toxic to man shall be designed and operated such that the occupational exposure limits to these gases are not exceeded. The building in which these gases are used, generated, or stored shall be monitored regularly and appropriate equipment shall be supplied to deal with releases of gas. Safety equipment (gas masks, etc.) shall be available on site. Evacuation procedures shall be prepared and rehearsed on a regular basis.



UV radiation can irritate eyes and skin. UV radiation systems shall be designed such that no UV irradiation can come in contact with eyes or skin. Lightlocks and electrical breakers are appropriate systems for preventing direct UV irradiation of eyes and skin.

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## Annex A (normative)

### Ozone system classification

Ozone systems shall be classified according to the key functional and physical attributes governing the system efficiency.

Table A.1 — Classification of ozone systems

Classification	Description	Estimated efficacy <sup>a, b, c</sup> grams of ozone residual in the water per kWh <sup>a, b</sup>
A	Non-mechanical contact tank using positive or negative injection with external release of waste gas and catalytic ozone destruction.	30 to 45
B	Packed tower contact tank (or equivalent) with contact tank-integration release of waste gas and destruction.	15 to 35
C	Mechanical agitation or diffused bubble contact tank with contact tank-integration release of waste gas and destruction.	5 to 25
<sup>a</sup> Measured under nominal test conditions defined in EN 12255-15. <sup>b</sup> The power consumption of the ozone destructor shall be included in the energy calculations. <sup>c</sup> When comparing the power consumption between a LOX-fed system with a non-LOX system, the power consumption of the feed-gas generation shall be excluded.		

## Annex B (informative)

### Measurement of ozone concentration in water

#### B.1 General

NOTE A standard is under development in CEN/TC164/WG16 which also covers measurement of ozone concentration. Annex B is based on ongoing work in CEN/TC164/WG16. Once this is published as a standard, it is intended to issue an amendment to EN 12255-14 which will replace Annex B with a reference to the CEN/TC164/WG16 standard to ensure compatibility of components, methodology and definitions.

Measurement of the ozone concentration are commonly measured through titrimetric or photometric method.

#### B.2 Titrimetric determination of the ozone concentration according to the KI method

##### B.2.1 Principle

The reaction of ozone with potassium iodide will only occur stoichiometrically in a neutral, buffered aqueous solution (pH 7) according to chemical Formula (B.1):



After acidification of the solution, the released iodine will be titrated with sodium thiosulphate solution where the reaction described in Formula (B.2) will occur:



##### B.2.2 Reagents

###### B.2.2.1 Potassium iodide solution

Dissolve 20,0 g potassium iodide (KI), analytical grade, and 7,3 g disodium hydrogen phosphate ( $Na_2HPO_4 \cdot 2H_2O$ ), analytical grade, and 3,5 g potassium dihydrogen phosphate ( $KH_2PO_4$ ), analytical grade, in 1 000 ml bidistilled water.

###### B.2.2.2 Sodium thiosulphate solution

$C(Na_2S_2O_3) = 0,1\text{mol/l}$

###### B.2.2.3 Citric acid, diluted

Carefully add 25 ml sulphuric acid ( $H_2SO_4$ ), analytical grade,  $\rho = 1,84\text{ g/ml}$ , to 75 ml bidistilled water and mix well.

###### B.2.2.4 Zinc iodide-starch solution

Analytical grade.

#### B.2.3 Apparatus

a) feed pipes made of stainless steel, glass or PTFE;

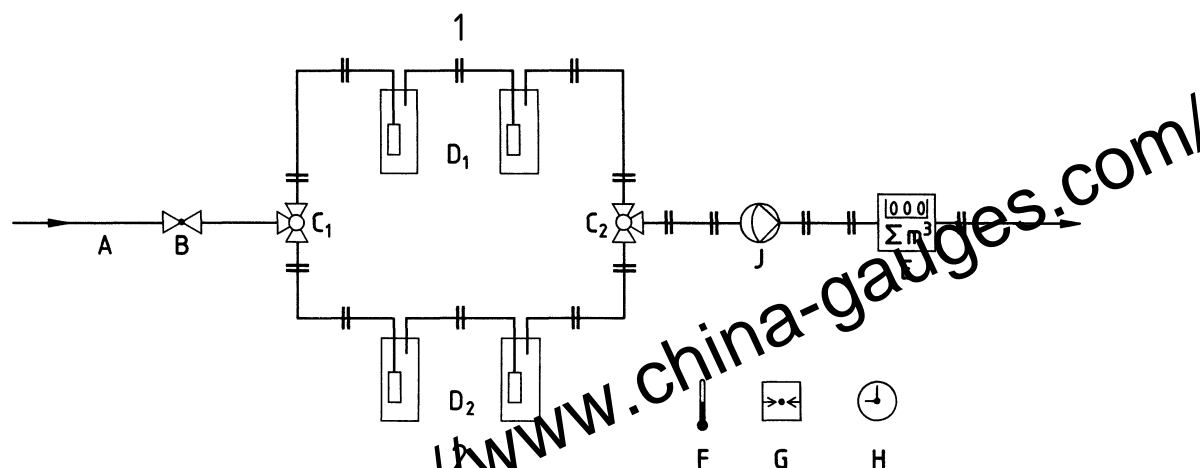
- b) wash bottles, volume 500 ml, according to Muenke;
- c) three-way stopcocks, with stopper made of PTFE;
- d) fine-adjustment valve, glass with spindle made of PTFE;
- e) diaphragm pumps, ozone-resistant (only required for plants operating at negative pressure);
- f) gas meter, of wet type, with pointer register and thermometer pocket for gas and liquids, discharge volume per rotation of the drum = 1 l;
- g) barometer;
- h) stopwatch.

#### B.2.4 General accessories

- i) glass hose couplings, fully drained tube material made of PE or PVC for short flexible connections;
- j) conical flasks, nominal volume 500 ml, e.g. flasks according to EN ISO 24450;
- k) graduated measuring cylinders, nominal volume 250 ml, e.g. measuring cylinders according to EN ISO 4788;
- l) burette, nominal volume 25 ml, e.g. burette according to EN ISO 385;
- m) pipettes, nominal volume 1 ml and 5 ml, e.g. pipette according to EN ISO 648;
- n) (advisable: magnetic stirrer with PTFE stirring rod).

#### B.2.5 Procedure

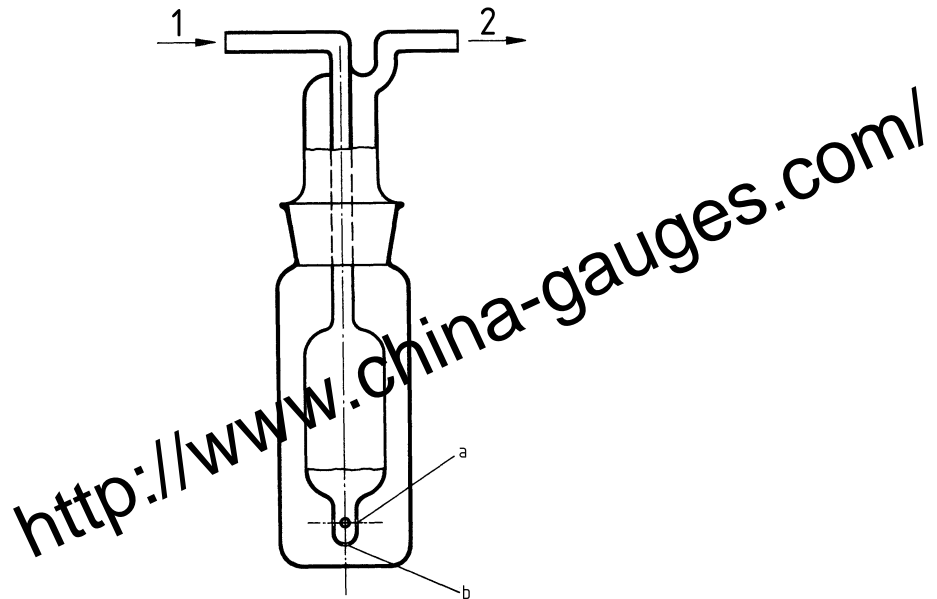
The measurement setup is illustrated in Figure B.1. The gas supply (A) should be as short as possible and be directly connected to the ozone generator. None of the parts of the measurement equipment coming into contact with the ozone-containing gas mixture shall show a loss of ozone. Necessary flexible hose couplings shall be as short as possible. In each case, fill two wash bottles connected in series with 200 ml potassium iodide solution and, according to the test setup of Figure 1, insert them into the sampling station in a practicable manner. Initially, adjust both three-way stopcocks such that the gas under test is led through the bypass section. With this adjustment, set the flow rate of the measuring gas at the throttle valve to achieve a volumetric flow rate of approximately 1 l/min. Measure the total discharged gas volume; it should be more than 1 l but not more than 5 l. After completion of the measurement, relocate the gas flow to the bypass section and repeat the measurement. During sampling, determine the air pressure and the measuring gas temperature. After acidification with 5 ml sulphuric acid, titrate the released iodide with sodium thiosulphate solution. Towards the end of titration, add 1 ml zinc iodide-starch solution to the light yellow coloured solution and titrate until paleness is reached. Especially in the case of a high ozone concentration, use both wash bottles.



**Key**

- 1 measuring section
- 2 bypass section
- A gas feed pipe (stainless steel e.g. according to EN 10088-3)
- B fine adjustment valve (PTFE)
- C1, C2 three way stopcocks (glass, PTFE)
- D1, D2 gas wash bottles (according to Muenke). See Figure B.2.
- E gas meter (max volumetric flow rate 200l/h)
- F thermometer (−10°C to +50°C)
- G barometer (950hPa to 1070hPa)
- H stopwatch
- J diaphragm pump (ozone resistant)

**Figure B.1 — Measurement setup for measuring ozone concentration**

**Key**

- 1 gas inlet
- 2 gas outlet
- a four holes equally distributed around the circumference
- b one hole at the bottom

**Figure B2 — Gas was bottles according to Muenke, nominal value 500 ml**

**B.2.6 Evaluation**

The concentration of the gas mixture is calculated according to Formula (B3):

$$\gamma = \frac{V_1 \cdot (\theta + T_n) \cdot Z_1}{V_L \cdot p_L} \quad (\text{B.3})$$

where

- $\gamma$  is the mass concentration of ozone ( $\text{O}_3$ ) in the gas mixture, related to normal temperature and pressure), in  $\text{mg/l}$  ( $\triangleq \text{g/m}^3$ );
- $V_1$  is the used amount of sodium thiosulphate solution, in  $\text{ml}$ ;
- $\theta$  is the actual temperature of the gas mixture, in  $^\circ\text{C}$  (actual temperature, in K, minus normal temperature, in K);
- $T_n$  is the normal temperature,  $T_n = 273,15 \text{ K}$ ;
- $Z_1$  is the intermediate value,  $Z_1 = 8,9 \text{ mg}\cdot\text{mbar}/(\text{ml}\cdot\text{K})$ ;
- $V_L$  is the volume of the discharged gas mixture, in  $\text{l}$ ;
- $p_L$  is the air pressure at the sampling point, in  $\text{mbar}$ .

The intermediate value  $Z_1$  is given by Formula (B.4):

$$Z_1 = \frac{c \cdot M\left(\frac{1}{2} \cdot O_3\right) \cdot p_n}{T_n} \quad (\text{B.4})$$

where

- $c$  is the molar concentration of the sodium thiosulphate solution;  
 $c = 0,1 \text{ mol/l} = 0,1 \text{ mmol/ml}$ ;
- $\left(\frac{1}{2} O_3\right)$  is the molar mass of an ozone equivalent during reaction with iodide,  
 $M\left(\frac{1}{2} O_3\right) = 24 \text{ g/mol} = 24 \text{ mg/mmol}$ ;
- $p_n$  is the normal pressure,  $p_n = 1013,25 \text{ mbar}$ ;
- $T_n$  is the normal temperature,  $T_n = 273,15 \text{ K}$ ;

### B.2.7 Errors

The error sum shall be estimated to 5 % (relative error) of the measurement value.

## B.3 Photometric determination within the UV range

### B.3.1 Method

Ozone has a broad absorption band between 200 nm and 300 nm, known as the Hartley band. At  $\lambda = 254 \text{ nm}$ , the ozone absorption shows a maximum. The principle of the method is based on the measurement of the optical absorption of monochromatic radiation of a wavelength of 254 nm in a gas absorption cell with quartz glass window. Absorption of light when passing through a defined absorbing layer, e.g. in a gas absorption cell, is described by the Beer-Lambert law which is presented in Formula (B.5).

$$I(\lambda) = I_0 \cdot e^{-n \cdot \sigma(\lambda) \cdot d} \quad (\text{B.5})$$

where

- $I$  absorption of light
- $I(\lambda)$  is the intensity of light of the wavelength  $\lambda$  after passing through the gas absorption cell;
- $I_0$  is the intensity of light prior to entering the gas absorption cell;
- $e$  is the Euler number = 2,718 28;
- $n$  is the number of ozone molecules per volume, in  $\text{m}^{-3}$ ;
- $\sigma(\lambda)$  is the activation cross-section at the wavelength  $\lambda$ , in  $\text{m}^2$ ;
- $d$  is the length of the gas absorption cell, in m.

The molar absorbance  $E(\lambda)$  is defined by Formula (B.6):

$$E(\lambda) = \log_{10} \left( \frac{I_0}{I(\lambda)} \right) \quad (\text{B.6})$$

Therefore, the molar absorbance coefficient  $\varepsilon(\lambda)$  is defined by Formula (B.7):

$$\varepsilon(\lambda) = \frac{E(\lambda)}{N \cdot d} \quad (\text{B.7})$$

or Formulae (B.8) and (B.9)

$$\varepsilon(\lambda) = N_A \cdot \sigma(\lambda) \cdot \log_{10}(e) \quad (\text{B.8})$$

with

$$n = N \cdot N_A \quad (\text{B.9})$$

where

$N$  is the amount of substance per volume, in mol/m<sup>3</sup>;

$N_A$  is the Avogadro constant =  $6,022 \times 10^{23}$  mol<sup>-1</sup>.

The mass concentration of ozone in the gas mixture,  $\gamma$  in g/m<sup>3</sup>, is hence given by Formula (B.10):

$$\gamma = N \cdot M = \frac{E(\lambda) \cdot M}{\varepsilon(\lambda) \cdot d} = \frac{E(\lambda) \cdot M}{N_A \cdot \sigma(\lambda) \cdot d \cdot \log_{10}(e)} \quad (\text{B.10})$$

where

$M$  is the molar mass of ozone (48 g/mol).

The measured concentrations are valid for the pressures and temperatures prevailing in the cell during the measurement. If they are to be converted to normal temperature and pressure (g/m<sup>3</sup><sub>n</sub>), Formula (B.11) applies:

$$\gamma_n = \gamma_z \cdot \frac{p_n}{p_z} \cdot \frac{(T_n + \theta_z)}{T_n} \quad (\text{B.11})$$

where

$\gamma_n$  is the concentration at normal temperature and pressure ( $T_n = 273,15$  K;  
 $p_n = 1\,013,25$  mbar), in g/m<sup>3</sup><sub>n</sub>;

$\gamma_z$  is the concentration under measurement conditions, in g/m<sup>3</sup>;

$p_z$  is the actual pressure inside the measuring cell, in mbar;

$\theta_z$  is the actual temperature inside the measuring cell, in °C (actual temperature, in K, minus the normal temperature, in K).

At the emission wavelength of mercury of  $\lambda = 254$  nm, the activation cross section for ozone is  $\sigma$  ( $\lambda = 254$  nm) =  $1,13 \cdot 10^{-21}$  m<sup>2</sup>  $\pm$  1 %.

Consequently, the molar absorbance coefficient for ozone at the wavelength  $\lambda = 254$  nm is given by Formula (B.12):

$$\varepsilon(\lambda = 254\text{nm}) = 300,0 \frac{\text{m}^3}{\text{m} \cdot \text{mol}} \pm 1\% \quad (\text{B.12})$$

### B.3.2 Errors

The measurement error is specific to each device and shall be specified by the manufacturer taking into account the uncertainty of the molar absorbance coefficient ( $\lambda = 254 \text{ nm}$ ) for ozone.

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## Bibliography

The following documents contain details which can be used within the framework of this document.

This list of documents which are published and used by the members of CEN was correct at the time of publication of this document but shall not be considered to be exhaustive.

### European standards

- [1] EN 170, *Personal eye-protection - Ultraviolet filters - Transmittance requirements and recommended use*
- [2] EN 752, *Drain and sewer systems outside buildings - Sewer system management*
- [3] EN 938, *Chemicals used for treatment of water intended for human consumption - Sodium chlorite*
- [4] EN 939, *Chemicals used for treatment of water intended for human consumption - Hydrochloric acid*
- [5] EN 10088-3, *Stainless steels - Part 3: Technical delivery conditions for semi-finished products, bars, rods, wire, sections and bright products of corrosion resisting steels for general purposes*
- [6] EN 16932 series, *Drain and sewer systems outside buildings — Pumping systems*

### National requirements

#### Austria

- [7] ÖNORM M 5873-1, *Geräte zur Desinfektion von Wasser mittels Ultraviolettstrahlung — Teil 1: Geräte mit UV-Niederdrucklampen — Anforderungen und Prüfung*
- [8] ÖNORM M 5878, *Anforderungen an Ozonungsanlagen zur Wasseraufbereitung*
- [9] ÖNORM M 5879-1, *Anforderungen an Chlorungsanlagen zur Wasserbehandlung — Teil 1: Chlorgas-Anlagen*
- [10] ÖNORM M 5879-2, *Anforderungen an Chlorungsanlagen zur Wasserbehandlung — Teil 2: Anlagen zur Desinfektion und Oxidation durch Natriumhypochlorit-Lösungen*
- [11] ÖNORM M 5879-3, *Anforderungen an Chlorungsanlagen zur Wasserbehandlung — Teil 3: Chlordioxidanlagen*

#### Germany

- [12] DIN 19606, *Chlorinators for water treatment — Technical requirements for equipment, installation and operation*
- [13] DIN 19627, *Ozone generation plants for water treatment*
- [14] DWA-M 205, 2013, *Desinfektion von biologisch gereinigtem Abwasser*

- [15] DVGW W 294, *UV-systems for the disinfection in drinking water supplies — Requirements and testing*<sup>2</sup>
- [16] DVGW W 623, *Dosage-installation for disinfectant and oxidising agent; dosage-installation for chlorine*<sup>2</sup>
- [17] DVGW W 624, *Dosing Plants for Disinfectants and Oxidation Agents — Preparation and Dosing Plants for Chlorine Dioxide*<sup>2</sup>
- [18] DVGW W 625, *Plants for the production and dosage of ozone in drinking water supply*<sup>2</sup>
- [19] ZH 1/474, Richtlinien für die Verwendung von Ozon zur Wasseraufbereitung
- [20] Pfeiffer, W.; Ultraviolet disinfection technology and assessment; European Water Management, Vol. 2, No. 1 (1998) — special issue on parasites and pathogens
- [21] Bernhardt et al, Desinfektion aufbereiteter Oberflächenwässer mit UV-Strahlen — erste Ergebnisse des Forschungsvorhabens, gwf - Wasser - Abwasser 133. (1992), Nr. 12, S. 632-643
- [22] Safert et al. Membranfiltration zur Keim- und P-Elimination im Ablauf kommunaler Kläranlagen, in: Rautenbach et al, Möglichkeiten und Perspektiven der Membrantechnik bei der kommunalen Abwasserbehandlung und Trinkwasseraufbereitung, A8, 1-14, Aachen (1997)

#### France

- [23] Fascicule 81, titre II: Fascicule interministériel applicable aux marchés publics de travaux de génie civil (CCTG) – Conception et exécution des installations d'épuration d'eaux usées

#### USA

- [24] Ultraviolet Disinfection Technology Assessment E.P.A. EPA, 832-R-92-004, USA, (1992)
- [25] EPA. Design Manual — Municipal Wastewater Disinfection, EPA/625/1-86/021, USA, (1986)

#### ISO standards

- [26] EN ISO 385, *Laboratory glassware - Burettes (ISO 385)*
- [27] EN ISO 648, *Laboratory glassware - Single-volume pipettes (ISO 648)*
- [28] EN ISO 4788, *Laboratory glassware - Graduated measuring cylinders (ISO 4788)*
- [29] EN ISO 6341:2012, *Water quality - Determination of the inhibition of the mobility of Daphnia magna Straus (Cladocera, Crustacea) - Acute toxicity test (ISO 6341:2012)*
- [30] EN ISO 24450, *Laboratory glassware - Wide-necked boiling flasks (ISO 24450)*
- [31] ISO 3857-4:2012, *Compressors, pneumatic tools and machines — Vocabulary — Part 4: Air treatment*
- [32] ISO 8637-3:2018, *Extracorporeal systems for blood purification — Part 3: Plasmafilters*

- [33] ISO 11348-3:2007, *Water quality — Determination of the inhibitory effect of water samples on the light emission of *Vibrio fischeri* (Luminescent bacteria test) — Part 3: Method using freeze-dried bacteria*

## Publications

- [34] Antonelli M., Turolla A., Mezzanotte V., Nurizzo C. Peracetic acid for secondary effluent disinfection: a comprehensive performance assessment. *Water Sci. Technol.* 2013, 68 pp. 2638–2644
- [35] Azzellino A., Antonelli M., Canziani R., Malpei F., Mainetti M., Nurizzo C. Multivariate modelling of disinfection kinetics: A comparison among three different disinfectants. *Desalin. Water Treat.* 2011, 29 pp. 128–139
- [36] Luukkonen T., Pehkonen J.O. Peracids in water treatment: A critical review. *Crit. Rev. Environ. Sci. Technol.* 2017, 47 (1) pp. 1–3
- [37] Wagner M., Brumelis D., Gehr R. Disinfection of Wastewater by Hydrogen Peroxide or Peracetic Acid : Development of Procedures for Measurement of Residual Disinfectant and Application to a Physicochemically Treated Municipal Effluent. *Water Environ. Res.* 2002, 74 (1) pp. 33–50
- [38] Rizzo L., Agovino T., Nahim-Granados S., Castro-Alfárez M., Fernández-Ibáñez P., Polo-López M.I. Tertiary treatment of urban wastewater by solar and UV-C driven advanced oxidation with peracetic acid: Effect on contaminants of emerging concern and antibiotic resistance. *Water Res.* 2019, 149 pp. 272–281
- [39] Collivignarelli M.C., Abbà A., Benigna I., Sorlini S., Torretta V. Overview of the main disinfection processes for wastewater and drinking water treatment plants. *Sustainability.* 2017, 10 p. 86
- [40] Karpova T., Pekonen P., Gramstad R., Öjstedt U., Laborda S., Heinonen-Tanski H. et al. Performic acid for advanced wastewater disinfection. *Water Sci. Technol.* 2013, 68 pp. 2090–2096
- [41] Luukkonen T., Teeriniemi J., Prokkola H., Rämö J., Lassi U. Chemical aspects of peracetic acid-based wastewater disinfection. *Water S.A.* 2014, 40 pp. 73–80
- [42] Kitis M. Disinfection of wastewater with peracetic acid: a review. *Environ. Int.* 2004, 30 pp. 47–55
- [43] Henao L.D., Turolla A., Antonelli M. Disinfection by-products formation and ecotoxicological effects of effluents treated with peracetic acid: A review. *Chemosphere.* 2018, 213 pp. 25–40
- [44] Chhetri R.K., Thornberg D., Berner J., Gramstad R., Öjstedt U., Sharma A.K. et al. Chemical disinfection of combined sewer overflow waters using performic acid or peracetic acids. *Sci. Total Environ.* 2014, 490 pp. 1065–1072
- [45] Hijnen W.A.M., Beerendonk E.F., Medema G.J. Inactivation credit of UV radiation for viruses, bacteria and protozoan (oo)cysts in water: A review. *Water Res.* 2006, 40 (1) pp. 3–22
- [46] Rebelo A., Ferra I., Gonçalves I., Marques A.M. A Risk Assessment Model for Water Resources: Releases of dangerous and hazardous substances. *J. Environ. Manage.* 2014, 140 pp. 51–59
- [47] Pekárek S., Rosenkranz J. Ozone and nitrogen oxides generation in gas flow enhanced hollow needle to plate discharge in air. *Ozone Sci. Eng.* 2002, 24 pp. 221–226

- [48] Futamura S., Zhang A., Yamamoto T. Behavior of N<sub>2</sub> and nitrogen oxides in nonthermal plasma chemical processing of hazardous air pollutants. *IEEE Trans. Ind. Appl.* 2000, 36 pp. 1507–1514
- [49] Huang L., Yang S., Liu S., Wang Q., Zhu Y. Removal of NO<sub>2</sub> produced by corona discharge in indoor air cleaning. *Journal of Advanced Oxidation Technologies.* 2009, 12 pp. 238–241
- [50] Kogelschatz U., Baessler P. Determination of Nitrous Oxide and Dinitrogen Pentoxide Concentrations in the Output of Air-Fed Ozone Generators of High Power Density. *Ozone Sci. Eng.* 1987, 9 pp. 195–206
- [51] Yuan D., Xie S., Ding C., Lin F., He Y., Wang Z. et al. The benefits of small quantities of nitrogen in the oxygen feed to ozone generators. *Ozone Sci. Eng.* 2018, p. 40
- [52] Humpert C., Pietsch G.J. Simulation of Ozone Synthesis in Oxygen- and Air-Fed Surface Discharge Arrangements. *Ozone Sci. Eng.* 2005, 27 pp. 59–68
- [53] Junhong C., Pengxiang W. Effect of relative humidity on electron distribution and ozone production by DC coronas in air. *IEEE Trans. Plasma Sci.* 2005, 33 pp. 808–812
- [54] Braun D., Kuchler U., Pietsch G. Behaviour of NO<sub>x</sub> in air fed ozonizers. *Pure Appl. Chem.* 1988, 60 (5) pp. 741–746

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