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Guidelines for treated wastewater use for irrigation projects —

Part 5:
Treated wastewater disinfection and equivalent treatments

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Foreword

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This document was prepared by Technical Committee ISO/TC 282, *Water reuse*, Subcommittee SC 1, *Treated wastewater reuse for irrigation*.

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

Disinfection of treated wastewater (TWW) is a critical phase in the process of TWW use. Its purpose is to reduce or eliminate major health risks to the wastewater treatment plant's operators and to anybody who may come in contact with TWW or with crops that were irrigated with TWW.

This document provides a guideline for the available methods of disinfection, their effectiveness and the factors impacting those methods, along with their advantages and disadvantages, regarding technical and environmental aspects and effective inactivation or removal of various pathogens in wastewater and TWW for use in irrigation.

Guidelines for treated wastewater use for irrigation projects —

Part 5:
Treated wastewater disinfection and equivalent treatments

1 Scope

This document provides a guideline for the application of various available methods of treated wastewater (TWW) disinfection for an effective inactivation or removal of pathogens from TWW, which is intended for irrigation purposes.

This document deals with:

— chemical and physical technologies, principles of operation, and establishment of effective doses to be applied, possible interferences, and technical guidance for design and monitoring;

— comparison of the advantages and disadvantages of various disinfection methods suitable for TWW;

— potential environmental effects of the disinfection methodologies and ways to minimize those impacts;

— disinfection at different locations in the TWW use system, including in the wastewater treatment plant, within the distribution system and at the point of use.

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

3.1 Term and definitions

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/

3.1.1
advanced oxidation process
AOP
process that generates hydroxyl radicals in sufficient quantity to remove organics by oxidation

3.1.2
ballast
unit inserted between the supply and one or more discharge lamps, which by means of inductance, capacitance, or a combination of inductance and capacitance, serves mainly to limit the current of the lamp(s) to the required value so as to convert and regulate incoming power to UV lamps to produce UV light

Note 1 to entry: The ballast provides the proper voltage and current required to initiate and generate UV photons.

3.1.3
fouling
process leading to deterioration of membrane flux due to surface or internal blockage of the membrane

Note 1 to entry: See AWWA B130-13[1].

3.1.4
pore size
size of the opening in a porous membrane

Note 1 to entry: Pore sizes are expressed either as nominal (average) or absolute (maximum), typically in terms of μm.

Note 2 to entry: See in AWWA B130-13[1].

3.1.5
reduction equivalent dose
RED
dose of UV in a given device which is determined by biodosimetry

Note 1 to entry: See *UV dose* (3.1.9) and "biodosimetry"

Note 2 to entry: This *UV dose* (3.1.9) 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.

3.1.6
ultrafiltration
UF
membrane filtration process with pore diameter nominally in the range of 0,005 μm to 0,1 μm

Note 1 to entry: See in AWWA B130-13[1].

3.1.7
UV disinfection system
combination of *UV disinfection units* (3.1.8) with associated controls and instrumentation

3.1.8
UV disinfection unit
independent combination of single or multiple bank(s) in series with a common mode of failure (e.g., electrical, cooling, cleaning system, etc.)

3.1.9
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

3.1.10
UV intensity sensor
UV irradiance meter or radiometer instrument to measure UV irradiance

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 (%) 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 formula (for a 1 cm path length): % UVT = 100×10^{-A}.

3.2 Abbreviated terms

A254	absorbance at 254
CT	product of the total residual chlorine and contact time
DBP	disinfection by-products
EPA	Environmental protection agency
DOC	dissolved organic carbon
DVGM	deutsher verien des gas-und wasserfaches e.v.
LP	low pressure
LPHO	low pressure high output
LRV	log removal value
MF	microfiltration
MP	medium pressure
MWCO	molecular weight cut off
NOM	natural organic matter
ONORM	*Österreichisches Normungsinstitut* (Austrian Standard)
QA/QC	quality assurance/quality control
RED	reduction equivalent dose
RO	reverse osmosis
TDS	total dissolved solides
THM	trihalomethanes
TMP	trans membrane pressure
TOC	total organic carbon
TWW	treated wastewater
UF	ultra-filtration

UV ultraviolet

UVT ultraviolet transmittance

WW wastewater

4 Wastewater pathogenic contaminants and their inactivation or removal

4.1 General

The most critical objective in a TWW reuse programme should be public health.

To achieve the main objective, other equally important objectives should be considered, including:

— environmental protection,

— aesthetics (odour and colour); and

— ability to meet irrigation requirements.

To protect public health and prevent environmental degradation, the TWW quality characteristics and pathogenic microorganisms contained in the wastewater should be assessed and consideration given to appropriate treatment to reduce the risk of negative impacts.

There are a wide range of technology options available to meet the water quality goals and to reduce the risk of disease transmission from pathogenic microorganisms that can be present in TWW and to meet the water quality goals.

In regular wastewater treatment plants, the two main processes that reduce the concentrations of pathogenic microorganisms in the water should be:

— the wastewater treatment process itself, which is intended mainly to reduce concentrations of suspended and dissolved organic matter;

— the process of disinfection of the TWW.

4.2 Type and occurrence of pathogens in wastewater

Use of urban wastewater intended for agricultural irrigation or for other purposes contains a variety of pathogenic microbial contaminants that can pose a risk to public health.

The type and number of pathogenic microorganisms in urban wastewater varies between countries and cities and with time/season (wet and dry), epidemics etc. When selecting disinfection method(s) the range of microorganisms that can be present should be considered, including parasites eggs, bacteria, amoebas and other protozoa, *Giardia* and viruses. Common infectious agents, associated diseases, and potential numbers of microorganisms found in domestic wastewater are shown in Table 1[2] (for the complete table see Table A.1).

Table 1 — Infectious agents potentially present in untreated (raw) wastewater[2]

Pathogen	Disease	Numbers in raw wastewater (per litre)
Shigella`	Shigellosis (bacillary dysentery)	Up to 10^4
Salmonella	Salmonellosis, gastroenteritis (diarrhoea, vomiting, fever), reactive arthritis, typhoid fever	Up to 10^5
Vibro cholera	Cholera	Up to 10^5
Campylobacter	Gastroenteritis, reactive arthritis, Guillain-Barré syndrome	Up to 10^4

Table 1 *(continued)*

Pathogen	Disease	Numbers in raw wastewater (per litre)
Enteroviruses (polio, echo, coxsackie, new enteroviruses, serotype 68 to 71)	Gastroenteritis, heart anomalies, meningitis, respiratory illness, nervous disorders, others	Up to 10^6
Adenovirus	Respiratory disease, eye infections, gastroenteritis (serotype 40 and 41)	Up to 10^6
Rotavirus	Gastroenteritis	Up to 10^5
Entamoeba	Amebiasis (amebic dysentery)	Up to 10^2
Giardia	Giardiasis (gastroenteritis)	Up to 10^5
Cryptosporidium	Cryptosporidiosis, diarrhoea, fever	Up to 10^4
Ascaris	Ascariasis (roundworm infection)	Up to 10^3
Ancylostoma	Ancylostomiasis (hookworm infection)	Up to 10^3
Trichuris	Trichuriasis (whipworm infection)	Up to 10^2

The practical measurement of all pathogenic pollutants in TWW is almost impossible.

The main reasons are:

— low concentrations of the pathogenic contaminants in the TWW;

— limitation of present technology to detect pathogens when they are present in low numbers;

— testing for pathogenic contaminants in the laboratory is lengthy and expensive.

Consequently, the control and monitoring of pathogenic microorganisms should be done by testing for indicator microorganisms, which are feasible and simple to measure as a result of their much larger numbers, and based on the premise that factors and treatment affecting their removal similarly affect the pathogens of interest.

4.3 covers the effect of the first process (WW treatment and the reduction of the concentration of contaminants). 4.4 covers the effects of the disinfection of the TWW.

4.3 Reduction of pathogenic microorganisms in various stages of wastewater treatment

Although wastewater treatment is mainly intended to eliminate suspended and dissolved organic matter, independent of disinfection, the treatment process can reduce the number of pathogenic and indicator microorganisms present in the wastewater. The degree of removal can depend (in part) on the type of treatment process, as illustrated in Table 2[2].

Table 2 — Indicative log removals of indicator microorganisms and enteric pathogens during various stages of wastewater treatment[2]

	Indicator microorganisms			Pathogenic microorganisms				
	***Escherichia coli* (indicator bacteria)**	***Clostridium perfringens***	***Phage* (indicator virus)**	**Enteric bacteria *(e.g., Campylobacter)***	**Enteric viruses**	***Giardia lamblia***	***Cryptosporidium parvum***	**Helminths**
Bacteria	X	X		X				
Protozoa and helminths						X	X	X
Viruses			X		X			
Indicative log reductions in various stages of wastewater treatment								
Secondary treatment	1 to 3	0,5 to 1	0,5 to 2,5	1 to 3	0,5 to 2	0,5 to 1,5	0,5 to 1	0 to 2
Dual media filtration[a]	0 to1	0 to 1	1 to 4	0 to 1	0,5 to 3	1 to 3	1,5 to 2,5	2 to 3
Reservoir storage	1 to 5	N/A	1 to 4	1 to 5	1 to 4	3 to 4	1 to 3,5	1,5 to >3

Key

N/A not available

NOTE 1 Reduction rates depend on specific operating conditions, such as retention time, contact time and concentrations of chemicals used, pore size, filter depths, pretreatment, and other factors. Ranges given should not be used as design or regulatory bases—they are meant to show relative comparisons only.

NOTE 2 See Table 3.

[a] Including coagulation.

As the reduction presented in the table for each type of treatment is only indicative, the exact values of pathogen reduction should be determined for each situation taking into account both the type of treatment and the environmental and operating conditions such as temperature, organic matter, turbidity, pH, ammonia, alkalinity, of each system.

4.4 Reduction of pathogenic microorganisms by different disinfection methods

The purpose of disinfecting TWW should be to remove or inactivate pathogenic microorganisms that remain in the TWW at the end of the standard treatment process. As complete inactivation is not always feasible or involves the investment in methods which could make the required treatment unpractical, pathogenic microorganisms should be brought to low levels that will not cause significant health damage when the wastewater is used for irrigation. Reduction of pathogenic microorganism concentrations may be integrated with additional control strategies that can prevent health impact such as setting limitations to irrigation with TWW based on the quality achieved.

The practical measurement of all pathogenic microorganisms in TWW is almost impossible for reasons, and indicator microorganisms are used (see 4.2).

The reduction of indicator and pathogenic microorganisms in TWW by different disinfection methods is indicated in Table 3[2].

Table 3 — Indicative log reductions of indicator microorganisms and enteric pathogens by various methods of disinfecting TWW[2]

	Indicator microorganisms			**Pathogenic microorganisms**				
	***Escherichia coli* (indicator bacteria)**	***Clostridium perfringens***	***Phage* (indicator virus)**	**Enteric bacteria (*e.g., Campylobacter*)**	**Enteric viruses**	***Giardia lamblia***	***Cryptosporidium parvum***	**Helminths**
Bacteria	X	X		X				
Protozoa and helminths						X	X	X
Viruses			X		X			
Indicative log reductions by various disinfection methods[a]								
Membrane filtration (UF, NF, and RO)[b]	4 > 6	>6	2 > 6	>6	2 > 6	>6	4 > 6	>6
Ozonation	2 to 6	0 to 0,5	2 to 6	2 to 6	3 to 6	2 to 4	1 to 2	N/A
UV disinfection	2 >6	N/A	3 > 6	2 > 6	1 > 6	3 > 6	3 >6	N/A
Advanced oxidation	>6	N/A	>6	>6	>6	>6	>6	N/A
Chlorination	2 >6	1 to 2	0 to 2,5	2 >6	1 to 3	0,5 to 1,5	0 to 0,5	0 to 1

Key

N/A not available

[a] Reduction rates depend on specific operating conditions, such as retention times, contact times and concentrations of chemicals used, pore size, filter depths, pretreatment, and other factors. Ranges given should not be used as design or regulatory bases—they are meant to show relative comparisons only.

[b] Removal rates vary dramatically depending on the installation and maintenance of the membranes.

5 Disinfection

A partial removal of microorganisms may be obtained in various treatment stages, while disinfection is the main process for microorganisms' inactivation or removal from the TWW.

A TWW reuse for irrigation scheme should include disinfection to reduce pathogenic microorganisms; it is one of the main barriers, compulsory for some uses and an option for others.

Note the process of disinfection reduces the number of microorganisms to the analytical detection limit but does not eliminate them. Complete destruction can only be done by the process of sterilization.

Disinfection of TWW may be achieved with the use of a variety of methods presented in Clauses 6 to 8, including:

— chemical disinfection,

— ultraviolet light, and

— membrane filtration.

The action of disinfectants on microorganisms is a result of various mechanisms occurring simultaneously or separately[3]:

— changes in DNA structure that thwart reproduction and thus infectivity,

— damage to cell wall,