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Guidelines for treated wastewater use for irrigation projects —

Part 2: Development of the project

Lignes directrices pour l'utilisation des eaux usées traitées en irrigation —

Partie 2: Développement du projet

Reference number
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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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Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 282, *Water reuse*, Subcommittee SC 1, *Treated wastewater use for irrigation*.

ISO 16075 consists of the following parts, under the general title *Guidelines for treated wastewater use for irrigation projects*:

— *Part 1: The basis of a reuse project for irrigation*

— *Part 2: Development of the project*

— *Part 3: Components of a reuse project for irrigation*

The following parts are under preparation:

— *Part 4: Monitoring*

Introduction

The increasing water scarcity and water pollution control efforts in many countries have made treated municipal and industrial wastewater a suitable economic means of augmenting the existing water supply especially when compared to expensive alternatives such as desalination or the development of new water sources involving dams and reservoirs. Water reuse makes it possible to close the water cycle at a point closer to cities by producing "new water" from municipal wastewater and reducing wastewater discharge to the environment.

An important new concept in water reuse is the "fit-to-purpose" approach, which entails the production of reclaimed water quality that meets the needs of the intended end-users. In the situation of reclaimed water for irrigation, the reclaimed water quality can induce an adaptation of the type of plant grown. Thus, the intended water reuse applications are to govern the degree of wastewater treatment required and inversely, the reliability of wastewater reclamation processes and operation.

Treated wastewater can be used for various non-potable purposes. The dominant applications for the use of treated wastewater (also referred to as reclaimed water or recycled water) include agricultural irrigation, landscape irrigation, industrial reuse, and groundwater recharge. More recent and rapidly growing applications are for various urban uses, recreational and environmental uses, and indirect and direct potable reuse.

Agricultural irrigation was, is, and will likely remain the largest reuse water consumer with recognized benefits and contribution to food security. Urban water recycling, landscape irrigation in particular, is characterized by fast development and will play a crucial role for the sustainability of cities in the future including energy footprint reduction, human well-being, and environmental restoration.

It is worth noting again that the suitability of treated wastewater for a given type of reuse depends on the compatibility between the wastewater availability (volume) and water irrigation demand throughout the year, as well as on the water quality and the specific use requirements. Water reuse for irrigation can convey some risks for health and environment, depending on the water quality, the irrigation water application method, the soil characteristics, the climate conditions, and the agronomic practices. Consequently, the public health and potential agronomic and environmental adverse impacts are to be considered as priority elements in the successful development of water reuse projects for irrigation. To prevent such potential adverse impacts, the development and application of international guidelines for the reuse of treated wastewater is essential.

The main water quality factors that determine the suitability of treated wastewater for irrigation are pathogen content, salinity, sodicity, specific ion toxicity, other chemical elements, and nutrients. Local health authorities are responsible for establishing water quality threshold values depending on authorized uses and they are also responsible for defining practices to ensure health and environmental protection taking into account local specificities.

From an agronomic point of view, the main limitation in using treated wastewater for irrigation arises from its quality. Treated wastewater, unlike water supplied for domestic and industrial purposes, contains higher concentrations of inorganic suspended and dissolved materials (total soluble salts, sodium, chloride, boron, and heavy metals), which can damage the soil and irrigated crops. Dissolved salts are not removed by conventional wastewater treatment technologies and appropriate good management, agronomic, and irrigation practices should be used to avoid or minimize potential negative impacts.

The presence of nutrients (nitrogen, phosphorus, and potassium) can become an advantage due to possible saving in fertilizers. However, the amount of nutrients provided by treated wastewater along the irrigation period is not necessarily synchronized with crop requirements and the availability of nutrients depends on the chemical forms.

This guideline provides guidance for healthy, hydrological, environmental and good operation, monitoring, and maintenance of water reuse projects for unrestricted and restricted irrigation of agricultural crops, gardens, and landscape areas using treated wastewater. The quality of supplied treated wastewater has to reflect the possible uses according to crop sensitivity (health-wise and agronomy-wise), water sources (the hydrologic sensitivity of the project area), the soil, and climate conditions.

This guideline refers to factors involved in water reuse projects for irrigation regardless of size, location, and complexity. It is applicable to intended uses of treated wastewater in a given project even if such uses will change during the project's lifetime as a result of the changes in the project itself or in the applicable legislation.

The key factors in assuring the health, environmental, and safety of water reuse projects in irrigation are the following:

— meticulous monitoring of treated wastewater quality to ensure the system functions as planned and designed;

— design and maintenance instructions of the irrigation systems to ensure their proper long-term operation;

— compatibility between the treated wastewater quality, the distribution method, and the intended soil and crops to ensure a viable use of the soil and undamaged crop growth;

— compatibility between the treated wastewater quality and its use to prevent or minimize possible contamination of groundwater or surface water sources.

Guidelines for treated wastewater use for irrigation projects —

Part 2:
Development of the project

1 Scope

This part of ISO 16075 covers the following issues:

— criteria for the design of treated wastewater (herinafter: TWW) irrigation projects intended to prevent public health risks within the population that has been in direct or indirect contact with the TWW or with any product that has come in contact with the TWW;

— specifications of the following:

i) the quality of the TWW that can be used for irrigation;

ii) the types of crops that can be irrigated with TWW;

iii) the combination of the qualities of the irrigated TWW and the types of crops that can be irrigated;

iv) the strategy of using barriers that can reduce the risks that arise from TWW irrigation;

v) the correlation between the quality of the TWW, the irrigated crops, and the types of barriers that can be used;

vi) the distance required between the TWW irrigation areas and residential areas.

vii) none of the parts of this part of ISO 16075 are intended to be used for certification purposes.

2 Normative references

There are no normative references.

3 Terms, definitions, and abbreviated terms

3.1 General

3.1.1
aquifer
underground layer of water-bearing permeable rock or unconsolidated materials (gravel, sand, or silt) from which groundwater can be extracted

3.1.2
background water
freshwater (3.1.10) supplied for domestic, institutional, commercial, and industrial use from which *wastewater* (3.1.22) is created

3.1.3
barrier
any means that reduces or prevents the risk of human infection by preventing contact between the TWW and the ingested produce or other means that, for example, reduces the concentration of microorganisms in the TWW or prevents their survival on the ingested produce

3.1.4
environment
surroundings in which an *organization* (3.1.13) operates including air, water, land, natural resources, flora, fauna, humans, and their interrelation

3.1.5
environmental aspect
element of an *organization's* (3.1.13) activities, projects, or products that can interact with the *environment* (3.1.4)

3.1.6
environmental impact
any change to environmental quality whether adverse or beneficial or wholly or partly resulting from an *organization's* (3.1.13) activities, projects, or *products* (3.1.15)

3.1.7
environmental parameter
quantifiable attribute of an *environmental aspect* (3.1.5)

3.1.8
fodder crops
crops not for human consumption such as pastures and forage, fiber, ornamental, seed, forest, and turf crops

3.1.9
food crops
crops which are intended for human consumption often further classified as to whether the food crop is to be cooked, processed, or consumed raw

3.1.10
freshwater
naturally occurring water on the Earth's surface (in ice, lakes, rivers, and streams) and underground as groundwater in *aquifers* (3.1.1)

Note 1 to entry: Freshwater includes desalinated seawater and desalinated brackish water, but excludes seawater and brackish water.

3.1.11
irrigation project
design, development, construction, selection of equipment, operation, and monitoring of works to provide suitable TWW irrigation

3.1.12
non-potable water
NPW
water that is not of drinking water quality

Note 1 to entry: It generally refers to *wastewater* (3.1.22) or TWW, but can also include other waters of non-drinking quality.

3.1.13
organization
group of people and facilities with an arrangement of responsibilities, authorities, and relationships

3.1.14
process
set of interrelated or interacting activities which transform inputs into outputs

Note 1 to entry: Inputs to a process are generally outputs of other processes.

Note 2 to entry: Processes in an *organization* (3.1.13) are generally planned and carried out under controlled conditions to add value.

3.1.15
product
any goods or services

Note 1 to entry: This includes interconnected and/or interrelated goods or services.

3.1.16
public health aspect
element of an *organization's* (3.1.13) activities, projects, or *products* (3.1.15) that can interact with the public health

3.1.17
public health impact
any change to public health, whether adverse or beneficial, wholly or partly resulting from an *organization's* (3.1.13) activities, projects, or *products* (3.1.15)

3.1.18
public health parameter
quantifiable attribute of a *public health aspect* (3.1.17)

3.1.19
soil
layer of unconsolidated material consisting of weathered material particles, dead and living organic matter, air space, and the *soil solution* (3.1.20)

3.1.20
soil solution
liquid phase of the *soil* (3.1.19) and its solutes

3.1.21
stakeholder
individual, group, or *organization* (3.1.13) that has an interest in an organization or activity

Note 1 to entry: Usually, a stakeholder can affect or is affected by the organization or the activity.

3.1.22
wastewater
wastewater collected principally by municipalities that can include spent or used water from domestic, institutional, commercial, or industrial sources and can include storm water

3.1.23
water reuse
use of treated wastewater for beneficial use

Note 1 to entry: Synonymous also to water reclamation and water recycling.

3.2 Use of treated wastewater (TWW)

3.2.1
agriculture
science or practice of farming including cultivation of the *soil* (3.1.19) for the growing of crops and the rearing of animals to provide food or other *products* (3.1.15)

3.2.2
landscape
all the visible features of an area of land often considered in terms of their aesthetic appeal such as public and private gardens, parks, and road vegetation including lawns and turfed recreational areas

3.2.3
restricted irrigation
use of TWW for non-potable applications in settings where public access is controlled or restricted by physical or institutional barriers

3.2.4
restricted urban irrigation
irrigation of areas in which public access during irrigation can be controlled such as some golf courses, cemeteries, and highway medians

3.2.5
unrestricted irrigation
use of TWW for non-potable applications in settings where public access is not restricted

3.2.6
unrestricted urban irrigation
irrigation of areas in which public access during irrigation is not restricted, such as some gardens and playgrounds

3.3 Wastewater quality

3.3.1
category A: very high quality TWW
raw wastewater (3.3.6) which has undergone physical and biological treatment, *filtration* (3.5.3) and *disinfection* (3.5.2), and its quality is according to the description in row A of Table 1

3.3.2
category B: high quality TWW
raw wastewater (3.3.6) which has undergone physical and biological treatment, *filtration* (3.5.3) and *disinfection* (3.5.2), and its quality is according to the description in row B of Table 1

3.3.3
category C: good quality TWW
raw wastewater (3.3.6) which has undergone physical and biological treatment and its quality is according to the description in row C of Table 1

3.3.4
category D: medium quality TWW
raw wastewater (3.3.6) which has undergone physical and biological treatment and its quality is according to the description in row D of Table 1

3.3.5
category E: extensively TWW
raw wastewater (3.3.6) which has undergone natural biological treatment process with long (minimum 10 d to 15 d) retention time and its quality is accordingly to the description in row E of Table 1

3.3.6
raw wastewater
wastewater (3.1.22) which has not undergone any treatment

3.3.7
thermo-tolerant coliforms
group of bacteria whose presence in the *environment* (3.1.4) usually indicates faecal contamination (previously called faecal coliforms)

Note 1 to entry: In order to determine the quality of TWW, one can test for Escherichia coli (E. coli) or for faecal coliforms since the difference in values is not significant.

3.4 Irrigation systems

3.4.1
boom sprinkler
mobile sprinkling machine (3.4.11) composed by two symmetrical pipes (booms) with sprinkler nozzles distributed in one of the pipes and with the sprinkler action complemented by a gun sprinkler placed at each end of both pipes; the nozzles work through a reaction effect (similar to a hydraulic tourniquet) which drives the boom rotation at a desired speed

3.4.2
center-pivot and moving lateral irrigation machines
automated irrigation machine consisting of a number of self-propelled towers supporting a pipeline rotating around a pivot point and through which water supplied at the pivot point flows radially outward for distribution by sprayers or *sprinklers* (3.4.24) located along the pipeline

3.4.3
emitter
emitting pipe
dripper
device fitted to an irrigation lateral and intended to discharge water in the form of drops or continuous flow at flow rates not exceeding 15 l/h, except during flushing

3.4.4
gravity flow irrigation systems
irrigation systems (3.4.8) where water is applied directly to the *soil* (3.1.19) surface and is not under pressure

3.4.5
in-line emitter
emitter (3.4.3) intended for installation between two lengths of pipe in an irrigation lateral

3.4.6
irrigation gun
large discharge device being either a part circle or full circle sprinkler

3.4.7
irrigation sprayer
device which discharges water in the form of fine jets or in a fan shape without rotational movement of its parts

3.4.8
irrigation system
assembly of pipes, components, and devices installed in the field for the purpose of irrigating a specific area

3.4.9
micro-irrigation system
system capable of delivering water drops, tiny-streams, or minispray to the plants

Note 1 to entry: Surface and sub-surface drip irrigation and *micro-spray irrigation* (3.4.10) are the main types of this system.

3.4.10
micro-spray irrigation systems
this system is characterized by water point sources similar to *sprinkler's* (3.4.24) miniatures (micro-sprinklers) which are placed along the laterals with a flow rate between 30 l/h and 150 l/h at pressure heads of 15 m to 25 m and the corresponding wetted area between 2 m and 6 m

3.4.11
mobile sprinkling machine
sprinkling unit which is automatically moved across the *soil* (3.1.19) surface during the water application

3.4.12
on-line emitter
emitter (3.4.3) intended for installation in the wall of an irrigation lateral either directly or indirectly by means such as tubing

3.4.13
perforating pipe system
emitting pipe (emitter/emitting pipe), continuous pipe, hose or tubing including collapsible hose with perforations intended to discharge water in the form of drops or continuous flow at emission rates not exceeding 15 l/h for each emitting unit

3.4.14
permanent system
stationary fixed-grid irrigation system (*sprinklers*) (3.4.24) for which sprinkler set positions are rigidly fixed by semi-permanent or permanently installed irrigation laterals, for example, portable solid-set irrigation system, buried irrigation system

3.4.15
portable system
system for which all or part of the network elements can be removed

3.4.16
pressurized irrigation systems
piped network systems under pressure

3.4.17
rotating sprinkler
device which, by its rotating motion around it's vertical axis, distributes water over a circular area or part of a circular area

3.4.18
self-moved system
unit where a lateral is mounted through the centre of a series of wheels and is moved as a whole

Note 1 to entry: *Rotating sprinklers* (3.4.17)/sprayers are placed on the lateral (also called wheel move).

3.4.19
self-propelled gun traveler
gun sprinkler on a cart or sled attached to the end of flexible pipe/hose

3.4.20
semi-permanent system
similar to the *semi-portable system* (3.4.21), but with portable laterals and permanent pumping plant, main lines, and sub-mains

3.4.21
semi-portable system
similar to the *portable system* (3.4.15) except that the water source and the pumping plant are fixed

3.4.22
solid-set system
temporary fixed network where the laterals are positioned in the field throughout the irrigation season

3.4.23
spray
release of water from a *sprinkler* (3.4.24)

3.4.24
sprinkler
water distribution device of a variety of sizes and types, for example, impact sprinkler, fixed nozzle, sprayer, and *irrigation gun* (3.4.6)

3.4.25
sprinkler irrigation systems
irrigation systems (3.4.8) composed of *sprinklers* (3.4.24)

3.4.26
stationary sprinkler systems
network of fixed *sprinklers* (3.4.24)

3.4.27
traveler irrigation machine
irrigation machine designed to irrigate a field sequentially strip by strip, while moving across the field

3.5 Wastewater system related components

3.5.1
additional disinfection
disinfection (3.5.2) of TWW in a *water reuse* (3.1.23) project intended to raise the quality of the TWW before irrigation

3.5.2
disinfection
process (3.1.14) that destroys, inactivates, or removes microorganisms

3.5.3
filtration
process (3.1.14) or device for removing solid or colloidal material from *wastewater* (3.1.22) by physically trapping the particles and removing them

3.5.4
membrane filtration
filtration (3.5.3) by membrane with pore size equal to or less than 0,45 µm

Note 1 to entry: Membrane filtration can also be considered as *disinfection* (3.5.2) according to the log units of pathogen reduction that it achieves.

3.5.5
reservoir
system to store temporarily unused TWW depending on the demand for water irrigation and the treatment plant discharge

Note 1 to entry: There are different types of reservoirs that can be used.

a) Open reservoirs which are commonly used for short-term storage with hydraulic residence times from one day to two weeks.

b) Closed reservoirs for short-term storage to limit bacterial regrowth and external contamination common with hydraulic residence time of 0,5 day to a week.

c) Surface reservoirs for long-term or seasonal storage of TWW to accumulate water during periods of treatment plant discharge higher than irrigation demand and to satisfy irrigation requirements when the demand is higher than the treatment plant discharge. The hydraulic residence time changes according to the seasons.

d) Aquifer storage and recovery for long-term storage which is commonly combined with soil aquifer treatment (by means of infiltration basins). The residence time is also a variable that is affected by the TWW discharge and irrigation demand. This aquifer storage should not contribute to the aquifer recharge for potential potable water use.

3.5.6
storage
retained temporary unused TWW for short- or long-term before their release for use in *irrigation systems* (3.4.8)

3.5.7
TWW pumping stations and transport systems
system of pipelines and pumps transporting the TWW from the WWTP to *storage* (3.5.6) reservoirs and to the use site

3.5.8
wastewater treatment plant
WWTP
facility designed to treat *wastewater* (3.1.22) by a combination of physical (mechanical) unit operations and chemical and biological processes for the purpose of reducing the organic and inorganic contaminants in the wastewater. There are different levels of wastewater treatment according to the desired quality of TWW and the level of contamination

3.6 Abbreviated terms

BOD	biochemical oxygen demand
CFU	colony forming units
COD	chemical oxygen demand
MF	microfiltration
NF	nanofiltration
NPW	non-potable water
NTU	nephelometric turbidity units
TSS	total suspended solids
TWW	treated wastewater
UF	ultrafiltration
UV	ultraviolet
WW	wastewater
WWTP	wastewater treatment plant

4 Public health and water quality parameters to take into consideration in TWW irrigation

4.1 Suggested treated wastewater quality levels

The various classes of TWW (based on quality levels) are characterized by the levels of the specified contaminants and further are correlated to the various potential uses and corresponding wastewater treatment. The definitions for the various quality levels of wastewater are set out in Clause 3 (3.3.1 to 3.3.7) correlated to their essential parameters and treatment types and are summarized in Table 1.

Table 1 — Suggested treated wastewater quality according to chemical, physical and biological parameters[a)]

Cat.	Type of treated wastewater	BOD[b), j)]		TSS		Turbidity[c)]		Thermo-tolerant coliforms[d)]		Intestinal nematodes[e), l)]		Potential uses without barriers	Potential corresponding treatment
		mg L^{-1}		mg L^{-1}		NTU		no./100 ml		Egg L^{-1}			
		Ave.	Max	Ave.	Max	Ave.	Max	95 %ile	Max	Ave.	Max		
A	Very high quality treated wastewater[d)]	≤5 mg/L	10 mg/L	≤5 mg/L	10 mg/L	≤2	5	≤10 or below the detection limit	100	—	—	Unrestricted urban irrigation [l)] and agricultural irrigation of food crops consumed raw	Secondary[f)], contact filtration or membrane filtration[g)] and disinfection[h)]

NOTE: With each type of treated-wastewater quality, the use of a higher quality treated wastewater is always possible.

a) The recommended limits are elaborated on the basis of international regulations, e.g. WHO (2006)[2] and USEPA (2012)[3] and apply to the reclaimed water at the outlet of the treatment facility. After storage in open reservoirs and for spray or localized irrigation, additional filtration could be necessary. Sampling frequency and the calculation of the average values are given in ISO 16075-4.

b) BOD is determined with a five-day test.

c) Continuous measurement of the turbidity can be implemented. The average value should be based on a 24-time period. If suspended solids are used in lieu of turbidity, the average TSS should not exceed 5 mg/L. If membrane filtration is used for treatment, the turbidity should not exceed 0,2 NTU.

d) Residual chlorine dosage between 0,2 mg/L and 1 mg/L that measured after 30 min contact time can be necessary for high and very high quality treated wastewater. If other method of disinfection achieving is used, it should also be monitored.

e) Intestinal nematodes (helminth eggs) might not be routinely monitored if it was demonstrated that the number of helminth eggs in untreated wastewater is consistently below 10 eggs/L.

f) Secondary treatment includes activated sludge, trickling filters, rotating biological contactors, biofilters, bioreactors, sequence batchreactors, etc.

g) Filtration includes microscreening, cartridge filtration, high rate sand filtration, dual media filtration, cloth filters, and disc filters without or with chemical addition (contact filtration) as well as membrane processes including membrane bioreactors.

h) Disinfection includes UV irradiation, ozonation, chlorination, or other chemical, physic chemical, or membrane processes.

i) High rate clarification includes coagulation, flocculation, and lamella settling.

j) Well-designed stabilization pond systems can meet coliform limits without additional disinfection. The soluble BOD values are considered.

k) The physical-chemical parameters (BOD, TSS) could be adjusted according to local wastewater treatment regulations with the possible addition of COD.

l) If there is a risk of aerosolization, the Legionella spp should be less than 1 000 CFU/L for Greenhouses.

Table 1 *(continued)*

Cat.	Type of treated wastewater	BOD[b), j)]		TSS		Turbidity[c)]		Thermo-tolerant coliforms[d)]		Intestinal nematodes[e), l)]		Potential uses without barriers	Potential corresponding treatment
		mg L−1		mg L−1		NTU		no./100 ml		Egg L−1			
		Ave.	Max	Ave.	Max	Ave.	Max	95 %ile	Max	Ave.	Max		
B	High quality treated wastewater[d)]	≤10 mg/L	20 mg/L	≤10 mg/L	25 mg/L	—	—	≤200	1 000	—	—	Restricted urban irrigation and agricultural irrigation of processed food crops	Secondary[f)], filtration[g)] and disinfection[h)]
C	Good quality treated wastewater	≤20 mg/L	35 mg/L	≤30 mg/L	50 mg/L	—	—	≤1 000	10 000	≤1	—	Agricultural irrigation of non-food crops	Secondary[f)] and disinfection[h)]

NOTE: With each type of treated-wastewater quality, the use of a higher quality treated wastewater is always possible.

a) The recommended limits are elaborated on the basis of international regulations, e.g. WHO (2006)[2] and USEPA (2012)[3] and apply to the reclaimed water at the outlet of the treatment facility. After storage in open reservoirs and for spray or localized irrigation, additional filtration could be necessary. Sampling frequency and the calculation of the average values are given in ISO 16075-4.

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g) Filtration includes microscreening, cartridge filtration, high rate sand filtration, dual media filtration, cloth filters, and disc filters without or with chemical addition (contact filtration) as well as membrane processes including membrane bioreactors.

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Table 1 *(continued)*

Cat.	Type of treated wastewater	BOD[b), j)]		TSS		Turbidity[c)]		Thermo-tolerant coliforms[d)]		Intestinal nematodes[e), l)]		Potential uses without barriers	Potential corresponding treatment
		mg L^{-1}		mg L^{-1}		NTU		no./100 ml		Egg L^{-1}			
		Ave.	Max	Ave.	Max	Ave.	Max	95 %ile	Max	Ave.	Max		
D	Medium quality treated wastewater[1]	≤60 mg/L	100 mg/L	≤90 mg/L	140 mg/L	—	—	—	—	≤1	5	Restricted irrigation of industrial and seeded crops	Secondary[f)] or high rate clarification with coagulation, flocculation[i)]
E	Extensively treated wastewater	≤20 mg/L	35 mg/L	—	—	—	—	—	—	≤1	5	Restricted irrigation of industrial and seeded crops	stabilization ponds and wetlands [j)]

NOTE: With each type of treated-wastewater quality, the use of a higher quality treated wastewater is always possible.

a) The recommended limits are elaborated on the basis of international regulations, e.g. WHO (2006)[2] and USEPA (2012)[3] and apply to the reclaimed water at the outlet of the treatment facility. After storage in open reservoirs and for spray or localized irrigation, additional filtration could be necessary. Sampling frequency and the calculation of the average values are given in ISO 16075-4.

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d) Residual chlorine dosage between 0,2 mg/L and 1 mg/L that measured after 30 min contact time can be necessary for high and very high quality treated wastewater. If other method of disinfection achieving is used, it should also be monitored.

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j) Well-designed stabilization pond systems can meet coliform limits without additional disinfection. The soluble BOD values are considered.

k) The physical-chemical parameters (BOD, TSS) could be adjusted according to local wastewater treatment regulations with the possible addition of COD.

l) If there is a risk of aerosolization, the Legionella spp should be less than 1 000 CFU/L for Greenhouses.

4.2 TWW quality needed for irrigation use

There should be limitations on the use of TWW for any irrigation use. The basic requirements for TWW qualities needed for each type of TWW use are described below. Furthermore, for each type of use, one or more barriers can be used corresponding to the quality of TWW used for the irrigation.

4.2.1 Agricultural use

a) For unrestricted irrigation only, very high quality TWW should be used.

b) For restricted irrigation, low, medium, high, or very high quality TWW can be used depending on the type of irrigated crop.

4.2.2 Urban use

a) For the irrigation of public gardens where public access is restricted during irrigation only, high or very high quality TWW should be used.

b) For the irrigation of public gardens where public access is unrestricted during irrigation only, very high quality TWW should be used.

c) For the irrigation of private gardens only, very high quality TWW should be used.

4.3 Barriers concept

In order to expand the group of crops or irrigation purposes that can be irrigated with the different qualities of TWW, the concept of creating barriers has been developed. These barriers prevent contact between the pathogens in TWW and humans who ingest the irrigated food crops or who use the irrigated land or who can inhale aerosols produced during irrigation.

The quality of the TWW is not the only parameter that can ensure the health of the consumers of the product irrigated. There are other means of eliminating the pathogens and preventing their transmission by vegetables or the fruits. There are also some characteristics of food crops that can prevent the ingestion of the pathogens by the consumer. By considering such characteristics, lower quality TWW can be used for the irrigation of food crops.

Methods to minimize the possibility of pathogens passing from the TWW to the vegetables or the fruits include the following:

a) disinfection of the TWW;

b) appropriate physical separation of the TWW and the vegetables or the fruits;

c) installation of a physical barrier (such as a sun-resistant cover sheet) between the TWW and the fruit;

d) use of subsurface drip irrigation so that contaminated water does not ascend to the ground surface by capillary action;

e) cessation of irrigation ahead of harvesting to allow pathogen die-off.

The characteristics of crops that can prevent the pathogens from being ingested by the consumer include the following:

a) fruit with an inedible skin (such as citrus fruits, banana, and nuts);

b) crops that are always cooked before consumption (such as potatoes);

c) fruit and cereals undergoing a very high-heat treatment prior to ingestion (such as wheat).

4.3.1 Types of barriers

The suggested types of barriers are presented in Table 2.

Subsurface drip irrigation systems (considered as two barriers) should be designed and implemented in a way that water does not rise to the surface (the detection of water puddles on the surface should disqualify the subsurface drip irrigation system from being considered as a barrier for the following years).

The barriers are qualified provided that good practices are implemented. For example, fruits and vegetables with edible skin should not be recovered from the ground.

4.3.2 Crops that can be irrigated without barriers

Crops which do not come in contact with the public or are protected from the survival of microorganisms on the crop as a result of their method of cultivation can be acceptable for irrigation by all the quality categories of TWW without the use of barriers. Following is a partial list of such crops:

— industrial crops (such as cotton);

— sun-dried fruit if harvested at least 60 d after the last irrigation (e.g. sunflower, popcorn, corn, chickpea, and wheat);

— irrigated crops of edible seeds or seeds for sowing which have not been irrigated for 30 d prior to harvesting;

— a grove or vegetation plot without public access;

— turf or grassland that is not intended for subsequent use for domestic lawns and for which there has been no public access during its cultivation;

— energy and fibre crops.

4.3.3 Barriers in the irrigation of public gardens

Irrigation when the public does not enter the garden is considered as one “barrier”.

4.3.4 Barriers in the irrigation of fodder crops

a) At least a 24 h time lapse between the last irrigation and the entrance of animals to the field.

b) Sun drying of fodder crops.

4.3.5 Possible barriers

Table 2 describes the type of barriers used as health protection measures that can be used in TWW irrigation and shows the number of barriers that can be accredited.

Table 2 — Suggested types and accredited number of barriers (adapted from WHO 2006[2] and USEPA 2012[3])

Type of barrier	Application	Pathogen reduction (log units)	Number of barriers
Irrigation of food crops			
Drip irrigation	Drip irrigation of low-growing crops such as 25 cm or more above from the ground	2	1
	Drip irrigation of high-growing crops such as 50 cm or more above from the ground	4	2
	Subsurface drip irrigation where water does not ascend by capillary action to the ground surface	6	3
Spray and sprinkler irrigation	Sprinkler and micro-sprinkler irrigation of low-growing crops such as 25 cm or more from the water jet	2	1
	Sprinkler and micro-sprinkler irrigation of fruit trees such as 50 cm or more from the water jet	4	2
Additional disinfection in field	Low level disinfection	2	1
	High level disinfection	4	2
Sun resistant cover sheet	In drip irrigation, where the sheet separates the irrigation from the vegetables	2 to 4	1
Pathogen die-off	Die-off support through irrigation cessation or interruption before harvest	0,5 to 2 per day[a)]	1 to 2[a)]
Produce washing before selling to the customers	Washing salad crops, vegetables, and fruits with drinking water	1	1
Produce disinfection before selling to the customers	Washing salad crops, vegetables, and fruits with a weak disinfectant solution and rinsing with drinking water	2	1
Produce peeling	Peeling of fruits and root crops	2	1
Produce cooking	Immersion in boiling water or under high temperature until the product is cooked	6 to 7	3
Irrigation of fodder and seeded crops			
Access control	Restricting entry into the irrigated field for 24 h and more after irrigation, for example, animal entering in pastures or entering of field workers	0,5 to 2	1
	Restricting entry into the irrigated field five days and more after irrigation	2 to 4	2
Sun drying of fodder crops	Fodder crops and other crops that are sun-dried and harvested before consumption	2 to 4	2
Irrigation of public gardens			
Access control	Irrigation by night when the public does not enter the irrigated parks, sport fields, and gardens	0,5 to 1	1

NOTE Applying disinfection to the TWW or filtering the TWW through appropriate membrane filter like MF, UF, or NF will destroy or remove pathogens.

a) According to crops and weather conditions.

Table 2 *(continued)*

Type of barrier	Application	Pathogen reduction (log units)	Number of barriers
Spray irrigation control	Spray irrigation at distances greater than 70 m from residential areas or places of public access	1	1
NOTE Applying disinfection to the TWW or filtering the TWW through appropriate membrane filter like MF, UF, or NF will destroy or remove pathogens.			
a) According to crops and weather conditions.			

4.3.6 Barriers needed for irrigation with TWW according to their quality

Table 3 indicates the number of barriers needed for irrigation with TWW taking in account the TWW quality level and the types of crops.

Table 3 — Suggested number of barriers that are needed for irrigation with TWW according to their quality (adapted from WHO (2006)[2] and USEPA (2012)[3], according to the practical experience of the members)

Type of treated wastewater	Category	Irrigation of private gardens and gardens landscape with unrestricted public access	Irrigation of gardens and landscape with restricted public access	Irrigation of vegetables consumed raw	Irrigation of vegetables after processing and pastures	Irrigation of food crops other than vegetables (orchards, vineyards) and horticulture	Irrigation of fodder and seeded crops	Irrigation of industrial and energy crops
Very high quality treated wastewater	A	0	0	0	0	0	0	0
High quality treated wastewater	B	1	0	1	0	0	0	0
Good quality treated wastewater	C	forbidden	1	3	2	1	0	0
Medium quality wastewater	D	forbidden	2	forbidden	forbidden	3	1	0
Extensively treated wastewater	E	forbidden	2	forbidden	2	2	0	0
Raw wastewater	—	forbidden	Forbidden	forbidden	forbidden	forbidden	forbidden	forbidden

4.3.7 Examples for calculating the numbers and types of barriers

Annex A shows examples for calculating the numbers and types of barriers.

5 Public health aspects of flood and furrow irrigation with TWW

Flood and furrow irrigation with untreated or partially TWW can increase helminth infection (mainly Ascaris infection) to fieldworkers and their families, particularly in children under 15 years old (WHO 2006[2]). This damage is caused by direct contact with the TWW that is used for the irrigation. Special attention should therefore be given to the quality of the TWW that is used for flood and furrow irrigation, especially to the concentration of intestinal nematodes in the TWW.

WHO's standards which are well-accepted by most countries allow less than 0,1 eggs/litre of intestinal nematodes in TWW if children under 15 years old are exposed and one egg/litre of intestinal nematodes if the children were not exposed.

Other public health principles of irrigating with TWW as described in this part should be similar for flood and furrow irrigation techniques as for closed (pressurized) irrigation systems.

The effluent quality required and barrier based strategy which can be used are identical for flood and furrow irrigations as for irrigation with TWW in closed (pressurized) systems (see Table 2).

As far as barriers related to the separation distance required between TWW and the fruit or vegetables are considered, these can be compared with the barriers prevailing for drip irrigation. However, cases where food crops can physically touch the ground while applying the TWW in the field by flood or furrow irrigation systems should be avoided because food crops can come in direct contact with the TWW.

Public health risks for workers and their families depend mainly on the quality of the TWW (WHO 2006[2]) and the irrigation methods and equipment used.

6 Public health risks for surrounding residents

Sprinkler irrigation systems that generate aerosols can pose potential risks for neighbours of irrigated plots. Aerosol-related risks depend on the TWW quality and wind velocity (responsible for the dissemination of aerosols in the surroundings of the irrigated area).

Minimal distances between irrigated areas and residential areas according to wastewater quality are shown in Table A.2.

Annex A
(informative)

Adjustment of the TWW quality used for irrigation and the barriers that can be used to the types of crops that can be irrigated with the TWW

A.1 Examples for calculating the numbers and types of barriers

Table A.1 shows examples for calculating the numbers and types of barriers that can be taken into consideration for each group of crops that it is intended to irrigate with TWW.

The number of barriers that can be used for each crop is calculated by adding the number of barriers allocated to each form of barrier or method of irrigation that can be applied. For example, to irrigate tropical fruits (e.g. mango, persimmon, and avocado), there can be one barrier for disinfection, two barriers for drip irrigation, one barrier for sun-resistant cover sheet and three barriers for subsurface drip irrigation, and there is one barrier for inedible skin.

NOTE TWW disinfection is a mandatory barrier for irrigation of vegetables eaten raw.

The disinfection system of TWW intended for the irrigation of vegetables shall include constant control of residual chlorine or other monitoring data with data recording and storage of the data when the system is connected to the operation of TWW supply.

Where crops which are permitted to be irrigated by extensive TWW are concerned, the number of required barriers depends on the time of the TWW retention in the pond. For TWW from a regular oxidation pond with 10 d retention, three barriers are required. For TWW from an oxidation pond with 15 d retention, two barriers are required.

Table A.1 — Examples of how to calculate the number and type of barriers

Number of required barriers (see Table 3)						Type of barrier (and number of barriers that can be attributed)						
Very high quality TWW (A)	High quality TWW (B)	Good quality TWW (C)	Medium quality TWW (D)	Extensively treated wastewater (E)	Example crops	TWW additional disinfection in field*	Distance from drip irrigation system using TWW **	Sun resistant cover sheet	Subsurface drip irrigation system	Inedible skin	Requires cooking	Prolonged air drying****
0	1	3	***	***	Food crops ingested raw, which grow above ground and edible portion is <25cm above soil surface (pepper, tomato, cucumber, zucchini, young beans)	1-2		1	3			
0	1	3	***	***	Food crops ingested raw, which grow above ground and edible portion is >25cm above soil surface (baby corn)	1-2 / 2		1	3	1		
0	1	3	***	***	Leafy vegetables grown on the soil surface eaten raw (lettuce, spinach, Asian cabbages, cabbage, celery)	1-2		1	3			

NOTE 1 * Depending on the local conditions of storage and conveying, an additional disinfection system of TWW can be required for the irrigation of vegetables that must include constant control of residual chlorine, or other monitoring data. Low-level disinfection is considered as one barrier: high-level disinfection is considered as two barriers (see Table 2).

NOTE 2 ** A distance of 50 cm of clean air between drip-irrigation and the vegetables and fruit is considered as two barriers. A distance of >25 cm of clean air between drip-irrigation and the vegetables and fruit is considered as one barrier. When irrigation is by spraying, (or sprinklers under the canopy), the distance should be calculated from the height to which the sprayed effluents arises and is considered as only one barrier because of the aerosols in the air.

NOTE 3 *** Effluents of medium quality and effluents of extensive TWW should not be used for the irrigation of vegetables.

NOTE 4 **** According to crops and weather conditions.