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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

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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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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

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

This second edition cancels and replaces the first edition (ISO 16075-2:2015), which has been technically revised. The main changes compared to the previous edition are as follows:

— updating the values of turbidity in Table 1— suggested treated wastewater quality according to chemical, physical and biological parameters);

— updating the issue of Irrigation of public gardens in Table 2 — Suggested types and accredited number of barriers;

— updating the subject of public and private gardens irrigation by treated wastewater (TWW);

— adding Clause 7: Public health aspects of garden irrigation with treated greywater and;

— updating Table A.1 added new column— washing or disinfection the produce.

A list of all parts in the ISO 16075 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

The 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 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-for-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 water reclamation processes and operation.

Treated wastewater (TWW) can be used for various non-potable purposes. The dominant applications for the use of TWW (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, reduction of water importation and environmental restoration.

The suitability of TWW 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 guidelines for the use of TWW is essential.

The main water quality factors that determine the suitability of TWW for irrigation are pathogen content, salinity, sodicity, specific ion toxicity, heavy metals’ concentration, 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 TWW for irrigation arises from its quality. TWW, 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 the irrigated crops. Dissolved salts are not removed by conventional wastewater treatment technologies and appropriate good management, agronomic, and irrigation practices are 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 TWW 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 TWW. The quality of supplied TWW is intended 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 TWW 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:

— adequate monitoring of TWW 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 TWW 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 TWW quality and its use to prevent or minimize possible contamination of groundwater or surface water sources.

This document is not intended to prevent the creation of more specific standards or guides which are better adapted to specific regions, countries, areas, or organizations. If such documents are written, it is recommended to reference this document to ensure uniformity throughout the TWW use community.

Guidelines for treated wastewater use for irrigation projects —

Part 2: Development of the project

1 Scope

This document covers the following issues:

— guideline for the design of treated wastewater (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) TWW quality for irrigation purposes;

ii) types of crops for TWW irrigated;

iii) TWW and crops qualities integration;

iv) use of barriers to reduce risks arising from TWW irrigation;

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

vi) distance between TWW irrigated areas and residential areas.

None of the documents of ISO 16075 are intended to be used for certification purposes.

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 20670:2018, *Water reuse — Vocabulary*

ISO 16075-1:2020, *Guidelines for treated wastewater for irrigation projects Part 1: The basis of a reuse project for irrigation*

3 Terms, definitions, and abbreviated terms

For the purposes of this document, the following terms and definitions given in ISO 20670 and ISO 16075-1:2020 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 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
TGW	treated grey water
TWW	treated wastewater
UF	ultrafiltration
UV	ultraviolet
WW	wastewater
WWTP	wastewater treatment plant

4 Public health and TWW quality to considerations

4.1 TWW quality levels

TWW classes (based on quality levels) should be characterized by the levels of specified contaminants and further correlated to the various potential uses and corresponding wastewater treatment.

Two main TWW quality parameters should be considered:

1. quality components that examine the level of the treatment of the wastewater in the treatment facility. These components include the levels of BOD and the TSS in the TWW, and
2. quality components that examine the sanitary quality of the TWW and the health risk associated with the use of TWW for irrigation. These components include concentrations of indicator bacteria and nematodes.

The quality levels of the TWW and the concentration of the various components according to which the quality level is determined are presented in Table 1. This table also presents the various potential uses and corresponding TWW.

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

Cat.	Type of TWW	BOD[b,j]		TSS		Turbidity[c]		Thermo-tolerant coliforms[d]		Intestinal nematodes[e,l]		Potential uses without barriers	Potential corresponding treatment
		mg/l		mg/l		NTU		no./100 ml		Egg/l			
		Ave.	Max	Ave.	Max	Ave.	Max	95 %ile	Max	Ave.	Max		
A	Very high quality TWW[d]	≤5	10	≤5	10	≤3	6	≤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 TWW is always possible.

[a] An example to the limits are elaborated on the basis of international regulations, e.g. WHO (2006) and USEPA (2012) 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_5 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 TWW. 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, physical 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 TWW	BOD[b,j]		TSS		Turbidity[c]		Thermo-tolerant coliforms[d]		Intestinal nematodes[e,l]		Potential uses without barriers	Potential corresponding treatment
		mg/l		mg/l		NTU		no./100 ml		Egg/l			
		Ave.	Max	Ave.	Max	Ave.	Max	95 %ile	Max	Ave.	Max		
B	High quality TWW[d]	≤10	20	≤10	25	—	—	≤200	1 000	—	—	Restricted urban irrigation and agricultural irrigation of processed food crops	Secondary[f], filtration[g] and disinfection[h]
C	Good quality TWW	≤20	35	≤30	50	—	—	≤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 TWW is always possible.

a An example to the limits are elaborated on the basis of international regulations, e.g. WHO (2006) and USEPA (2012) 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_5 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 TWW. 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, physical 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 TWW	BOD[b,j]		TSS		Turbidity[c]		Thermo-tolerant coliforms[d]		Intestinal nematodes[e,l]		Potential uses without barriers	Potential corresponding treatment
		mg/l		mg/l		NTU		no./100 ml		Egg/l			
		Ave.	Max	Ave.	Max	Ave.	Max	95 %ile	Max	Ave.	Max		
D	Medium quality TWW	≤60	100	≤90	140	—	—	—	—	≤1	5	Restricted irrigation of industrial and seeded crops	Secondary[f] or high rate clarification with coagulation, flocculation[i]
E	Extensively TWW	≤20	35	—	—	—	—	—	—	≤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 TWW is always possible.

[a] An example to the limits are elaborated on the basis of international regulations, e.g. WHO (2006) and USEPA (2012) 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_5 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 TWW. 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, physical 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.

4.2 TWW quality 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 in 4.2.1-4.2.2. 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/or preventing their transmission by vegetables or fruits. There are also some characteristics of vegetables and fruits that can prevent the passage of pathogens from the TWW to the edible part of the fruit or vegetable. By considering such characteristics (which are later defined as barriers), lower quality TWW can be used for the irrigation of food crops.

4.2.1 Agricultural use

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

Due to the health risk, it is very important to disinfect all the TWW that is used to irrigate vegetables eaten raw.

The disinfection system of TWW intended for the irrigation of vegetables eaten raw should include constant control of the disinfection process with monitoring data, data recording and storage of the data when the system is connected to the operation of TWW supply.

b) For restricted irrigation, very high, high, good, medium quality or extensively treated TWW may be used depending on the type of irrigated crop and the barriers in place, as described in 4.3.

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.

d) For the irrigation of public areas without public access (traffic islands, roadsides and interchanges), high quality TWW should be used.

NOTE Monitoring irrigation conditions at private gardens could be limited. Accidental connection of a TWW pipe to a drinking water pipe could cause risk to public health.

4.3 TWW irrigation barriers

4.3.1 General

In order to expand the group of crops for irrigation purposes that can be irrigated with the different qualities of TWW, the concept of creating barriers has been developed. The barriers are methods to minimize the possibility of pathogens passing from the TWW to the vegetables or ingestion by the consumers. Irrigation barriers may be used to prevent contact between pathogens in TWW and humans who ingest irrigated food crops or may inhale aerosols produced during irrigation.

The barriers should 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) irrigation under the foliage when the fruit is at an appropriate distance from the TWW.

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

The characteristics of crops that can be considered as preventing the pathogens from being ingested by the consumer should 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).

4.3.2 Types of barriers

The types of barriers that should be used in TWW projects 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 proposed here should be considered only when they actually exist. For example, if the barrier refers to crops that grow 25 cm or more above the ground, this barrier will not apply to crops whose fruits fell on the ground.

4.3.3 Crops for irrigation without limitations

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 may be irrigated by TWW of all 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.

4.3.4 Barriers in the irrigation of public gardens

Irrigation when the public does not enter the garden (e.g. interchange on the side of the road) should be considered as two “barriers”.

4.3.5 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.

4.3.6 Applicable barriers that may be use

Table 2 describes the types of barriers used as health protection measures that may be used in TWW irrigation.

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

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[a]	2	1
	High level disinfection[b]	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[c]	1 to 2[c]
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[d]	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

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

[a] Low level disinfection – chlorination that leave less than 1 mg/l of total chlorine, after 30 minutes of chlorination.

[b] High level disinfection – chlorination that leave more than 1 mg/l of total chlorine, after 30 minutes of chlorination.

[c] According to crops and weather conditions.

[d] Although produce cooking reduces pathogen count there is need to consider cross contamination occurring from polluted vegetables in a home kitchen during food preparation.

Table 2 *(continued)*

Type of barrier	Application	Pathogen reduction (log units)	Number of barriers
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
	Irrigation where the public has no access (Interchange on the side of the road)	2 to 4	2
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, all or part of the pathogens.			
[a] Low level disinfection – chlorination that leave less than 1 mg/l of total chlorine, after 30 minutes of chlorination.			
[b] High level disinfection – chlorination that leave more than 1 mg/l of total chlorine, after 30 minutes of chlorination.			
[c] According to crops and weather conditions.			
[d] Although produce cooking reduces pathogen count there is need to consider cross contamination occurring from polluted vegetables in a home kitchen during food preparation.			

4.3.7 Barriers needed for irrigation with TWW according to their quality

Table 3 indicates the number of barriers that should be used 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) and USEPA (2012), 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 energy crops and in areas where the public has no access
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

Relevant and efficient controls should be performed to ensure conformance with forbidden irrigation for categories C, D and E.

See examples of barriers' types and numbers calculation in Annex A

5 Public health aspects of flood and furrow irrigation with TWW

Flood and furrow irrigation with untreated wastewater or partially TWW can increase helminth infection (mainly Ascaris infection) to fieldworkers and their families, particularly in children under 15 years old[3]. 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.

For example, 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 are not exposed.

It should be noted that the same risk of bacteria, virus and protozoa, is present in the flood and furrow irrigation, as in the other irrigation methods. The risk of helminth is worse in gravitation irrigation. 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.

TWW quality and barrier-based strategy should be identical for flood and furrow irrigations as for irrigation with TWW in closed (pressurized) systems (see Table 2).

Barriers related to the separation distance between TWW and the fruit or vegetables should be compared with the barriers prevailing for drip irrigation.

However, food crops physically touching the ground while applying 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[3] 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 depends on the TWW quality and wind velocity (responsible for the dissemination of aerosols in the surroundings of the irrigated area). The risks also depend on the characteristics of the sprinkler system and operation pressure of the system (sprinkler, drops size, etc.)

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

7 Public health aspects of garden irrigation with treated greywater

7.1 General

In most cases, greywater systems are small systems using greywater of one dwelling unit, or using water from a number of apartments in one building (the number can be small or large). Accordingly, the greywater treatment facility is usually located near the building, and the use of the treated greywater (TGW) is done within or near the building itself.

The main uses of TGW are toilet flushing (WC washing) inside the apartments and / or irrigation of the building's garden.

NOTE As this document deals with irrigation, the use of greywater for toilet flushing is not discussed.

7.2 Protecting public health

Public health protection is of particular importance in the use of TGW, since the use of this water is in close proximity to residential buildings; irrigated gardens are often used for recreation and children's games.

However, risk to public health caused by TGW is lower than that caused by TWW. According to WHO - greywater contains 1,000-fold lower concentrations of pathogenic pollutants in comparison to wastewater[3].

The risk to public health from TGW irrigation may be characterized as following:

— risk of creating cross-connections between the TGW irrigation system and the drinking water system in the building;

— risk of TWG splashing that reach the residents of the building, particularly children;

— risk of TGW drinking from irrigation fixtures by children, and

— risk of TWG contact with residents, particularly children, through wet TGW irrigated plants.

Public health protection should prevent these risks; risk prevention measures described in 7.2.1-7.2.5 should be followed.

7.2.1 Maintaining high quality of TGW used for irrigation

In order to protect public's health, TGW used for garden irrigation should be of high quality, in accordance with Table 4.

Table 4 — TGW quality used for garden irrigation

Parameter	Sprinkler irrigation	Drip irrigation	Underground drip irrigation	Units
Thermo-tolerance bacteria	10	25	N.A.	No. in 100 ml.
Turbidity	10	25	N.A.	NTU
Residual chlorine	1	0,5	N.A.	mg l^{-1}
NOTE Minimal treatment – filtration.				

7.2.2 Preventing contamination of the drinking water distribution network

Drinking water distribution network in buildings should be protected of cross-connection by ensuring that the TGW distribution system is in accordance with ISO 16075-3, 6.6, which includes maintaining a minimum distance between drinking water pipelines and TGW pipelines, and appropriate signage of the TGW irrigation pipelines.

7.2.3 TGW irrigation time

TGW irrigation should only take place when the designated garden is free of residents, for instance during night time.

7.2.4 TGW irrigation equipment

Irrigation equipment in the area that residents have access to, should be of a type that does not allow direct contact and/or water consumption.

The best method to avoid contact with the TGW is drip irrigation or underground drip irrigation.

In spray irrigation, pop up irrigation heads or pop-up water relief valves (also commonly known as a pop-up drainage emitter) should be used.

7.2.5 Signage

Suitable signage to remind residents to avoid contact with water in the garden should be set up.

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 for TWW irrigation.

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.

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.

It should be taken into consideration that TWW disinfection is a mandatory barrier for irrigation of vegetables eaten raw.

Due to the health risk, it is very important to disinfect all the TWW used to irrigate vegetables eaten raw.

The disinfection system of TWW intended for the irrigation of vegetables eaten raw includes constant control of the disinfection process with monitoring data, 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.

A distance of 50 cm of clean air between drip irrigation and the fruit and vegetables may be considered as two barriers. A distance of 25-50 cm of clean air between drip irrigation and the fruit and vegetables may be considered as one barrier.

When the field is irrigated by spraying (or sprinklers, under the canopy), the distance should be calculated from the height to which the sprayed effluents arise and be considered as one barrier only, because of the aerosols in the air.

Prolonged air drying of the edible part of the crop should be considered as 1-2 barriers in accordance with the type of crop and weather conditions.

Table A.1 — Examples of barriers' types and number calculation

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	Washing or disinfection the produce	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	1-2			
0	1	3			Food crops ingested raw, which grow above ground and edible portion is >25cm above soil surface (baby corn)	1-2		1	1-2	1-2	1		
0	1	3			Leafy vegetables grown on the soil surface eaten raw (lettuce, spinach, Asian cabbages, cabbage, celery)	1-2		1	3				

Table A.1 *(continued)*

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	Washing or disinfection the produce	Inedible skin	Requires cooking	Prolonged air drying
0	1	3			Food crops that can be ingested raw, which grow in the soil (carrot, radish, green onion)	1-2				1-2			
0	0	2		2	Food crops grown above ground where edible portion is <25cm above soil surface, eaten cooked or processed (eggplant, pumpkin, green beans, artichoke)	1-2		1	3	1-2	1	3	
0	0	2		2	Food crops eaten cooked, which grow in the soil (potato)	1-2				1-2		3	
0	0	2		2	Food crops which grow in the soil than can be eaten after peeling (peanut)	1-2					1		1-2

Table A.1 *(continued)*

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 disinfec-tion in field	Distance from drip irrigation system using TWW	Sun resist-ant cover sheet	Subsur-face drip irrigation system	Wash-ing or disinfec-tion the produce	Inedible skin	Re-quires cooking	Prolonged air drying
0	0	2		2	Food crops grown above ground that can be eaten after drying and cooking (dry beans, lentils)	1-2						3	1-2
0	0	2		2	Food crops grown on the soil that can be eaten raw after peeling (watermelon, melon, pea)	1-2		1	3	1-2	1		
0	1	3		2	Food crops grown above ground where edible portion is >25cm above soil surface, eaten cooked or pro-cessed (corn)	1-2	2	1	3		1		
0	0	0	1	0	Seeded crops (cereals) eaten dried and cocked (wheat, oats, barley, rice)	1-2	1				1	3	1-2