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BSI Standards Publication

Guidelines for treated wastewater use for irrigation projects

Part 3: Components of a reuse project for irrigation

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National foreword

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

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

Partie 3: Éléments d'un projet de réutilisation en irrigation

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Contents

Page

Foreword

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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 in 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 are intended to 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 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;

— maintenance and design 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 3: Components of a reuse project for irrigation

1 Scope

This part of ISO 16075 covers the system's components needed for the use of TWW for irrigation which relate to various pressure and open irrigation systems specifically drip irrigation as this method represents an efficient method of water delivery and water saving. Despite the fact that water quality and filtration of treated wastewater (herein TWW) using drip irrigation are critical, open irrigation systems are more popular and are frequently used for irrigation with TWW and therefore are covered in this part of ISO 16075.

This part of ISO 16075 will cover the issues related to the main components of a TWW irrigation project, including the following:

— pumping station;

— storage reservoirs;

— treatment facilities (for irrigation purposes): filtration and disinfection;

— distribution pipeline network;

— water application devices: irrigation system components and treatment.

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 including physical or process steps 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* (3.1.15) that can interact with the *environment* (3.1.4)

3.1.6
environmental impact
any change to environmental quality, whether adverse or beneficial, 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* (3.1.16)

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* (3.1.22) for beneficial use

Note 1 to entry: Water reuse is synonymous 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, 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 ISO 16075-2[1], Table 1, row A

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 ISO 16075-2[1], Table 1, row B

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 ISO 16075-2[1], Table 1, row C

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 ISO 16075-2[1], Table 1, row D

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 according to the description in ISO 16075-2[1], Table 1, row E

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 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 mini-spray 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 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 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, and 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) 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 its 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 system (3.4.8) composed of *sprinkler* (3.4.24)

3.4.26
stationary sprinkler systems
network of fixed *sprinkler* (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. 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 one 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 shall 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 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

Note 1 to entry: 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
COD	chemical oxygen demand
HDPE	high-density polyethylene
NPW	non-potable water
PVC	polyvinyl chloride
TWW	treated wastewater
UV	ultraviolet
WW	wastewater
WWTP	wastewater treatment plant

4 Storage reservoir

4.1 General

TWW is sent by a transmission pipeline to the distribution centre where water is distributed to agricultural or other customers.

Operational and seasonal storage facilities are needed downstream the wastewater treatment plant to equalize daily and seasonal variations in flow from the WWTP to the distribution centre to meet peek irrigation demands, store excess of TWW entering the irrigation system in relation to irrigation demands (including winter storage), and minimize the consequences of a disruptive operation of WWTP or temporary the existence of unsuitable quality to the operation of the irrigation system.

Storage reservoirs can also be used to provide additional treatment to the TWW when managers of irrigation systems need to control changes of wastewater quality that can affect the operation of the irrigation system or to increase the TWW quality.

4.2 Reservoir types

Storage facilities can be **open** tanks (reservoirs or ponds) or **closed** reservoirs (covered or underground).

Closed reservoirs are more expensive, but have several advantages: reduced evaporation, lower potential for algal growth, reduction of odour emissions, no possibility of contact of wastewater with people or animals, and protection of stored wastewater from rainfall runoff. The disadvantage of these reservoirs is that they require periodic cleaning due to biofilm formation and biofouling.

4.3 Storage time

According to the requirements of the irrigation project, there are two main types of storage, the **short-term** and **long-term storage**.

Short-term storage is needed in most irrigation systems for equalizing and balancing TWW supply and application that occur during one or more days (according to the needs of the irrigation system).

Short-term storage is usually provided by concrete or plastic tanks and small ponds while long-term storage is usually provided by dams, large ponds, lakes, or aquifer storage and recovery.

4.4 Problems and strategies

During the storage period, wastewater is subject to changes that affect its physical, chemical, and biological quality. Bacterial regrowth, nitrification, algae growth, and production of H_2S (responsible for odour emission and risk of corrosion to metal components in the irrigation system) are the main biological processes affecting the quality of stored wastewater. Increase in suspended solids and sediments, modification of pH, reduction of nutrients (particularly nitrogen), dissolved oxygen, and residual disinfectant are also effects that result from storage. Natural decay of microorganisms during storage depends on the water retention time and operation conditions of the reservoir.

Due to the high dependency of chemical and biological reactions with the temperature and the pH of the wastewater, climate conditions and type of reservoir (open or closed) considerably affect the wastewater quality during storage. Temperature, particularly in warm regions, and rainfall are important factors for stored water quality particularly in open reservoirs.

Management strategies that should be adopted to reduce physical, chemical, and biological problems associated with wastewater storage in open and closed reservoirs are indicated in Table 1 and Table 2.

Table 1 — Problems associated with wastewater storage in open reservoirs and management strategies

Problems	Management strategies
— Temperature stratification — Low content of dissolved oxygen — Release of odours	— Installation of aeration facilities – submerged or surface mixers or recirculating pumps — Maintaining elevated oxygen concentrations (positive redox) through the water column and mainly at the sediment water interface will prevent phosphorus from entering the water column and keep it in the sediment
— Sediments	— Periodic mechanical or hydraulic dredging of accumulated sediments (every one to five years)[a]
— Excessive growth of algae and zooplankton — Reduction of internal recycling of phosphorous	— Proper mixing of wastewater in order to improve the photo-oxidation of organic matter induced by the sunlight — Addition of chemical algaecides. Copper sulfate should not be used due to the toxicity effects associated with copper accumulation (overdosing has adverse impacts on reservoir ecosystem) — Maintenance of fish that eat algae and zooplankton Addition of chemical dyes to reduce sunlight penetration as well as the growth of algae. — Biomanipulation of zooplankton (in shallow reservoirs) — Ultrasonic emissions placed into the open reservoir
— High content of suspended solids	— Suspended solids removal depends on particle size and residence time so consideration should be given to these factors when designing the storage tanks

[a] According to the surface area and depth of the reservoir.

Table 1 *(continued)*

Problems	Management strategies
— Microorganisms regrowth	— Increase of disinfectant residual — Decrease of residence time — Improvement of storage quality and facilities — Isolate and disinfect problematic sites in pipelines
— Increasing of insects namely mosquitoes	— Spraying of adequate insecticides — Mechanical methods such as keeping the water moving — Biological controls such as natural larvicides and use of larvae eating fish — Keeping banks trimmed
[a] According to the surface area and depth of the reservoir.	

Table 2 — Problems associated with wastewater storage in closed reservoirs and management strategies

Problems	Management strategies
Wastewater stagnation	Recirculation of wastewater (pumping and configuration of inlet and outlet piping promoting water recirculation) Maintaining elevated oxygen concentrations (positive redox) through the water column and especially at the sediment water interface will help prevent phosphorus from entering the water column and keep it locked in the sediment
— Low content of dissolved oxygen — Release of odours	Aeration (aeration devices)
— Loss of disinfectant residual — Regrowth of microorganisms	Proper management of operational regime on the reservoirs

5 Additional treatment facilities

5.1 General

Additional treatment steps can be necessary to achieve the wastewater (physical, chemical, or biological) quality required for the planned use of TWW.

The need for additional treatment of wastewater to be used in irrigation basically depends on the TWW quality, irrigation system, crops to be irrigated, regulatory requirements, and potential adverse environmental and public health impacts of irrigation.

Filtration (particularly in sprinkler and micro-irrigation systems) and disinfection (chlorination) are often needed.

5.2 Filtration

The concentration of suspended solids and sediments in TWW is generally low enough for most irrigation systems. However, in pressurized irrigation systems, to limit algae content and prevent biological growth in pipes and clogging of sprinklers head and emitters, filtration is installed upstream of the pumping station (particularly in drip and low-volume sprinkler irrigation systems).

Common filters used in pressurized systems include granulated media filters (gravel or sand filters), disc, and strainer filters. In drip irrigation systems, two different filters (e.g. sand and screen filters) can be installed in series.

Filtration could be set up downstream in open long-term storage reservoirs using a gravel filter, a sand filter, or a disc filter.

The characteristics of filters commonly used in irrigation systems are indicated in Table 3.

Table 3 — Characteristics of filter types commonly used in pressurized irrigation systems

Filter type	**Special features**	**Pressure head losses**
Strainer type filters Disc filters	— Irrigation systems with moderate level of suspended solids — Used in drip irrigation systems as back up of a media filter — Adequate to moderate level of filtration	Very low if screen or disks are clean
Granulated media filter (fine gravel or sand)	— Often used in drip systems	1,0 m to 1,20 m

5.3 Additional disinfection

Disinfection of TWW that is supplied from storage reservoirs and through pipeline network should be ensured to avoid bacterial regrowth and algal development.

Disinfection technologies may include oxidation materials to protect the irrigation system.

The selection of the disinfection process for a specific irrigation system should take into consideration its effectiveness (bacteria, algae, virus, and protozoa removal or inactivation), reliability and complexity, safety concerns, residual toxicity, and costs.

Chlorine has a residual toxicity for fish so it is not possible to use it in open reservoirs. It is adequate for chlorine injection into the irrigation system provided there is an acceptable risk related with the chlorinated by-products in that specific irrigation system.

The chlorination demand for TWW should be determined to define chlorine dosage and superchlorination techniques should be avoided to minimize organochlorinated compounds formation.

6 Distribution systems

6.1 Pumping stations

Pressure irrigation requires the TWW to be raised from its source to the field surface through the distribution system. The water is pumped by a water pump which is generally operated by an electrical motor. It can also be used to boost the water in an existing water distribution line to force it through the irrigation system at a desired pressure head. In all cases, the pump should be designed to lift the required amount of water from the source to the highest point in the irrigation field and to maintain an adequate pressure head.

6.2 Pipelines

A distribution network consists of one or more main and sub-main pipes that ensure the TWW transport from the distribution reservoir to the plots to be irrigated. The pipe materials most commonly used in wastewater distribution network are ductile iron (DI), steel, polyvinyl chloride (PVC), high-density polyethylene (HDPE), aluminium, and for large (main) irrigation networks, a commonly used material is glass-fibre reinforced polyester (GRP) for diameters >900 mm. All the referred materials require special bedding to limit deflection. Their chemical resistance to pH and fertilizers is summarized in 6.4 (Table 5 and Table 6). Pipe characteristics according to the constituent material are indicated in Table 4.

Table 4 — Special features of common pipe constituent materials

Material	Special features
Ductile iron steel	— Strong and flexible — Protection against internal and external corrosion required — Special joints at changes in direction are required[a]
PVC[b] HDPE	— Light weight, easy installation — Protection against internal and external corrosion not required — Available only in some classes of pressure — Special joints at changes in direction are required[c]
Aluminium	— Light weight — Can be assembled and dismantled easily and rapidly — Resistant to mechanical damage and to sunlight — Vulnerable under freezing conditions (pipe splitting) — Attacked by fertilizers and chemicals
Glass-fibre reinforced polyester (GRP)	— Mainly used for diameters >900 — Light weight, easy installation — High strength and robustness (low weight to strength ratio) — High corrosion resistance
Steel-core concrete[d, e]	— Strong — Protection against internal and external corrosion

[a] For flanged joints (DI) and flanged or welded joints (steel).

[b] Damaged by sunlight.

[c] HDPE might not be required depending on diameter and angle of direction change.

[d] If concrete pipe is used, oxidation is not recommended.

[e] According to experience in Portugal.

6.3 Accessories

6.3.1 General

As in every water distribution network in TWW irrigation systems, it is necessary to install the accessories that support the correct operation and maintenance of the system namely the following.

6.3.2 Valves

Shut-off valves — Shut-off valves greater than 75 mm are typically gate or butterfly valves. Smaller ones are usually plug valves.

Air release valves — These valves that remove air and gases trapped in pressurized pipelines should be installed in all high points of the network where gases accumulate.

Air release/vacuum relief valves — These valves that release air and gases and allow atmospheric air to enter in pipes should be installed to eliminate the vacuum created when pipes are drained.

Back-flow preventers — These valves that prevent the wastewater back-flow are necessary whenever wastewater back-flow from the irrigation system to the potable water system occur. Backflow preventer devices should incorporate a full backflow prevention assembly including a port that enables verification that the device is working properly

Automatic multi-zone valves — Valves used to discharge wastewater in sequence to different zones of the irrigation area.

Solenoid valves — These valves open and close automatically by means of low-voltage signals are used to flush filters or drip-lines or to send water to a specific zone of the irrigated plot.

Pressure regulator valves — Valves that are necessary to maintain the water pressure at a fixed value or in a range of values (valves of fixed or variable pressure, respectively). Pressure valves should be able to support the maximum pressure in the pumping system and to provide the pressure needed for drip emitters operation.

6.3.3 Blowoffs

Blowoffs are small pipes with a valve at the end that should be installed at piping dead ends and at low elevation connection points of the network to allow the draining of the pipes and to remove the sediments accumulated on it by pipe flushing.

6.3.4 Flowmeters

In small facilities, displacement-type meters can be used. Turbine meters, propeller meters, and magnetic flowmeters are used in larger services. Magnetic flowmeters are recommended due to the suspended solids and sediments in TWW.

6.3.5 Hydrants

This accessory is used when temporary access to TWW supply is needed as it happens with portable sprinkler systems or the group of elements used to derivate water from a general network to a private plot.

6.4 Resistance of irrigation material to pH and fertilizers

The irrigation pipes and accessories should be selected according to their chemical resistance and to the quality of the wastewater (in particular pH) and the type of fertilizer applied when using fertigation (Table 5 and Table 6).

To know the technical characteristics of pipes and accessories for irrigation, like for PH and fertilizers resistance, amongst others, it is useful to contact the manufacturers of the pipes and accessories.

Table 5 — Permitted pH of irrigation water according to the material of irrigation pipes and accessories (according to experience in Portugal)

Sprinkler irrigation material	pH of the irrigation water
Iron and steel	>6,5
Aluminium	>5,5
PVC/PE	It is recommended to consult with the supplier regarding the specific resistance of the products to chemicals and to the pH in the water

Table 6 — Resistance of sprinkler irrigation pipes and fertigation accessories to fertilizers (according to experience in Portugal)

Fertilizers	Degree of restriction on use[a]				
	PVC	PE	Stainless steel	Iron	Aluminium
Ortho-phosphoric acid	1	2	3	4	4
Potassium chloride	1	2	2	3	3
Ammonium phosphate	1	2	2	3	3
Ammonium nitrate	1	2	1	2	2
Calcium nitrate	1	2	1	2	2
Potassium nitrate	1	2	1	2	1
Potassium sulfate	1	2	1	2	1
Urea	1	2	2	2	1

[a] 1 (lower restriction) to 4 (stronger restriction).

6.5 Maintenance of distribution networks to prevent bacterial regrowth

The main problem related to the distribution of TWW is the possibility of degradation of the TWW quality in the distribution network particularly in hot climates and long distribution networks (i.e. long residence times at high temperatures). The challenge is to prevent the odour release and bacterial growth.

To prevent bacterial regrowth associated to chlorine decay, it is recommended to

— periodically purge the distribution network,

— flush and chlorinate the pipes before each irrigation,

— isolate the problematic parts of the pipeline network and chlorination at critical points,

— the addition of nitrates that will promote the growth of bacteria that will not reduce sulfates (production of hydrogen sulphide), and

— physical periodic cleaning of the irrigation mains (plugs/pigs pushed through the piping that scrape the bacteria off).

6.6 Design and operation of distribution network to protect drinking water sources

6.6.1 General

The use of TWW for irrigation creates a potential risk for water sources (surface or underground) due to possible ruptures or leaks in **the TWW distribution system to the irrigated fields. TWW leaks could reach the aquifer water or the surface water and contaminate** it.

The main risk is penetration of pathogenic pollutants to drinking water sources. To prevent this risk, it is required to separate the TWW main supply lines from the drinking water sources (wells) to a distance which will ensure that TWW does not flow directly to the well and that TWW seeping to the soil will flow in the aquifer for at least 40 d until it reaches the well (the time during which annihilation of the pathogenic pollutants is effective).

In a sandy aquifer, water flows slowly through the sand layers (providing additional filtration) and therefore, the radius of the protective zone around the wells are relatively small. In fissured aquifers, water can flow through the cracks and reach the wells relatively quickly, therefore, the protection zone radiuses are much larger than those in sandy soils.

6.6.2 Stipulating a protective radius

Countries in which a legislation or guidance for protective radius from drinking water sources already exists should comply with those local requirements. However, in countries without any such guidance, the following principles can be used. The main transmission lines of TWW intended for agricultural irrigation will be at a distance from drinking water wells as follows (according to the Israeli experience):

— in a sandy aquifer: 50 times the distance L (expressed in meters);

— in a cracked aquifer: 200 times the distance L (expressed in meters).

Use the following empirical equation (based on pathogen die off in the soil):

$$L=\sqrt{\frac{Q*k}{d}} \tag{1}$$

where

L is the distance (expressed in meters) of main transmission lines from drinking water wells;

Q is the flow rate of the well (expressed in m^3/h);

k is the constant which has a value of 1 h;

d is the distance (expressed in meters) between the surface of the water at the static saturation zone of the well and the bottom of the well.

In lines transmitting TWW (such as high and very high quality treated wastewater) which is continuously disinfected by chlorine, the distances can be reduced by half or more depending on the local context.

6.6.3 Principles of TWW irrigation above (underground or surface) drinking water pipelines

Sometimes, the irrigation with TWW is carried out above drinking water supply pipes and in such cases, protective measures should be taken to protect the drinking water supply system from the penetration of pathogens if leaks occur in the drinking water pipelines. The irrigation of non-disinfected TWW above drinking water lines is forbidden. However, the irrigation of TWW which is continuously disinfected by adequate chlorine dose (or an equivalent disinfection for the destruction of pathogenic microorganisms) is permitted.

6.6.4 Principles of cross-connection

6.6.4.1 General

The creation of a cross-connection between two water supply systems could be caused by mistake when an unskilled person carries out pipeline repairs. The observance of a minimum distance between drinking water pipes and pipes transporting other qualities of water significantly reduces the risk of inadvertent cross-connection. Clear marking of pipes and fittings regarding the quality of water transported is also a key method to reduce the chance of cross connections.

6.6.4.2 Control requirement

When the distance between pipes of drinking water and pipes of non-potable water (NPW) is less than 20 m, the NPW supplier should conduct inspections under the supervision of a supervising authority to search for the existence of cross-connections between the two types of water systems.

6.6.4.3 Control method

The most desirable method of control is using a mechanism which enables the detection of a direct connection between the two types of water, e.g. by detecting a certain element or compound which is found only in one type of water. If this is impractical, control should be carried out by shutting down the water supply in one of the systems and detecting whether water flow continues in that system (as a result of water entry from the other).

6.6.5 Principles of painting and marking TWW irrigation pipelines and systems

6.6.5.1 General

Water pipelines and their related equipment for use with TWW should be marked to prevent cross connections between them and drinking-water pipelines.

Due to traditions and regulations for local uses of colour to identify pipes conveying various media (such as date, highway signal controls, gases, electricity, water, and wastewater) a universal international specification for pipe marking is not practicable. In countries where specific regulations and guidance already exist, those local colour and labelling specifications should take precedence. However, in countries where there is no established marking and labelling requirements and where they would not lead to any local confusion or where the suggested scheme is already adopted, the following specifications are recommended.

The recommended specifications for marking TWW transmission lines and related equipment are presented below.

6.6.5.2 Examples for marking pipelines of up to 75 mm diameter

Table 7 — Examples of painting and marking TWW irrigation pipelines and systems

<table>
<tr><th>Liquid type</th><th>Colour of buried pipe</th><th>Colour of exposed pipe and related equipment</th><th>Marking ribbon</th><th>Signage on a fence around the water equipment</th></tr>
<tr><td>Wastewater</td><td></td><td>Brown</td><td rowspan="3">Purple + caption:
Caution – below are pipes of wastewater or water that are forbidden to drink</td><td>Caution - Wastewater – Do not drink</td></tr>
<tr><td>High and very high quality TWW</td><td>Purple</td><td>Purple</td><td>Caution - Treated wastewater – Do not drink</td></tr>
<tr><td>Good and medium quality TWW</td><td>Purple</td><td>Purple with intermittent orange stripes on 30 % of the surface</td><td>Caution - Treated wastewater – Do not drink</td></tr>
</table>

Accessories and related equipment found above ground will be marked on a signboard of at least (50 cm × 40 cm) made of material resistant to weather elements, written in red or purple on a white background, and in letters not less than 7 cm in height.

6.6.5.3 Water transmission pipeline of a diameter exceeding 75 mm

The pipeline and its related equipment found above ground will be painted with a durable colour which is suitable for the type of piping in a colour that matches the type of water transmitted in it (as indicated in Table 7).

Pipeline found in the ground will be accompanied by marking ribbons in the suitable colour which will be buried at a depth of at least 0,5 m below ground surface and at a distance of 0,3 m to 0,5 m above the top of the pipe.

The signage suitable for the type of water transmitted in the pipe will be imprinted on the ribbon as indicated in Table 7.

The ribbons will be made of polyethylene and at least 12 cm wide. The size of letters in the caption on the ribbon will not be less than 5 cm.

Accessories and related equipment found above ground will be accompanied by signage of at least 50 cm × 40 cm in size, made of material resistant to weather elements, and written in red or purple on a white background. The size of the letters will not be less than 7 cm.

7 Irrigation systems

7.1 Classification

Wastewater irrigation systems used in agricultural and landscape irrigation can be classified in two groups according to the way the water flows from the distribution centre (where water from the wastewater treatment plant is delivered to the customers) to the irrigated area: pressurized irrigation systems and gravity flow irrigation systems.

Taking into account the method used to apply the TWW to the soil, it is possible to distinguish three types of irrigation systems: open irrigation systems, sprinkler irrigation systems, and micro-irrigation systems.

The more common irrigation systems are indicated schematically in Table 8.

Table 8 — Irrigation systems and techniques used in common pressurized irrigation and gravity flow systems

Pressurized irrigation		Gravity flow irrigation
Sprinkler irrigation systems	**Micro-irrigation systems**	**Surface irrigation systems**
— Using stationary sprinkler systems (Portable, semi-portable, semi-permanent, solid set or permanent equipment)	Drip irrigation — Surface — Sub-surface	Border irrigation — Straight — Contour
— Using mobile sprinkling machines (Self-moved sprinklers, boom sprinkler, self-propelled gun traveller or continuous move laterals	Micro-spray irrigation	Check basin irrigation — Rectangular — Contour — Ring Furrow irrigation — Graded furrow — Corrugation

7.2 Pressurized irrigation systems

7.2.1 Sprinkler systems

7.2.1.1 General

In these systems, water is sprayed into the air and falls on the soil surface like rainfall. These systems (especially the overhead systems) might not be used when TWW quality is low. This limitation concerns the salinity and biological quality since the water comes in contact with the foliage and higher aerosol effects are developed with public health risks to the farmers, hired workers, and the population of surrounding areas of the irrigation site.

7.2.1.2 Types of sprinkler

Based on the arrangement for spraying the irrigation water, the sprinkler systems are classified as rotating sprinklers, perforating pipe system, and gun sprinklers. The rotating sprinklers are the most common ones. In particular, "pop-up" rotating sprinklers are especially adapted to irrigate lawns. The classification of sprinklers according to the working pressure is presented in Table 9.

Table 9 — Classification of sprinklers according to the working pressure

Agricultural sprinklers	Nozzle diameter (mm)	Pressure (bars)	Discharge (m^3/h)	Diameter of coverage (m)
Low pressure	1,0 to 3,5	0,7 to 2,0	0,3 to 1,5	6 to 13
Medium pressure	1,0 to 5,0	2,0 to 4,0	1,5 to 3,0	12 to 25
High pressure	7 to 40	4,0 to 7,0	5,0 to 65,0	25 to 60

Based on the portability and mobility, the sprinkler systems are classified into the following groups:

a) stationary sprinkler systems
   — portable system
   — semi-portable system
   — semi-permanent system
   — solid-set
   — permanent system

b) mobile sprinkling machines
   — self-moved system
   — boom sprinkler
   — self-propelled gun traveller
   — continuous move laterals
   — center-pivot
   — continuous linear move laterals

7.2.1.3 Pipes

Water is taken from the main pipes to the sub-mains and from these to the laterals. Mains, sub-mains, and lateral pipes can be permanent or portable depending on the type of the sprinkler irrigation system.

Asbestos-cement, PVC, PE, glass-fibre reinforced polyester, or steel are often used for most permanent main lines. PVC, PE, and aluminium pipes with quick couplers are used for most portable main and sub-main lines. PVC and aluminium pipes with quick couplers with rubber gaskets are used for laterals. In stationary systems, the sprinklers are mounted on the laterals through risers.

The diameter and length of the laterals should be conditioned to the 20 % rule which states that the pressure head variation along the lateral should be limited to 20 % of the operating pressure head of the sprinklers.

7.2.1.4 Sprinklers head

The sprinkler head is the most important component of a sprinkler irrigation system. Its operating characteristics under optimum pressure head and climate conditions, mainly the wind speed, will define its suitability and the efficiency of the system.

7.2.2 Micro-irrigation systems

7.2.2.1 General

Micro-irrigation systems are classified as drip (or trickle) irrigation systems (surface drip irrigation or sub-surface drip irrigation depending on where the laterals and drippers are placed) and micro-spray irrigation systems. Surface and sub-surface drip irrigation are the most suitable systems for the application of wastewater due to the lower contamination risk.

7.2.2.2 Drip irrigation equipment

— The dripper is characterized by nominal discharge and operating pressure.

— The subsurface drip irrigation system in TWW can be used as a barrier between the water and the irrigated crop. In such case, the dripper should have a valve action to prevent the passage of soil particles into the system.

— The drip irrigation system should be accompanied by means for preventing the penetration of roots, mainly in the underground sections of the irrigation system. One way to reduce root penetration is by chemical means using a pre-emergence herbicide (e.g. properly applied trifluralin).

7.2.2.3 Micro-jet system

7.2.2.3.1 General

Unlike the drip irrigation system where water passages are small and the volumetric flow rate is low, micro-jets have larger water passages and their flow rate is higher. There are many types of micro-jets with different water passages and different support methods, such as

— micro-jets on a spike, mainly for orchards and gardening, and

— upside-down micro-jets, with or without a bridge.

7.2.2.3.2 Micro-jets on a spike

Where TWW of low quality is concerned, it is recommended not to use sprinkler discharges lower than 30 l/h. At a lower capacity, the water outlet that is less than 1 mm in diameter is susceptible to clogging.

7.2.2.3.3 Upside-down micro-jets

Where TWW of low quality is concerned, it is recommended not to use sprinkler discharges lower than 50 l/h. At a lower capacity, the water outlet that is less than 1 mm in diameter is susceptible to clogging.

7.2.3 Filtration

The filtration level and location of the filter namely the filter media type in the irrigation system should be chosen with respect to the intended water quality. Filtration is not a stand-alone treatment, but rather an integral part of the various treatments required. During the design process, the lowest possible water quality at that location should be considered.

Two filtration levels can be specified in order to reach the required filtration level, e.g. 120 µm or as recommended by the manufacturer/planner. It is also recommended to install the filtration as close to the distribution point as possible. Only in cases where the distance between the last filter and the lateral exceeds 400 m and/or if a control filter is to be installed, the installation of an additional filter should be considered.

7.2.4 Automation of the irrigation

According to the degree of automation of the irrigation system, it is possible to distinguish the following levels of automation: no automation, partial automation, sequential automation, high automation, and full automation.

7.3 Instructions for preventive treatments, regular maintenance, and handling pressurized irrigation system failures subject to TWW quality

7.3.1 General

For the purpose of simplifying the use and handling of TWW intended for agricultural irrigation, the necessary parameters for selecting an appropriate irrigation water quality have been examined. Water quality for the definition (or adaptation) of irrigation system maintenance should be measured in terms of chemical and physical parameters at the end-users when needed according to the water quality and at the water supplier's outlets. It is recommended that sampling points will be located as follows: at the water source (WWTP, reservoir), in the irrigated plot after the treatment area (filtration, disinfection, etc.), and at the end of a lateral flushing until turbidity remains constant.

A monthly lab test of the water should be initially carried out. From the results of the analysis, the required test frequency should be determined and also which additional parameters such as: iron concentration, manganese concentration, $CaCO_3$, and chemical precipitates or dissolved solids should be monitored to accurately analyse the water quality.

7.3.2 Water quality parameters required for the treatment and maintenance of irrigation systems, for micro-sprinklers and drip irrigation systems

Table 10 summarizes the minimum parameters required to define the qualities of irrigation water, for irrigation equipment maintenance.

Each of the following parameters is used to specify the three qualities of irrigation water for equipment maintenance purposes namely good (graded 1), medium (graded 2), and low (graded 3) (see Table 10).

a) **Potential clogging**: A physical test which will be performed with a Clogging Potential Meter (CPM) (1)

b) **pH**: Testing the water's level of acidity or alkalinity (2)

c) **Chlorine requirement**: Will be checked by the redox potential test (3)

Table 10 — Definitions of the suitability of water quality to the irrigation system according to clogging potential, pH, and redox potential

Water quality[a]	Parameter		
	Clogging potential – (1)[b]	**pH (2)**	**Redox – (3)[c]**
	Time		mV
Good	Longer than 7 min	<7,2	Between 300 and 500
Medium	Between 3 min and 6 min	Between 7,2 and 8,0	Between 250 and 300 and between 500 and 600
Low	Shorter than 3 min	>8,0	<250 and >600

[a] These levels are suitable for water to maintain the irrigation system rather than for irrigation water specified elsewhere in this guide.

[b] The Clogging Potential Meter (CPM) tests using a 150 µm mesh.

[c] The redox potential has been chosen as an index of the organic substances found in the water. A chlorine requirement test is not possible for continuous measurement since the instrument for such test is extremely costly and can be installed only in large irrigation systems. The redox has been chosen to be part of the monitor system as a default, although it is not an accurate index for organic material. It will be mentioned in the guide that if chlorination efficiency should be tested, a continuous chlorine meter will be used

7.3.3 Required equipment and treatments for micro-sprinklers and drip irrigation systems

7.3.3.1 General

To match the various water qualities to irrigation equipment and accessories, consideration should be given to factors such as regular treatments, preventive treatments, and treatments for returning equipment to proper working order following failure. For the recommended Annexes for reading, see Annex A to Annex E for more detailed information on the drip irrigation topics raised in this section.

Recommended annexes for reading are the following:

— guidelines for injecting chlorine into drip irrigation systems (Annex A);

— guidelines for acid use (Annex B);

— guidelines for injecting hydrogen peroxide into drip irrigation systems (Annex C);

— guidelines for sampling drip irrigation pipes (Annex D);

— permitted chemical (Annex E).

7.3.3.2 Irrigation system treatments

7.3.3.2.1 Preventive and maintenance for different water qualities in drip irrigation systems

a) Treatment 1 — Suitable for a drip irrigation system fed with good quality of water[1)]

It is recommended to use three levels of filtration such as an automatic 150 µm filter in the reservoir or at the head of the system and a 130 µm control filter. The system should be flushed twice in each season–at the beginning and at the end of the season (instructions for flushing drip irrigation pipeline and laterals are included in Annex D).

b) Treatment 2 — Suitable for a drip irrigation system fed with medium quality of water

Where the clogging potential element is dominant, it is recommended to use three levels of filtration that include a 150 micron filter at the water source or at the head of the system, a filter in the water

1) As specified in Table 10.

transportation system, and a control filter at the beginning of the plots with flushing of laterals and manifolds every two months.

c) Treatment 3 — Suitable for a drip irrigation system fed with medium quality of water

Where the pH element is dominant, it is recommended that in addition to the two levels of filtration, an acid dosing will be used. Treat with acid four times annually at a concentration of 1 l of hydrochloric acid (or an equivalent) for a flow rate of 1 m^3/h so that the pH level will be 4 to 5 at the end of the last extension when measured after 1,5 h of contact time. Flush the laterals and manifolds every two months (instructions for acid treatment are included in Annex B).

d) Treatment 4 — Suitable for a drip irrigation system fed with medium quality of water

Where the potential redox element is dominant, it is recommended to use two levels of filtration and chlorine dosing. Treatment with chlorine for prevention at a dosage of 10 mg/L for a flow rate of 10 m3/h so that the level of residual chlorine will be 2 mg/L to 3 mg/L. Alternatively, hydrogen peroxide can be used. For prevention dosage of 1 l of hydrogen peroxide for a flow of 10 m3/h at the last hour of the irrigation and for shock treatment when the flow decreases in 20 % to 30 %, a dosage of 10 l of hydrogen peroxide per 10 m3/h for 1 h at the end of irrigation cycle, closing the water for 12 h to 24 h, and then flushing the tubes.

e) Treatment 5 — Suitable for a drip irrigation system fed with low quality of water

Where the clogging potential and pH elements are dominant, it is recommended to use two levels of filtration, systematic acidification (continuous or at high frequency) for lowering the pH, and flushing of laterals and manifolds every two weeks.

f) Treatment 6 — Suitable for a drip irrigation system fed with low quality of water

Where the clogging potential and redox element are dominant, it is recommended to use two levels of filtration and weekly high dose chlorination. To flush the water supply system from the reservoir, use a concentration of 30 mg/L for a flow rate of 10 m^3/h. Chlorinate the plots twice a week until the residual chlorine at the end of a lateral is 1 mg/L and flush of laterals and manifolds every two weeks.

g) Treatment 7 — Suitable for a drip irrigation system fed with low quality of water

Where all elements are problematic, it is recommended to use two levels of filtration, constant or monthly acid treatment, constant weekly chlorination in the reservoir at a concentration of about 3 mg/L, and a chlorine treatment in the plot three times a week up to a chlorine level of 1 mg/L at the end of the last lateral. Flushes should be performed once a week. Alternatively, hydrogen peroxide can be used. For prevention dosage of 1 l of hydrogen peroxide for a flow of 10 m^3/h at the last hour of the irrigation and for shock treatment when the flow decreases in 20 % to 30 %, a dosage of 10 l of hydrogen peroxide per 10 m^3/h for 1 h at the end of irrigation cycle, closing the water for 12 h to 24 h, and then flushing the tubes.

7.3.3.2.2 Preventive and maintenance for different water qualities in micro-sprinkler systems

The treatment needs for micro-jet and micro-sprinkler systems are fewer than for the drip irrigation systems and only require filtration.

a) **Filtration specification for a micro-sprinkler irrigation system fed with good quality of water**: One level of filtration should be used; a 180 µm control filter.

b) **Filtration specification for a micro-sprinkler irrigation system fed with medium quality of water**: Two levels of filtration should be used; an 80 µm mesh filter at the water source or system head and a 180 µm control filter at plot heads.

c) **Filtration specification for a micro-sprinkler irrigation system fed with extensively quality of water**: Two levels of filtration should be used; a 180 µm filter at the reservoir and a 120 µm filter at the area head.

7.3.3.2.3 Drip irrigation systems by water quality

Table 11 summarizes the recommended treatments for drip irrigation systems according to the water quality parameters in Table 10.

Table 11 — Details of the recommended treatments by water quality parameter level

Treatment model	Water quality index level		
	Clogging potential	PH	Redox
1	1	1	1
4	2	1	1
6, 4	3	1	1
3	1	2	1
6	2	2	1
7, 6	3	2	1
3	1	3	1
5	2	3	1
7	3	3	1
2	1	1	2
2	2	1	2
4	3	1	2
3	1	2	2
4, 5	2	2	2
6	3	2	2
3	1	3	2
6	2	3	2
7	3	3	2
2	1	1	3
4	2	1	3
6	3	1	3
5	1	2	3
4	2	2	3
6	3	2	3
5	1	3	3
7	2	3	3
7	3	3	3

Table 11 combines the values obtained from Table 10 to specify the water quality based on three parameters (clogging potential, pH, and redox) with the recommended treatment or treatments (see 7.3.3.2). To determine the appropriate type of treatment for the irrigation system, it is recommended to take into consideration the test results of all three parameters. In other words, if clogging potential is in level 3, pH in level 2, and redox in level 1, the recommended type of treatment will be treatment 6 or 7.

NOTE The treatment model's numbers provided in Table 11 present the recommended characteristics of the treatment options. However, every characteristic has a variety of possible additions which depend upon the precise water quality parameters.

The treatments presented in Table 11 are appropriate to the frequent TWW quality. For other qualities, a special treatment should be determined.

7.3.4 Restoring working order of an irrigation system after failure

7.3.4.1 General

Failure is likely to occur due to an inflow of a large mass of particulate or suspended material or both. Restoration from failure can be the responsibility of the water supplier as well as the system maintenance supplier.

7.3.4.2 Severe failure

A severe failure is likely to be caused by a massive inflow to the irrigation system of organic or inorganic matter in the form of particulate or suspended material or both. The recommended treatment is high-pressure flushing of the manifolds after disconnecting the manifolds from the laterals. High-pressure flushing of the laterals, treatment with hydrogen peroxide for degrading the organic material whether by immersion or regular treatment (injection of hydrogen peroxide followed by immediate flushing) should be repeated 2 to 4 times a day. Treatment of the outlets such as micro-jets or drippers with acid by immersion or regular flushing should be repeated 2 to 3 times and then pressure flushed.

Annex A
(informative)

Guidelines for injecting chlorine into drip irrigation systems

A.1 General

Chlorine is a strong oxidizer. It is useful for the following purposes:

a) preventing and eliminating the growth of organic slime, iron slime, and sulfur slime;

b) oxidation of elements such as iron, sulfur, manganese, etc.;

c) cleaning organic sedimentation and bacterial slime from irrigation systems;

d) improving the filtration efficiency especially sand/media filtration.

NOTE 1 Chlorine is effective only on organic matter.

NOTE 2 Chlorine is ineffective on inorganic matter such as sand, silt, scale, etc.

A.2 Safety

WARNING — Chlorine material (liquid, solid, or gas) is dangerous to humans.

Before using chlorine, read all safety instructions provided by the chlorine manufacturer.

Regard all instructions for acid treatment as subordinate to all legal provisions and to the instructions of the acid manufacturer.

— Before filling any tank with chlorine solution, be sure to wash it very carefully in order to remove any fertilizer remains.

— Avoid contact with eyes.

Contact of chlorine with the eyes can cause blindness.

— Avoid contact with skin.

Contact of chlorine with skin can cause burns.

— Use protective clothing when working with chlorine.

Wear goggles, gloves, full-length trousers and sleeves, and closed high shoes.

— Avoid swallowing or inhaling.

Swallowing chlorine or inhaling its fumes can be fatal.

— Be present during treatment.

Be present for the full duration of the treatment. Keep all unauthorized persons away from the treatment area.

NOTE 1 Direct contact between chlorine and fertilizers can cause an explosive thermal reaction. This is extremely dangerous.

NOTE 2 Direct contact between chlorine and acid releases a toxic gas.

NOTE 3 Injecting chlorine into irrigation water containing fertilizer is not hazardous.

A.3 Materials

Chlorine is available for commercial use in several forms. Each type has its advantages and disadvantages. Consider the convenience, availability, and price of each material before deciding which to use.

Commonly available forms include the following:

— **gaseous chlorine (Cl2);**

— **solid chlorine (Calcium Hypochlorite);**

When both the calcium level and alkalinity of the water are above medium and the pH is above 8,0, consult an expert for advice on whether Calcium Hypochlorite can be used.

— **liquid chlorine (Sodium Hypochlorite).**

Liquid chlorine is unstable and decomposes spontaneously in the storage tank according to time, temperature, and solar radiation.

Do not store liquid material for a long period of time. Keep it in the shade and paint the storage tank white if you should keep it in direct sunlight.

A.4 Usage

A.4.1 Methods of application

Generally, there are two methods of chlorination.

a) **Continuous injection**

Chlorine should be continuously injected throughout the whole irrigation cycle. This is the most efficient method, but chlorine consumption is highest.

b) **Selective injection**

Chlorine should be injected during the last hour of irrigation. Do not forget to consider the time required to for the chlorine to reach the end of the system (see Annex C, Table C.3 to Table C.8). With this method, both the chlorine consumption and efficiency are lower than with continuous chlorination.

Annex B
(informative)

Guidelines for acid use in drip irrigation systems

B.1 Forbidden chemicals

It is forbidden to use certain chemical in drip irrigation systems.

— Never use fertilizers containing more than 20 units of Phosphorus.

— Never use any Poly-phosphate.

— Never use red Potassium Chloride.

— Never use Red Potassium Sulfate.

— Never use Borax.

— Never use organic products with high contents of suspended solids (without preliminary treatment).

— Never use products and fertilizers with low solubility, e.g. gypsum.

— Never use waxy chemicals, oil solvents, petroleum products, and detergents.

— Never use active chlorine (at the injection point) with more than 40 ppm.

— Never use acid with a pH lower than 2.

B.2 Appropriated chemicals

A list of permitted chemical is provided in Annex E.

B.3 Acid treatment for drip systems

Acids can be used to dissolve and decompose salts, carbonates, phosphate, and hydroxide deposits.

NOTE Acid treatment is ineffective with most organic matters.

B.3.1 Safety

WARNING — Acids are types of poison and are dangerous to humans. Before using acid, read all safety instructions provided by the acid manufacturer.

Regard all instructions for acid treatment as subordinate to all legal provisions and to the instructions of the acid manufacturer.

— Always add acid to water – NEVER add water to acid.

— Avoid contact with eyes.

Contact of acid with the eyes can cause blindness.

— Avoid contact with skin.

Contact of acid with skin can cause burns.

— Use protective clothing when working with acid.

Wear goggles, gloves, full-length trousers and sleeves, and closed high shoes.

— Avoid swallowing or inhaling.

Swallowing acids or inhaling their fumes can be fatal.

— Be present during treatment.

Be present for the full duration of the treatment. Keep all unauthorized persons away from the treatment area.

B.3.2 Usage

B.3.2.1 Injecting Acid into the System

To apply an acid treatment to the system, perform the following steps:

a) make sure that the injection pump is high capacity and acid resistant;

Acids are very corrosive to materials such as steel, aluminium, asbestos-cement, etc. PE and PVC pipes are resistant to acids. Consider these factors before planning the treatment.

b) before starting the treatment, flush all system components thoroughly using maximum flow;

NOTE Failure to flush the system prior to using acid is harmful to the system.

c) inject the acid into the irrigation system for the required time according to the desired concentration;

d) turn off the injection pump;

e) continue to irrigate for the required period of time according to Annex C, Table C.3 to Table C.8.

B.3.2.2 Acid concentrations

The level of acid concentration added to the irrigation water depends on the type of acid being used, its percentage, and valence.

Acids should be free of insoluble impurities, e.g. gypsum, etc.

Table B.1 — Recommended acid concentrations

Acid percentage	Recommended concentration in treated water
Hydrochloric acid, 33 %	0,6 %
Phosphoric acid, 85 %	0,6 %
Nitric acid, 60 %	0,6 %
Sulphuric acid, 65 %	0,6 %

If your acid has a different percentage other than the ones listed in Table B.1, adjust the percentage accordingly.

Calculate the acid concentration when using a different starting concentration as follows:

EXAMPLE 98 % Sulphuric acid is available. What percentage Y should be used?

$$Y \times 98\% = 0,6\% \times 65\%$$

$$Y = \frac{(0,6\% \times 65\%)}{98\%} = 0,4\%$$

Annex C
(informative)

Guidelines for injecting hydrogen peroxide into drip irrigation systems

C.1 General

Hydrogen peroxide is one of the most powerful oxidizers known. Hydrogen peroxide always decomposes exothermically into water and oxygen gas.

$$2\,H_2O_2 \rightarrow 2\,H_2O + O_2$$

A sequence of hydrogen peroxide treatments followed by a chlorine treatment can have a powerful and prolonged oxidizing effect. Combining the two treatments is forbidden.

Do not use hydrogen peroxide when using steel, cement coating, and asbestos cement tanks and pipes.

NOTE Hydrogen peroxide is not efficient for the prevention or dissolution of scale sediments, sand, silt, etc.

C.2 Safety

WARNING — Hydrogen peroxide is dangerous to humans and animals. Before using hydrogen peroxide, read all safety instructions provided by the manufacturer.

Regard all instructions for hydrogen peroxide treatment as subordinate to all legal provisions and to the instructions of the manufacturer.

— Before filling any tank with hydrogen peroxide solution, be sure to wash it very carefully in order to remove any fertilizer remains.

— Avoid contact with eyes.

Contact of hydrogen peroxide with the eyes can cause blindness.

— Avoid contact with skin.

Contact of hydrogen peroxide with skin can cause burns.

— Use protective clothing when working with hydrogen peroxide.

Wear goggles, gloves, full-length trousers and sleeves, and closed high shoes.

— Avoid swallowing or inhaling.

Swallowing hydrogen peroxide or inhaling its fumes can be fatal.

— Be present during treatment.

Be present for the full duration of the treatment. Keep all unauthorized persons away from the treatment area.

— Avoid contact with oil and grease.

— Can cause explosions or fire.

NOTE 1 Direct contact between hydrogen peroxide and fertilizers containing ammonia can cause an explosive thermal reaction which can cause the tank to explode. This is extremely dangerous.

NOTE 2 Injecting hydrogen peroxide into irrigation water containing fertilizer is not hazardous.

C.3 Physical and chemical properties

Benefits of using hydrogen peroxide include the following:

— its rapid oxidation reaction causes immediate consumption upon contact with the irrigation water and there is no continuous oxidation activity throughout the irrigation system (as is the case when chlorine is used);

— it is environmentally friendly;

— it does not create dangerous residues;

— preventing the accumulation of bacterial slime in pipes and dripper line extensions;

— cleaning the dripperline system in which organic sedimentation and bacterial slime have accumulated;

— oxidation of microelements to prevent the development and reproduction of bacteria (iron, manganese, and sulfur);

— improving the efficiency of initial filtering under high organic stress conditions;

— disinfecting irrigation, sewage, wastewater, and drinking water;

— prevention and removal of odours in the water impairing biological activity;

— lowering BOD/COD values by oxidizing the polluting substance both organic and inorganic.

Table C.1 lists the physical and chemical properties of hydrogen peroxide at different concentrations.

Due to safety and cost considerations, the recommendation is to use a 35 % or 50 % concentration of hydrogen peroxide.

Table C.1 — Physical and chemical properties of hydrogen peroxide

	Concentration			
	35 %	**50 %**	**60 %**	**70 %**
Physical state	Liquid	Liquid	Liquid	Liquid
Colour	Colourless	Colourless	Colourless	Colourless
Characteristic odour	Yes	Yes	Yes	Yes
Molecular weight H_2O_2	34,01	34,01	34,01	34,01
Boiling point	108 °C	114 °C		125 °C
Freezing point	−32 °C	−51 °C		−37 °C
Vapor pressure at 25 °C	23 mm Hg	18 mm Hg		11 mm Hg
Specific gravity (H_2O = 1)	1,132	1,195	1,240	1,288
pH	<5	<4		<2

C.4 Usage

Injected hydrogen peroxide is the concentration (ppm) of hydrogen peroxide calculated at the injection point.

Residual hydrogen peroxide is the concentration (ppm) of hydrogen peroxide measured at the most distant part of the treatment system.

The hydrogen peroxide requirements are high for waste and industrial waste water and low for municipal supply water and other types of water with no organic load.

In waste and industrial wastewater conditions, it is not possible to calculate the required concentration of hydrogen peroxide and therefore, it is necessary to inject an arbitrary amount, use the test kit to check the residual concentration at the end of the system, and then correct the dosage accordingly. In municipal supply water conditions or conditions due to other types of water with no biological load, it is easy to calculate the amount of hydrogen peroxide to be injected into the system.

C.4.1 Methods of Application

Generally, there are two methods of applying hydrogen peroxide.

a) Continuous injection at low dosage — Hydrogen peroxide should be continuously injected throughout the whole irrigation.

b) Selective injection — Hydrogen peroxide should be continuously injected throughout the whole irrigation to consider the time required to for the hydrogen peroxide to reach the end of the system (see Table C.3 to Table C.8). With this method, both the consumption and efficiency are lower than with continuous injection of hydrogen peroxide at low dosage.

Hydrogen peroxide residue should be checked at the most distant part of the system. Open the end of the third lateral from the edge and let water flow for 10 s before sampling.

C.4.2 Determining the injection point

Hydrogen peroxide can be injected in two different points in a system. Each position has hydrogen peroxide that can be injected in two different points in a system.

Table C.2 — Hydrogen peroxide - injection point

Injection point location	Remarks
After the water pump and before the pipes	Protects the main and secondary pipes against accumulation of bacterial slime on the walls of the pipes when waste or industrial waste water is used
Directly into the system head	The water supply should be without organic loads (municipal freshwater, brackish water, well water, etc.)

C.5 Treatment

NOTE All examples and recommendations provided in this manual are based on Triflurilin of concentration 480 g/litre.

a) Turn on the water and let it run until the pressure in the system stabilizes.

b) Fill a clean tank with a volume of water equal to 10 injection minutes. (40 l solution in example above) and use immediately. If you calculated the solution quantity correctly, injection will end in 10 min.

c) Inject the Treflan into the system for a minimum of 10 min, but not longer than 15 min.

d) Before turning off the system, let the water continue to run in the system for the required period of time (specified in Table C.3 to Table C.8).

The time required for the system to run after the injection is important. Don't delay turning off the system after this time.

e) After treatment with Treflan has been completed, wait at least 24 h before resuming irrigation.

C.6 Injection times for chemical/fertigation treatment

Dripperline flow time (minutes) for chemical/fertigation injection.

Table C.3 — 17 mm OD to 14,6 mm ID dripperlines

Distance between drippers (meter)	**0,3**				**0,5**				**0,8**				**1,0**			
Nominal dripper flow rate (l/h)	1,0	1,6	2,3	3,5	1,0	1,6	2,3	3,5	1,0	1,6	2,3	3,5	1,0	1,6	2,3	3,5
Total lateral length (meter)																
100	16	12	8	5	30	18	13	8	43	27	19	12	52	33	23	15
200	18	13	9	6	33	21	14	9	49	31	21	14	59	37	26	17
300	19	14	10	6	35	22	15	10	52	33	23	15	63	39	27	18

Table C.4 — 16,5 mm OD to 15,9 mm ID dripperlines

Distance between drippers (meter)	**0,3**				**0,5**				**0,8**				**1,0**			
Nominal dripper flow rate (l/h)	0,8	1,1	1,6	2,7	0,8	1,1	1,6	2,7	0,8	1,1	1,6	2,7	0,8	1,1	1,6	2,7
Total lateral length (meter)																
100	29	21	14	8	36	26	18	11	51	37	25	15	64	47	32	19
200	32	23	16	9	40	29	20	12	57	41	29	17	73	53	36	22
300	33	24	17	10	43	31	21	13	61	44	30	18	77	56	39	23

Table C.5 — 20 mm OD to 17,5 mm ID dripperlines

Distance between drippers (meter)	**0,3**				**0,5**				**0,8**				**1,0**			
Nominal dripper flow rate (l/h)	1,0	1,6	2,3	3,5	1,0	1,6	2,3	3,5	1,0	1,6	2,3	3,5	1,0	1,6	2,3	3,5
Total lateral length (meter)																
100	28	17	12	8	42	26	18	12	62	39	27	18	75	47	33	21
200	31	19	13	9	47	30	21	14	70	44	31	20	85	53	37	24
300	32	20	14	9	50	31	22	14	75	47	33	21	91	57	39	26
400	34	21	15	10	52	33	23	15	78	49	34	22	95	59	41	27
500	35	22	15	10	54	34	23	15	81	51	35	23	98	61	43	28

Table C.6 — 23 mm OD to 20,8 mm ID dripperlines

Distance between drippers (meter)	0,3				0,5				0,8				1,0			
Nominal dripper flow rate (l/h)	1,0	1,6	2,3	3,5	1,0	1,6	2,3	3,5	1,0	1,6	2,3	3,5	1,0	1,6	2,3	3,5
Total lateral length (meter)																
100	39	24	17	11	60	37	26	17	88	55	38	25	106	66	46	30
200	43	27	19	12	67	42	29	19	99	62	43	28	120	75	52	34
300	46	29	20	13	71	44	31	20	106	66	46	30	128	80	56	37
400	47	30	21	14	74	46	32	21	111	69	48	32	134	84	58	38
500	49	30	21	14	76	48	33	22	114	71	50	33	138	86	60	39

Table C.7 — 22,7 mm OD to 22,2 mm ID dripperlines

Distance between drippers (meter)	0,3				0,5				0,8				1,0			
Nominal dripper flow rate (l/h)	0,8	1,1	1,6	2,7	0,8	1,1	1,6	2,7	0,8	1,1	1,6	2,7	0,8	1,1	1,6	2,7
Total lateral length (meter)																
100	56	40	28	16	71	51	35	21	99	72	50	29	126	91	63	37
200	62	45	31	18	79	57	39	23	111	81	56	33	142	103	71	42
300	65	47	33	19	83	61	42	25	118	86	59	35	151	110	75	45
400	67	49	34	20	87	63	43	26	123	89	62	36	157	115	79	47
500	69	50	35	21	89	65	45	26	127	92	63	38	163	118	81	48

Table C.8 — 25,7 mm OD to 25,0 mm ID dripperlines

Distance between drippers (meter)	0,3				0,5				0,8				1,0			
Nominal dripper flow rate (l/h)	0,8	1,1	1,6	2,7	0,8	1,1	1,6	2,7	0,8	1,1	1,6	2,7	0,8	1,1	1,6	2,7
Total lateral length (meter)																
100	70	51	35	21	90	65	45	27	126	91	63	37	159	116	80	47
200	78	57	39	23	100	73	50	30	141	102	70	42	180	131	90	53
300	82	60	41	24	106	77	53	31	150	109	75	44	191	139	96	57
400	86	62	43	25	110	80	55	33	156	113	78	46	200	145	100	59
500	88	64	44	26	113	82	57	34	161	117	80	48	206	150	103	61

Annex D
(informative)

Guidelines for sampling drip irrigation pipes

D.1 General

In order to diagnose dripperline problems, fill in the required data and follow the instructions outlined below.

— When the area comprises several plots, take the sample from one plot only.

— Take the sample from 30 cm lengths of lateral sections with the dripper's hole in the centre as shown in Figure D.1.

D.2 General data

a) Purpose of the sampling:

   — routine test

   — clogged drippers

   — other: ____

b) Specify type and the age of the system: __________________________________

c) Specify the water source:

   — Well

   — River

   — Dam

   — Pond

   — Other: ____

   NOTE These instructions are suitable for both integral and online drippers. When taking samples of using online drippers, send the drippers with the 30 cm pipe sample as described below.

d) To take a dripper sample from dripperlines, perform the following steps:

   1) starting from both the beginning and the end of the lateral, cut a 30 cm sample (15 cm on each side of dripper's hole) from drippers 4 and 5;

   2) wrap the 16 samples tightly with wet paper and put in a plastic bag;

   3) send the samples for analysis;

   4) repair the pipes in the field.

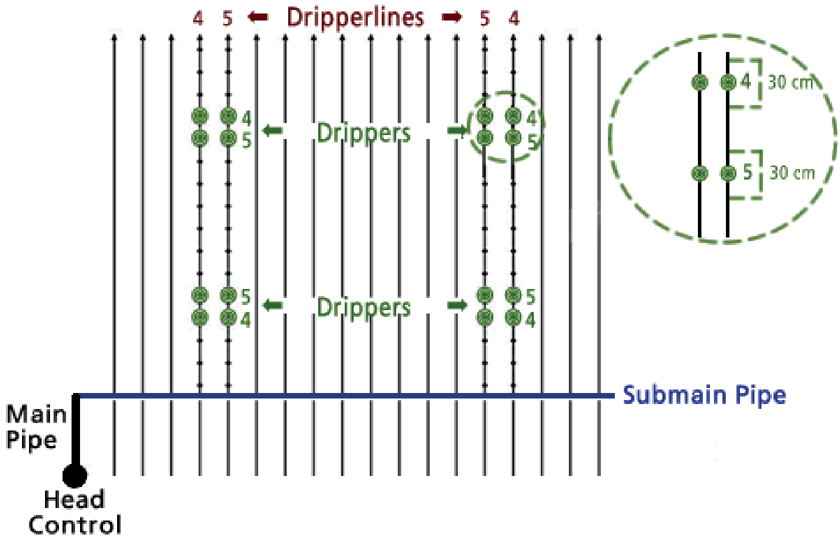

Figure D.1 — Taking samples from dripperlines

Annex E
(informative)

Appropriated chemicals

E.1 General

Before using any chemical, it is essential to obtain information from its manufacturer regarding its chemical quality, purity, recommended dosage, and manufacturer regarding its chemical quality, purity, and recommended dosage.

Remove the membrane or oily surface layer formed after fertilizer preparation.

The following chemicals (liquid or highly soluble) are permitted for injection in drip irrigation systems.

E.2 N – Nitrogen

— urea

— ammonium nitrate

— nitrate acid

E.3 P – Phosphorus

— phosphoric acid

— MAP = mono ammonium phosphate (with high solubility)

— ammonium phosphate

E.4 K – Potassium

— potassium nitrate

— potassium chloride

E.5 Microelements

— chelates

— EDTA

— DTPA

— EDDHA

— HEDTA

— ADDHMA

— EDDCHA

— EDDHSA

— boric acid

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