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**Guidelines for treated wastewater use  
for irrigation projects —**

**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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## Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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](http://www.iso.org/directives)).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see [www.iso.org/patents](http://www.iso.org/patents)).

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

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](http://www.iso.org/iso/foreword.html).

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

This second edition cancels and replaces the first edition (ISO 16075-3:2015), which has been technically revised.

The main changes compared to the previous edition are as follows:

- editorial changes;
- addition of [Annex F](#).

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](http://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 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, 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.

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 need 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 document 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 should 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 document 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:

- 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 published, it is recommended to reference this document to ensure uniformity throughout the treated wastewater use community.

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# Guidelines for treated wastewater use for irrigation projects —

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

### 1 Scope

This document covers the system's components needed for the use of treated wastewater (TWW) for irrigation. Emphasis is placed on irrigation methods, mainly drip irrigation, as this method represents an efficient method of irrigation and water saving, while reducing the pollution of the crops. 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 document.

This document covers issues related to the main components of a TWW irrigation project, including the following:

- pumping stations;
- storage reservoirs;
- treatment facilities (for irrigation purposes);
- filtration and disinfection;
- distribution pipeline networks;
- water application devices: irrigation system components and treatment.

This document is not 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, *Water reuse — Vocabulary*

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

### 3 Terms, definitions and abbreviated terms

#### 3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 20670 and ISO 16075-1 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/>

### 3.2 Abbreviated terms

BOD	biochemical oxygen demand
COD	chemical oxygen demand
HDPE	high-density polyethylene
NPW	non-potable water
PE	polyethylene
PVC	polyvinyl chloride
TWW	treated wastewater
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 users.

Operational and seasonal storage facilities should be placed downstream the wastewater treatment plant to equalize daily and seasonal variations in flow from the WWTP to the distribution centre, so as to:

- meet peak irrigation demands;
- store excess of TWW entering the irrigation system in relation to irrigation demands (including winter storage);
- minimize the consequences of a disruptive operation of WWTP or temporary flow of unsuitable quality of TWW 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** reservoirs or ponds or **closed** reservoirs.

Closed reservoirs can be fixed roof reservoirs including underground reservoirs or reservoirs with removable floating cover (partial or full covered).

Closed reservoirs are more expensive, but can have several advantages:

- reduced evaporation;
- lower potential for algal growth;
- no possibility of contact of wastewater with people or animals;
- protection of stored wastewater from rainfall runoff.

The disadvantage of these reservoirs is that they require periodic cleaning due to biofilm formation and biofouling, and due to the lack of photosynthesis there is greater potential for the development of anaerobic conditions and therefore odour emission.

### 4.3 Storage time

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

Long-term storage can be divided to:

- Seasonal storage, that accumulate water during long periods of treatment plant discharge higher than irrigation demand. The stored TWW may be used when the irrigation demands are higher than the treatment plant discharge. This storage is generally used in open large reservoirs. The residence time is generally months.
- Aquifer storage, which is commonly combined with soil aquifer treatment (by means of infiltration basins). The residence time may be months or years.

### 4.4 Problems and strategies

During the storage period, wastewater is subject to changes that affect its physical, chemical, and biological quality. Bacterial regrowth and/or entering from the surroundings, nitrification, algae growth, and production of H<sub>2</sub>S (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 TWW. Increase in suspended solids sediments and dissolved oxygen, modification of pH, decrease of nutrients concentration (particularly nitrogen), and residual disinfectant are also effects that result from storage. Natural decay of microorganisms (especially pathogenic 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 TWW 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
<ul style="list-style-type: none"> <li>— Temperature stratification</li> <li>— Low content of dissolved oxygen</li> <li>— Release of odours</li> </ul>	<ul style="list-style-type: none"> <li>— Installation of aeration facilities – submerged or surface mixers or recirculating pumps</li> <li>— Maintaining elevated oxygen concentrations (positive redox) through the water column and mainly at the sediment water interface to prevent phosphorus from entering the water column and keep it in the sediment</li> </ul>
<ul style="list-style-type: none"> <li>— Sediments</li> </ul>	<ul style="list-style-type: none"> <li>— Periodic mechanical or hydraulic dredging of accumulated sediments at an interval according with the particular local conditions (five years is considered an acceptable period)<sup>a</sup></li> </ul>
<ul style="list-style-type: none"> <li>— Excessive growth of algae and zooplankton</li> <li>— Reduction of internal recycling of phosphorous</li> </ul>	<ul style="list-style-type: none"> <li>— Proper mixing of wastewater in order to improve the photo-oxidation of organic matter induced by the sunlight</li> <li>— Addition of chemical algaecides. Copper sulfate can have toxicity effects associated with copper accumulation (overdosing has adverse impacts on reservoir ecosystem). According to this: caution is required when using copper sulfate and quantities should be reduced as much as possible</li> <li>— Maintenance of fish that eat algae and zooplankton. Addition of chemical dyes to reduce sunlight penetration as well as the growth of algae. Chemical dyes should be such as do not harm health, plant or the environment</li> <li>— Biomanipulation of zooplankton (in shallow reservoirs)</li> <li>— Ultrasonic emissions placed into the open reservoir</li> </ul>
<ul style="list-style-type: none"> <li>— High content of suspended solids</li> </ul>	<ul style="list-style-type: none"> <li>— As suspended solids removal depends on particle size and residence time, consideration should be given to these factors when designing the storage reservoirs</li> </ul>
<ul style="list-style-type: none"> <li>— Microorganisms regrowth</li> </ul>	<ul style="list-style-type: none"> <li>— Increasing disinfectant residual</li> <li>— Disinfecting the TWW that enter the irrigation system</li> <li>— Increasing residence time<sup>b</sup></li> <li>— Improving storage quality and facilities</li> <li>— Isolating and disinfecting problematic sites in pipelines</li> </ul>
<ul style="list-style-type: none"> <li>— Increase of insects namely mosquitoes</li> </ul>	<ul style="list-style-type: none"> <li>— Spraying of adequate insecticides</li> <li>— Mechanical methods such as keeping the water moving</li> <li>— Biological controls such as natural larvicides and use of larvae eating fish</li> <li>— Keeping banks trimmed</li> </ul>
<p><sup>a</sup> According to the surface area and depth of the reservoir and the accumulation of the sediments.</p>	
<p><sup>b</sup> Sometime there can be an increase in contaminants, due to the increase in residence time, because of secondary contamination.</p>	

**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, to 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	Improved 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 depends on:

- the TWW quality;
- irrigation system;
- crops to be irrigated;
- regulatory requirements;
- 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 can be 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 can 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	— Irrigation systems with moderate level of suspended solids	Very low if screen or disks are clean
— Disc filters	— Used in drip irrigation systems as back up of a media filter — Adequate to moderate level of filtration	
— 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 can 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.

As Chlorine has a residual toxicity for fish, it is not possible to use it in open reservoirs with fish population. 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, because 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. The water pump 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 should consist of one or more main and sub-main pipes that ensure the TWW transport from the distribution reservoir or the storage 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, glass-fibre reinforced polyester (GRP). Special bedding according to the installation procedures provided by the manufacturer should be used for all of the referred materials 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	<ul style="list-style-type: none"> <li>— Strong and flexible</li> <li>— Vulnerable to corrosion</li> <li>— Special joints at changes in direction are required<sup>a</sup></li> </ul>
— PVC <sup>b</sup> — HDPE	<ul style="list-style-type: none"> <li>— Light weight, easy installation</li> <li>— Resistant to corrosion</li> <li>— The acceptable pressures in irrigation systems</li> <li>— Special joints at changes in direction are required<sup>c</sup></li> </ul>
— Aluminium	<ul style="list-style-type: none"> <li>— Light weight</li> <li>— Can be assembled and dismantled easily and rapidly</li> <li>— Resistant to mechanical damage and to sunlight</li> <li>— Vulnerable under freezing conditions (pipe splitting)</li> <li>— Attacked by fertilizers and chemicals</li> </ul>
— Glass-fibre reinforced polyester (GRP)	<ul style="list-style-type: none"> <li>— Light weight, easy installation</li> <li>— High strength and robustness (low weight to strength ratio)</li> <li>— High corrosion resistance</li> </ul>
— Steel-core concrete <sup>d, e</sup>	<ul style="list-style-type: none"> <li>— High strength</li> <li>— Protection against internal and external corrosion</li> </ul>
<sup>a</sup>	For flanged joints (DI) and flanged or welded joints (steel).
<sup>b</sup>	Damaged by sunlight.
<sup>c</sup>	HDPE might not be required depending on diameter and angle of direction change.
<sup>d</sup>	If concrete pipe is used, oxidation is not recommended.
<sup>e</sup>	According to experience in Portugal.

### 6.3 Accessories

#### 6.3.1 General

As in every water distribution network in TWW irrigation systems, accessories should be installed to support the correct operation and maintenance of the system namely the following components:

#### 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 TWW back-flow should be used whenever TWW back-flow from the irrigation system can 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 should be used to discharge wastewater in sequence to different zones of the irrigation area.

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

**Pressure regulator valves** — These valves should be used 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 may 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 may be 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 devices 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 (see [Table 5](#) and [Table 6](#)).

To know the technical characteristics of pipes and accessories for irrigation, such as for pH and fertilizers resistance, amongst others, the manufacturers of the pipes and accessories may be contacted.

**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	The supplier should be consulted on 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 <sup>a</sup>				
	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

<sup>a</sup> 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 regrowth.

To prevent bacterial regrowth associated to chlorine decay, the following actions may be taken:

- periodically purge the distribution network by flowing TWW with high chlorine concentration;
- flush and chlorinate the pipes before each irrigation or few irrigation cycles;
- isolate the problematic parts of the pipeline network and chlorinate at critical points;
- avoid high nitrate concentration that promote the growth of bacteria that should reduce sulfates (production of hydrogen sulphide);
- periodically clean the irrigation mains physically (plugs/pigs pushed through the piping that scrape off the biofilm that created on the walls of the pipes).

## 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 bodies (surface or underground) due to possible ruptures or leaks in the TWW main 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, the TWW main supply lines should be separated from the drinking water sources (wells) to a distance that 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 200 days until it reaches the well (the time during which annihilation of the pathogenic pollutants is effective).

However, the distance between irrigated plots to a well will be at least 50 days, because only a very small portion of irrigated TWW seeps into the soil depth, and they pass effective filtration through the soil, destroying most of the pathogens.

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 fast; therefore, the protection zone radiuses should be much larger than those in sandy soils.

### 6.6.2 Stipulating a protective radius

A detailed hydrological calculation of the necessary protective radius around each drinking water well should be done.

In countries without local guidance, the following principles should be used:

- For each drinking water well, it is advisable to perform a detailed hydrological calculation, to determine where the main transmission lines (of TWW intended for agricultural irrigation with TWW) are permitted. The calculation can take into consideration the existing soil conditions in the area, a trapped aquifer if existed, or the natural filtration of the TWW that undergoes when it flows through sandy aquifer and the flow directions of the water in the aquifer.

An estimation of the minimum distance between the main transmission lines of TWW intended for agricultural irrigation and drinking water wells can be done by following empirical equations, depending on the local regulations.

- in a sandy aquifer: 50 times the distance  $L$  (expressed in meters);
- in a cracked aquifer: 200 times the distance  $L$  (expressed in meters).

The following empirical equation, [Formula \(1\)](#), may be use (based on pathogen die off in the soil):

$$L = \sqrt{\frac{Q * k}{d}} \quad (1)$$

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) that is continuously disinfected by chlorine, the distances may 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, TWW irrigation is performed above drinking water supply pipes. 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. In such cases, the area can be irrigated using TWW, which is continuously disinfected by adequate chlorine dose (or an equivalent disinfection). When the drinking water pipelines lies above ground level, the area can be irrigated by drip irrigation with TWW that is not disinfected.

### 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 uninformed 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 that should be used 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 shall conduct inspections under the supervision of a supervising authority and the FW supplier 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 that enables the detection of a direct connection between the two types of water, e.g. by detecting a certain element or compound that 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 with 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. 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 may be used.

In the absence of marking and labelling requirements Examples of painting and marking TWW irrigation pipelines and systems are given in [Table 7](#):

#### 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**

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

Accessories and related equipment found above ground should 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 situated above ground should 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 situated in the ground should be accompanied by marking ribbons in the suitable colour, which should 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 should be imprinted on the ribbon as indicated in [Table 7](#).

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

Accessories and related equipment found above ground should 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 should not be less than 7 cm.

**7 Irrigation systems**

**7.1 Classification**

TWW irrigation systems used in agricultural and landscape irrigation may be classified into 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, three types of irrigation systems can be distinguished: 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
<ul style="list-style-type: none"> <li>— Using stationary sprinkler systems (Portable, semi-portable, semi-permanent, solid set or permanent equipment)</li> <li>— Using mobile sprinkling machines (Self-moved sprinklers, boom sprinkler, self-propelled gun traveller or continuous move laterals)</li> </ul>	<ul style="list-style-type: none"> <li>Drip irrigation                             <ul style="list-style-type: none"> <li>— Surface</li> <li>— Sub-surface</li> </ul> </li> <li>Micro-spray irrigation</li> </ul>	<ul style="list-style-type: none"> <li>Border irrigation                             <ul style="list-style-type: none"> <li>— Straight</li> <li>— Contour</li> </ul> </li> <li>Check basin irrigation                             <ul style="list-style-type: none"> <li>— Rectangular</li> <li>— Contour</li> <li>— Ring</li> </ul> </li> <li>Furrow irrigation                             <ul style="list-style-type: none"> <li>— Graded furrow</li> <li>— Corrugation</li> </ul> </li> </ul>

## 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) should 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 should be 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 <sup>3</sup> /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 should be classified into the following groups:

- a) stationary sprinkler systems:
  - portable system;
  - semi-portable system;
  - semi-permanent system;
  - solid-set system;
  - permanent system.
- b) mobile sprinkling machines:
  - self-moved system;
  - boom sprinkler;
  - self-propelled gun traveller;
  - continuous move laterals;
  - centre-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 should be used for most permanent main lines. PVC, PE, and aluminium pipes with quick couplers should be used for most portable main and sub-main lines. PVC and aluminium pipes with quick couplers with rubber gaskets should be used for laterals. In stationary systems, the sprinklers should be 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 Sprinkler 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, should be 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 may 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.

### 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, sprinkler discharges lower than 30 l/h should not be used. 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, sprinkler discharges lower than 50 l/h should not be used. 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 water quality. Filtration in the irrigation system is not a stand-alone treatment, but rather an integral part of the various treatments required in the system. During the design process, the lowest possible water quality at that location should be considered.

Two filtration levels may be specified in order to reach the required filtration level, e.g. 120 µm or as recommended by the manufacturer/planner. The filtration should be installed 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, the following levels of automation may be distinguished:

- no automation;
- partial automation;
- sequential automation;
- high automation;
- full automation.

## 7.3 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 to be 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. Sampling points should be located 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. According to the results of the analysis, the required test frequency should be determined and also which additional parameters should be monitored to analyse accurately the water quality. Additional parameters are: iron concentration, manganese concentration, CaCO<sub>3</sub>, 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 that should be performed with a Clogging Potential Meter (CPM).
- b) **pH:** testing the water’s level of acidity or alkalinity.
- c) **Chlorine requirement:** should be checked by the redox potential test.

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

Water quality <sup>a</sup>	Parameter		
	Clogging potential - <sup>b</sup>	pH	Redox - <sup>c</sup>
	Time		mV
Good - Grade 1	Longer than 7 min	<7,2	Between 300 and 500
Medium - Grade 2	Between 3 min and 6 min	Between 7,2 and 8,0	Between 250 and 300 and between 500 and 600
Low - Grade 3	Shorter than 3 min	>8,0	<250 and >600

<sup>a</sup> These levels are suitable for water to maintain the irrigation system rather than for irrigation water specified elsewhere in this document.

<sup>b</sup> The CPM tests using a 150 µm mesh.

<sup>c</sup> 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 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.

See [Annex A](#) to [Annex F](#) for more detailed information on drip irrigation related topics discussed in this subclause:

- 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 chemicals ([Annex E](#));
- flushing the drip irrigation pipes ([Annex F](#)).

### 7.3.3.2 Irrigation system treatments

#### 7.3.3.2.1 Equipment and preventative maintenance actions for different water qualities in drip irrigation systems

In drip irrigations systems, the following different types of equipment and maintenance actions have to be considered for different water qualities:

- a) Treatment 1 — Suitable for a drip irrigation system fed with good quality of water<sup>1)</sup>

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 F](#)).

- b) Treatment 2 — Suitable for a drip irrigation system fed with medium quality of water<sup>1)</sup>

Where the clogging potential element is dominant, three levels of filtration should be used that include a 150 micron filter at the water source or at the head of the system, a filter in the water 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<sup>1)</sup>

Where the pH element is dominant, in addition to the two levels of filtration, an acid dosing should be used. Treatment with acid should be applied four times annually at a concentration of 1 l of hydrochloric acid (or an equivalent) for a flow rate of 1 m<sup>3</sup>/h so that the pH level will be 4 to 5 at the end of the last lateral when measured after 1,5 h of contact time. 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<sup>1)</sup>

Where the potential redox element is dominant, two levels of filtration and chlorine dosing should be used. Treatment with chlorine for prevention at a dosage of 10 mg/l for a flow rate of 10 m<sup>3</sup>/h so that the level of residual chlorine should be 2 mg/l to 3 mg/l. Alternatively, hydrogen peroxide may be used. For prevention dosage of 1 l of hydrogen peroxide for a flow of 10 m<sup>3</sup>/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<sup>3</sup>/h for 1 h should be applied 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<sup>1)</sup>

Where the clogging potential and pH elements are dominant, two levels of filtration should be used, systematic acidification (continuous or at high frequency) should be used 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<sup>1)</sup>

Where the clogging potential and redox element are dominant, two levels of filtration and a high dose chlorination should be used weekly. To flush the water supply system from the reservoir, a concentration of 30 mg/l should be used for a flow rate of 10 m<sup>3</sup>/h. The irrigation system should be chlorinated twice a week until the residual chlorine at the end of a lateral is 1 mg/l and laterals and manifolds should be flushed every two weeks.

- g) Treatment 7 — Suitable for a drip irrigation system fed with low quality of water<sup>1)</sup>

Where all elements are problematic, two levels of filtration should be used 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

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1) As specified in Table 10.

lateral. Flushes should be performed once a week. Alternatively, hydrogen peroxide may be used. For prevention dosage of 1 l of hydrogen peroxide for a flow of 10 m<sup>3</sup>/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<sup>3</sup>/h for 1 h should be applied 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 Preventative and maintenance actions for different water qualities in micro-sprinkler systems**

The treatment needs for micro-jet and micro-sprinkler systems are less 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**

Water quality index level			Recommended treatment model
Clogging potential	pH	Redox	
1	1	1	1
2	1	1	4
3	1	1	6, 4
1	2	1	3
2	2	1	6
3	2	1	7, 6
1	3	1	3
2	3	1	5
3	3	1	7
1	1	2	2
2	1	2	2
3	1	2	4
1	2	2	3
2	2	2	4, 5
3	2	2	6
1	3	2	3
2	3	2	6
3	3	2	7
1	1	3	2
2	1	3	4

Table 11 (continued)

Water quality index level			Recommended treatment model
Clogging potential	pH	Redox	
3	1	3	6
1	2	3	5
2	2	3	4
3	2	3	6
1	3	3	5
2	3	3	7
3	3	3	7

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, the test results of all three parameters should be taken into consideration.

**EXAMPLE** If clogging potential is in level 3, pH in level 2, and redox in level 1, the recommended type of treatment is 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 TWW 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, all safety instructions provided by the chlorine manufacturer should be read.**

**All instructions for acid treatment should be regarded as subordinate to the instructions of the acid manufacturer.**

- Before filling any tank with chlorine solution, it should be washed very carefully in order to remove any fertilizer remains.
- Contact with eyes should be avoided.  
Contact of chlorine with the eyes can cause blindness.
- Contact with skin should be avoided.  
Contact of chlorine with skin can cause burns.
- Protective clothing should be used when working with chlorine.  
Wear goggles, gloves, full-length trousers and sleeves, and closed high shoes.
- Swallowing or inhaling should be avoided.  
Swallowing chlorine or inhaling its fumes can be fatal.
- Operator should be present during treatment.

Be present for the full duration of the treatment. All unauthorized persons should be kept 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. The convenience, availability should be considered, and price of each material before deciding which to use.

Commonly available forms include the following:

- **gaseous chlorine (Cl<sub>2</sub>);**
- **solid chlorine (Calcium Hypochlorite);**

When both the calcium level and alkalinity of the water are above medium and the pH is above 8,0 an expert should be consulted 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.

Liquid material should not be stored for a long period of time. It should be kept in the shade and paint the storage tank white if kept 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. The time required to for the chlorine to reach the end of the system should be considered (see [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

Certain chemical should not be used in drip irrigation systems.

The following instructions should be followed:

- Never use any Polyphosphate.
- 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) a concentration higher than 40 mg/l.
- Never use acid with a pH lower than 2.

#### B.2 Appropriated chemicals

A list of appropriated chemicals is provided in [Annex E](#).

#### B.3 Acid treatment for drip systems

Acids may 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, all safety instructions provided by the acid manufacturer should be read.**

**All instructions for acid treatment should be regarded as subordinate to all legal provisions and to the instructions of the acid manufacturer.**

- Acid should always be added to water – Water should NEVER be added to acid.
- Contact with eyes should be avoided.  
Contact of acid with the eyes can cause blindness.
- Contact with skin should be avoided.  
Contact of acid with skin can cause burns.

— Protective clothing should be used when working with acid.

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

— Swallowing or inhaling should be avoided.

Swallowing acids or inhaling their fumes can be fatal.

— Operator should 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, the following steps should be performed:

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 [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.

If the acid has a different percentage other than the ones listed in [Table B.1](#), the percentage should be adjusted accordingly.

**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 %

The acid concentration in the treated water resulting from the use of a different acid starting concentration should be calculated as follows:

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

—  $Y$  = Recommended concentration in treated water.

— In [Table B.1](#), data for Sulphuric acid is 65 %.

The starting concentration should be calculated as follows:

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

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

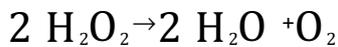
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## Annex C (informative)

### 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.



A sequence of hydrogen peroxide treatments followed by a chlorine treatment can have a powerful and prolonged oxidizing effect. The two treatments should not be combined.

Hydrogen peroxide should not be used 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, all safety instructions provided by the manufacturer should be read.**

**All instructions for hydrogen peroxide treatment should be regarded as subordinate to all legal provisions and to the instructions of the manufacturer.**

- Before filling any tank with hydrogen peroxide solution, it should be washed very carefully in order to remove any fertilizer remains.
- Contact with eyes should be avoided.  
Contact of hydrogen peroxide with the eyes can cause blindness.
- Contact with skin should be avoided.  
Contact of hydrogen peroxide with skin can cause burns.
- Protective clothing should be used when working with hydrogen peroxide.  
Wear goggles, gloves, full-length trousers and sleeves, and closed high shoes.
- Swallowing or inhaling should be avoided.  
Swallowing hydrogen peroxide or inhaling its fumes can be fatal.
- Operator should be present during treatment.  
Be present for the full duration of the treatment. Keep all unauthorized persons away from the treatment area.

— Contact with oil and grease should be avoided.

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 dripperline laterals;
- 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 %
<b>Physical state</b>	Liquid	Liquid	Liquid	Liquid
<b>Colour</b>	Colourless	Colourless	Colourless	Colourless
<b>Characteristic odour</b>	Yes	Yes	Yes	Yes
<b>Molecular weight H<sub>2</sub>O<sub>2</sub></b>	34,01	34,01	34,01	34,01
<b>Boiling point</b>	108 °C	114 °C		125 °C
<b>Freezing point</b>	-32 °C	-51 °C		-37 °C
<b>Vapor pressure at 25 °C</b>	23 mm Hg	18 mm Hg		11 mm Hg
<b>Specific gravity (H<sub>2</sub>O = 1)</b>	1,132	1,195	1,240	1,288
<b>pH</b>	<5	<4		<2

## C.4 Usage

### C.4.1 General

Injected hydrogen peroxide is the concentration (mg/l) of hydrogen peroxide calculated at the injection point.

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

The hydrogen peroxide requirements are high for waste and industrial wastewater 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, an arbitrary amount should be injected, the test kit should be used 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.4.2 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. The end of the third lateral should be opened from the edge and water should flow for 10 s before sampling.

### C.4.3 Determining the injection point

Hydrogen peroxide may 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. See [Table C.2](#).

**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

The following instructions should be followed:

- 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 (calculate the quantity of material to be introduced in the tank according to the hydrogen peroxide manufacturer's recommendations) and use immediately. If the calculation of the solution quantity is correct, injection will end in 10 min.

- c) Inject the hydrogen peroxide 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. Turning off the system should not be delayed after this time.

- e) After treatment with hydrogen peroxide 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