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Treated wastewater reuse for irrigation — Guidelines for the adaptation of irrigation systems and practices to treated wastewater

Réutilisation des eaux usées traitées en irrigation — Lignes directrices pour l'adaptation des systèmes et pratiques d'irrigation aux eaux usées traitées

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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

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

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

Introduction

Irrigation is gaining importance all over the world, and the lack of water available from surface or groundwater is driving the introduction of treated wastewater for this purpose. Accordingly, some adaptation is needed to the equipment included in the irrigation system to ensure its proper functioning.

The composition of treated wastewater (TWW) is different from that of freshwater. TWW contains more nutritional elements and microbial populations. It is also characterized by a higher salt concentration, anions and cations with a high precipitation potential of sediments of low solubility salts. These characteristics can severely disrupt the operation of the TWW irrigation systems, which can result in poor performance of the system, and potentially harmful to the environment.

Changes in water quality of reservoirs or secondary water resources can affect the water systems' efficiency, as all parts of the irrigation system, such as filters, pipes and emitters, can be adversely affected by low quality water.

The transport efficiency of irrigation equipment is dependent on the quality of the treated wastewater used, due to several factors such as:

— formation of biofilm on interior pipe walls,

— scale precipitation, organic material and fertilizers, and

— excess build-up of sediment.

Irrigation systems clogging types can be classified into three categories:

— organic and inorganic particles (minerals) sedimentation,

— chemical precipitation of low solubility salts, and

— biofouling -attachment/detachment of microorganism colonies on the irrigation system interior surface, which results in biofilm development.

This document provides guidelines on how to use TWW in or with irrigation systems and to protect them from clogging.

Treated wastewater reuse for irrigation — Guidelines for the adaptation of irrigation systems and practices to treated wastewater

1 Scope

This document provides guidelines to planners and practitioners on how to adjust irrigation equipment so as to allow direct utilization of treated wastewater (TWW) for irrigation. It deals with the adjustment of all components of irrigation systems to TWW quality in respect to physical, chemical and biological parameters.

This document provides guidelines on how to protect irrigation equipment so as to guarantee water systems functionality at high levels of efficiency.

This document includes recommendations for

a) pumping stations,

b) filtration,

c) water network systems,

d) irrigation equipment: emitters (drippers, sprinklers, mini sprinklers, micro sprinklers, sprayers and irrigation machine (sprinklers and sprayers),

e) physical treatment of irrigation equipment, and

f) chemical treatment of irrigation equipment.

This document defines TWW parameters at the irrigation system inlet after a wastewater treatment plant, in order to allow optimal and continual functioning of the irrigation systems and to allow uniformity of emitters' discharge.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1 Treated wastewater (TWW)

3.1.1
wastewater
water arising from any combination of domestic, industrial or commercial activities, which can include surface runoff and any accidental sewer inflow/infiltration water and which can include collected storm water, discharged to the environment or sewer

[SOURCE: ISO 20670:2018, 3.80]

3.1.2
treated wastewater
TWW
wastewater that has gone through physical, chemical and/or biological processes to remove contaminants

3.1.3
clogging capacity meter
device used for measuring the time to reach a specified pressure loss across a standard filter screen, at a constant flow rate

[SOURCE: ISO 18471:2015,3.2]

3.1.4
biofilm
attached/detached microorganism colonies on the irrigation systems' interior surface, which results in organic matter development

3.1.5
self-cleaning strainer
filter located in the reservoir that protects the pumping chamber from clogging and has continuous flushing capability

3.1.6
bottom pumping chamber
subsystem that pumps water from the bottom of a water source such as a reservoir or pond, which includes pumping equipment, motors, piping, valves and liquid level controls

3.1.7
floating suction head
unit pumping TWW from the upper level of the reservoir whose pumping point level can be adjusted according to the quality of TWW

3.2 Filtration

3.2.1
filtration
physical process that separates solid particles from water, by passing the water through a physical porous barrier to trap and separate suspended solids from the water

Note 1 to entry: Examples of barrier include media bed, surface or depth filter, screen, disc or membrane.

[SOURCE: ISO 20670:2018, 3.27, modified — Note 1 to entry, the word “disc” has been added.]

3.2.2
nominal flow rate of filtration
flow rate through a filter for proper filtration, as declared by manufacturer

[SOURCE: _ISO 9912–1:2004, 2.37]

3.2.3
check filter
filter located before the irrigation emitters (drip, sprayers and micro sprinklers)

3.2.4
flushing differential pressure
differential pressure between two points, one upstream and one downstream of the filter media, which initiates the flushing cycle

3.2.5
emitter
dripper
device fitted to an irrigation lateral and intended to discharge water in the form of drops or recommended continuous flow at flow rates not exceeding 24 l/h except during flushing

Note 1 to entry: Other emitters flow at flow rates between 24 l/h and 60 l/h.

[SOURCE: ISO 16075–1:2015, 3.4.3]

3.2.6
on-line emitter
emitter intended for installation in the wall of an irrigation lateral, either directly or indirectly by means such as tubing

[SOURCE: ISO 16075–1:2015, 3.4.12]

3.2.7
in-line emitter
emitter intended for installation between two lengths of pipe in an irrigation lateral

[SOURCE: ISO 9261:2004, 3.2]

3.2.8
unregulated dripper
non-pressure compensating emitter/emitting pipe

Note 1 to entry: An unregulated dripper's flow rate varies with inlet water pressure.

[SOURCE: ISO 9261:2004, 3.10]

3.2.9
regulated dripper
pressure compensating emitter/emitting pipe

Note 1 to entry: A regulated dripper maintains a relatively constant flow rate at varying water pressures.

[SOURCE: ISO 9261:2004, 3.8]

3.2.10
sprinkler
water distribution device of a variety of sizes and types, for example, impact sprinkler, fixed nozzle, sprayer, irrigation gun

[SOURCE: ISO 16075-1:2015, 3.4.24]

3.2.11
rotating sprinkler
device which by its rotating motion around its vertical axis distributes water over a circular area or part of a circular area

[SOURCE: ISO 15886-1:2012, 2.38]

3.2.12
irrigation sprayer
device which discharges water in the form of fine jets or in a fan shape without rotation movements of its parts

[SOURCE: ISO 16075-1:2015, 3.4.7]

3.2.13
center pivot
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 located along the pipeline

[SOURCE: ISO 16075-1:2015, 3.4.2]

4 TWW quality monitoring for micro-irrigation

4.1 General

4.1.1 Micro-irrigation equipment should be adapted to the quality of the given water.

4.1.2 Water quality parameters should fulfill the recommended values shown in Table A.1 and Table B.1.

4.1.3 Since TWW quality changes from season to season, from month to month, from week to week, from day to day or even during the course of one day, TWW users should closely monitor the TWW quality in the system at key points, to be able to respond to quality changes, which can otherwise quickly clog the entire micro-irrigation system.

4.1.4 Monitoring of TWW quality (see 4.2) can provide users with efficient real-time information.

4.1.5 Changes in TWW quality should be responded to by the adaptation of irrigation parameters, such as flow reduction, filters insertion and chemical treatments.

4.1.6 The quality of TWW should be monitored using the devices listed in 4.2, and according to the procedure described in 4.3.

4.2 TWW quality monitoring devices

4.2.1 Flushing counter for automated filters

A flushing counter for automated filters monitors changes that occur between one period of flushing and the next period of flushing.

A change in flushing frequency should indicate changes in water quality.

4.2.2 pH level sensor

A pH level sensor indicates calcium and calcium carbonate levels, as well as the expected efficiency of any injected chlorine (see Annex C).

4.2.3 Clogging capacity meter

A clogging capacity meter provides immediate information about changes in TWW and identifies the main material causing the clogging.

The clogging capacity meter allows a thorough examination of water quality changes and clogging causes throughout the water supply — from the pump to the dripperlines.

4.2.4 Chlorine demand sensor

A chlorine demand sensor informs TWW users about changes in the concentration of slime or organic matter in the water.

4.3 TWW quality monitoring procedure

4.3.1 The quality of TWW should be monitored in accordance with the requirements of the irrigation system, the plantation and the crop.

4.3.2 The monitoring procedure should depend on water quality.

4.3.3 The monitoring procedure should start at the TWW reservoir and continue through the main head system, while checking the filters, all the way through to the last emitter.

5 TWW reservoirs

5.1 General

Reservoirs for TWW systems balance any disproportions between the TWW routine production and the TWW irrigation consumption throughout the year. Such reservoirs are normally open to the atmosphere.

5.2 TWW reservoir safety

The design of reservoir systems should include safety measures (fence construction surrounding the reservoir, signing and pipeline painting).

5.3 TWW reservoir design

In TWW reservoir design, the following parameters should be considered:

a) the type of TWW stored in the reservoir (see 5.4);

b) TWW quality (see 5.5);

c) reservoir processes affecting TWW quality and derived reservoir operation (see 5.6);

d) engineering data and design (see 5.7);

e) pumping station (see Clause 7);

f) TWW quality monitoring (see Clause 4);

g) reservoir biological and chemical treatment (see 5.8, Annex H);

h) safety measures (see 5.2).

5.4 Type of TWW stored in the reservoir

A reservoir should store TWW.

Surface runoff may also be discharged into the reservoir.

5.5 Quality of TWW stored in the reservoir

The quality of the TWW stored in the reservoir should be in accordance with Annex A of this document, and ISO 16075-1 to −4.

5.6 Reservoir processes affecting TWW quality and derived reservoir operation

The residence of TWW in an open reservoir can affect its quality, due to the following factors and processes, which can become more intensive as the TWW quality decreases.

a) growth of living organisms (bacteria, algae, algae predators, zooplankton, etc.) and organic material transformation;

b) external pollution (dust, birds, insects, fumigation);

c) climate influences;

d) surface runoff flow and rainfall over the reservoir causing a salt concentration decrease in the TWW;

e) evaporation from the reservoir causing a salt concentration increase in the TWW;

f) winds contributing to the formation of waves resulting in TWW layers inversion;

g) layers development in the reservoir;

h) chemical processes that characterize TWW open reservoir storage, e.g. rising pH levels, changes in the relative concentration of nitrogen components.

5.7 Reservoir engineering data and design

In a TWW reservoir design for irrigation, the following should be complied:

a) Engineering data should be collected;

   1) TWW data: TWW sources and discharge distribution throughout the year;

   2) soil data: type of soil, soil compatibility to reservoir construction, soil hydraulic conductivity;

   3) groundwater data: type, depth and flow direction;

b) A minimum residual TWW volume should be maintained in the reservoir while using a bottom pumping chamber, to avoid mud penetration to the irrigation system;

c) TWW level control systems should be installed to prevent overflow and control the operative storage;

d) Environmental and human health damage resulting from TWW excess overflow should be prevented;

e) The reservoir's maintenance should be tested. See an example of maintenance control guidelines in Annex G.

5.8 Biological treatment in reservoirs

5.8.1 Where oxygen levels in open reservoirs are between 0,5 mg/l to 1,0 mg/l, different types of fish can be introduced to clean the reservoir from surface and subsurface algae, and reduce filter flushing events.

An oxygen level of 1,0 mg/l or more does not require a more extensive use of oxygen fountains and/or expenses.

5.8.2 The introduction of fish can help to remove clogging causes such as algae, zooplankton in the upper part of the TWW column and algae at the bottom and walls of the reservoir.

5.8.3 The following species are generally recommended for stocking open reservoirs in warm climates. In other climates or geographical regions, the fish species selected for stocking the reservoir should reflect local species and climate conditions.

a) big-head carp,

b) grass carp to treat plants and huge algae,

c) silver carp to feed on plankton and zooplankton, and

d) black carp to feed on snails and slugs.

5.8.4 The fish population introduced into the reservoir should consist of either male fish or female fish, to avoid reproduction.

5.8.5 Death of fish in TWW reservoir should be controlled. One or more of the following methods may be used:

a) monitoring TWW quality conditions to anticipate, detect or predict distress during critical season,

b) installing aeration units where conditions of low oxygen levels are likely or known to occur, or

c) introducing freshwater.

5.8.6 To prevent conditions of distress for fish, the oxygen level should not be lower than 1 mg/l.

NOTE Oxygen levels lower than 1 mg/l can occur during early morning hours.

5.8.7 Un-ionized ammonia concentration should not be higher than 0,5 mg/l.

5.8.8 Oxygen fountains of at least 1,5 pH each should be introduced, in accordance with the size of the reservoir.

5.8.9 Oxygen fountains as well as electricity cables should be prepared in advance to allow spreading 50 metres from shoreline.

6 Filtration systems

6.1 General

6.1.1 The design of the filtration system should take into account the worst case scenario due to seasonal changes in TWW quality in a reservoir (see Annex I). Unpredicted occurring events should also be considered.

6.1.2 Where TWW is used, biofilm is often formed and developed in laterals and emitters. Filtration, a physical water treatment, removes suspended material from the water entering the system to avoid its deposition in pipes and emitters. The filtration system is a primary, multistep means that facilitates the separation and disposal of suspended materials.

6.1.3 With few exceptions such as high flow sprinklers or irrigation gun, irrigation systems should be filtered.

6.1.4 The degree of filtration (mesh/micron) should be defined by the system requirements and should be sized according to the emitter manufacturer's specifications.

6.1.5 As filtration alone cannot provide a complete solution for the factors affecting the performance of emitters applying TWW, chemical and physical treatments should be used (see Clause 10 for physical treatment and Clause 11 for chemical treatment).

6.1.6 Depending on the circumstances, as many as three or more filtration locations, with a different filtration degree, should be installed along the system.

6.1.7 A filtration system should be designed to consider the reservoir, TWW intake quality and distance between the reservoir and the irrigated field.

6.1.8 Filtration should be carried through the following stages:

a) pre-filtration unit — in the reservoir outlet;

b) primary filtration unit — with filtration requirements per emitter manufacture recommendations;

c) check filter — following the primary filtration, which should not be finer than the primary filtration.

6.1.9 With TWW quality (see Table A.1, column "Poor Quality"), if the distance between two filter locations is more than 500 metre–700 metre, an additional filter station should be installed.

6.1.10 Pre-filter and primary filters [6.1.8 a) and 6.1.8 b)] in the multistep filtration should be self-cleaning filters.

If a signal is not received after a certain time period has passed, the flushing process should start.

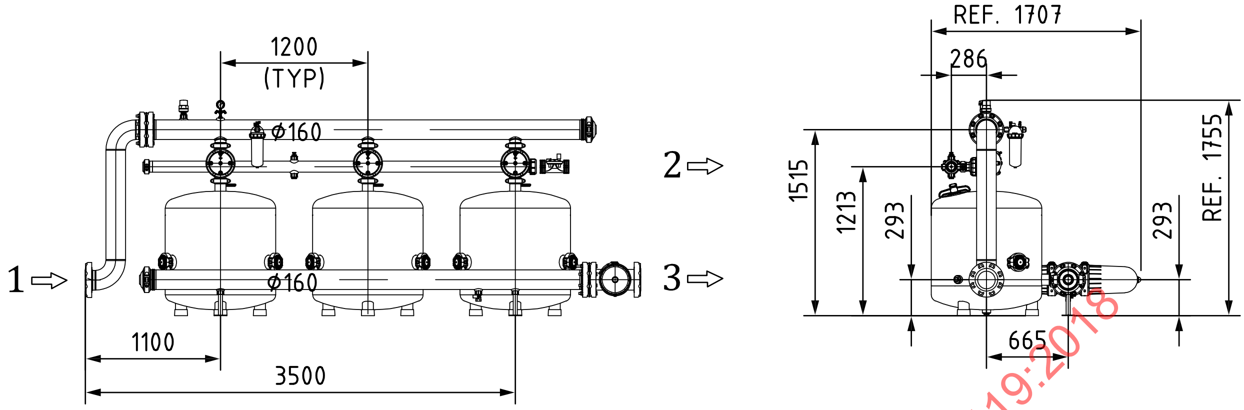
6.1.11 In automatic filter batteries, a flushing controller should detect excessively frequent self-cleaning or flushing cycles shorter than time pre-set. Excessive flushing cycles or short run cycles should indicate adverse change in TWW quality such as increased dirt load requiring the operator's immediate attention.

6.1.12 Suspended material content in the TWW should be measured by a clogging capacity meter (see Annex D).

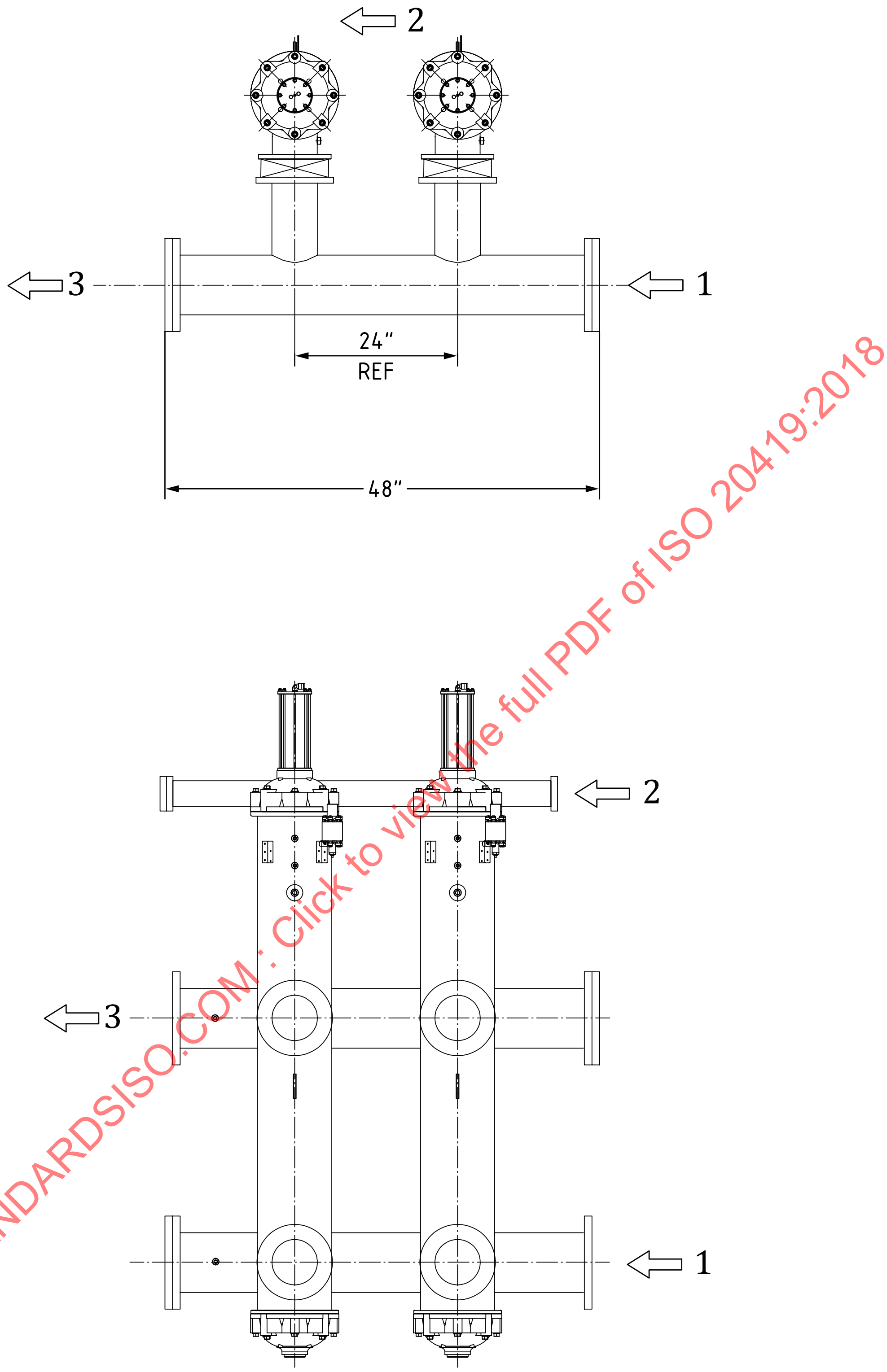
6.2 Filtration battery manifold structure

6.2.1 Due to TWW quality variation, a filtration battery manifold should include extra fittings that should be ready for a fast connection of supplementary filter units, in case they are needed. See examples of filter batteries in Figure 1.

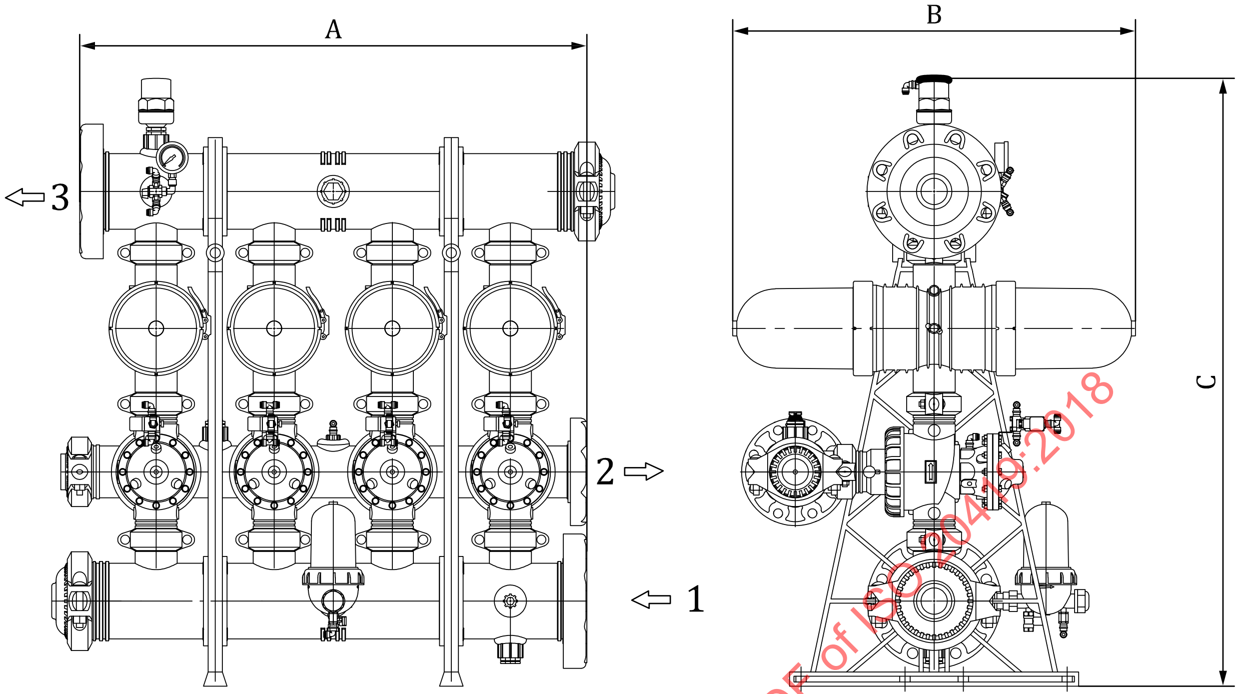
6.2.2 To balance the load on the battery's filters, the battery should be installed in a way that allows for each filtration unit to have the same hydraulic loss.



a) Gravel filtration batter



b) Screen filtration battery



c) Disc filtration battery

Key

1 inlet
2 drain
3 outlet

Figure 1 — Examples of filter batteries

6.3 Filtration technology — Filtration media

A filtration media should be used for TWW.

The type of filtration media (e.g. screen, disc, gravel) should be selected according to its resistance to corrosive water and the chemicals utilized (see Clause 11).

6.4 Flow/filter area ratio

Depending on the TWW quality at the reservoir, harsh TWW conditions should be considered. Filtration systems should be designed allowing 50 %–70 % of the nominal flow rate of filtration in order to overcome high backwash frequencies.

6.5 Filtration stations location in accordance with flow direction

6.5.1 A self-cleaning strainer filtration unit with a 250 and coarser micron pore size for the removal of coarse dirt should be installed at the outlet of a low quality TWW source or at pump suction inlet, see Figure 2 and Figure 3.

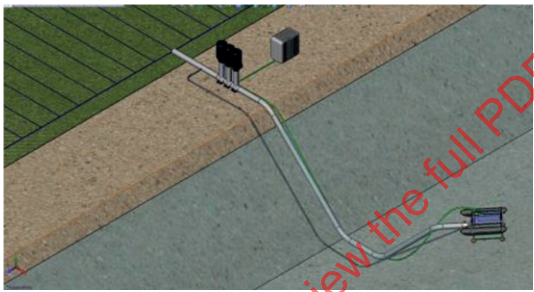


Figure 2 — Self-cleaning strainer in water

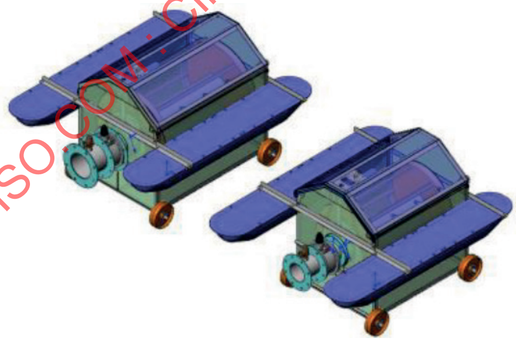


Figure 3 — Self-cleaning strainer

6.5.2 The main filtration TWW passage should comply with dripper/micro-sprinkler requirements (see 6.6)

The battery or the filter should have an automatic flushing mechanism.

The main filtration should be in proximity to the irrigated plots.

The filtration system should consist of a battery of filters in order to prevent irrigation interruption.

The check filter should be a manually flushed disc and screen filter of 130 micron, to enable examination of the materials accumulated on the filtration mediator.

6.5.3 When the battery is located near the operational reservoir, backflush TWW should be returned to the reservoir, at a location distant from the pumping point. Wind regime in site should be considered.

6.5.4 When a battery is located at an area where flushing TWW cannot be discharged, a special pipe installation should be considered, to return flushing TWW back to the reservoir.

Such a piping system should include hydraulic considerations in the design.

Resistance along the return stream should be minimized, to optimize the backflush efficiency.

An alternative way to return backflush TWW from the filter to the reservoir can be employed by filling up a water tank which is occasionally emptied into the reservoir, at a location which is distanced from the pumping point.

6.5.5 For a distant or isolated irrigation plot inlet, to prevent flushing TWW nuisances, backflush TWW should be captured and removed in a way that does not contaminate the soil and underground water resources.

6.6 Filtration grade

The size of filtration required (e.g. media discs or screen) should correspond with the requirements of the emitters as prescribed by the manufacturer. In filtration, water passages ratio should be 1:10 in drip irrigation, and 1:7 in micro-irrigation.

6.7 Manual filter cleaning

If flushing cannot remove all particles, to avoid accumulation of scale or sticky substances on the body of the filter, the filtration mediator should be cleaned periodically and thoroughly.

The periodical cleaning of the disc filter should be executed by dismantling the filter interior out of the filter housing and immersing it in chemicals, i.e. acid and hydrogen peroxide.

7 Pumping stations

7.1 General

In a reservoir, TWW quality can vary with water depth, which can cause an increase in risks of irrigation systems clogging.

Due to biofilm development in the piping or distribution systems, the reservoir design should include a disinfection port in the pumping station, in accordance with maintenance protocol (see Annex G).

To improve the quality of TWW delivered to the field, the location of pumping stations should be considered. See possible pumping station locations in 7.1.1 and 7.1.2.

7.1.1 Bottom pumping chamber

The installation of a bottom pumping chamber should prevent the invasion of accumulated sediments and bottom materials into the pumps.

7.1.2 Floating suction head

The installation of a floating suction head should allow suction depth adaptation, in order to reach an optimal pumping level.

See Figure 4 for an example of a floating pumping station location.

Figure 4 — Floating pumping station location

7.2 Reservoir stratification prevention

When using a floating suction head in a reservoir, the reservoir stratification should be considered.

In warm and/or hot seasons while no wind condition exist stratification can be formed in reservoirs during daytime and remain at night time.

In winter season when temperatures change between day and night and wind condition exist there is no stratification.

Electrical conductivity at the bottom strata of the reservoir is much higher than that on the water surface. The amount of energy required to prevent stratification in reservoirs under warm weather conditions is relatively small.

The use of size of mixer should be examined in accordance with local conditions and size of reservoirs.

Stratification prevention has the following benefits:

a) improved oxygen balance: water mixing that spreads oxygen throughout the depth of the reservoir;

b) prevention of algae growth: in non-stratified reservoirs there is less algae;

c) improved removal of pathogenic bacteria: bacteria mortality is much higher on the surface due to sun radiation.

For more information on thermal stratification, see Figure 5 and Annex F.

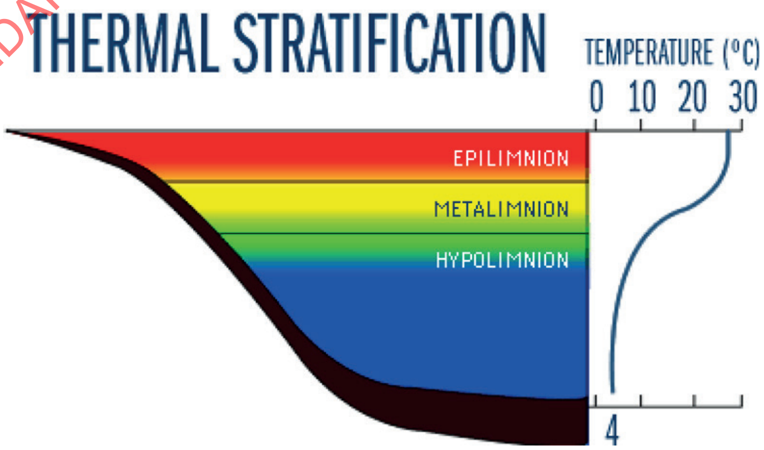


Figure 5 — Thermal stratification

8 Adaptation of emitters to TWW

8.1 General

Pipelines of secondary and tertiary TWW should be continuously and systematically monitored and maintained in order to detect clogging potential and preserve the system's functionality for long term durability.

8.2 Emitters classification

Drippers' classification is specified in ISO 9261.

Other emitters such as rotating sprinklers' classification is specified in ISO 15886-1 to -4.

8.3 Drippers

8.3.1 General

Drippers can be used for TWW application, as they can minimize the physical contact between the irrigation TWW and crops and the operators. Drip irrigation can also prevent aerosol dispersion and limit odours, which are typical in emitters dispersing water in the air.

Source: Israel Ministry of Health, Public Health Services, Department of Environmental Health, *Standards and guidelines for irrigation with effluents in Israel*, 1999, Clauses 4.2, 4.3, Jerusalem.

8.3.2 On-surface dripper and sub-surface dripper

The selection of the best compatible dripper and its installation should comply with the recommendations provided by the manufacturer.

Following are drippers' features that are compatible for sub-surface systems:

a) unregulated dripper,

b) regulated dripper,

c) in-line emitter, and

d) on-line emitter.

8.4 Durability and longevity of dripper

The system's operation and maintenance should comply with the manufacturer's recommendations, to improve durability and longevity (see Clause 10 and Clause 11).

8.5 Functional features of the dripper

8.5.1 General

The structure of the dripper can affect its functionality and performance when used with TWW.

The functional features of the dripper should be as described in 8.5.2.1 to 8.5.2.4.

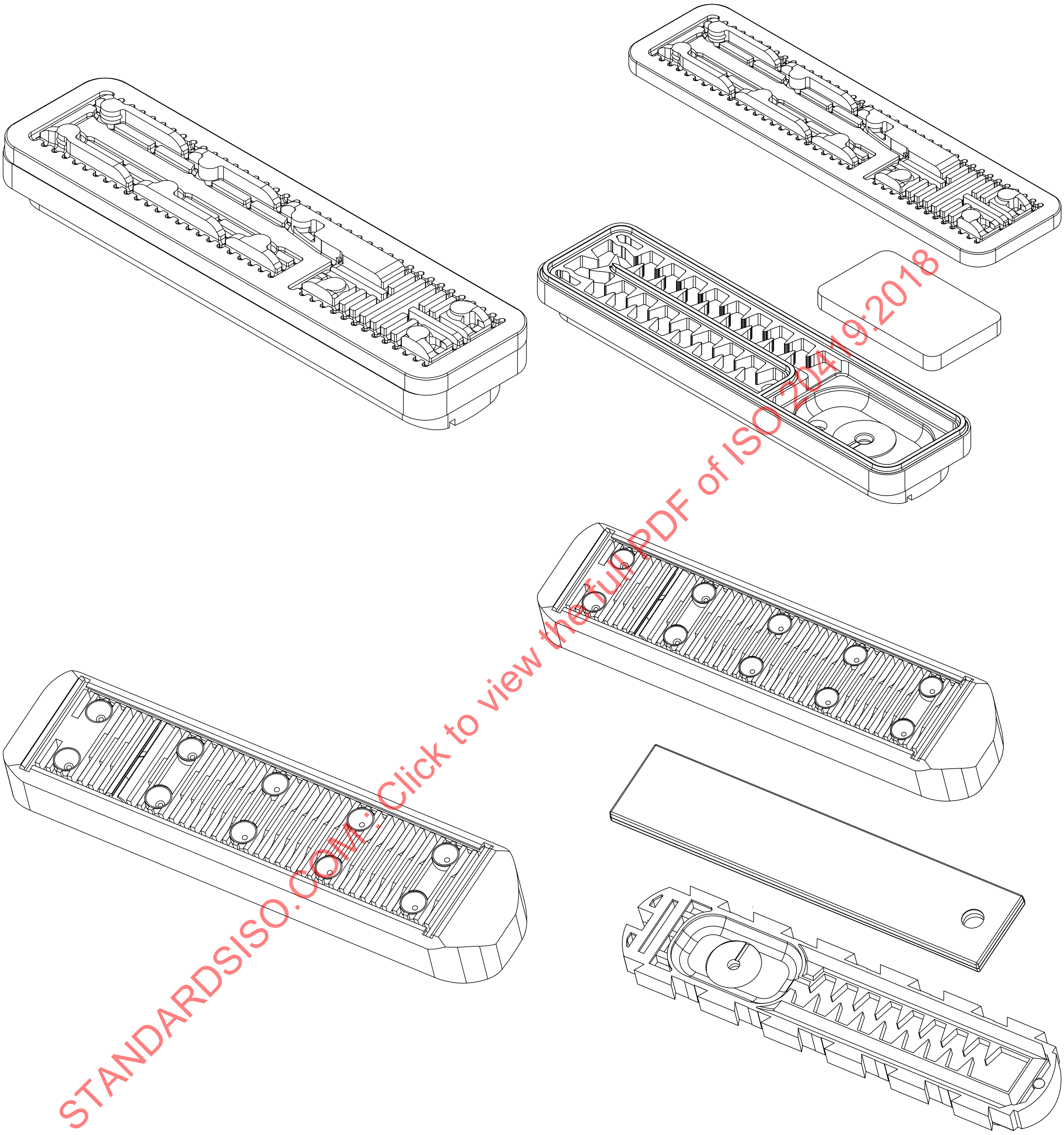
8.5.2 Functional features

8.5.2.1 Water inlet of the dripper

The dripper's water inlet into the flow path should go through a filter, which should be adapted to TWW use.

The net filtration area should be as large as possible.

See examples of water inlets in Figure 6.



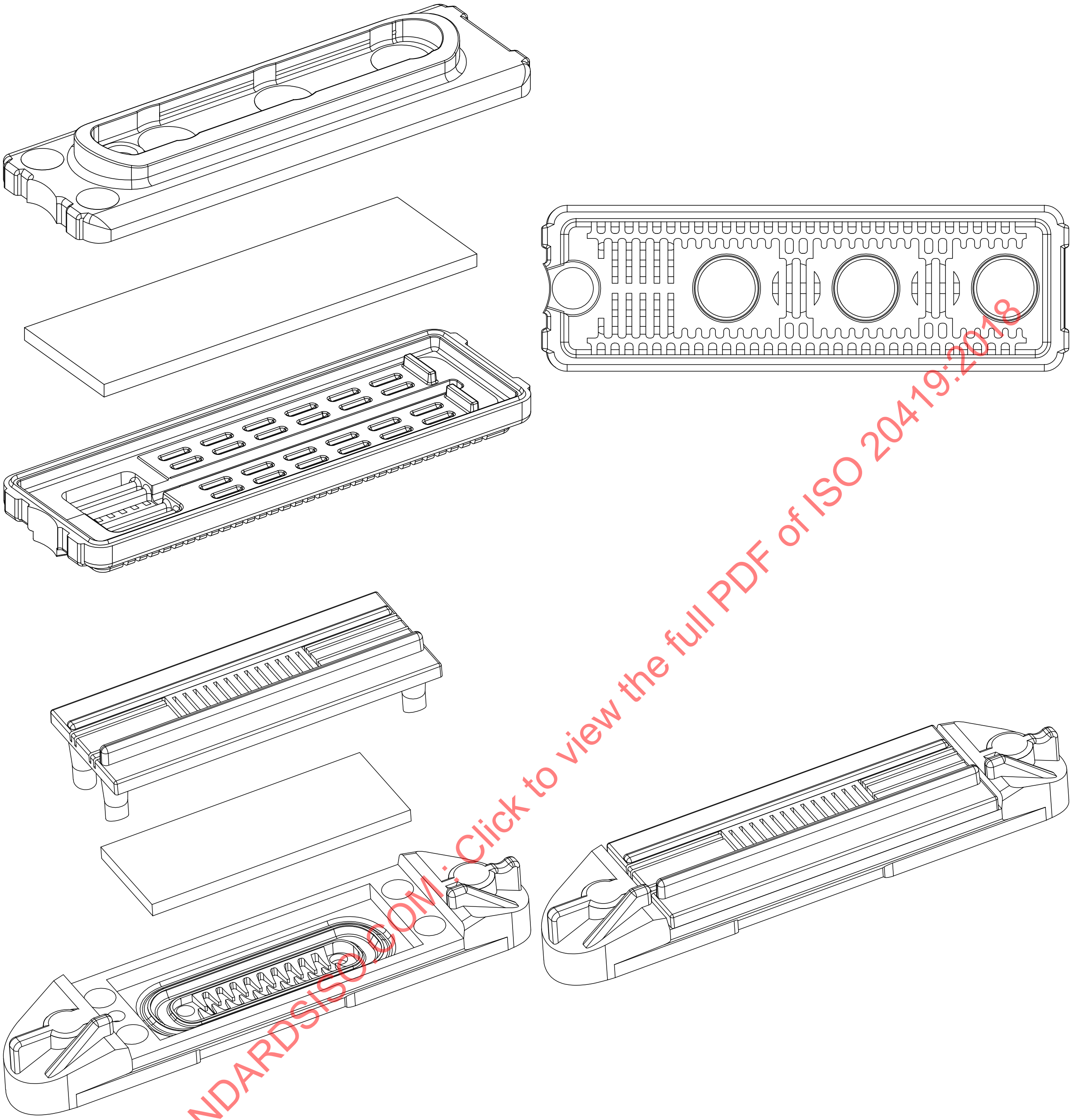


Figure 6 — Examples of water inlets into the dripper

8.5.2.2 Labyrinth flow path

Flow path dimensions should be as following:

a) The overall length of the water flow path in regulated drippers should include a regulation area. This area, combined with the flow path, is critical for the performance of the dripper.

b) The flow path's cross-sectional area should be as large as possible with more effective self-cleaning mechanism. Flow path length should be as short as possible and irrigation water flow regime should be more turbulent.

See examples of labyrinth flow paths in Figure 7.

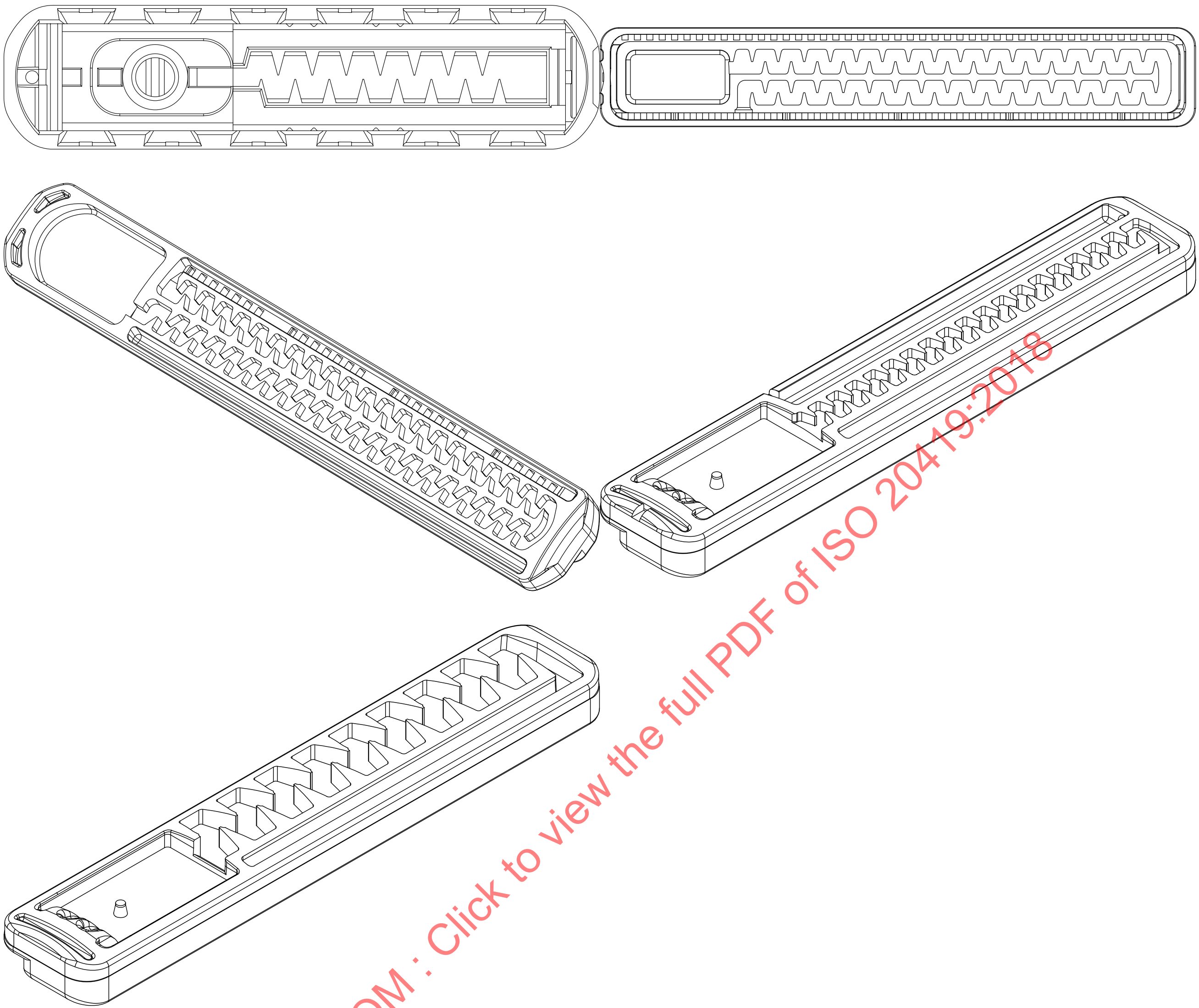


Figure 7 — Examples of labyrinth flow paths

8.5.2.3 Water outlet of the dripper

The dripper's water outlet should include a means to prevent or reduce particles, for example:

a) root intrusion mechanism,

b) outlet cover,

c) inherent anti -suction mechanism.

The dripper should include at least two outlets.

8.5.2.4 Dripper's sensitivity to changes in discharge

As the use of TWW can entail accumulation of suspended solids within the laterals and drippers the following implications in the use of low flow drippers (with a flow lower as 1,0 l/h or even lower) should be considered:

a) In unregulated drippers, the accumulation of sediments in any part of the water flow-path can reduce the dripper's flow rate and lead to clogging.

b) In regulated drippers two effects can occur:

1) Drippers clogging,

2) Accumulation of sediments inside the regulation chamber, which can cause random flow increase or decrease followed by complete clogging.

8.6 Sprinkler/centre pivot/frontal pivot

8.6.1 General

Sprinklers/irrigation machine sprinklers and sprayers should be made of materials resistant to TWW chemical composition.

Sprinklers nozzles should be connected to the sprinkler body in a way that allows easy cleaning and dismantling.

In micro-sprinklers, when the clogging is exterior and mainly caused by calcium carbonate or organic matter, the equipment should be removed from the plot, immersed in diluted 30 % acid/chlorine or hydrogen peroxide for a duration not exceeding 2 hours, and then flushed with clean water, and reinstalled.

8.6.2 Overhead sprinkler

Overhead sprinkler features should be as follows:

a) discharge range: 800 l/h and higher,

b) water distribution: as the irrigated land is fully wetted, sprinklers should be installed on top of a riser from 0,7 metre to 1 metre above ground or can be installed at the surface of the soil.

This method should be used for industrial crops or pastureland irrigation. For other agricultural crops, public landscape or golf course irrigation, the manufacturer's recommendations should be followed. For more information, see Table E.1.

If the mini -sprinkler system includes a main filter, an individual filter is not required.

See overhead sprinkler example in Figure 8.

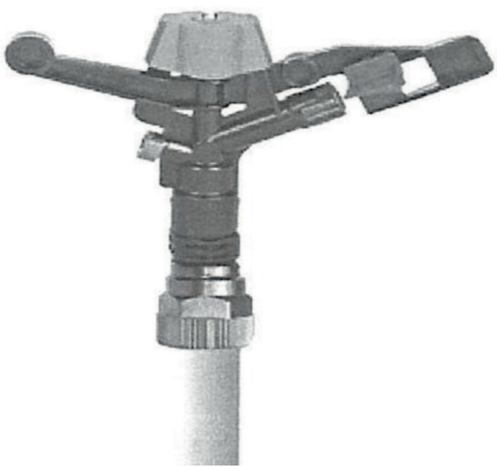


Figure 8 — Overhead sprinkler

8.6.3 Mini sprinklers

Mini sprinklers should be made of plastic or metal materials resistant to TWW chemical composition, see Figure 9.

Mini sprinklers' nozzles should be connected to the sprinkler's body in a way that allows easy cleaning and dismantling.

To keep mini sprinklers system well operated, when clogged sprinklers are detected, they should be treated outside the field.

Figure 9 — Mini sprinklers

Mini sprinklers should be installed on top of a riser or mini sprinklers stand at a height of 0,7 m to 1,0 m.

Mini sprinklers discharge range should be 120 l/h to 800 l/h and higher.

8.6.4 Micro sprinklers and sprayers

8.6.4.1 Discharge range

Micro sprinklers discharge range should be 20 l/h to 400 l/h and higher.

Sprayers discharge range should be 20 l/h to 120 l/h and higher.

8.6.4.2 Water distribution

As the irrigated land is fully wetted, mini sprinklers, micro sprinkler and sprayers should be installed according to manufacturer's recommendations.

8.6.4.3 Drop suspension

Sprinkler irrigation should be limited to windless conditions, to reduce odour nuisance and aerosols transport/drift related risks, as following:

a) water distribution pattern (localized water distribution, under fruit trees canopy). Area between rows should remain dry. TWW stream height should be 25 cm to 50 cm;

b) distance between dispersed TWW and irrigated fruit trees: there should be some distance; still a chance of random wetting remains. Sprinklers should be used for fruits with inedible peel;

c) staff safety: there can be contact between workers and dispersed TWW; workers can be in the field during irrigation.

NOTE The WHO Guidelines make a case for a variety of measures allowing farmers to protect themselves e.g. wearing gloves and rubber boots, immunization and hand washing, and other post-harvest measures like produce washing before consumption.

8.6.5 Center pivot sprinklers/sprayers

Sprinklers/emitters set at the first 2 or 3 spans of a centre pivot should be:

a) disconnected from the main system;

b) connected to a separate polyethylene pipe;

c) filtered with an automated filter or manual filter in accordance with TWW quality.

9 Design parameters for TWW irrigation

9.1 General

In TWW use for irrigation, and particularly drip irrigation systems, the following aspects should be designed:

a) head control,

b) water delivery pipes,

c) main and sub-mains, and

d) dripperlines.

9.2 Design parameters for TWW irrigation systems (drippers, sprinkler irrigation machines)

9.2.1 Delivery pipes should be resistant to corrosive chemicals such as: hydrochloric acid or phosphoric acid, hydrogen peroxide and chlorine. Metal piping with cement coating is likely to be damaged by such chemicals.

9.2.2 Flow velocity in delivery and distribution pipes for irrigation systems should be around 1,5 m/s at the tube inlet. While flushing distribution pipes and drip tubes, the flow velocity along distribution pipes can increase to 2 m/s due to the additional flow through the end of laterals or flushing manifolds.

9.2.3 Delivery and distribution piping should allow internal cleaning using physical means, e.g. through the use of sponges. At the end of the delivery piping, a flush valve should be installed.

9.2.4 Organic matter and slime sediments develop within the drip tubes, resulting in a smaller tube diameter. Therefore drip tube diameter should be as large as possible (see Figure 10).

Figure 10 — Clogged dripperline

9.2.5 Dripperline length should be designed in accordance with TWW quality and allow a flow velocity of 0,5 m/s.

9.2.6 Collector pipes should be designed at the end of the dripperlines, to facilitate flushing. The diameter of collector pipes and number of dripperlines should be determined by irrigation designer to allow a flow velocity of 0,5 m/s for collectors during flushing.

10 Physical treatment

10.1 General

Physical treatment in TWW irrigation systems should be able to remove bacterial sludge and other material accumulated inside the pipes and dripperlines, and prevent biofilm formation.

Physical treatment should follow 10.2 and 10.3.

10.2 Flushing mains, sub-mains and tubes

During pipes and dripperlines flushing, pressure protection such as direct pressure control valve or hydraulic pilot for valves should be disabled. Consecutive sets of dripperlines should be opened and flushed until clean water is observed. The last set of dripperlines should remain open until pressure protection is restored.

The frequency of flushing should depend upon TWW quality changes, see 4.2.1.

10.3 Collector pipes

10.3.1 To improve the flushing process, several dripperlines should be connected to a collector pipe with a valve at its end.

10.3.2 The diameter of the collector pipe and number of dripperlines connected to it should be determined by the irrigation designer. The collector pipe diameter should be similar to the sub main diameter or smaller in one diameter size.

EXAMPLE If a sub main pipe is of 50 mm diameter, the collector pipe would be 50 mm or 40 mm.

10.3.3 At the end of the collector pipe, a hydraulic valve and timer can be installed, to allow irrigation dripperlines flushing without an irrigator's presence.

11 Chemical treatment

11.1 TWW can carry different types of materials into the irrigation system, such as bacterial sludge, biofilm colonies, chemical materials producing sediments, industrial TWW, medicines and laboratory originated materials, which can form a variety of compounds that can accumulate and cause biofilm formation inside the irrigation system, particularly in drip irrigation systems.

11.2 TWW use can include 3 main clogging substances (see a list of substances' parameters in Annex A):

a) physical substances,

b) chemical substances, and

c) biological substances.

11.3 The clogging substances can form a variety of compounds that can accumulate and cause biofilm formation in irrigation systems, particularly drip irrigation systems.

11.4 Chemical materials should be used to prevent biological sediments and chemical sediments.

Due to the great variety of sediments, treatment should be in accordance with water analysis.

11.5 To protect irrigation systems, the following materials should be used:

a) liquid chlorine (see Annex C as a whole, and also Figure C.1);

b) chlorine tablets (See Annex C as a whole, and also Figure C.1);

c) hydrogen peroxide concentrated to 35 %;

d) hydrochloric acid concentrated to 33 % or Phosphoric acid concentrated to 46 % (if phosphorus is needed to be added to the soil).

11.6 The use of these materials should be in accordance with ISO 16075-3.

Annex A
(informative)

Definition of TWW quality and treatment recommendations for micro-sprinkler irrigation or drip irrigation

Table A.1 — Definition of TWW quality and treatment recommendations for micro-sprinkler or drip irrigation

Parameter	Units	Good TWW quality[a]	Medium TWW quality[b]	Poor TWW quality[c]	Treatment
Suspended solids	(mg/l)	< 20	20 to 60	> 60	Pumping, sedimentation and filtering
Sand	(mg/l)	< 1	1 to 5	> 5	Pumping, sedimentation and filtering
Silt and Clay	(mg/l)	< 20	20 to 60	> 60	Pumping, sedimentation and filtering
Calcium conc. (as $CaCo_3$)		< 150	150 to 300	> 300	Softening, pH rectification
	(mg/l)	To be calculated separately for each water type			
Iron	(mg/l)	< 0,1	0,1 to 0,5	> 0,5	Oxidization and iron removal
Manganese	(mg/l)	< 0,02	0,02 to 0,3	> 0,3	Oxidization and manganese removal
Sulfide	(mg/l)	< 0,01	0,01 to 0,2	> 0,2	Oxidization and purification
Algae (Chlorophyll A)	(mg/l)	< 0,3	0,3 to 0,8	> 0,8	Treatment at water source. Filtering and chlorination
Plankton					Treatment at water source and Filtering
Dissolved Oxygen (DO) [d]	(mg/l)	> 2,0	2,0 to 0,5	< 0,5	Treatment at water source. Pumping point
pH		6 to 7,5	7,6 to 8,0	> 8,0	pH rectification to required level
Sulfuric bacteria	(mg/l)	< 0,3	0,3 to 1,0	> 1,0	Oxidization and disc or gravel filter
Iron bacteria	(mg/l)	< 0,3	0,3 to 1,0	> 1,0	Oxidization and disc or gravel filter
Manganese bacteria	(mg/l)	< 0,3	0,3 to 1,0	> 1,0	Oxidization and disc or gravel filter
Snails and shells		0	Presence	Growth	Avoid development
BOD	(mg/l)	< 10	10 to 50	> 50	Sewage treatment, filtering and oxidization
COD	(mg/l)	< 50	50 to 80	80	Sewage treatment, filtering and oxidization
TSS	(mg/l)	< 30	30 to 70	70	Sewage treatment, filtering and oxidization

Key

[a] Good TWW quality: No special treatment recommendations other than regular filtering.

[b] Medium TWW quality: Medium TWW quality in only one parameter requires attention and occasionally treatment. Medium TWW quality in two or more parameters requires specific treatment in all the parameters.

[c] Poor TWW quality: Requires treatment in all the parameters of a high value parameters.

[d] Low dissolved oxygen does not lead directly to the plugging of the drippers, but a lack of oxygen in the water usually points to the presence of sulfide.

Annex B
(informative)

TWW quality parameters and test methods

Table B.1 — TWW quality parameters and test methods

Parameter		Test Method
BOD	Biochemical Oxygen Demand	TWW sampling method should comply with ISO 16075 or comply with SM or EPA.
COD	Chemical Oxygen Demand	
TSS	Total Suspended Solids	
Clogging capacity meter		
DO	Oxygen (dissolved)	
P	Phosphorus concentration	
Ca	ICP Calcium concentration Ca Calcium concentration	
pH	4 500 H^+	
Fe	ICP Iron concentration	
Mn	ICP Manganese concentration	
Alkalinity	Alkalinity Titration Method	
SDI (Silt Density Index)	Standard Test Method for Silt Density Index (SDI) of water	
Reservoir temperature	Temperature — Laboratory and Field Methods	
Irrigation system temperature	Temperature — Laboratory and Field Methods	

Annex C
(informative)

pH effect on Chlorine concentration

C.1 The most important reaction in the chlorination of an aqueous solution is the formation of hypochlorous acid, a form of chlorine very effective for killing germs. Hypochlorous acid is a ‘weak’ acid, meaning that it tends to undergo partial dissociation to form a hydrogen ion (H^+) and a hypochlorite ion (OCl^-). In a water environment HOCl tends to dissociate into these ions.

$$HOCl \leftrightarrow H^+ + OCL^- \quad (C.1)$$

C.2 In water between 5 pH and 8,5 pH, the reaction is incomplete and both species are present to some degree. Since H^+ is one of the ions formed and its concentration is expressed as pH, a change of pH levels will influence the balance of this reaction and with it, the availability of hypochlorous acid for reaction. Therefore, in an aqueous environment, the water pH will affect the chemistry of chlorine through its pH sensitivity; this is important as the pH value increases.

$$H_2O \leftarrow H^+ + OH \quad (C.2)$$

C.3 Three effects follow from this form of ionization:

C.3.1 Since the tendency of these two ions to react and form H_2O is much stronger than the tendency of water to break down into the ions, as the pH increases there are fewer H^+ ions and more OH^- ions.

C.3.2 The H^+, released by the breakdown of HOCl [Formula (C.1)], react to form water [Formula (C.2)] and leave behind residual OCl^- ions. Hypochlorite does not react readily so the chlorine is weaker.

C.3.3 If the pH decreases and H^+ ions become readily available again, the OCl^- ions revert to HOCl, which is the killing form of chlorine.

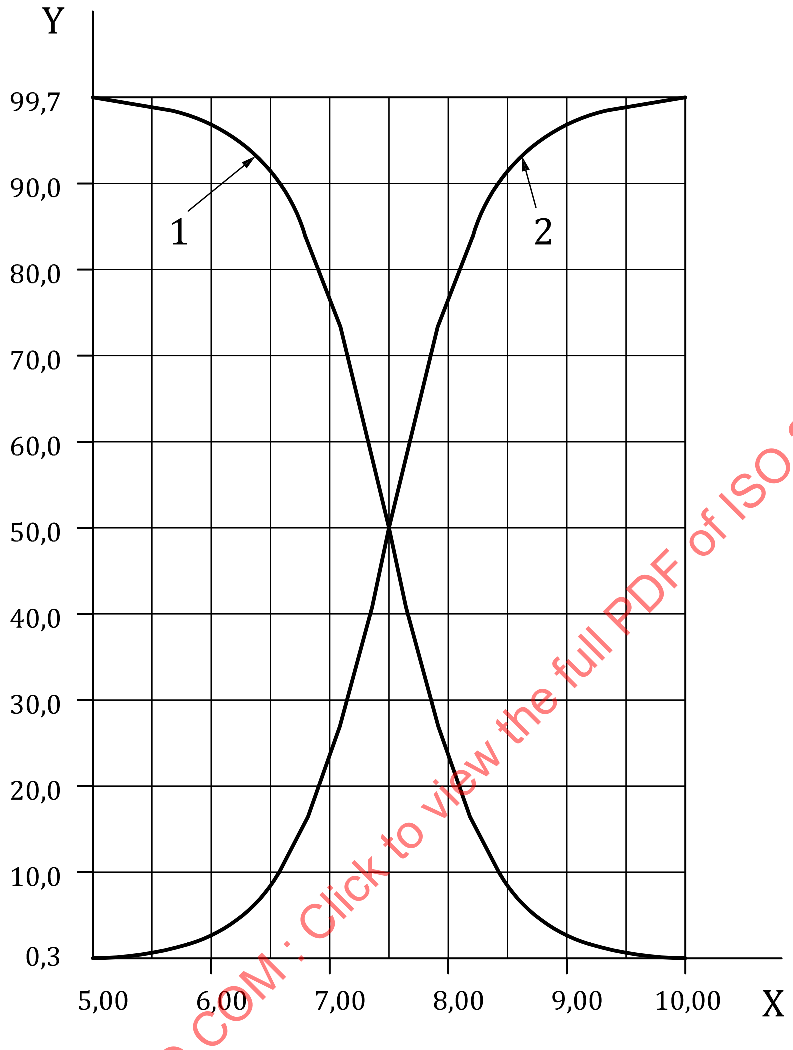
C.4 In the chemical industry, there are a number of terms used to indicate the various forms of chlorine that are of interest. These terms tend to be used rather loosely and not necessarily consistently. For that reason, the following terms are defined:

C.4.1 **Free Available Chlorine** refers to the hypochlorous acid (HOCl) form of chlorine only. It is the free, uncombined form of chlorine that is effective for disinfection.

C.4.2 **Total Free Chlorine** refers to the sum of hypochlorous acid (HOCl) and hypochlorite ion (OCl^-). The hypochlorite ion is not effective for disinfection, but it is in a free form. All of the total free chlorine would be in the form of hypochlorous acid if the pH was low enough.

C.4.3 **Combined Chlorine** refers to chlorine which is not readily available. For example, chlorine combined as chloramines or organic nitrogen is not an effective disinfectant and will not readily convert to hypochlorous acid or hypochlorite ion.

C.4.4 Total Residual Chlorine refers to the sum of total free chlorine and combined chlorine. Low total residual chlorine is of particular interest to ensure there are no downstream consequences for aquatic life.



Key

X pH

Y % concentration

1 Hypochlorous acid (HOC)

2 Hypochlorite ion (OCl-)

Source: EPA, 2011, Water treatment manual disinfection, 4.4.2: Effect of pH and temperature

Figure C.1 — % Chlorine concentration vs pH

Annex D
(informative)

Clogging capacity meter

D.1 General

The following are technical specifications, operational and troubleshooting instructions for a clogging capacity meter.

a) Clogging Capacity Meters (C.C.M.) have been developed to enable uniform grading of irrigation TWW quality.

b) This gauge includes a filter of a chosen size, to allow a flow rate of 10 l/min, controlled by a flow regulator.

c) Due to dirt collecting on the screen of the filter, a pressure drop of 3 metres on the screen surface can be caused.

d) The length of time it takes for the pressure drop to form indicates the quality of the irrigation TWW.

The C.C.M. is suitable for the following purposes:

a) determining TWW quality before filtration (for making decisions on the type and level of filtration required),

b) testing the TWW after filtration: to test the effectiveness of filtration and to locate deficiencies in the filtration system,

c) diagnosing changes in TWW quality, and

d) identifying causes of blockages according to flushing differential pressure.

D.2 Gauge structure

The C.C.M is built in two main parts interconnected by pressure pipes (see Figure D.1).

a) **Control unit** — this unit includes a digital timer (6), an inlet pressure gauge (9) and a differential pressure gauge (10). This unit is connected to the sampler at points 2 and 5 (see Figure D.1).

This unit measures the length of time needed for the screen (4) on the sampler to become partially blocked, creating a pressure drop of 3 metres.

b) **Sampler** — a unit combining a filter screen (4) and flow rate regulator (5) through which flows the TWW to be tested.

The filter screen can be replaced and cleaned.

The flow of TWW through the sampler is controlled at 10 l/min by the flow regulator.

D.3 Operating instructions

a) insert a clean filter screen (4) into the filter housing (3), open the record, re-tighten the record;

b) connect the sampler TWW input (1) to the irrigation system. Ascertain a minimum pressure of 20 m in the pressure gauge (9);

c) set the digital timer (6) by pressing the set button (11);

d) open the TWW inflow to the sampler while pressing on the operating button (12) in the control unit;

e) watch the increase in pressure on the differential pressure gauge (10). When it goes into the red part of the gauge the digital timer (6) stops;

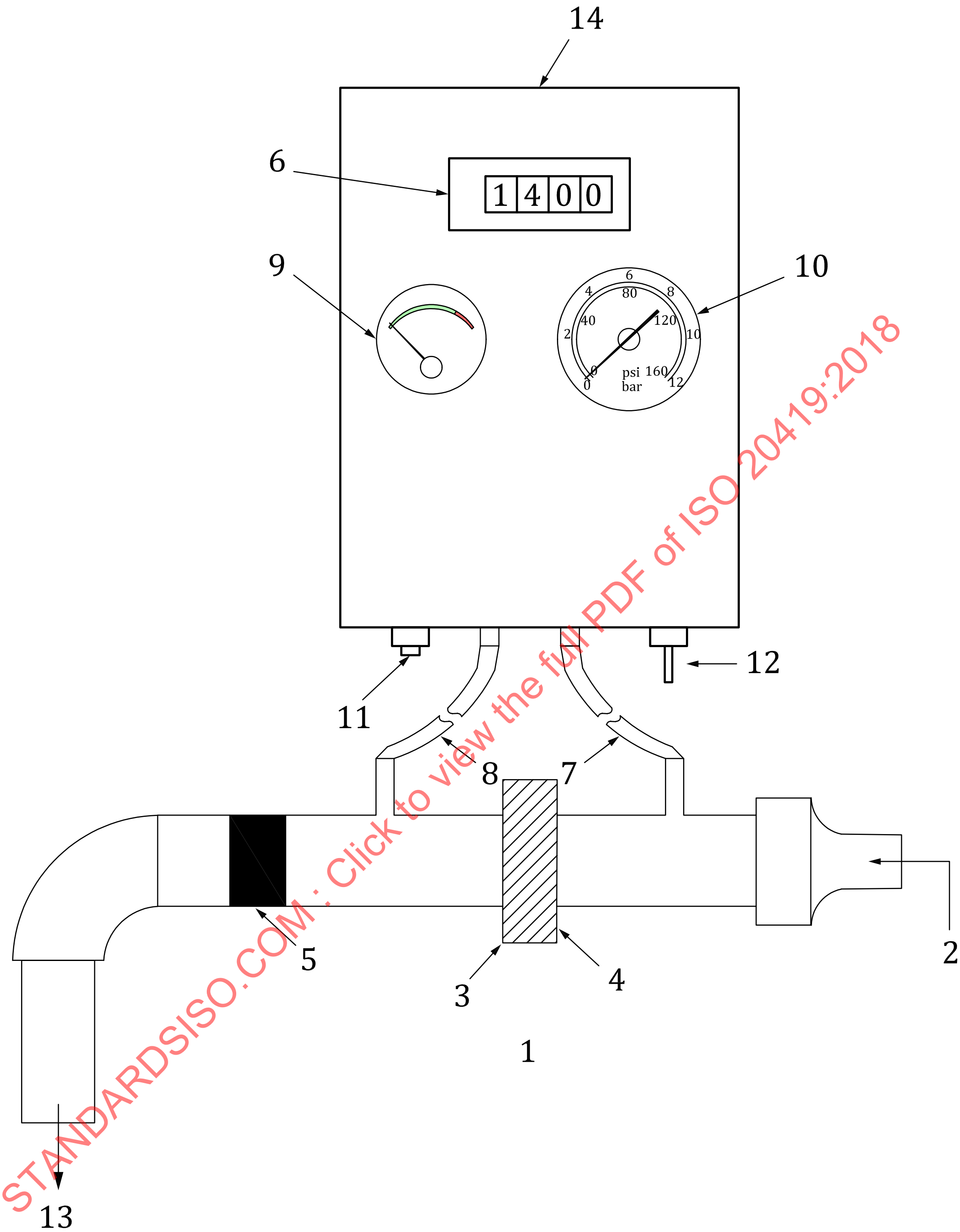
f) press the start/stop button (12) and only after this close the TWW inflow to the sampler;

g) read the length of time for blockage on the digital timer (6).

D.4 Troubleshooting

In case of leaks from the record — stop testing, ascertain that the filter screen is inserted properly, tighten the sampler and start the test again.

Warning — Do not let the control unit get wet.



Key

1	sampler	8	low-pressure tube
2	inflow of water testing	9	differential pressure gauge
3	screen housing	10	pressure gauge
4	filtering screen	11	reset button
5	flow rate regulator	12	operating switch
6	digital timer	13	water outflow
7	high-pressure tube	14	control unit

Source: IWWA, Clogging capacity meter technical pages

Figure D.1 — Clogging capacity meter