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Water Reuse in Irrigation

Réutilisation des Eaux Usées Traitées en Irrigation

مؤسسة المقاييس والمواصفات اللبنانية
-------- LIBNOR --------

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Foreword

The Lebanese Standard NL 819:2024 was elaborated according to the internal procedures of LIBNOR.

The technical committee responsible for this standard was “NL TC 282 SC1 – Treated Water reuse for irrigation”.

The Standard, described in this document, was developed through a working framework involving the participation and the effective communication of stakeholders representing different national institutions from the public and private sectors, including universities, etc…. The committee worked on reviewing and assessing all available scientific references, with the scientific support from the International Water Management Institute (IWMI) through the ReWaterMENA and From Fragility to Resilience in CWANA projects.

The board of directors of LIBNOR approved this standard, on 18/8/2024 without modification, as a Lebanese standard, based on the recommendation of LIBNOR technical committee: “*NL TC 282 SC 1*” in its meeting held on 24/6/2024**.**

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Abbreviated terms

Al aluminum

As arsenic

Be beryllium

Bo boron

BOD biochemical oxygen demand

Ca calcium

Cd cadmium

CDR Council for Development and Reconstruction

CFU colony forming units

Co cobalt

COD chemical oxygen demand

Cr chromium

Cu copper

EC electrical conductivity

F fluoride

Fe iron

HCO_3 carbonates

Hg mercury

LARI Lebanese Agricultural Research Institute

Li lithium

MF membrane filtration

Mg magnesium

Mn manganese

Mo molybdenum

MoA Ministry of Agriculture

MoE Ministry of Environment

MoET Ministry of Economy and Trade

MoEW Ministry of Energy and Water

MoI Ministry of Industry

MoPH Ministry of Public Health

Na sodium

Ni nickel

NF Nanofiltration

Pb lead

PO_4 phosphate

SAR sodium adsorption rate

Se selenium

SO_4 sulfate

TDS total dissolved solids

TSS total suspended solids

TW treated water

UF ultrafiltration

UV ultraviolet

V vanadium

WE Water Establishment

WTP wastewater treatment plant

WW wastewater

Zn zinc

Definitions

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

Barrier (in water reuse projects): any means including physical or process steps that reduces or prevents the risk of human infection by preventing contact between the TW and the ingested produce or other means that, for example, reduces the concentration of microorganisms in the TW or prevents their survival on the ingested produce.

Direct Water Reuse: treated or untreated wastewater delivered to individual users or users associations for beneficial purposes with no previous mixing or dilution with freshwater.

Disinfection: process that destroys, inactivates, or removes microorganisms. In a water reuse project disinfection of TW intends to raise the quality of the TW before irrigation.

Drip irrigation: (also called trickle irrigation) is a micro-irrigation system capable of delivering water drops or tiny streams to the plants and involves dripping water onto the soil or directly under its surface at very low rates (2-20 L/h) from a system of small diameter plastic pipes fitted with outlets called emitters or drippers.

Environmental impact: any change to environmental quality, whether adverse or beneficial, wholly or partly resulting from an organization's activities, projects, or products.

Filtration: process or device for removing suspended solids or colloidal material from water by physically trapping the particles.

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

Freshwater: naturally occurring water on the Earth's surface (in ice, lakes, rivers, and streams) and underground as groundwater in aquifers.

Hazard: is a biological, chemical, physical or radiological agent that has the potential to cause harm to people, animals, crops, plants or organisms; to the soil, air or water; or to the general environment.

Indirect Water Reuse: utilization of treated or untreated wastewater for beneficial purposes with previous mixing or dilution with freshwater in a canal, river, lake etc.

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

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

Multiple-Barrier Approach (in water reuse projects for irrigation): An integrated combination of measures to prevent health risks along food value chains that use treated wastewater. Such measures include wastewater treatment, adoption of safe irrigation practices that minimize contact between crops and water or that favor pathogen die-off (e.g. drip irrigation or stop irrigation before harvesting) and hygienic practices by food vendors and consumers. It also includes controlling public access during irrigation (e.g. restricting public access through physical or other barriers, such as fences, warning signs or temporary ban).

Non-food crops: crops not for human consumption such as pastures and forage, fiber, ornamental, seed, forest, and turf crops.

Pressurized irrigation systems: piped irrigation network systems that use pumps to move water.

Public health impact: any change to public health, whether adverse or beneficial, wholly or partly resulting from an organization's activities, projects, or products.

Raw wastewater: wastewater which has not undergone any treatment

Reservoir (in water reuse projects): system to store temporarily unused TW when demand for irrigation is lower than the treatment plant discharge.

Restricted irrigation: use of TW for non-potable applications in settings where public access is controlled or restricted by physical or institutional barriers.

Risk: is the likelihood that a hazard will harm exposed populations or receiving environments in a particular timeframe.

Sprinkler irrigation systems: irrigation systems composed of sprinklers.

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

Storage (in water reuse projects): retained temporary unused TW for short- or long-term before its release for use in irrigation systems.

Unrestricted irrigation (in water reuse projects): use of TW for non-potable applications in settings where public access is not restricted.

Wastewater treatment plant (WTP): facility designed to treat wastewater by a combination of physical (mechanical) unit operations and chemical and biological processes, with the purpose of reducing the organic and inorganic contaminants in the wastewater. It could be a conventional plant as well as a natural treatment system (stabilization ponds, constructed wetland, macrophyte treatment, etc.).

Wastewater: used water discharged from homes, businesses, industry, cities and agriculture. According to this definition, there are as many types of wastewater as water uses (e.g. urban wastewater, industrial wastewater, or agricultural wastewater). Where the wastewater is collected in a municipal piped system (sewerage), it is also called sewage. The term 'wastewater' as used in this standard is basically synonymous with urban (or municipal) wastewater which is usually a combination of one or more of the following: Domestic effluent consisting of blackwater (from toilets) and greywater (from kitchens and bathing); water from commercial establishments and institutions, including hospitals; industrial effluent; storm water and other urban runoff.

Water reuse project: design, development, construction, selection of equipment, operation, and monitoring of works to provide suitable treated water irrigation.

Water reuse: use of treated water for beneficial use.

Chapter 1. Introduction to water reuse

1.1. The need for water reuse in MENA and Lebanon

The Middle East and North Africa (MENA) is a region with an average per capita renewable water resources availability 10 times less than the global average (Lahham *et al.*, 2022). Population growth, a rapid urbanization, agricultural expansion and intensification, and changing consumption patterns constitute the main drivers to the increase of water demand that is forecasted to rise by 50% in 2050 (IPCC, 2023). In addition, much of the MENA region is expected to experience more warming than the global average, with average temperatures projected to rise by at least 4°C by 2050. Precipitation is also forecast to decrease in most of the MENA region by mid-century (IPCC, 2023; Lahham *et al.*, 2022).

In MENA region, demographic growth and urbanization have also translated into greater wastewater production. The capacity for sanitation and wastewater treatment is not growing at the same rate and therefore the amount of wastewater discharged untreated into the environment keeps rising in some countries. Although many countries are substantially improving their wastewater treatment rate, about 40% of produced wastewater in the region is left untreated (Mateo-Sagasta et al., 2023) which increases water pollution and aggravates water scarcity. However, it is the only water source that is renewable, growing with time and contains resources that can be productive. Therefore, it is part of the problem and part of the solution (Mateo-Sagasta et al., 2022).

Box 1.1. The benefits of planned water reuse in agriculture

The recovery of resources such as water, nutrients/fertilizers and organic matter from wastewater, in support of food production, can have benefits for all sectors involved: agriculture, cities, and the environment.

- Agriculture can benefit from the reuse of urban effluents in several ways, the most important being: (i) improving the reliability of the water supply, (ii) improving the fertilizing capacity of the nutrients of the urban effluents and (iii) bringing agricultural production closer to consumption centers.
- Cities can benefit from reuse mainly for three reasons: (i) they can strengthen their food security by supplying peri-urban agriculture with water and nutrients; (ii) reuse can effectively contribute to solve their wastewater treatment problem and in particular the removal of nutrients, which can be used by plants rather than ending up in water bodies causing eutrophication of lakes or pollution of groundwater with nitrates; and (iii) they can increase their water availability, when wastewater is reused for municipal uses, or when reclaimed water is exchanged for fresh water between cities and agriculture.
- The environment, and especially aquatic ecosystems, can benefit from the safe treatment and reuse of wastewater. Reuse can improve water quality and increase its availability for environmental uses. In addition, reuse systems associated with peri-urban agriculture and agroforestry have a high potential for carbon sequestration and climate change mitigation.

Source: Published in Lahham et al., 2022

Treated water (TW) is an excellent alternative water source and has high potential to reduce pressure on non-renewable water sources (Velpuri *et al.*, 2023). It can be used for agricultural irrigation, landscape irrigation, artificial lakes, industrial reuse, and groundwater recharge. It can also be used for various urban uses, habitat wetlands, recreational and environmental uses, etc. However, 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 (WHO, 2006). Consequently, public health and potential agronomic and environmental adverse impacts are to be considered as priority elements in the successful development of water reuse projects for irrigation.

Lebanon is a country in MENA region. As of 2022 population estimates ranged from 4.8 to 6.5 million inhabitants (Eid-Sabbagh et al., 2022). Accordingly, the volume of municipal wastewater generated in the country was considered to vary between 275 million cubic meters (Mm^3) and 328 Mm^3 per year. As of 2022 the total volume of treated water was about 25-30% of the annually generated wastewater. Only 34% of the treated water could be considered fit for reuse in 2022, which amounts to about 8-10% of the total municipal wastewater generated, but this figure in planned to increase substantially in the future (MoEW, 2020). Information on the existing water treatment plants (WTPs) in the country can be consulted in IWMI study on the "Potential of Water Reuse in Lebanon" (Eid-Sabbagh et al., 2022).

The updated National Water Sector Strategy for the years 2020-2035 estimates the gross demand for irrigation water at 879 Mm^3 per year and mentions a serious gap of 25% between irrigation water demand and current irrigation water use (MEW, 2020). In addition, alternative freshwater sources in the country are becoming increasingly contaminated (Abi Saab et al., 2022; Eid-Sabbagh et al., 2022). The use of TW for irrigation can augment the available water resources and contribute to address the water gap, but water reuse needs to be safe for people, crops, plants and the environment. Therefore, there is a need for a systematic adoption of a local standard for the reuse of TW in the country.

1.2.The need for appropriate water reuse standards in Lebanon

Lebanon needs realistic and affordable water reuse standards that promote risk minimization and provide legal security and economic opportunities to farmers and confidence to consumers.

Within this context, the Lebanese National Water Reuse Standard, described in this document, is based on reviewing international experiences in the field of developing regulations, guides and codes for water reuse (Table 1). It also considers local scientific evidence on water treatment and reuse through investigating the existing scientific research trials (Abi Saab et al., 2018; 2020; 2021; 2022). In addition, it is focused on the approach of the World Health Organization (WHO) guidance published in four volumes in 2006 (Table 1). This approach employs a quality management system at all stages of water treatment and reuse, and is harmonized with the WHO Water Safety Plan (WSP). The health risks which may arise from reusing treated water are managed based on an acceptable risk limit. In addition, it is a preventative approach, which applies the Multiple-Barrier Principle focusing on the water lifecycle and utilization of a package of barriers (Figure 1), as follows:

- Water treatment requirements;
- Specification of restricted and unrestricted crops;
- Specification of irrigation methods and requirements;
- Public health requirements for the handling of crops;
- Public health requirements with regard to agricultural workers; and
- Establishing a monitoring and control system.

Table 1. The reviewed international and national studies for the development of the Lebanese National Water Reuse Standard

Source name	**Year of publication**	**Area of specification/interest**
WHO guidelines	2006	Quality management of wastewater treatment and reuse value chain
Water reuse in the Middle East and North Africa: A sourcebook	2022	The book includes a complete analysis of the state of water reuse in MENA, provides a collection of featured case studies and guidelines to expand water reuse. It includes a review of water reuse policy and institutional development in MENA (chapter 3) and an analysis of water quality standards and regulation for agricultural reuse in MENA (Chapter 5).
Local research trials on reused water in irrigation conducted within the following projects: • FAO-project GCP/INT/124/ITA "Coping with water scarcity – the role of agriculture. Phase III: Strengthening national capacities; wastewater reuse in agriculture". Published study: Abi Saab *et al*. 2021. • EU- project "Adaptation to Climate Change through improved water demand management in irrigated agriculture by introduction of new technologies and best agricultural practices – ACCBAT". Published studies: Abi Saab *et al*. 2020; Mcheik *et al*., 2017; 2018. • IWMI-project on "Wastewater Reuse in the MENA Region: Addressing the Challenges"-RewaterMENA. Published study: Abi Saab *et al*. 2022. • EU-project, MAGO-PRIMA on "Developing Mediterranean wAter management solutions for a sustainable aGriculture".	2022; 2021; 2020; 2018; 2017	Generated local evidence on the impact of irrigation with reused water on crops, soil and human health, and recommended safe practices.

This standard provides water quality threshold values depending on authorized uses and defines practices to ensure health and environmental protection considering local specificities. The water quality parameters include the following:

- agronomic parameters: nutrients (nitrogen, phosphorus and potassium) and salinity factors (total salt content, chloride, boron, and sodium concentration);
- other chemical element parameters (heavy metals);
- microbial parameters.

The standard aims to minimize health risks for agricultural workers, workers involved in the handling or packaging of produced crops, consumers, the general public who frequent parks and green spaces, pedestrians and residents of the vicinity.

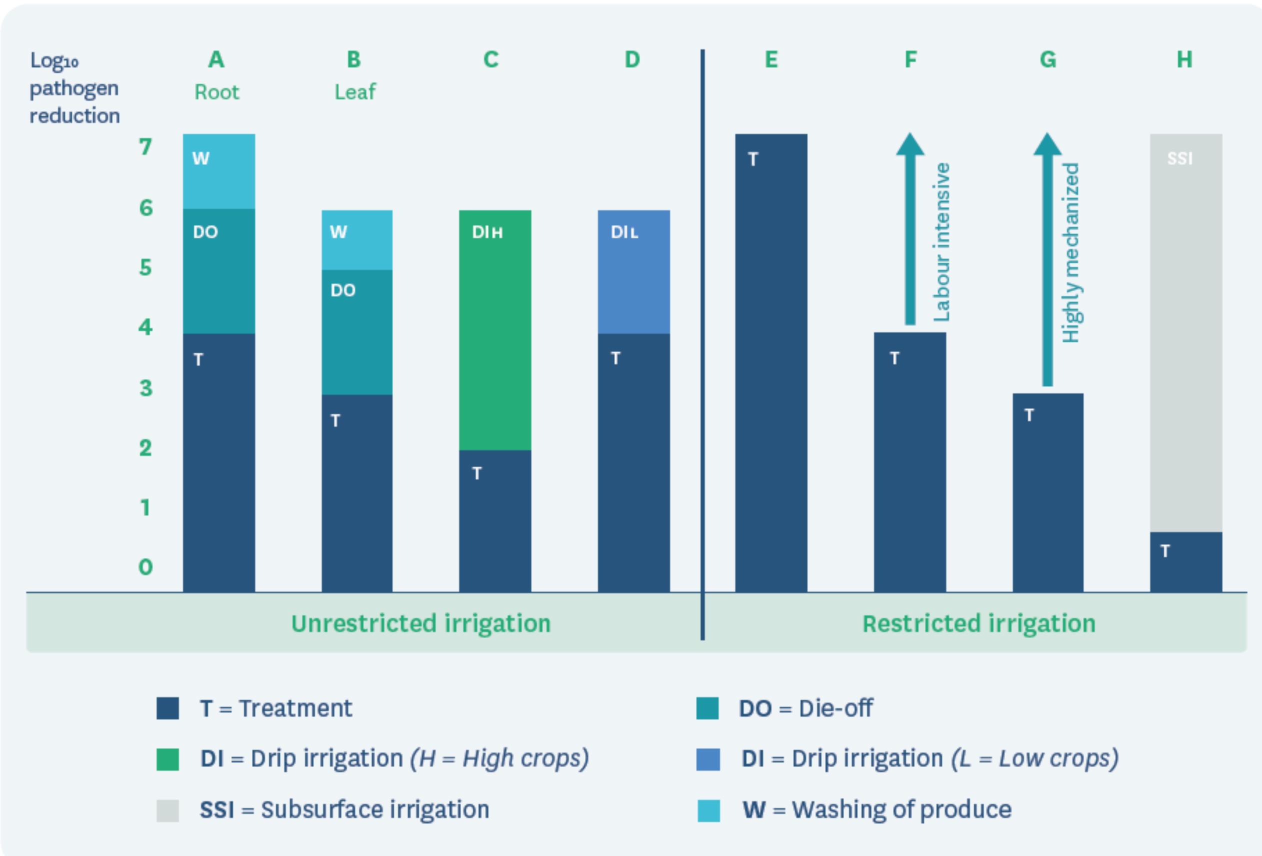


Figure 1. Examples of options (referred as A, B, C, D, E, F, G, and H in the Figure) for the reductions of pathogens by different combination of health measures (referred as T, DI, SSI, DO, DI, and W in the Figure) that achieve the health-based target of < or = 10^{-6} DALYS (disability-adjusted life year) per person and per year (*Source: WHO 2006).*

1.3.The scope of Lebanese National Water Reuse Standard

This standard is addressed to the direct reuse of treated water (TW) for:

- Food crops;
- Non-food crops;
- Irrigation of public and private gardens and landscape areas

This standard and the threshold values reported in Chapter 2, Table 2, are compulsory for direct reuse projects, i.e. for treated waters delivered to individual users or users associations with no previous mixing or dilution with freshwater, even if the treated water is subsequently mixed with other waters by users or user associations. This standard can also be used as voluntary safety guideline for all types of irrigation schemes regardless the source of water along the food value chain, as illustrated in Figure 2.

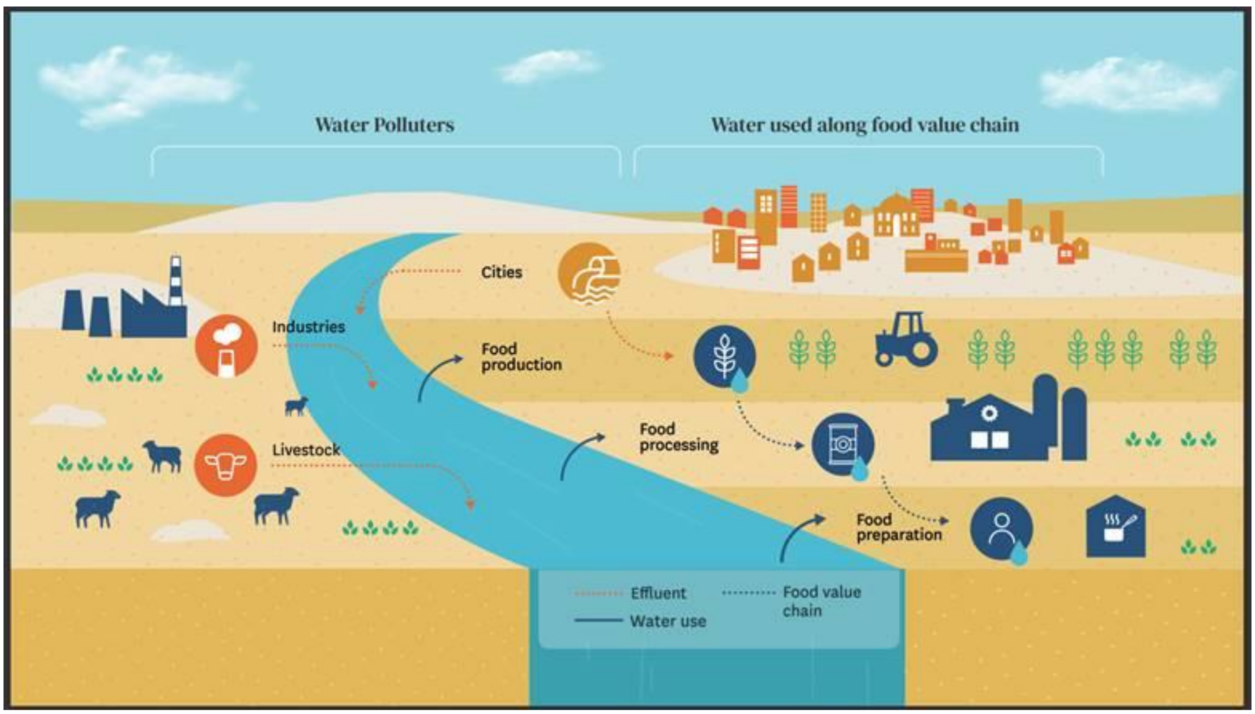


Figure 2. The fate of wastewater showing the sources of wastewater and its direct and indirect uses along the food value chain (*Source: Published in Mateo-Sagasta et al. 2022 and Mateo-Sagasta et al., 2023).*

The National Water Reuse Standard is valid for all irrigation and agricultural applications of TW from all types of municipal or domestic wastewater treatment plants (WTPs) regardless of whether such plants are publicly or privately owned, centralized or decentralized, conventional or unconventional systems (such constructed wetlands, water stabilization ponds, macrophyte treatment etc.). These standards are not for the effluents of WTPs that exclusively treat industrial wastewater. Finally, it is not concerned with any of the other uses of treated water, such as for industrial purposes, fire-fighting or aquaculture.

This National Water Reuse Standard describes processes and factors for assuring the health, environmental and safety of water reuse projects in irrigation, namely:

- Meticulous monitoring of treated water quality to ensure the system functions as planned and designed in order to avoid disease transmission by the pathogens in the water.
- Design and maintenance instructions of the irrigation systems to ensure their proper long-term operation;
- Compatibility between the treated water quality, the distribution method, and the intended soil and crops to ensure a viable use of the soil and undamaged crop growth;
- Compatibility between the treated water quality and its use to prevent or minimize possible contamination of groundwater or surface water sources.

The success of projects which use treated water for irrigation and agricultural purposes requires concerted efforts of the bodies concerned with agriculture, irrigation, health, the environment, etc. It is imperative that the bodies responsible for implementing this National Water Reuse Standard understand that reusing water in irrigation comes as a final stage in a series of processes, beginning with wastewater collection networks, and followed by transportation and treatment at treatment plants. This means that the final return and impact on the environment and on public health are directly influenced by all preceding stages.

The National Water Reuse Standard is developed in 5 Chapters, 1 normative Annex and informative annexes as follows:

Chapter 1. Introduction to water reuse

Chapter 2. Standards of treated water quality to be used in irrigation

Chapter 3. Controls and requirements for the protection and effective performance of technology and infrastructure

Chapter 4. Controls and requirements for health protection for farmers, operators and consumers

Chapter 5. Self-monitoring and inspection of water reuse projects

Annex 1: Normative Annex

Chapter 2. Standards of treated water quality allowed for use in irrigation

In this chapter, the standards of treated water quality allowed for use in irrigation are described. The various classes of treated water are characterized by the levels of the specified contaminants and are correlated to the various potential uses.

2.1. The types of irrigated plants and crops

This Standard allows growing all types of plants, except underground crops that are consumed raw such as carrots or onions. Plants and crops, which can be irrigated with TW are classified in following categories:

- **Food crops:** All crops which are used for human food. For the purposes of this Standard, food crops are divided into six categories:
  1. ***Vegetables eaten raw:*** Vegetables which are eaten raw (uncooked), such as lettuce, cucumber, and tomato.
  2. ***Fruit peeled before eating***: Fruit trees which produce a fruit with an inedible skin, such as banana, mango, lemon, citrus, and nut trees.
  3. ***Fruit eaten without peeling:*** Fruit trees which produce a fruit with an edible skin, such as apple, apricot, pear, and plum trees.
  4. ***Processed food crops:*** Crops which are eaten after being cooked at home or processed under high temperature conditions, such as wheat, barley, oat, and maize, in addition to vegetables which are eaten cooked.
  5. ***Tuber and root crops:*** Crops the edible part of which grows underground and has physical contact with irrigation water, such as carrot, onion, radish, beet, and potato.
  6. ***Medicinal plants:*** Consumed raw, sun dried or processed into spices, such as thyme (Lebanese Zaatar), cumin, etc.

- **Non-food crops:** Crops that are not intended for human consumption:
  1. ***Crops to feed milk- or meat-producing animals:*** Forages, pastures, etc.
  2. ***Industrial Crops:*** Crops which are used in industrial production, which have been divided as follows: a) Fiber Crops: Such as cotton and flax; b) Biofuel and energy oil crops.
  3. ***Ornamentals:*** Plant nurseries, ornamental nurseries, etc

- **Gardens and landscape areas:**
  1. ***Areas with direct public exposure:*** Parks, public gardens, private gardens, lawns, sport fields, other areas.
  2. ***Areas with limited public exposure:*** Lawns, wooded areas, road sides outside urban areas, other areas.
  3. ***Areas with no access to the public***: Wooded areas, forests, other areas.

2.2. Requirements applicable to treated water to be used for irrigation

The classes of treated water quality as well as the allowed use and irrigation methods for each class are listed in Table 2.

Table 2. Classes of reclaimed water quality

Reclaimed water quality class[1]	BOD_5 (mg/L)	COD (mg/L)	TSS (mg/L)	*E. coli* (CFU/100 ml)	Intestinal nematodes_helminth eggs (eggs/L)	Other
I	≤ 20	≤ 100	≤25	≤100	≤1	*Legionella spp.: <1,000 CFU/L where there is risk of aerosolization in greenhouses*
II	≤ 25	≤ 125	≤ 25	≤1000		
III	≤100	≤250	≤ 60	≤10000		

[1] *With each type of treated water quality, the use of a higher quality treated water is always possible. In addition, in case there are several crops grown in the same field, the water quality class will be the most stringent for the most sensitive crop.*
The threshold values in Table 2 are compulsory for direct water reuse projects. However, they can be used as safety guideline values for all types of irrigation schemes regardless the source of water.
These standards are applicable to any water treatment system or technology as long as they can generate the required water quality. Such systems/technology may include conventional treatment systems, natural biological treatment systems (constructed wetlands, stabilization ponds, macrophyte systems, etc.), etc.
Indicative technologies include:

- *Secondary treatment such as activated sludge, trickling filters, rotating biological contactors, biofilters, bioreactors, sequence batch reactors, etc.*
- *Filtration such as micro-screening, cartridge filtration, high rate sand filtration, dual media filtration, cloth filters, and disc filters without or with chemical addition (contact filtration) as well as membrane processes including membrane bioreactors.*
- *Disinfection such as UV irradiation, ozonation, chlorination, or other chemical, physic chemical, or membrane processes. Residual chlorine dosage has to be maintained between 0.2 mg/L to 1 mg/L, and measured after 30 min contact time. If there is a risk of aerosolization, the Legionella spp should be less than 1,000 CFU/L for greenhouses.*

The reclaimed water will be considered compliant with the requirements set out in Table 2, if the measurements meet all of the following criteria:

- The indicated values for *E. coli* and *Legionella spp* and intestinal nematodes are met in 90 % or more of the samples (see Chapter 5). None of the values of the samples can exceed the maximum deviation limit of 1 log unit from the indicated value for *E. coli* and *Legionella spp* and 100 % of the indicated value for intestinal nematodes.

- The indicated values for BOD_5 and TSS in Class I are met in 90 % or more of the samples. None of the values of the samples can exceed the maximum deviation limit of 100 % of the indicated value.
- Monitoring in the first year(s) of the establishment of the water reuse project should be more frequent. Once a WTP/system has shown to be reliable, the monitoring can be less frequent (following the monitoring protocol provided in Table ٩_Chapter 5).
- Finally, these standards are not to prevent pollution at the source, however, any existing national regulations to prevent pollution at the source should be met.

Table 3. Classes of reclaimed water quality and allowed agricultural use and irrigation methods

Minimum reclaimed water quality class	Plant and crop category	Plant and crop sub-category	Irrigation method
I	Food crops	Vegetables eaten raw where the edible part is produced above ground and is not in direct contact with reclaimed water.	Drip and sub-drip irrigation only
	Gardens and landscape areas	With direct public exposure	All irrigation methods*
II	Food crops	Processed food crops	All irrigation methods
		Fruit peeled before eating	All irrigation methods
		Fruit eaten without peeling	All irrigation methods except sprinklers
		Tuber and root crops that are eaten cooked	All irrigation methods
		Medicinal plants consumed raw, sun dried or processed into spices	All irrigation methods
	Non-food crops	Crops to feed milk- or meat-producing animals	All irrigation methods
	Gardens and landscape areas	With limited public exposure	All irrigation methods*
III	Non-food crops	Industrial and energy crops	All irrigation methods
		Ornamentals	All irrigation methods
	Gardens and landscape areas	with no access to the public	All irrigation methods

* *It is only permissible to use low-pressure high discharge pop-up sprinklers at an angle of less than 11 degrees*

2.3. Maximum limits for chemicals and metals in treated water

Table 4 provides the requirements for chemicals and metals in treated water. The given requirements are irrespective from the type of crop and irrigation methods and are relevant to all classes of treated water. Most of the parameters' thresholds are taken from the publication of the Food and Agriculture (FAO) 'Water Quality in Agriculture' (Ayers and Westcot, 1985) considering that those parameter values continue to be widely used and reported in different international and national guidelines, standards or regulations. The thresholds refer to the maximum recommended values for the protection of both crops and human health.

It is important to highlight that the provided values for chemicals and metals are compulsory. They have to be compulsory monitored in treated water according to the indications provided in Table ٩_Chapter 5 that explains the monitoring process of those elements in water, crops, and soil.

Table 4. Maximum limits of chemical elements in TW used for irrigation purposes

Parameter	Unit	Value
Aluminum	$mg.L^{-1}$	5
Arsenic	$mg.L^{-1}$	0.1
Beryllium	$mg.L^{-1}$	0.1
Boron	$mg.L^{-1}$	1
Calcium	$mg.L^{-1}$	230
Cadmium	$mg.L^{-1}$	0.01
Cobalt	$mg.L^{-1}$	0.05
Chromium	$mg.L^{-1}$	0.1
Copper	$mg.L^{-1}$	0.2
Electrical conductivity EC	$dS.m^{-1}$	3[a]
Fluorine	$mg.L^{-1}$	1
Iron	$mg.L^{-1}$	5
Bicarbonates	$mg.L^{-1}$	400
Mercury	$mg.L^{-1}$	0.002
Lithium	$mg.L^{-1}$	2.5
Magnesium	$mg.L^{-1}$	100
Manganese	$mg.L^{-1}$	0.2
Molybdenum	$mg.L^{-1}$	0.01
Sodium	$mg.L^{-1}$	230
Nickel	$mg.L^{-1}$	0.2
Lead	$mg.L^{-1}$	0.2[b]
Phenols	$mg.L^{-1}$	0.002
Phosphates	$mg.L^{-1}$	30
Nitrates	$mg.L^{-1}$	30
Selenium	$mg.L^{-1}$	0.02
Sulfates	$mg.L^{-1}$	500
Sodium Adsorption Ratio (SAR)	-	6 – 9
Total dissolved solids (TDS)	$mg.L^{-1}$	2000[a]
Vanadium	$mg.L^{-1}$	0.1
Zinc	$mg.L^{-1}$	2

Source: Adapted from Ayers and Westcot, 1985;
[a]The relative tolerance of each crop type to irrigation water salinity has to be taken into consideration. Tables classifying the crops according to their tolerance and sensitivity to salinity will be provided in Chapter 4.
[b]The maximum threshold value for Pb of 0.2 $mg.L^{-1}$ was taken from the Jordanian Standards (Jordan, 2014). It is more strict than the value of 5 $mg.L^{-1}$ provided by Ayers and Westcot (1985).

Chapter 3. Controls and requirements for the protection and effective performance of technology and infrastructure

This part of the Standard covers the controls and requirements for the protection and effective performance of the system's technical components (storage and additional treatment facilities; distribution pipeline network; irrigation systems) for the reuse of TW for irrigation.

3.1. Instructions for storage and additional treatment facilities

According to this Standard, TW storage facilities can be installed for the following conditions:

- When there is a need to manage daily and seasonal variations in TW flow to meet peak irrigation demands, storage excess of TW, and minimize the consequences of a disruptive operation of WTP. In such cases, operational and seasonal storage facilities are needed to be installed downstream the WTP.
- If there is a need to provide additional treatment to the TW, when managers of irrigation systems need to control changes of water quality that can affect the operation of the irrigation system or to improve the TW quality. In such cases, storage facilities can also be used.

Additional treatment steps might be necessary to achieve the TW (physical, chemical, or biological) quality required for the planned use (according to Chapter 2). For example, filtration (particularly in sprinkler and micro-irrigation systems) and disinfection (e.g. chlorination) are often needed.

Additional information on the types of storage facilities and the management strategies that should be adopted to reduce physical, chemical, and biological problems associated with water storage are indicated in Annex A.

3.2. Instructions for the distribution pipeline network

Like any irrigation project, a TW distribution network consists of a pump, pipelines and fittings. A description of such network is provided in Annex B.

- It is imperative to maintain the distribution network to prevent bacterial regrowth through flushing and periodically purging or chlorinating the pipelines.
- The Standard requires separating the TW main supply lines from the drinking water sources (wells) to a distance that will ensure that TW does not flow to the well. Other information and recommendations are provided in Annex C
- It is also necessary to paint (for example in red) water pipelines and their related equipment for use with TW to prevent cross connections with drinking water pipelines. Examples of painting and marking TW irrigation pipelines and systems are presented in Annex C.

3.3.Instructions for the effective performance of the irrigation systems

This Standard allows using two groups of irrigation systems for agricultural and landscape irrigation: pressurized irrigation systems and gravity flow irrigation systems, as indicated in Table 5.

Table 5. Irrigation systems and techniques used in common pressurized irrigation and gravity flow systems

Pressurized irrigation		**Gravity irrigation flow**
Sprinkler irrigation systems	**Micro-irrigation systems**	**Surface irrigation systems**
Using stationary sprinkler systems (portable, semi-portable, semi-permanent solid set or permanent equipment)	Drip irrigation: • Surface • Sub-surface Micro-spray irrigation	Border irrigation: • Straight • Contour Check basin irrigation: • Rectangular • Contour • Ring Furrow irrigation: • Graded furrow • Corrugation

Source: NL ISO 16075-1 (2015)

- Sprinkler systems:
  - These systems (especially the overhead systems) must not be used to irrigate vegetables eaten raw and trees with fruits eaten without peeling.
  - It is only permissible to use low pressure high discharge pop-up sprinklers at an angle of less than 11 degrees when irrigating gardens and landscape areas with direct or limited public exposure.
  - With sprinkler irrigation, it is suggested to respect the recommended minimal distances between irrigated areas and residential areas according to TW quality, as shown in Table 6. This would help preventing aerosols that can pose potential risks for farmers, hired workers, and the population surrounding the irrigated plots.

Table 6. Distance between irrigated borders and “protected” areas according to TW quality considering wind speed of up to 4 m/s (adapted from Molle et al. (2009) and ISO standards listed in the references).

TW category	**Sprinkler characteristics**		**Distance between wetted area [a] and area to be protected [b]**	
	Radius of throw	**Maximum operating pressure [c]**	**With screen [d]**	**Without screen**
I	Low radius: <10 m	≤3,5 bar	5 m	20 m
	Medium radius: 10 m to 20 m	≤4,0 bar	10 m	30 m
	Large radius: >20m	≤5,5 bar	10 m	40 m
II	Low radius: <10 m	≤3,5 bar	10 m	40 m
	Medium radius: 10 m to 20 m	≤4,0 bar	15 m	50 m

	Large radius: >20 m	≤5,5 bar	20 m	60 m
III	Low radius: <10 m	≤3,5 bar	20 m	50 m
	Medium radius: 10 m to 20 m	≤4,0 bar	30 m	60 m
	Large radius: >20 m	≤5,5 bar	40 m	70 m

a) Area receiving water without wind.
b) Residences, playgrounds, gardens, road, gardens open to the public (sport fields, etc.), and industrial buildings.
c) It is recommended that the system will include a device that prevent higher pressure than specified.
d) Trees constituting a hedge or any other fixed or mobile screen (walls, wind breaking nets, etc.) which minimum height is jet maximum height

- Micro-irrigation systems 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 microspray irrigation systems:
  This Standard allows using only surface and subsurface drip systems for the irrigation of vegetables eaten raw and trees with fruits eaten without peeling.
  The microspray systems might not be used to irrigate vegetables eaten raw and trees with fruits eaten without peeling.
- When needed, it is recommended to analyze irrigation water at the following sampling points: the water source (WTP, reservoir), in the irrigated plot after the treatment area (filtration, disinfection, etc.), and at the end of a lateral flushing until turbidity remains constant. This would help preventing water emitters clogging. The results of the analysis would guide about the required test frequency and also which additional parameters, such as: iron, manganese, $CaCO_3$, and chemical precipitates or dissolved solids should be monitored to accurately analyze the effect of water quality on the irrigation system. It should be noted that this action is not mandatory.

Additional recommended annexes for reading are the following:

- Guidelines for injecting chlorine into drip irrigation systems (Annex D);
- Guidelines for acid use (Annex E);
- Permitted chemicals (Annex F).

3.4.Emergency plan

Each project has to have an emergency plan in case the WT system fails. Particularly in the early stages of the implementation of the water reuse project, a contingency plan that addresses potential difficulties and disasters has to be developed. The plan should include a detailed series of steps to be followed in each case.
The emergency plan may include:

- Back-up power for unforeseen power cuts
- Actions for unusual events (flooding, earthquakes, etc.)
- Reserve or equalization tanks, by-pass or alternative pathways for disposal of untreated water or non-conforming effluent.
- Identification of an alternative source of irrigation water in case the supply of treated water is interrupted due to an emergency. This source can be groundwater, or any other source of water, or treated water supplied by another water treatment plant through temporary pipelines or any other means.

Chapter 4. Controls and requirements for health protection for farmers, operators and consumers

The present chapter of the National Water Reuse Standard provides the controls and requirements for health protection for farmers, operators and consumers. Particularly, instructions on the various options/barriers, with respect to the WHO multibarrier approach, to reduce the health risks of using TW to irrigate crops are given.

Information on the concept of the WHO multiple barrier approach is provided in Annex G.

4.1. Instructions on the types of barriers

The suggested types of barriers can be adopted as health protection measures, as presented in Table 7. For each type, a number of corresponding barriers is accredited as shown in the table shown. The barriers are qualified as preventive measures provided that good practices are implemented. For example, fruits and vegetables with edible skin should not be recovered from the ground.

Table 7. Suggested types and accredited number of barriers (adapted from WHO 2006, USEPA 2012 and ISO standards listed in the references).

Type of barrier	Application	Pathogen reduction (log units)	Accredited number of corresponding barriers
Irrigation of food crops			
Drip irrigation	Drip irrigation of low-growing crops such as 25 cm or more above from the ground	2	1
	Drip irrigation of high-growing crops such as 50 cm or more above from the ground	4	2
	Subsurface drip irrigation where water does not ascend by capillary action to the ground surface	6	3
Spray and sprinkler irrigation	Sprinkler and micro-sprinkler irrigation of low-growing crops such as 25 cm or more from the water jet	2	1
	Sprinkler and micro-sprinkler irrigation of fruit trees such as 50 cm or more from the water jet	4	2
Additional disinfection in field	Low level disinfection	2	1
	High level disinfection	4	2
Sun resistant cover sheet	In drip irrigation, where the sheet separates the irrigation from the vegetables (plastic mulch)	2 to 4	1
Pathogen die-off	Die-off support through irrigation cessation or interruption before harvest	0,5 per day [a)]	1 to 2 [a)]
Produce washing before selling to the customers	Washing salad crops, vegetables, and fruits with drinking water	1	1

Produce disinfection before selling to the customers	Washing salad crops, vegetables, and fruits with a weak disinfectant solution and rinsing with drinking water	2	1
Produce peeling	Peeling of fruits and root crops	2	1
Produce cooking	Immersion in boiling water or under high temperature until the product is cooked	6 to 7	3
Irrigation of fodder and seeded crops			
Access control	Restricting entry into the irrigated field for 24 h and more after irrigation, for example, animal entering in pastures or entering of field workers	0,5 to 2	1
	Restricting entry into the irrigated field five days and more after irrigation	2 to 4	2
Sun drying of fodder crops	Fodder crops and other crops that are sun-dried and harvested before consumption	2 to 4	2
Irrigation of public gardens			
Access control	Irrigation by night when the public does not enter the irrigated parks, sport fields, and gardens	0,5 to 1	1
Spray irrigation control	Spray irrigation at distances greater than 70 m from residential areas or places of public access	1	1

NOTE Applying disinfection to the TW or filtering the TW through appropriate membrane filter like Micro Filtration, Ultra Filtration, or Nano Filtration will destroy or remove pathogens.

[a] According to crops and weather conditions.

4.2. Barriers needed for irrigation with TW according to their quality

Table 8 indicates the number of barriers needed for irrigation with TW taking into account the TW quality level and the types of crops that are provided here in the Lebanon Standard document. In addition, examples for calculating the numbers and types of barriers are provided in Annex H.

Table 8. Suggested number of barriers that are needed for irrigation with TW according to their quality (adapted from WHO 2006, USEPA 2012 and ISO standards listed in the references).

Category of TW	Irrigation of gardens and landscape areas with direct public exposure	Irrigation of gardens and landscape areas with limited public exposure	Irrigation of gardens and landscape areas with no public access	Vegetables eaten raw where the edible part is produced above ground and is not in direct contact with reclaimed water.	Processed food crops	Fruit Peeled before Eating	Fruit Eaten without Peeling	Tuber and root crops that are eaten cooked	Medicinal plants consumed raw, sun dried or processed into spices	Crops to feed milk- or meat-producing animals	Industrial and energy crops	Ornamentals
I	1	1	0	1	0	0	1	0	0	0	0	0
II	forbidden	1	0	3	2	1	1	0	0	0	0	0
III	forbidden	forbidden	0	forbidden	forbidden	3	3	2	2	1	0	0
Raw wastewater	forbidden	forbidden	Forbidden	forbidden	forbidden	forbidden	forbidden	forbidden	forbidden	forbidden	forbidden	forbidden

4.3. Instructions on crop Selection and irrigation strategy in response to salinity and toxicity hazards

In selecting which crop to grow, it is important to take into account the crop tolerance to the salinity and toxicity hazards.

- For higher salinity of TW (more than 3.0 dS/m) and sensitive crops, increasing leaching to satisfy a leaching requirement greater than 25 to 30% might not be practiced because of the excessive amount of water required. In such a case, consideration must be given to changing to a more tolerant crop that will require less leaching, to control salts within crop tolerance levels. Annex I presents a list of crops classified according to their tolerance and sensitivity to salinity (Table I1), while Table I2 illustrates the maximum soil salinity (electrical conductivity of soil saturated paste extract – ECe (dS/m)) that crops can tolerate before showing a decrease in production.
- When the farmer has additional sources of water supply, it is recommended to blend conventional water with treated effluent or use the two sources in rotation. By blending its salinity would be reduced.
- Some guidance on the sensitivity of crops to sodium, chloride and boron in water and soil are given in Annex I, Tables I3, I4, I5 and I6.

Chapter 5. Self-monitoring and inspection of water reuse projects

As per the requirements of this Water Reuse Standard, the key prerequisites for the success of the TW reuse project are the adoption of:

- A quality assurance plan for self-monitoring and inspection.
- A health risk management plan with health risk mitigation measures along the reuse value chain.

5.1. A quality assurance plan for self-monitoring and inspection

5.1.1. Water quality

Monitoring water quality is necessary to ensure that TW intended for reuse satisfies the requirements of this Standard, in line with the 3 grades of quality (I, II and III, as described in Chapter 2):

The control must be carried out along the whole TW reuse project, particularly at the exit of the WTP (WTP_Outlet) (refer to Figure 3_Annex1 that illustrates a TW reuse project).

A minimum of three water samples must be collected per each sampling time. The minimum analysis frequencies of taken samples are specified in Table 9.

The quality of the TW will be considered adequate to the requirements of this Standard if:

- At least three out of the three samples will have results lower than the threshold values in all parameters specified in Table 2_Chapter 2.

5.1.2. Crops/plants, soil groundwater and workers' health

Samples of crops/plants irrigated using TW must be collected at the point of use, before getting delivered to the market to be tested for *E. coli*, *fecal streptococcus*, nematodes, etc. The sampling frequency schedule is provided in Table ٩.

Soil samples from the point of use should be collected and analyzed particularly for salinity and metals accumulation, based on the frequency schedule provided in Table 10. Collected samples must be representative of the soil in the site, with a composite sample taken from every 1 dunum.

Risks of groundwater pollution depend on the quality of TW and the depth of the water table. Therefore, groundwater samples should be collected by the MoE in collaboration with the MoEW for analysis once per year during summer season.

The protection requirements for agricultural workers include periodic checkups to be conducted based on the frequency schedule provided in Table ٩. Personal hygiene and related practices, such as hand washing, drinking, eating, smoking and using toilets, must be confined to premises outside the farms and fields irrigated with TW, in order to reduce the risk of pathogen infections.

If self-monitoring or inspections detect, at any time, an issue, immediate corrective actions must be taken as soon as possible by the responsible entity.

5.1.3. Inspection visits and reporting

The entity responsible for inspection can visit and inspect the water reuse project anytime without being obliged to inform in advance the entity responsible for operating and maintaining the project. The entity responsible for inspection shall collect and analyze samples as required, at the expense of the entity responsible for operation and maintenance, based on the minimum frequency schedule provided in Table ٩, and shall take the necessary actions in case of non-conformity. However, the inspecting entity may carry out as many analyses and inspections as it deems appropriate to verify the characteristics of the TW and the performance of the TW reuse project. To this end, the owners or operators of the facilities subject to surveillance or inspection are obliged to facilitate access to their administration, as well as to collaborate and provide the necessary documentation to the requirement of the inspection work. All the results derived from the quality control must be included in a registration system that will be available when needed.

Reports on the results of the quality assurance plan must be presented every year to the "Committee of Regulators" lead by the MoEW (refer to Annex 1, paragraph 1.1.3). The Committee shall review submitted reports and ensure that corrective actions are implemented.

Table 9. Minimum sampling frequency of monitoring and inspection along the TW reuse project

What to sample?		Self-monitoring schedule: Minimum frequency of sampling for self-monitoring – TW Class I	Self-monitoring schedule: Minimum frequency of sampling for self-monitoring – TW Class II	Self-monitoring schedule: Minimum frequency of sampling for self-monitoring – TW Class III	Self-monitoring schedule: Who will self-monitor?	Self-monitoring schedule: Where to self-monitor?	Inspection schedule: Minimum frequency of sampling for inspection	Inspection schedule: Who will inspect?	Inspection schedule: Where to inspect?
Water	BOD_5 - COD - TSS	3 times a week	3 times a week	Weekly	Operator of the WTP; Operator of the Reuse Network[2]	WTP_Outlet; [3]	at least once per month during the season[4]	MoEW; MoE[5]	WTP_Outlet[3]
	E. coli	3 times a week	3 times a week	Weekly					
	Helminth eggs - *Legionella* (when necessary)[1]	Weekly	Weekly	Weekly					
	Other contaminants (example metals, etc.)	Every 6 Months	Annually	Annually					
Soil		Annually	Annually	Annually	User[2]	Point of Use[2]	Annually	MoA	Point of Use
Crops/Plants		Every Season	Every Season	Every Season	User	Point of Use	Every season	MoA; MoPH	Point of Use
Groundwater		–	–	–	–	–	Annually (Summer time)	MoE; MoEW	Along the whole chain of the TW reuse project
Medical Checkups for Farm Workers		Annually	Annually	Annually	Operator of the WTP; Operator of the Reuse Network; User	Along the whole chain of the TW reuse project	Annually	MoPH	Along the whole chain of the TW reuse project

[1] *Legionella must be monitored only when there is a risk of aerosolization in greenhouses (refer to Table 2 in Chapter 2).*

[2] *Annex 1 provides more explanation on the role and responsibilities of the different actors along the key points of a TW reuse project. Particularly, Figure 4 will illustrate the distribution of responsibilities in self-monitoring and inspection of a TW reuse project.*

[3] *When the irrigation scheme of the reuse project consists of open or closed canals, effluent analysis must be performed not only at WTP_Outlet but also at TW_Delivery points in order to check its compliance with the limit values of this Standard (Table 2 in Chapter 2).*

[4] *A season is a period of the year during which a crop is cultivated and harvested.*

[5] *For* ***a direct reuse of TW****, the MoEW will be the inspection entity that will have to monitor the compliance of the TW with the limit values of this Standard (Table 2 in Chapter 2).*

WTP: Wastewater Treatment Plant; TW: Treated Water; WTP_Outlet: TW at the outlet of the WTP before it enters the Reuse Network; TW_Delivery point: TW leaving the Reuse Network and being delivered to the point of use; MoEW: Ministry of Energy and WATER; MoE: Ministry of Environment; MoA: Ministry of Agriculture; MoPH: Ministry of Public Health.

5.2. A health risk management plan

A TW reuse project must ensure that public health and the environment are protected. This is best achieved through a risk management approach, which involves identifying and managing risks, rather than simply reacting to problems if they arise.

It is always recommended to have a risk management plan designed and implemented by the different agents of the TW reuse project for the self-monitoring along the whole TW reuse chain.

The present Standard provides a stepwise method to follow for assessing risks to human health and the environment. The approach is illustrated in the Figure 3. In addition, it focuses on managing those risks through the WHO multiple barriers approach by using a series of preventive measures referred to as multiple barriers to control potential hazards, as described in Chapter 4.

Assessing risks to human health		Assessing risks to the environment
Identify the hazards that might be present in water and what effect those hazards may have on human health.	**Step 1.** Identify hazards and hazardous events	**Identify the hazards** that might be present in water and the hazardous events that could occur, and the effect they may have on the environment.
Work out how likely it is that humans will be exposed and the amount (dose) of the hazard that relates to the likelihood of illness (response).	**Step 2.** Estimate likelihood	**Work out how likely it is that hazardous events** (such as a sudden increase in salinity) will happen.
Consider the possible impacts of a hazard or hazardous event, in terms of the potential seriousness of the impact and the size of the population likely to be affected	**Step 3.** Assess impact	**Consider the possible effects of a hazard** or hazardous event, both where the TW will first be used (e.g. to water crops) and where it might end up (e.g. in groundwater).
Combine the information gained from Steps 1–3 to assess the overall risk posed by each potential hazard.	**Step 4.** Characterize the risk	**Combine the information gained from Steps 1–3 to assess the overall risk** posed by each potential hazard or hazardous event..

Figure 3. A stepwise approach for assessing risks to human health and the environment.

The process of risk management can be summarized as a series of questions that fall into three main categories:

- **Assessing risks**
  - What might happen?
  - What is the likelihood that it will happen?
  - How serious will it be if it does happen (i.e. impact or consequence)?
- **Managing risks**
  - What can we do to stop it happening?
- **Monitoring and reviewing risks**
  - Are the individual measures operating correctly?
  - Did the management system work?

The table below shows how each of these questions might apply to a TW reuse project. Each question is illustrated with examples of risks to human health and the environment.

Table 10. Process of risk management with some examples

Question	Action	Example—human health	Example—environment
What might happen?	Look at possible hazards in the TW that could affect human health or the environment	Presence of *E. coli*, which could cause illness to people	High levels of salinity, which could negatively impact crop yields
What is the likelihood that it will happen? How serious will it be if it does happen?	For each hazard identified, assess through the whole project how likely it is that the event will happen and the potential consequences if it did	Raw wastewater is highly likely to contain *E. coli* bacteria; TW less likely, if treatment process is efficient. Infection with *E. coli* can cause severe illness in some cases.	TW have a high level of salinity. Salinity can corrode assets, stress plants, and contaminate groundwater and surface water
What can we do to stop it happening?	Identify preventive measures (multiple barriers) to control hazards	Adopt some of the WHO multiple barriers that are described in Chapter 4 (for example ensuring an efficient treatment of water, use drip or subdrip irrigation system, etc.)	Avoid growing crops that are sensitive to salinity; blend TW with fresh water in order to reduce its salinity
Are the individual measures operating correctly? Did the management system work?	Monitor to ensure that the preventive measures are working effectively, and verify to check that the system consistently provides TW of a quality that is fit for its intended use	Monitor quality of treated water and performance of treatment processes; make sure that farmers are using drip or subdrip systems	Monitor to ensure that quality of treated water and soil salinity is maintained at appropriate levels

Annex 1 (Normative)

This annex covers the institutional aspects of implementing irrigation reuse projects, as well as the requirements and procedures for assessing the environmental and health impacts of using treated water in agriculture. This annex serves as a foundation for ensuring effective oversight by the relevant public administrations and institutions over water reuse projects, to verify compliance with the requirements set in this standard when it is issued as a technical regulation. It also outlines an effective coordination mechanism between the various concerned parties.

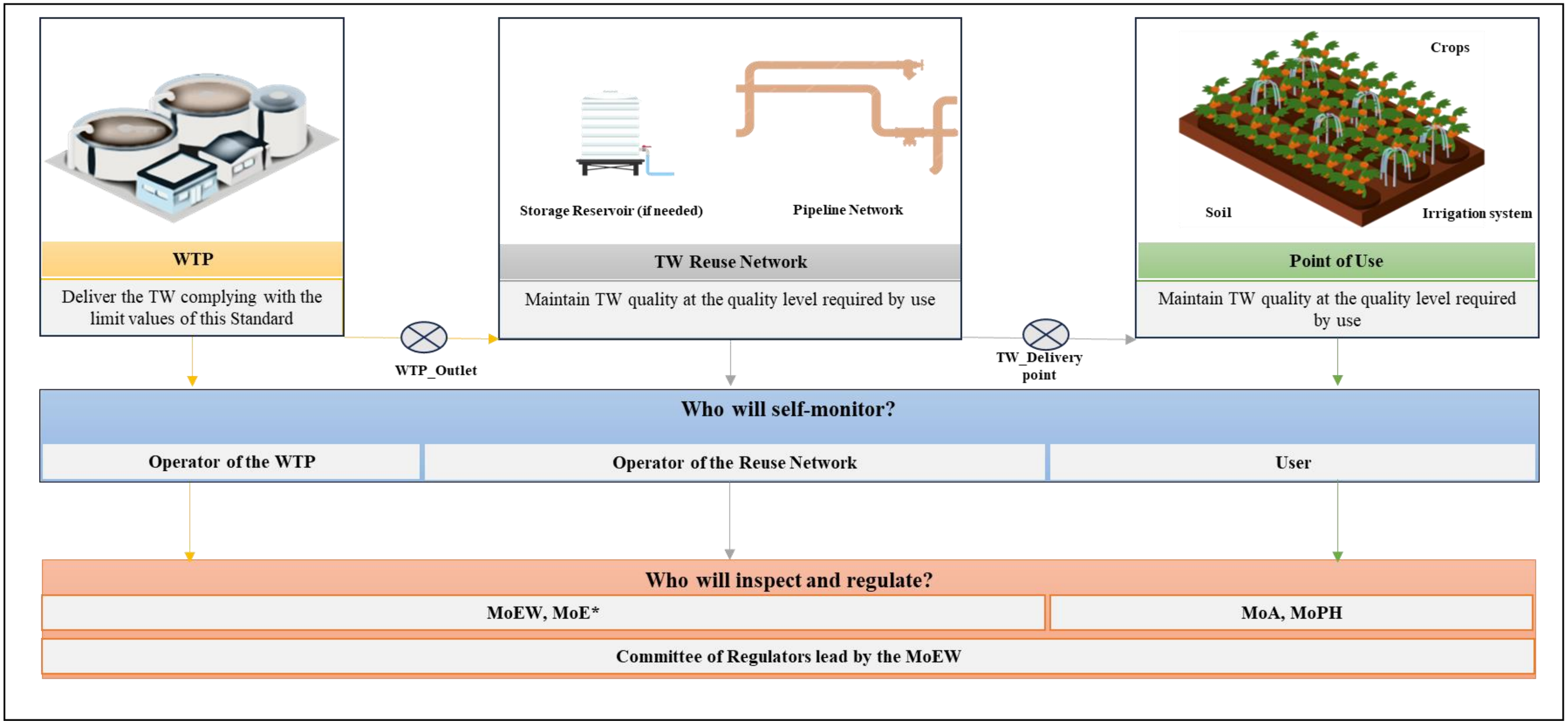
The administrations mentioned in this annex, in accordance with applicable laws and regulations, are responsible for issuing the necessary decisions to ensure the implementation of the proposed mechanism outlined below.

1-1 Institutional aspects of implementing irrigation reuse projects

The agents involved in a TW reuse project respectively assume certain responsibilities that are summarized below:

- **The Operator of the WTP** is responsible for the quality of the discharge and of its control up to the outlet point of the WTP **(WTP_Outlet)**.
- **The Operator of the reuse network** is responsible of the quality of the TW and its control from the point at which TW water enters the reuse system until the delivery point **(TW_Delivery Point)**.
- **The User** of the TW is responsible for avoiding the deterioration of its quality from the TW_Delivery Point to the **Point of Use**.

Figure 4 summarizes the distribution of responsibilities in self-monitoring and inspection of a TW reuse project.



** For a **direct reuse of TW**, the MoEW will be the inspection entity that will have to monitor at both WTP_Outlet and TW_Delivery Point (only for irrigation schemes composed of open or closed canals) the compliance of the TW with the limit values of this Standard (Table 2 in Chapter 2).*

WTP: Wastewater Treatment Plant; TW: Treated Water; WTP_Outlet: TW at the outlet of the WTP before it enters the Reuse Network; TW Reuse Network: consists of the storage reservoir (if needed) and pipeline carrying TW to the point of use; TW_Delivery point: TW leaving the Reuse Network and being delivered to the point of use; MoEW: Ministry of Energy and WATER; MoE: Ministry of Environment; MoA: Ministry of Agriculture; MoPH: Ministry of Public Health.

Figure 4. Distribution of responsibilities in self-monitoring and inspection of a TW reuse project.

1.1.1 Responsibilities of the agents involved in a TW reuse project

The responsibilities of these entities with regard to the implementation of this National Water Reuse Standard are as follows:

- The government entity (such as the four Regional Water Establishments (WEs), the Council of Development and Reconstruction (CDR), and Municipalities) responsible for the establishment of WTP of which a project could be implemented shall be responsible for the TW Reuse project as of the planning phase. Such reuse project shall be deemed an integral part of the wastewater treatment project and that government entity shall be responsible for coordination with the "Committee of Regulators" (refer to paragraph 6.3) that is led by the Ministries of Energy and Water (MoEW) at all phases of implementation.
  These entities shall be responsible for planning TW reuse projects and for developing initial studies and preliminary designs for all components of such projects.
- The Operator of the reuse network, in collaboration with the Users, must assure implementing farm infrastructure works, while ensuring satisfaction of environmental and health protection requirements in accordance with the environmental and health impact study and in line with the requirements of this Standard.
- The Operator of the reuse network, in collaboration with the Users, must undertake all aspects of agricultural management of the farm, based on a cultivation plan developed in line with this Standard.
- The Operator of the reuse network, in collaboration with the Users, must train workers in health and environmental safety practices, providing them with tools and personal requirements and ensuring they undergo periodic checkups.
- The Operator of the reuse network must ensure painting all TW pipelines in other color (red for example as recommended in Chapter 3) and clearly printing the phrase "Wastewater. Unsuitable for drinking or human use" or other.
- The Operator of the reuse network, in collaboration with the Users, must maintain an appropriate system for recording, keeping, and reporting data in electronic or paper form. Backup files must also be kept to safeguard against data loss.
- The Operator of the reuse network, in collaboration with the Users, must implement the quality assurance plan, as described in Chapter 5.
- The Operator of the reuse network, in collaboration with the Users, must implement the monitoring plan for health risk reduction measures, as described in Chapter 5.
- The Operator of the reuse network shall submit the reports on the results of the self-monitoring and inspection program every year to the "Committee of Regulators" lead by the MoEW. The committee shall review submitted reports and ensure that corrective actions are implemented.

1.1.2 Responsibilities of local regulators

Government entities shall be responsible for discharging their regulatory duties, in their respective areas of competence, to ensure compliance on part of the entity responsible for TW reuse. Therefore, the MoEW will lead a "Committee of Regulators" with representatives from the MoA, MoE, MoPH, MoI.

This committee will be supported by local research institutions and laboratories, such as the Lebanese Agricultural Research Institute (LARI), in order to have scientific support on the topic of water reuse and to collect samples of water, soil and crops for laboratory analyses.

The "Committee of Regulators" shall have the competency to:

- Review environmental and health impact assessment studies for projects involving the reuse of treated water in agriculture that are convened by the MoE, as described in Annex 1, section 1.2.
- Review and approve the submitted reports by the Operator of the TW reuse project on the self-monitoring and inspection programs and ensure that corrective actions are implemented.
- Ensure that regulators will perform their inspection duties on the TW reuse projects in their respective areas of competence, as follows:

The MoEW shall be responsible for:

- Ensuring that the four Regional Water Establishments are efficiently operating and maintaining WTPs, pursuant to the relevant Standard.
- Where other entities, such as the CDR and municipalities, are contracted to manage and operate projects for the reuse of TW in agriculture, verifying that their works are in compliance with this Standard.
- Where private sector entities are contracted to manage and operate projects for the reuse of TW in agriculture, verifying that contracts are in compliance with this Standard.
- Inspection of TW quality at WTP_Outlet and TW_Delivery Point (for irrigation schemes composed of open or closed canals) for projects involving direct reuse of TW.
- Cooperate with MoE for the monitoring and inspection of groundwater quality.

The MoA shall be responsible for:

- Agricultural extension services.
- Inspection pollutants effects on the soil.
- Ensuring that the Users at the Point of Use of TW maintain compliance with this Standard with regard to selection of plants and crops.
- Taking legal action in case of non-compliance with the types of crops specified in this Standard and removal of violating crops.
- Inspection of irrigation water quality at the Point of Use in collaboration with LARI.
- Inspection of harvested crops and plants to ensure that they are free from pathogens and other pollutants, in cooperation with the Ministry of Health.

The MoE shall be responsible for:

- Ensuring compliance with the requirements provided of the environmental and health impact study for the reuse project in its construction and operation phases.
- Inspection of groundwater quality, in cooperation with MoEW, once per year during summer time.

The MoPH shall be responsible for:

- Ensuring the implementation of the Standard with regard to health protection for workers.
- Health controls for crops and agricultural products, if any, in cooperation with the MoA.

The Ministry of Industry (MoI) shall be responsible for:

- Performing inspections of industrial facilities that discharge into the wastewater network to ensure compliance with the national requirements and notify the competent manager at the WTP of the situation of violating facilities.

1.1.3. Additional responsibilities of different institutions along the sanitation food value chain

In addition to the responsibilities of the different institutions that are listed in paragraph 1.1.2., the following requirements shall also be taken into account along the sanitation food value chain to ensure water and food safety:

- The requirement to meet the environmental quality standards for priority substances and certain other pollutants of national concern (i.e. pesticides; disinfection by-products; pharmaceuticals; other substances of emerging concern; anti-microbial resistance): responsibility of the MoE and the MoI.
- The requirements regarding hygiene of foodstuffs and feed as well as microbiological risks in fresh fruits and vegetables at primary production set out in national standards or regulations: responsibility of the MoA.
- The requirement to comply with the relevant microbiological criteria and hygiene of foodstuffs and feed at the level of traders, retailers and consumers set out in national standards or regulations: responsibility of the MoPH, MoET.
- The requirements regarding maximum levels for certain contaminants in foodstuffs and seeds set out in national standards or regulations: responsibility of the MoI, MoA, MoPH, MoET.
- The requirements regarding animal health set out in national standards or regulations: responsibility of the MoA, MoPH, MoET.

1.1.4. Private Sector Owned Projects

The private sector may establish or manage projects for the reuse of TW in agriculture, while ensuring compliance with applicable clauses of this Standard, as follows:

- Conducting an environmental and health impact study for the project, obtaining the approval of the competent authority, and following the procedures set out in para.1.2 of this Annex.
- Complying with all requirements elaborated in this Standard with regard to water quality, types of plants and crops, methods of irrigation, and health and environmental safety requirements.
- All private sector entities responsible for managing projects for the reuse of TW in agriculture shall be subject to all provisions of Clause 1.1.3 with regard to monitoring and oversight by government authorities, each in its area of competence.

1-2 Requirements and procedures for assessment of the environmental and health impact of a project for using treated water in agriculture

- The entity, which is legally responsible for the implementation of a TW reuse project, whether a government entity or a private entity, shall conduct the environmental and health impact study for the project. The study shall be submitted to the MoE, following all procedures applicable in dealing with environmental impact assessment studies for projects.
- MoE shall convene the study to the “Committee of Regulators” (refer to paragraph 1.1.2 of this Annex). That committee shall have the competency to review the environmental and health impact assessment studies for projects involving the reuse of treated wastewater in agriculture.
- Required data can be summarized as follows:
  a. A report on the preliminary examination of the wastewater treatment plant, supported by design standards.
  b. Desired quantitative performance standards, including flow rate as well as the physical, chemical and biological composition of inflowing and outflowing effluent.
  c. Description of the site proposed for reuse, including:
     - A map of the general location including data of the surrounding environment endorsed by the competent authorities.
     - A survey map of the site.
     - A soil-boring report outlining characteristics of the soil and the extent of its suitability for agriculture.
     - Description of nearby watercourses (if any).
     - Determination of the level and quality of groundwater in the area.
  d. Description of the plan for the agricultural exploitation of the site, the method of irrigation to be applied and expected number of workers.
  e. A detailed analytical study of all expected environmental and health effects of the project over 30 years after commencement of operation.
  f. Description of mitigation measures and actions to be taken to reduce negative environmental and health effects to safe levels.
  g. Description of the water storage method to achieve a balance between the supply of treated water and the daily needs of water for irrigation.
  h. A plan for operating and maintaining the reuse facilities and equipment at the site.
  i. An emergency plan to address sudden changes in operational conditions and respond to disasters, including responses to environmental disasters.

j. A comprehensive environmental monitoring plan, including sampling and laboratory tests, pursuant to the requirements set out in this Standard.

- An environmental record for the project shall be maintained and made available for inspection at any time.
- A quality assurance plan (as described in Chapter 5) shall be put in place.

Annex A (informative)

Guidelines for the management of TW storage and additional treatment facilities

Source: NL ISO 16075-1_2015

A.1. Storage facilities types

Storage facilities can be **open tanks** (reservoirs or ponds) or **closed reservoirs** (covered or underground). Closed reservoirs are more expensive, but have several advantages: reduced evaporation, lower potential for algae growth, reduction of odor emissions, no possibility of contact of wastewater with people or animals, and protection of stored wastewater from rainfall runoff. The disadvantage of these reservoirs is that they require periodic cleaning due to biofilm formation.

There are two main types of storage, the short term and long-term storage. Short-term storage is needed in most irrigation systems for equalizing and balancing TW supply and application that occur during one or more days. 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.

A.2. Problems and management strategies of TW storage facilities

During the storage period, TW is subject to changes that affect its physical, chemical, and biological quality. Bacterial regrowth, nitrification, algae growth, and production of H_2S (responsible for odor emission and risk of corrosion to metal components in the irrigation system) are the main biological processes affecting the quality of stored wastewater. Increase in suspended solids and sediments, modification of pH, reduction of nutrients (particularly nitrogen), dissolved oxygen, and residual disinfectant are also effects that result from storage. Natural decay of microorganisms during storage depends on the water retention time and operation conditions of the reservoir. Management strategies that should be adopted to reduce physical, chemical, and biological problems associated with water storage in open and closed reservoirs are indicated in Tables A1 and A2.

Table A1. Problems associated with TW storage in open reservoirs and management strategies

Problems	**Management strategies**
Temperature stratification; Low content of dissolved oxygen; Release of odors	Installation of aeration facilities submerged or surface mixers or recirculating pumps; Maintaining elevated oxygen concentrations through the water column and mainly at the sediment water interface will prevent phosphorus from entering the water column and keep it in the sediment
Sediments	Periodic mechanical or hydraulic dredging of accumulated sediments (every one to five years)[a]

Excessive growth of algae and zooplankton	Proper mixing of water in order to improve the photo-oxidation of organic matter induced by the sunlight; Addition of chemical algaecides. Copper sulfate should not be used due to the toxicity effects associated with copper accumulation (overdosing has adverse impacts on reservoir ecosystem); Addition of chemical dyes to reduce sunlight penetration as well as the growth of algae; Biomanipulation of zooplankton (in shallow reservoirs); Ultrasonic emissions placed into the open reservoir
High content of suspended solids	Suspended solids removal depends on particle size and residence time, so consideration should be given to these factors when designing the storage tanks
Microorganisms' regrowth	Increase of disinfectant residual; Decrease of storage residence time; Isolate and disinfect problematic sites in pipelines
Increasing of insects namely mosquitoes	Spraying of adequate insecticides; Mechanical methods to keep the water moving; Biological controls such as natural larvicides and use of larvae eating fish; Keeping banks trimmed.

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

Source: adapted from NL ISO 16075-1_2015

Table A2. Problems associated with TW storage in closed reservoirs and management strategies

Problems	**Management strategies**
Water stagnation	Recirculation of water (pumping and configuration of inlet and outlet piping promoting water recirculation); maintaining elevated oxygen concentrations through the water column and especially at the sediment water interface will help prevent phosphorus from entering the water column and keep it locked in the sediment.
Low content of dissolved oxygen; Release of odors	Aeration (aeration devices)
Loss of disinfectant residual; Regrowth of microorganisms	Disinfection operation

Source: adapted from NL ISO 16075-1_2015

A.3. Filtration

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

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

Filtration could be set up downstream in open long-term storage reservoirs using a gravel filter, a sand filter, or a disc filter. The characteristics of filters commonly used in irrigation systems are indicated in Table A3.

Table A3. Characteristics of filter types commonly used in pressurized irrigation systems

Filter type	**Special features**	**Pressure head losses**
Strainer type filters; Disc filters	Irrigation systems with moderate level of suspended solids; Used in drip irrigation systems as back up of a media filter; Adequate to moderate level of filtration	Very low if screen or disks are clean
Granulated media filter (fine gravel or sand)	Often used in drip systems	1.0 m to 1.20 m

Source: adapted from NL ISO 16075-1_2015

A.4. Additional disinfection

Disinfection of TW that is supplied from storage reservoirs and through pipeline network should be ensured to avoid bacterial regrowth and algae development. Disinfection technologies may include oxidation materials to protect the irrigation system. The selection of the disinfection process for a specific irrigation system should take into consideration its effectiveness (bacteria, algae, virus, and protozoa removal or inactivation), reliability and complexity, safety concerns, residual toxicity, and costs. The chlorination demand for TW should be determined to define chlorine dosage and super chlorination techniques should be avoided to minimize organochlorinated compounds formation.

Annex B (informative)

Technical components of a water reuse distribution network
Source: NL ISO 16075-1_2015

B.1. Pumping stations

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

B.2. Pipelines and accessories

A distribution network consists of one or more main and sub-main pipes that ensure the TW transport directly from the WTP or from the distribution reservoir to the plots to be irrigated. The pipe materials most commonly used are ductile iron (DI), steel, polyvinyl chloride (PVC), high-density polyethylene (HDPE), aluminum, etc. Their chemical resistance to pH and fertilizers is summarized in Tables B1 and Table B2.

As in every water distribution network, it is necessary to install the accessories that support the correct operation and maintenance of the system namely:

- 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 water back-flow are necessary whenever TW back-flow from the irrigation system to the potable water system occur. Backflow preventer devices should incorporate a full backflow prevention assembly including a port that enables verification that the device is working properly.
- Automatic multi-zone valves: Valves used to discharge water in sequence to different zones of the irrigation area.
- Solenoid valves: These valves that open and close automatically by means of low-voltage signals are used to flush filters or drip-lines or to send water to a specific zone of the irrigated plot.
- Pressure regulator valves: Valves that are necessary to maintain the water pressure at a fixed value or in a range of values. Pressure valves should be able to support the maximum pressure in the pumping system and to provide the pressure needed for drip emitters operation.
- Blowoffs: 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 in it by pipe flushing.

- Flowmeters: In small facilities, displacement-type meters can be used. Turbine meters, propeller meters, and magnetic flowmeters are used in larger services. Magnetic flowmeters are recommended due to the suspended solids and sediments in TW that hinder the correct functioning of turbine or propeller meters.
- Hydrants: This accessory is used when temporary access to TW 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.

Table B1. Permitted pH of irrigation water according to the material of irrigation pipes and accessories

Sprinkler irrigation material	**pH of the irrigation water**
Iron and steel	>6.5
Aluminium	>5.5
PVC/PE	It is recommended to consult with the supplier regarding the specific resistance of the products to chemicals and to the pH of the water

Source: adapted from NL ISO 16075-1_2015

Table B2. Resistance of sprinkler irrigation pipes and fertigation accessories to fertilizers

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

[a] 1 (low restriction) to 4 (strong restriction)

Source: adapted from NL ISO 16075-1_2015

Annex C (informative)

Recommendations on the design and operation of distribution network to protect drinking water sources

Source: NL ISO 16075-1_2015

C.1. Design and operation of distribution network to protect drinking water sources

The use of TW for irrigation creates a potential risk for water sources (surface or underground) due to possible ruptures or leaks in the TW distribution system to the irrigated fields. TW 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.

Stipulating a protective radius
It is recommended to set up the main transmission lines of TW intended for agricultural irrigation at a distance from drinking water wells as follows (*NL ISO 16075-1_2015)*:

- in a sandy aquifer: 50 times the distance L;
- in a fractured aquifer: 200 times the distance L.

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

where
L is the distance (in meters) of main transmission lines from drinking water wells;
Q is the flow rate of the well (in m^3/h);
k is a constant which has a value of 1 h;
d is the distance (in meters) between the static water level in the well and the bottom of the well.

C.2. Principles of painting and marking TW irrigation pipelines and systems

Water pipelines and their related equipment for use with TW should be marked to prevent cross connections between them and drinking-water pipelines. Examples of painting and marking TW irrigation pipelines and systems are presented below (Table C1).

Table C1. Examples of painting and marking TW irrigation pipelines and systems

Liquid type	**Color 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 is forbidden to drink	Caution, Wastewater – Do not drink
TW quality class I	Purple		Caution – Treated water – Do not drink
TW quality class II or III	Purple with intermittent orange stripes		Caution – Treated water – Do not drink

Source: NL ISO 16075-1_2015

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

Annex D (informative)

Guidelines for injecting chlorine into drip irrigation systems

Source: NL ISO 16075-1_2015

D.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.

D.2 Safety

WARNING — Chlorine material (liquid, solid, or gas) is dangerous to humans. Before using chlorine, read all safety instructions provided by the chlorine manufacturer. Regard all instructions for acid treatment as subordinate to all legal provisions and to the instructions of the acid manufacturer.

- Before filling any tank with chlorine solution, be sure to wash it very carefully in order to remove any fertilizer remains.
- Avoid contact with eyes. Contact of chlorine with the eyes can cause blindness.
- Avoid contact with skin. Contact of chlorine with skin can cause burns.
- Use protective clothing when working with chlorine. Wear goggles, gloves, full-length trousers and sleeves, and closed high shoes.
- Avoid swallowing or inhaling. Swallowing chlorine or inhaling its fumes can be fatal.
- Be present during treatment. Be present for the full duration of the treatment. Keep all unauthorized persons away from the treatment area.

NOTE 1: Direct contact between chlorine and fertilizers can cause an explosive thermal reaction. This is extremely dangerous.
NOTE 2: Direct contact between chlorine and acid releases a toxic gas.
NOTE 3: Injecting chlorine into irrigation water containing fertilizer is not hazardous.

D.3 Materials

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

- **gaseous chlorine (Cl_2);**
- **solid chlorine (calcium hypochlorite):** When both the calcium level and alkalinity of the water are above medium and the pH is above 8.0, consult an expert for advice on whether calcium hypochlorite can be used.

- **liquid chlorine (sodium hypochlorite):** Liquid chlorine is unstable and decomposes spontaneously in the storage tank according to time, temperature, and solar radiation. Do not store liquid material for a long period of time. Keep it in the shade or paint the jerrycan white if you should keep it in direct sunlight.

D.4 Usage

Generally, there are two methods of chlorination.

a) **Continuous injection**

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

b) **Selective injection**

Chlorine is injected during the last hour of irrigation. Do not forget to consider the time required to for the chlorine to reach the end of the system (see Tables D.1 and Table D.2). With this method, both the chlorine consumption and efficiency are reduced.

D.5 Injection times for chemical/fertigation treatment

Dripper line flow time (minutes) for chemical/fertigation injection.

Table D.1. Dripper lines of 16 mm diameter

Distance between drippers (m)	**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 (m)																
100	28	17	12	8	42	26	18	12	62	39	27	18	75	47	33	21
200	31	19	13	9	47	30	21	14	70	44	31	20	85	53	37	24
300	32	20	14	9	50	31	22	14	75	47	33	21	91	57	39	26
400	34	21	15	10	52	33	23	15	78	49	34	22	95	59	41	27
500	35	22	15	10	54	34	23	15	81	51	35	23	98	61	43	28

Table D.2. Dripper lines of 20 mm diameter

Distance between drippers (m)	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 (m)																
100	39	24	17	11	60	37	26	17	88	55	38	25	106	66	46	30
200	43	27	19	12	67	42	29	19	99	62	43	28	120	75	52	34
300	46	29	20	13	71	44	31	20	106	66	46	30	128	80	56	37
400	47	30	21	14	74	46	32	21	111	69	48	32	134	84	58	38
500	49	30	21	14	76	48	33	22	114	71	50	33	138	86	60	39

Annex E (informative)

Guidelines for acid use in drip irrigation systems

Source: NL ISO 16075-1_2015

E.1 Forbidden chemicals

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

- Never use fertilizers containing more than 20 units of phosphorus.
- Never use a poly-phosphate.
- Never use red potassium chloride.
- Never use red potassium sulfate.
- Never use borax.
- Never use organic products with high contents of suspended solids (without preliminary treatment).
- Never use products and fertilizers with low solubility, e.g. gypsum.
- Never use waxy chemicals, oil solvents, petroleum products, and detergents.
- Never use active chlorine (at the injection point) with more than 40 ppm.
- Never use acid with a pH lower than 2.

E.2 Appropriated chemicals

A list of permitted chemicals is provided in Annex F.

E.3 Acid treatment for drip systems

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

NOTE: Acid treatment is ineffective with most organic matters.

E.3.1 Safety

WARNING — Acids are poisonous and dangerous to humans. Before using acid, read all safety instructions provided by the acid manufacturer. Regard all instructions for acid treatment as subordinate to all legal provisions and to the instructions of the acid manufacturer.

- Always add acid to water; NEVER add water to acid.
- Avoid contact with eyes. Contact of acid with the eyes can cause blindness.
- Avoid contact with skin. Contact of acid with skin can cause burns.
- Use protective clothing when working with acid. Wear goggles, gloves, full-length trousers and sleeves, and closed high shoes.
- Avoid swallowing or inhaling. Swallowing acids or inhaling their fumes can be fatal.
- Be present during treatment. Be present for the full duration of the treatment. Keep all unauthorized persons away from the treatment area.

E.3.2 Usage

E.3.2.1 Injecting acid into the system

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

a) make sure that the injection pump is high capacity and acid resistant; acids are very corrosive to materials such as steel, aluminum, asbestos-cement, etc. PE and PVC pipes are resistant to acids. Consider these factors before planning the treatment.

b) before starting the treatment, flush all system components thoroughly using maximum flow; NOTE: Failure to flush the system prior to using acid is harmful to the system.

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

d) turn off the injection pump;

e) continue to irrigate for the required period of time according to Annex A, Tables D.1 and D.2.

E.3.2.2 Acid concentrations

The level of acid concentration added to the irrigation water depends on the type of acid being used, its percentage, and valence. Acids should be free of insoluble impurities, e.g. gypsum, etc.

Table E.1 — Recommended acid concentrations

Acid percentage	Recommended concentration in treated water
Hydrochloric acid, 33 %	0.6 %
Phosphoric acid, 85 %	0.6 %
Nitric acid, 60 %	0.6 %
Sulphuric acid, 65 %	0.6 %

If your acid has a different percentage other than the ones listed in Table E.1, adjust the percentage accordingly. Calculate the acid concentration when using a different starting concentration as follows:

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

$Y \times 98\% = 0.6\% \times 65\%$

$Y = (0.6\% \times 65\%)/98\% = 0.4\%$

Annex F (informative)

Appropriated chemicals
Source: NL ISO 16075-1_2015

F.1 General

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

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

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

F.2 N – Nitrogen

- urea
- ammonium nitrate
- nitrate acid

F.3 P – Phosphorus

- phosphoric acid
- MAP = mono ammonium phosphate (with high solubility)
- ammonium phosphate

F.4 K – Potassium

- potassium nitrate
- potassium chloride

F.5 Microelements

- chelates
- EDTA
- DTPA
- EDDHA
- HEDTA
- ADDHMA
- EDDCHA
- EDDHSA
- boric acid

Annex G (informative)

Information on the WHO multiple barriers concept

In order to expand the group of crops or plants that can be irrigated with the different qualities of TW, the concept of creating barriers has been developed (WHO, 2006). These barriers prevent contact between the pathogens in TW and humans who ingest the irrigated food crops or who use the irrigated land or who can inhale aerosols produced during irrigation.

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

Some on-farm practices or barriers to minimize the possibility of pathogens passing from the TW to the vegetables or the fruits include:

a) Disinfection of the TW;
b) Appropriate physical separation of the TW and the vegetables or the fruits;
c) Installation of a physical barrier (such as a sun-resistant cover sheet) between the TW and the fruit;
d) Drip irrigation
e) Subsurface drip irrigation so that contaminated water does not ascend to the ground surface by capillary action;
f) Cessation of irrigation ahead of harvesting to allow pathogen die-off.

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

a) Fruit with an inedible skin (such as citrus fruits, banana, and nuts);
b) Crops that are always cooked before consumption (such as potatoes);
c) Fruit and cereals undergoing a very high-heat treatment prior to ingestion (such as wheat).

Annex H (informative)

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

Source: NL ISO 16075-2_2015

Examples for calculating the numbers and types of barriers

Table G1 shows examples for calculating the numbers and types of barriers that can be taken into consideration for each group of crops that it is intended to irrigate with TW. The number of barriers that can be used for each crop is calculated by adding the number of barriers allocated to each form of barrier or method of irrigation that can be applied.

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

T**able H1.** Examples of how to calculate the number and type of barriers

Number of required barriers (see Table 8)				Type of barrier (and number of barriers that can be attributed) (see Table 7)						
TW category I	**TW category II**	**TW category III**	**Example crops**	**TW additional disinfection in field***	**Distance from drip irrigation system using TW ****	**Sun resistant cover sheet**	**Subsurface drip irrigation system**	**Inedible skin**	**Requires cooking**	**Prolonged air drying ********
1	3	***	Food crops ingested raw which grow above ground and edible portion is <25cm above soil surface (pepper, tomato, cucumber, zucchini, young beans)	1_2		1	3			
1	3	***	Food crops ingested raw, which grow above ground and edible portion is >25cm above soil surface (baby corn)	1_2 / 2		1	3	1		
1	3	***	Leafy vegetables grown on the soil surface	1_2		1	3			

			eaten raw (lettuce, spinach, Asian cabbages, cabbage, celery)							
1	3	***	Food crops that can be ingested raw which grow in the soil (carrot, radish, onion)	1_2						
0	2	***	Food crops grown above ground where edible portion is <25cm above soil surface, eaten cooked or processed (eggplant, pumpkin, green beans, artichoke)	1_2		1	3	1	3	
0	2	***	Food crops eaten cooked, which grow in the soil (potato)	1_2					3	
0	2	***	Food crops which grow in the soil than can be eaten after peeling (peanut)	1_2				1		1_2
0	2	***	Food crops grown above ground that can be eaten after drying and cooking (dry beans, lentils)	1_2					3	1_2
0	2	***	Food crops grown on the soil that can be eaten raw	1_2		1	3	1		

			after peeling (watermelon, melon, pea)							
1	1	3	Orchards for fruits with edible skin (apple, plum, pear, peach, apricot, persimmon, cherry, citrus fruits, dates)	1_2	2		3	1		
0	1	3	Orchards for fruits eaten after peeling (mango, avocado, papaya, pomegranate)	1_2	2	1	3	1		
0	1	3	Orchards for fruits eaten after processing (olives)	1_2	2	1	3		3	
0	1	3	Orchards for nuts (almonds, pistachios)	1_2	2		3	1		
0	1	3	Vineyards with trellising	1_2	1_2		3			
			Vineyards without trellising	1_2		1	3			

** Depending on the local conditions of storage and conveying, an additional disinfection system of TW can be required for the irrigation of vegetables that must include constant control of residual chlorine, or other monitoring data. Low-level disinfection is considered as one barrier: high-level disinfection is considered as two barriers (see Table 13).*

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

**** Forbidden*

Annex I (informative)

Information about salinity and toxicity hazards and crop selection

Table I1. Crops classified according to their tolerance and sensitivity to salinity (adapted from Villalobos et al. (2017) based on data derived from Ayers and Westcott (1989))

	S	MS	MT	T
Cereals and pseudo cereals	Rice, paddy	Maize (grain, sweet), millet	Oats, rye, sorghum, wheat	Barley, durum wheat
Fruit trees, vines and shrubs	Almond, apple, apricot, avocado, blackberry, cherry, grapefruit, lemon, orange, peach, pear, plum, raspberry, walnut	Banana, grape	Coconut, fig, pineapple, pomegranate, rosemary	Date, palm
Horticultural crops	Bean (green), strawberry	Broadbean, broccoli, brussels sprouts, cabbage, cauliflower, celery, cucumber, eggplant, lettuce, melons, pea, pepper, pumpkin, radish, spinach, squash, scallop, tomato, watermelon	Artichokes	Asparagus
Legumes	Bean (dry), pea	Chickpea, faba bean, peanut	Cowpea (seed), soybean	
Roots, tubers, and bulbs	Carrot, onion, parsnip	Potato, sweet potato, turnip, cassava, garlic		
Sugar, oil and fiber crops	Sesame	Castorbean, flax/linseed, safflower	Olive, sugarcane, sunflower	Cotton, kenaf, rapeseed, sugar beet

S: sensitive; MS: moderately sensitive; MT: moderately tolerant; T: tolerant

Table I2. Crop response to soil salinity: the maximum soil salinity (electrical conductivity of soil saturated paste extract – ECe (dS/m)) that crops can tolerate before showing a decrease in production (adapted from Villalobos et al. (2017) based on data derived from Ayers and Westcott (1989))

ECe (dS/m)					
Crops		**Response to salinity**	**Crops**		**Response to salinity**
Cereals and pseudo cereals	Rice, paddy	3	**Fruit trees, vines and shrubs**	Apple	1
	Oats	5		Lemon	1
	Wheat, durum	5.9		Pear	1
	Wheat	6		Raspberry	1
	Sorghum	6.8		Avocado	1.3
	Barley, grain	8		Orange	1.3
	Rye	11.4		Almond	1.5
	Maize (grain, sweet)	12		Blackberry	1.5
Legumes	Bean (dry)	1		Boysenberry	1.5
	Pea	1.5		Grape	1.5

	Faba bean	1.6		Plum	1.5
	Peanut	3.2		Prune	1.5
	Cowpea (seed)	4.9		Apricot	1.6
	Soybean	5		Peach	1.7
Roots, tubers, and bulbs	Turnip	0.9		Grapefruit	1.8
	Carrot	1		Date, palm	4
	Onion	1.2		Pomegranate	4
	Sweet potato	1.5		Fig	4.2
	Potato	1.7		Rosemary	4.5
	Garlic	3.9	**Forages**	Clover (red)	1.5
Sugar, oil and fiber crops	Flax/Linseed	1.7		Clover, white	1.5
	Sugarcane	1.7		Meadow (foxtail)	1.5
	Olive	5		Orchard (grass)	1.5
	Sunflower	5.5		Maize (forage)	1.8
	Safflower	6.5		Paspalum	1.8
	Sugar beet	7		Alfalfa	2
	Cotton	7.7		Clover, berseem	2
	Kenaf	8.1		Lovegrass	2
	Rapeseed	10.5		Siratro	2
Horticultural crops	Bean (green)	1		Sesbania	2.3
	Strawberry	1		Setaria	2.4
	Eggplant	1.1		Townsville stylo	2.4
	Pumpkin, winter squash	1.2		Cowpea (vegetative)	2.5
	Radish	1.2		Sudan grass	2.8
	Lettuce	1.3		Trefoil, big	3
	Pepper	1.5		Vetch	3
	Broadbean	1.6		Wheatgrass, crested	3.5
	Brussels sprouts	1.8		Fescue	3.9
	Cabbage	1.8		Phalaris	4.2
	Cauliflower	1.8		Trefoil, birdsfoot	5
	Celery	1.8		Ryegrass	5.6
	Spinach	2		Barley, forage	6
	Melons	2.2		Barley, hay	6
	Cucumber	2.5		Bermuda grass	6.9
	Pea	2.5		Wheatgrass, fairway	7.5
	Squash	2.5		Wheatgrass, tall	7.5
	Tomato	2.5			
	Broccoli	2.8			
	Squash, scallop	3.2			
	Beet (table)	4			
	Asparagus	4.1			
	Squash, Zucchini	4.7			
	Artichokes	6.1			
	Kale	6.5			

Table I3. Sodium and chloride tolerance of different crops (adapted from Villalobos et al. (2017) based on data derived from Ayers and Westcott (1989))

	Toxicity			
	Na or Cl in water (meq/L Na or Cl)			
	<5	**5-10**	**10-20**	**>20**
Cereals and pseudo cereals			Barley, sweet maize, sorghum	
Forages			Alfalfa, forage barley, forage maize	
Fruit trees, vines and shrubs	Almond, apricot, cherry, grapefruit, lemon, orange, prune	Grape		
Horticultural crops		Pepper, tomato	Cucumber	Beet (table), cauliflower
Roots, tubers, and bulbs		Potato		
Sugar, oil and fiber crops			Safflower, sesame	Cotton, sugar beet, sunflower

Table I4. Boron tolerance of different crops (adapted from Villalobos et al. (2017) based on data derived from Ayers and Westcott (1989))

	Toxicity						
	B in soil (mg/L saturated extract)						
	<0.5	**0.5-0.75**	**0.75-1**	**1-2**	**2-4**	**4-6**	**6-15**
Cereals and pseudo cereals			Barley, wheat		Maize (grain, sweet), oats	Sorghum	
Forages					Clover, white	Alfalfa, vetch	
Fruit trees, vines and shrubs	Blackberry, lemon	Apricot, avocado, cherry, fig, grape, grapefruit, orange, peach, plum, walnut					
Horticultural crops			Strawberry	Cucumber, pea, pepper, radish	Artichokes, cabbage, celery, lettuce, melons, squash	Beet (table), tomato	Asparagus
Legumes		Cowpea (seed)	Peanut	Pea			
Roots, tubers, and bulbs		Onion	Sweet potato, garlic	Carrot, potato			
Sugar, oil and fiber crops			Sesame, sunflower			Sugar beet	Cotton

Table I5. Tolerance of different crops to sodium in soil (adapted from Villalobos et al. (2017) based on data derived from Ayers and Westcott (1989))

	Na in soil (ESP) (%)		
	<15	**15-40**	**>40**
Cereals and pseudo cereals	Maize (grain, sweet)	Oats, paddy rice, rye, sorghum, wheat	Barley, grain
Forages		Clover berseem, clover white, cowpea, fescue, paspalum, ryegrass, vetch	Alfalfa, bermuda grass, wheatgrass crested, wheatgrass fairway, wheatgrass tall
Fruit trees, vines and shrubs	Almond, apricot, avocado, blackberry, cherry, fig, grapefruit, lemon, orange, peach, pear, plum, prune, rasberry, walnut		
Horticultural crops	Bean (green), pea	Lettuce, radish, spinach, tomato	Beet (table)
Legumes	Bean (dry), chickpea, cowpea, peanut		
Roots, tubers, and bulbs		Carrot, onion	
Sugar, oil and fiber crops		Sugarcane	Cotton, sugarbeet

Table I6. Crop tolerance and yield potential of selected crops, as influenced by irrigation water salinity (ECw) and soil salinity (ECe)[1] (FAO, 1985).

Yield potential[2]	100%		90%		75%		50%		0% "maximum"[3]	
Crops	EC values for soil (EC_e) and for water (EC_w)									
	EC_e	EC_w	EC_e	EC_w	EC_e	EC_w	EC_e	EC_w	EC_e	EC_w
Field crops										
Barley (*Hordeum vulgare*)[4]	8.0	5.3	10	6.7	13	8.7	18	12	28	19
Cotton (*Gossypium Hirsutum*)	7.7	5.1	9.6	6.4	13	8.4	17	12	27	18
Sugarbeet (*Beta vulgaris*)[5]	7.0	4.7	8.7	5.8	11	7.5	15	10	24	16
Sorghum (*Sorghum bicolor*)	6.8	4.5	7.4	5.0	8.4	5.6	9.9	6.7	13	8.7
Wheat (*Triticum aestivum*)[4,6]	6.8	4.0	7.4	4.9	9.5	6.3	13	8.7	20	13
Wheat, durum (*Triticum turgidum*)	5.7	3.8	7.6	5.0	10	6.9	15	10	24	16
Soyabeans (*Glycine max*)	5.0	3.3	5.5	3.7	6.3	4.2	7.5	5	10	6.7
Cowpeas (*Vigna unguiculata*)	4.9	3.3	5.7	3.8	7.0	4.7	9.1	6	13	8.8
Groundnuts (peanuts) (*Arachis hypogea*)	3.2	2.1	3.5	2.4	4.1	2.7	4.9	3.3	6.6	4.4
Rice (paddy) (*Oriza sativa*)	3.0	2.0	3.8	2.6	5.1	3.4	7.2	4.8	11	7.6
Sugarcane (*Saccharum officinarum*)	1.7	1.1	3.4	2.3	5.9	4.0	10	6.8	19	12
Corn (maize) (*Zea mays*)	1.7	1.1	2.5	1.7	3.8	2.5	5.9	3.9	10	6.7
Flax (*Linum usitatissimum*)	1.7	1.1	2.5	1.7	3.8	2.5	5.9	3.9	10	6.7
Broadbeans (*Vicia faba*)	1.5	1.1	2.6	1.8	4.2	2.0	6.8	4.5	12	8
Beans (*Phaseolus vulgaris*)	1.0	0.7	1.5	1.0	2.3	1.5	3.6	2.4	6.3	4.2
Vegetable crops										
Squash, zucchini (courgette) (*cucurbita pepo melopepo*)	4.7	3.1	5.8	3.8	7.4	4.9	10	6.7	15	10
Beet, red (*Beta vulgaris*)[5]	4.0	2.7	5.1	3.4	6.8	4.5	9.6	6.4	15	10
Squash, scallop (*Cucurbita pepo melopepo*)	3.2	2.1	3.8	2.6	4.8	3.2	6.3	4.2	9.4	6.3
Broccoli (*Brassica oleracea botrytis*)	2.8	1.9	3.9	2.6	5.5	3.7	8.2	5.5	14	9.1
Tomatoes (*Lycopersicon esculentum*)	2.5	1.7	3.5	2.3	5.0	3.4	7.6	5.0	13	8.4
Cucumbers (*Cucumis sativus*)	2.5	1.7	3.3	2.2	4.4	2.9	6.3	4.2	10	6.8
Spinach (*Apium graveolens*)	2.0	1.3	3.3	2.2	5.3	3.5	8.6	5.7	15	10
Celery (*Apium graveolens*)	1.8	1.2	3.4	2.3	5.8	3.9	9.9	6.6	18	12
Cabbages (*Brassica oleracea capitata*)	1.8	1.2	2.8	1.9	4.4	2.9	7.0	4.6	12	8.1
Potatoes (*Solanum tuberosum*)	1.7	1.1	2.5	1.7	3.8	2.5	5.9	3.9	10	6.7
Corn, sweet (maize) (*Zea mays*)	1.7	1.1	2.5	1.7	3.8	2.5	5.9	3.9	10	6.7
Sweet potatoes (*Ipomoea batatas*)	1.5	1.0	2.4	1.6	3.8	2.5	6.0	4.0	11	7.1
Peppers (*Capsicum annuum*)	1.5	1.0	2.2	1.5	3.3	2.2	5.1	3.4	8.6	5.8
Lettuce (*Lactuca sativa*)	1.3	0.9	2.1	1.4	3.2	2.1	5.1	3.4	9.0	6.0
Radishes (*Raphanus sativus*)	1.2	0.8	2.0	1.3	3.1	2.1	5.0	3.4	8.9	5.9
Onions (*Allium cepa*)	1.2	0.8	1.8	1.2	2.8	1.8	4.3	2.9	7.4	5.0
Carrots (*Daucus carota*)	1.0	0.7	1.7	1.1	2.8	1.9	4.6	3.0	8.1	5.4
Beans (*Phaseolus vulgaris*)	1.0	0.7	1.5	1.0	2.3	1.5	3.6	2.4	6.3	4.2
Turnips (*Brassica rapa*)	0.9	0.6	2.0	1.3	3.7	2.5	6.5	4.3	12	8.0
Forage crops										
Wheat grass, tall (*agropyron elongatum*)	7.5	5.0	9.9	6.6	13	9.0	19	13	31	21
Wheargrass, fairway crested (*agropyron crostatum*)	7.5	5.0	9.0	6.0	11	7.4	15	9.8	22	15
Bermuda grass (*Cynodom dactylon*)[7]	6.9	4.6	8.5	5.6	11	7.2	15	9.8	23	15
Barley (forage) (*Hordeum vulgare*)[4]	6.0	4.0	7.4	4.9	9.5	6.4	13	8.7	20	13
Ryegrass, perennial (*Lolium perenne*)	5.6	3.7	6.9	4.6	8.9	5.9	12	8.1	19	13
Trefoil, narrowleaf birdsfoot[8] (*Lotus corniculatus tenuifolium*)	5.0	3.3	6.0	4.0	7.5	5.0	10	6.7	15	10
Harding grass (*Phalaris tuberosa*)	4.6	3.1	5.9	3.9	7.9	5.3	11	7.4	18	12
Fescue, tall (*Festuca elatior*)	3.9	2.6	5.5	3.6	7.8	5.2	12	7.8	20	13
Wheatgrass, standard crested (*Agropyron sibiricum*)	3.5	2.3	6.0	4.0	9.8	6.5	16	11	28	19
Vetch, common (*Vicia angustifolia*)	3.0	2.0	3.9	2.6	5.3	3.5	7.6	5.0	12	8.1
Sudan grass (*Sorghum sudanese*)	2.8	1.9	5.1	3.4	8.6	5.7	14	9.6	26	17
Wildrye, beardless (*Elymus triticoides*)	2.7	1.8	4.4	2.9	6.9	4.6	11	7.4	19	13
Cowpea (Forage) (*Vigna unguiculata*	2.5	1.7	3.4	2.3	4.8	3.2	7.1	4.8	12	7.8
Trefoil, big (*Lotus uliginosus*)	2.3	1.5	2.8	1.9	3.6	2.4	4.9	3.3	7.6	5.0
Sesbania (*Sesbania exaltata*)	2.3	1.5	3.7	2.5	5.9	3.9	9.4	6.3	17	11.0
Sphaerophysa (*Sphaerophysa salsula*)	2.2	1.5	3.6	2.4	5.8	3.8	9.3	6.2	16	11.0
Alfalfa (*Medicago sativa*)	2.0	1.3	3.4	2.2	5.4	3.6	8.8	5.9	16	10.0
Lovegrass (*Eragrostis sp.*)[9]	2.0	1.3	3.2	2.1	5.0	3.3	8.0	5.3	14	9.3
Corn (Forage) (Maize) (*Zea mays*)	1.8	1.2	3.2	2.1	5.2	3.5	8.6	5.7	15	10
Clover, berseem (*Trifolium alexandrinum*)	1.5	1.0	3.2	2.2	5.9	3.9	10	6.8	19	13
Orchard grass (*Dactylis glomerata*)	1.5	1.0	3.1	2.1	5.5	3.7	9.6	6.4	18	12
Foxtail, meadow (*alopecurus pratensis*)	1.5	1.0	2.5	1.7	4.1	2.7	6.7	4.5	12	7.9
Clover, red (*Trifolium pratense*)	1.5	1.0	2.3	1.6	3.6	2.4	5.7	3.8	9.8	6.6
Clover, alsike (*Trifolium hybridum*)	1.5	1.0	2.3	1.6	3.6	2.4	5.7	3.8	9.8	6.6
Clover, ladino (*Trifolium repens*)	1.5	1.0	2.3	1.6	3.6	2.4	5.7	3.8	9.8	6.6
Clover, strawberry (*Trifolium fragiferum*)	1.5	1.0	2.3	1.6	3.6	2.4	5.7	3.8	9.8	6.6

Fruit crops[10]										
Date palm (*Phoenix dactylifera*)	4.0	2.7	6.8	4.5	11	7.3	18	12	32	21
Grapefruit (*Citrus paradisi*)[11]	1.8	1.2	2.4	1.6	3.4	2.2	4.9	3.3	8.0	5.4
Orange (*Citrus sinensis*)	1.7	1.1	2.3	1.6	3.3	2.2	4.8	3.2	8.0	5.3
Peach (*Prunus persica*)	1.7	1.1	2.2	1.5	2.9	1.9	4.1	2.7	6.5	4.3
Apricot (*Prunus armeniaca*)[11]	1.6	1.1	2.0	1.3	2.6	1.8	3.7	2.5	5.8	3.8
Grape (*vitus sp.*)[11]	1.5	1.0	2.5	1.7	4.1	2.7	6.7	4.5	12	7.9
Almond (*Prunus dulcis*)[11]	1.5	1.0	2.0	1.4	2.8	1.9	4.1	2.8	6.8	4.5
Plum, prune (*Prunus domestica*)[11]	1.5	1.0	2.1	1.4	2.9	1.9	4.3	2.9	7.1	4.7
Blackberry (*Rubus sp.*)	1.5	1.0	2.0	1.3	2.6	1.8	3.8	2.5	6.0	4.0
Boysenberry (*Rubus ursinus*)	1.5	1.0	2.0	1.3	2.6	1.8	3.8	2.5	6.0	4.0
Strawberry (*Fragaria sp.*)	1.0	0.7	1.3	0.9	1.8	1.2	2.5	1.7	4	2.7

[1] Adapted from Maas and Hoffman (1977) and Maas (1984). These data should only serve as a guide to relative tolerances among crops. Absolute tolerances vary depending upon climate, soil conditions and cultural practices. In gypsiferous soils, plants will tolerate about 2 dS/m higher soil salinity (ECe) than indicated but the water salinity (ECw) will remain the same as shown in this table.

[2] ECe means average root zone salinity as measured by electrical conductivity of the saturation extract of the soil, reported in deciSiemens per metre (dS/m) at 25°C. ECw means electrical conductivity of the irrigation water in deciSiemens per metre (dS/m). The relationship between soil salinity and water salinity (ECe = 1.5 ECw) assumes a 15–20 percent leaching fraction and a 40-30-20-10 percent water use pattern for the upper to lower quarters of the root zone. These assumptions were used in developing the guidelines in Table 1.

[3] The zero yield potential or maximum ECe indicates the theoretical soil salinity (ECe) atwhich crop growth ceases.

[4] Barley and wheat are less tolerant during germination and seeding stage; ECe should not exceed 4–5 dS/m in the upper soil during this period.

[5] Beets are more sensitive during germination; ECe should not exceed 3 dS/m in the seeding area for garden beets and sugar beets.

[6] Semi-dwarf, short cultivars may be less tolerant.

[7] Tolerance given is an average of several varieties; Suwannee and Coastal Bermuda grass are about 20 percent more tolerant, while Common and Greenfield Bermuda grass are about 20percent less tolerant.

[8] Broadleaf Birdsfoot Trefoil seems less tolerant than Narrowleaf Birdsfoot Trefoil.

[9] Tolerance given is an average for Boer, Wilman, Sand and Weeping Lovegrass; Lehman Lovegrass seems about 50 percent more tolerant.

[10] These data are applicable when rootstocks are used that do not accumulate Na+ and Cl- rapidly or when these ions do not predominate in the soil. If either ions do, refer to the toxicity discussion in Section 4.

[11] Tolerance evaluation is based on tree growth and not on yield.

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