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BEST PRACTICES MANUAL

Mission for the Safe and Efficient Reuse of Treated Wastewater of the Jordanian Pilot Project Decentralized Wastewater Treatment Plant at The Public Security Directorate (PSD) in Moqabalain, Jordan

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List of abbreviations

BMZ	German Federal Ministry for Economic Cooperation and Development
EU	European Union Delegation
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH
gpm	Gallon Per Minute
HDPE	High Density Polyethylene
LIS	Landscape Irrigation System
MREA	Mission Régionale Eau Agriculture
MWI	Ministry of Water and Irrigation
PSD	Public Security Directorate
TSS	Total Suspended Solids
WWTP	Wastewater Treatment Plant

1. Introduction

The Wastewater Treatment Plant (WWTP) at the Public Security Directorate (PSD) site will have the capacity to generate 150m^3/day of wastewater. The effluent will meet category 'A' according to the Jordan Reclaimed Water Specifications JS 893/2006. The effluent is used to irrigate the Directorate's green areas, which encompass 20du of olive trees and some side road ornamental plants. The majority of plants present at the PSD at the time of elaborating this manual were ornamental perennials irrigated with freshwater bought by PSD.

The aim of this manual is to formulate best practices on how to ensure that the reuse of treated wastewater for PSD's landscape irrigation follows Jordanian standards and poses no risks to humans and the environment. Due to already an already existing landscape system (irrigation network and crops/plants) in place at PSD, this manual is adapted to ensure that only minimal changes need to be made and respected for an effective and efficient irrigation system using treated wastewater. The manual is of general nature, outlining steps for the effective and efficient irrigation with treated wastewater. Where needed, the manual makes recommendations specific to the needs and context of the PSD site.

Landscape irrigation systems (LIS) are prone to a number of problems during operation, therefore management and monitoring of the LIS is important. Understanding the components of the LIS and how they function contributes to preventing health hazards and prolonging the components' service life span.

Treated wastewater is an important unconventional source of water especially in an arid country such as Jordan. With proper treatment and proper management, wastewater can be safely and successfully used and soil degradation through increased salinity and adverse chemical and biological effects can be prevented.

2. Components of the Irrigation System

Irrigation is defined as the application of water to soil for supplying the moisture essential for plant growth. An irrigation system is the group of tools and devices that put together allow water to reach the crop or landscape.

Irrigation systems of freshwater and treated wastewater consist of the same components. The difference resides in the wastewater's high Total Suspended Solids (TSS) and biological contents, which need to be considered by installing highly effective filters, which in turn manage the effects of salinity and applied nutrients. Not all irrigation systems can be used. Moreover, and very importantly, the operator needs to operate the irrigation system taking into consideration the safety of workers and the surrounding environment (e.g. the passersby).

The Jordan Reclaimed Water Specifications JS 893/2006 do not specify the kind of irrigation system to use with treated wastewater but they prohibits the use of sprinklers unless the irrigated area is a golf course.

a. Water meters

Proper management of irrigation water use requires a determination of how much water the system uses. Water meters - properly selected and maintained - can be the most accurate and easiest method for measuring the water flow.

Water meters are used for the following purposes:

1. Improving the efficiency of irrigation water use by enabling an accurate measurement of the applied water.
2. Detecting problems in the pumping potential or irrigation system.

Impeller meters are an accurate and convenient tool for measuring both flow rate and volume when properly selected, installed, and maintained. The effective use of an impeller water meter requires:

1. Proper selection of the meter based on pipe size, range of flow and head loss characteristics.
2. Proper installation of the meter so the pipe is always flowing full, turbulence is not excessive and the meter is positioned correctly.
3. Provision of good maintenance so that the meter remains accurate and has a long, useful service life.

Figure 1. An irrigation flow meter.

Units of Water Measurement

A water meter can measure a given amount of water under stationary or mobile conditions. Volume units are used to measure a given amount of water at rest. Water in motion is described in terms of flow rate, which is a volume unit per a unit of time.

Volume

Volume units describe how much space an amount of water will occupy. Water tanks, ponds, and in-soil storage are examples of water at rest. Common volume units are liters, cubic meters, and gallons.

Figure 2: Measuring pressure using a pressure gauge at a lateral ending (Source: MREA, 2004).

Flow Rates

b. Flow rates tell how fast a given volume of water is moving past a fixed location. They can be used to describe the discharge of a pump, flow in a pipe, and the discharge of a dripper or emitter. Flow units commonly used in irrigation are gallons per minute (gpm) and liters per hour (l/hour).
1 gpm = the rate of the flow necessary to fill a gallon container in one minute. 1 l/hour is equal to the flow rate necessary to fill a liter container in one hour. If flow rates are known, the volume of water applied by an irrigation system during a period of time can be calculated by multiplying the flow rate by the time

c. Pressure gauges

Pressure gauges (gages) are used to indicate the operating pressure at any point in the LIS (see **Figure 2**). Typically, pressure gauges are installed before and after filters, before and after water meters, and at various locations in the LIS.

d. Drip lines (also called laterals)

Laterals are flexible pipes or tubing made of high density polyethylene (HDPE) and of 16mm - 90mm in diameter. Their color is black (if fresh water is being used) or violet/ pink (if treated wastewater is being used). The pressure variation between two extreme points of any lateral should not be more than 15 - 20% and discharge variation should not be more than 10%.

e. Emitters (also called drippers)

Emitters discharge water through laterals to the plants. There are various types and size of drippers, based on different operating principles. They are made of plastic such as polythene or polypropylene. Different kinds of drippers have different characteristics, advantages and disadvantages which

determines its use. Emitters may be on the lateral (on-line emitters) or inside the lateral (in-line emitters).

The emitters used for almost all of PSD's green area are the "pressure compensating" (on-line) kind. Pressure compensating emitters ensure the delivery of the same flow rate despite pressure alternations and ground slope. In the context of TWW reuse, their assumed service life time is three to five years.

Figure 4: A treated wastewater filtration unit consisting of sand filers (in blue) and a disc filter (in black) (source: MREA, 2006).

A small part of the PSD landscape is covered with grass (a lawn). Before the construction of the WWTP, the lawn was irrigated manually by hose. However, it is equipped with a subsurface system and pressurized sprinklers (that pop out and spray water once water circulates in the laterals). Based on article 4.2.2.3 in the Jordan Reclaimed Water Specifications JS 893/2006, **it is prohibited to irrigate with sprinklers when using treated wastewater**. For alternative suggestions, see the recommendations in **section 3: Operation of the Landscape Irrigation System**.

Figure 5: On-line emitters (top left: Source: MIRRA. Image by Haidar Malhas; an in-line emitter (bottom; source: www.pro-sprinkler.com).

f. Filters

The success of wastewater application depends largely on the efficiency of the filtration system. Filters remove suspended particles in the irrigation water, preventing the blockage of emitters or drippers. The kind of filtration needed depends on water quality and emitter type. The most common and effective filtration system for treated wastewater reuse in irrigation is a two-stage filter unit (sand filter and disc filter). The specifications of the filtration unit for PSD's LIS are in Annex 1.

Sand Filters

Sand filters are effective against inorganic suspended solids, biological substances, and other organic materials. These suspended solids are stopped and accumulated inside the media in the filter. The sand filter consists of small basalt gravel or sand (usually 1 to 2mm in diameter) placed in a cylindrical metal tank. Water enters from the top and flows through the gravel, leaving the dirt in the filter. The clean water is discharged at the bottom.

The filter is cleaned by reversing the direction of the flow, which is a process called **back flushing**. Pressure gauges are fitted at the inlet and outlet of the filter. When the dirt accumulates, the pressure difference between the inlet and outlet increases and when the pressure difference exceeds 0.5-1.0 bar then the filter should be cleaned or back flushed.

Disc Filters

Disc filters are commonly used in irrigation systems in Jordan. They are sturdy and well-adapted to rugged conditions. However, **disc filters should not be used alone to filter treated wastewater and should always be used in combination with sand filters.**

Figure 6: Centrifugal pump (source: www.pentax-pumps.it).

In this type of filter, grooved plastic discs that are piled together around a telescopic core are used to achieve the desired filtration. Both sides of the discs are grooved and the grooves cross each other when piled up and tightened together. The housing is made of plastic or metal. The water passes through the filter from the outside to the inside. The filtration is affected in two stages: the larger outer surface operates as a screen filter and collects the larger particles. The grooves inside the disc allow the adhesion of fine particles, mainly organic matter. The filter element can be cleaned easily. When opening the core, the discs are released and can easily be rinsed under running water.

g. Irrigation pump

The irrigation pump is used to provide adequate pressure and the right flow to operate the different irrigation elements described above. Pumps have characteristic curves that relate the delivered flow with the total head.

Pumps should be sized based on the demand of the system in a manner that provides the desired flow with adequate pressure, guaranteeing that the emitters will be operated under optimal conditions which prevent clogging and increases the life time of the laterals.

Figure 7: Irrigation Controller (Source: www.rainbird.com).

Irrigation system operators should avoid operating the pump beyond its designed capacity; i.e. flow or pressure. In other words; operators should monitor the pressure and flow (as described above) and make sure that these values are within the characteristic curve range to ensure optimal power consumption, low wearing levels and a long lifetime of the pump.

h. System automation

Irrigation automation is usually used to facilitate the irrigation process, reduce irrigation labor costs, maintain irrigation duration and/or frequency accuracy or reduce the hazard of contamination by decreasing the contact possibilities between treated wastewater and the irrigation operator.

The standard automation system components are:

1- Controller,
2- Solenoid valves, and
3- Cables.

Some advanced systems might include:

4- Central control software to operate remotely
5- Sensors: flow, rain, frost, temperature…etc. to control irrigation events occurrence, frequency or duration.
6- Other custom features based on the client/site needs and requirements.

Figure 8: Solenoid Valve (Source: www.rainbird.com)

Programming the controller to operate the irrigation system automatically is a relatively easy process: the operator should start by setting the operation start time(s), valve operation duration and operation days.

The operation duration and frequency must satisfy the plants water requirements taking into consideration the plants growth stage, weather conditions environmental aspects, salinity control, and other factors.

Figure 9: The original disc-filter in PSD.
(Source: MIRRA. Image by Haidar Malhas).

3. Operation of the Landscape Irrigation System

The system should be operated the way it was designed to. If in doubt, always contact the contractor – he/she will know exactly the right advice to provide. Always check the irrigation system components for malfunctioning, leaks, or deterioration (see figure 9). These seemingly minor details could negatively impact the longevity of the irrigation system risking.

It is necessary to always utilize drip irrigation for PSD, and to make sure that no sprinklers are used on the premises. **As mentioned earlier on, the use of sprinklers is prohibited according to Jordan Reclaimed Water Specifications JS 893/2006 due to the associated health and sanitation hazards.**

There is an area of 20du of olive trees, which will also be irrigated with the same water.

The recommendations:

1. For the landscape in general, slowly introduce different plants. PSD will eventually replace the existing plants with new ones because they simply will not be able to tolerate the water salinity (see Annex 2 for suitable plant species).
2. For the lawn area, it is highly advisable to either:
   a. Remove it completely and replace it with crops from Annex 2, or
   b. Design and install a new sub-surface irrigation system according to the Jordanian Standards.
3. The olive area:
   a. Place warning signs everywhere, and
   b. Train the responsible staff and agricultural labor continuously. **Make sure to train the seasonal agricultural workers because they change! Make sure to forbid them of harvesting the fruits that have fallen to the ground!**

In all cases, the PSD irrigation system is in desperate need of a reliable filtration unit. For specifications, see the filters section **2. Components of an irrigation system/ filters** and **Annex A for suitable specifications of a filtration unit**.

Figure 10: Warning signs at the Public Security Directorate regarding the use of treated wastewater in irrigation.
(Source: MIRRA. Image by: Nour Habjoka).

4. Monitoring Programme

The following is a monitoring programme for preventive maintenance of the components of the irrigation system. The programme should be followed according to the frequencies indicated.

Component	Observations	Frequency
Water meters	Record water meter reading before and after each irrigation for each irrigation block separately	Each irrigation event
Pressure gauges	Record pressure readings during each irrigation event, and before and after each flushing	Each Irrigation and Each Flushing
Drip lines (laterals)	Flow of emitters	Measure the flow of selected emitters three times per year
	Uniformity	Calculate the Uniformity Coefficient of the system three times per year
	Clogging of emitters	Check for clogged emitters every month
	Clogging of laterals	Flush (clean) laterals and observe any suspended materials every week
Clogged emitters	Observe cause of clogging: 1) Bacterial films, 2) Carbonate precipitation, or 3) Algae	Every month
Sand filters	Record pressure readings before (upstream) and after (downstream) of the sand filter.	Each irrigation event
	Register the number of back-flushing events.	
	Register the time and quantity of water required to clean the filter.	
Disc filters	Record pressure readings before (upstream) and after (downstream) of the sand filter.	Each irrigation event
	Register the number of back-flushing events.	
	Register the time and quantity of water required to clean the filter.	

5. Maintenance

The performance of a drip irrigation system may rapidly deteriorate if it is not routinely maintained by checking for leaks, backwashing and cleaning filters, cleaning or replacing clogged emitters, and evaluating and monitoring system performance.
Proper maintenance of a drip irrigation system contributes to prolongation of its life span and enhancing its performance. Regular checkups reduce the likelihood of non-uniform water applications due to emitter plugging and reduce operational costs.
This manual is mainly concerned with routine, preventive maintenance which all drip irrigation systems should receive regardless of age. The following are the different parts of the system, and how they should be handled during routine maintenance:

a. Pumps

Follow the manufacturer's recommendations to maintain the centrifugal pumps.
During the irrigation season, check aboveground pumps **on a daily basis** for the following:

- Excessive or unusual noise or vibration
- Water leakage
- Proper flow rate and pressure
- Intake screen obstructions

b. Power units

The electric motor routine maintenance involves the following:

- Dirt and corrosion:
  Clean (vacuum or wipe) or blow accumulated dirt from the frame and air passages. Check for signs of corrosion and repaint/ repair if needed.
- Lubrication: Lubricate the bearings only on schedule, if they make noise, or if they are hot. Do not over-lubricate! Lubricant accumulates dirt and damages the bearings!
- Heat, noise, and vibration: The motor frame and bearings should not feel excessively hot or vibrate a lot. If you hear abnormal noises, immediately identify and address the source of the problem by calling a professional.

c. Pressure gauges and flow meters

Check the pressure gauges from time to time to make sure that they are working properly. Replace broken gauges with high-quality liquid-filled gauges. Make sure the range of pressure measured by the gauge covers the operating range of the system, **which is from 0 to 10 bar**. Check gauge accuracy by comparing it with a new one. Occasionally observe flow meters while the irrigation system is operating as follows:

- Make sure the observed flow rate falls within the optimal operational range of the pump (check pump manual).
- Repair or replace malfunctioning flow meters immediately!

d. Filters

An effective filtration process is crucial to minimize emitter plugging. All filters must be regularly checked and cleaned of debris and dirt. **A clogged filter (partially or fully) can cause reductions in**

system pressure, resulting in reduced and un-uniform water application. **Clogged filters can also raise the pump pressure head, thereby consuming more energy**.
Backwashing is one of the methods by which filters can be cleaned. Backwashing should be scheduled based on pressure differential. Backwash when the pressure difference between water going into and coming out of the sand filter exceeds **0.5 - 1.0 bar**. Alternatively, backwash at a fixed time schedule depending on the time it takes the particles to accumulate in the filter media. **In the PSD's case, backwash approx. every day.**
Check sand media filters at least **three times a year** for the following:

- Check for appropriate sand level (mark and note down the original sand level when purchased).
- Check that the media material is not "caked" or compacted.
- Make sure the media (the sand) was not flushed out during backwash.
- Make sure cavities have not opened up.

In the case of **disc filters, inspect and clean them weekly** (or more frequently) by removing the cover and examining the media. Check for accumulated organic material on the outside of the discs, and check for sand or other particles that may have gotten stuck between the discs.

e. Chemical injection equipment

Visually inspect injection equipment components (the hoses, valves, and the injector) each time a chemical is injected into the irrigation system.
Be sure to flush the injection system with water after each chemical injection so that the chemicals do not remain in the equipment.

f. Automatic valves

The automatic diaphragm valves are important and require periodic inspection to assure proper operation. If a valve fails, the pump or power unit could be damaged or water could start to seep where it is not needed.
Once a year, inspect and clean the diaphragm valves. A valve can usually be cleaned without removing it from the line.

- Clean the deposits that have accumulated on the valve stem.
- Remove encrustation with a wire brush, a weak acid (like vinegar), or very fine sand paper.

When a valve is opened, inspect the diaphragm, seat, and O-ring seals. Replace any components that are beginning to wear out.
Periodically inspect adjustable pressure regulating valves to ensure correct setting.

g. Main-line, sub-main, laterals and emitters

Check the components of the irrigation systems visually for any leaks during field visits. Leaks usually occur in plastic system parts and in pipe fittings, emitters, and hose adapters.
Observe or listen for excessive water flow. Check for this problem by surveying the emitters while they operate.

Troubleshooting Guide

Below is a troubleshooting guide that is adapted to the PSD site[1].

PUMP Outlet Pressure[2]	Low	High
System flow meter	High	Low
Possible Problem and Solution	1. There is a leak in the system. Inspect visually all the system components for any leakages and fix them. 2. A valve has faulty opening. Check if each valve is closing after the irrigation program is over.	1. Filters are clogged and should be back flushed. 2. Emission devices are clogged. Look for dry areas and fix/replace clogged items. 3. Block valve(s) is/are not opening, test all valves. 4. Too few valves are open, additional valve(s) should be opened. 5. Pressure regulator(s) are over throttled, calibrate pressure regulators.

FILTER Outlet pressure	Low	Low	High
System Flow Meter:	Low	High	Low
Possible Problem and Solution:	1. Filters are clogged and should be back flushed/ cleaned.	1. There is a leak in the system. Inspect visually all the system components for any leakages and fix them. 2. A valve has faulty opening. Check if each valve is closing after the irrigation program is over.	1. Filters are clogged and should be back flushed. 2. Emission devices are clogged. Look for dry areas and fix/replace clogged items. 3. Block valve(s) is/are not opening, test all valves. 4. Too few valves are open, additional valve(s) should be opened. 5. Pressure regulator(s) are over throttled, calibrate pressure regulators.

BLOCK VALVE Outlet Pressure:	High	Low	Low	High
System Flow Meter:	High	Low	High	Low
Possible Problem and Solution:	1. Pressure regulator(s) is/are under throttled, calibrate pressure regulator(s).	1. Pressure regulator is over throttled, calibrate pressure regulator. 2. Filters are clogged and should be back flushed.	1. There is a leak in the system. Inspect visually all the system components for any leakages and fix them. 2. A valve has faulty opening. Check if each valve is closing after the irrigation program is over.	1. Filters are clogged and should be back flushed. 2. Emission devices are clogged. Look for dry areas and fix/replace clogged items. 3. Block valve(s) is/are not opening, test all valves. 4. Too few valves are open, additional valve(s) should be opened. 5. Pressure regulator(s) is/are over throttled, calibrate pressure regulators.

[1] Adapted from Toro Micro-Irrigation Owner's Manual.

[2] Pressure and flow reading should be compared to the benched values (refer to pressure and flow benchmarking).

Recommended Maintenance Schedule:

Recommended maintenance schedule for the LSI system components.

What to check	*Frequency*	*Compared to what*	*What to look for*	*Possible causes*
Pump flow rate and pressures for each zone	Weekly	Benchmark flow rate and pressures (refer to pressure and flow benchmarking)	▪ High flow and/or low pressure ▪ Low flow and/or high pressure	▪ Leaks in pipelines ▪ Leaks in laterals ▪ Opened flush valves; opened ends of laterals ▪ Closed valves; pipeline obstruction ▪ Dripper clogging ▪ Pump malfunctions
Pressure difference across filter	Every irrigation	0.5-1.0 bar	▪ Exceeds or is close to maximum allowable	▪ Filter becoming clogged ▪ Obstruction in filter
Operating pressures at ends of laterals	Monthly, unless other checks indicate possible clogging	Benchmark pressures	▪ Pressure greater than expected (1 bar) ▪ Pressure lower than expected (1bar)	▪ Possible clogging; obstruction in dripper ▪ Broken lateral; leaks in lateral; low system pressure
Water quality (colour, debris,…) at lateral ends and flush valves	Bi-weekly	Water source	▪ Particles in water ▪ Other debris	▪ Broken pipeline ▪ Particles smaller than disc; filter problem ▪ Chemical/ fertilizer sedimentation due to use of insoluble substances ▪ Algae growth; bacterial growth
Overall pump station	Weekly	Manufacturer's specifications	▪ Leaks, breaks, noise	▪ Poor maintenance ▪ Old equipment
Fertiliser pump settings	Weekly	Calibrated setting at start up (should be benchmarked)	▪ Proper setting for length of injection time	
Overall system	Weekly	System at start up	▪ Leaks in pipes ▪ Wilting crop	▪ Indicates possible buildup of minerals, fertiliser, algae, and/or bacterial slime ▪ Pest or mechanical damage ▪ Lateral blowout from high pressure ▪ Crop may be affected by pathogens ▪ Lateral clogged, obstructed, or broken

6. Crop considerations

Treated wastewater is characterized by a high salinity content. Consider the following comparison:

Classification	*Salinity (dS/m)* [3]
Freshwater	less than 0.7 dS/m
Slight to moderate salinity	0.7-3.0 dS/m
Highly saline water	more than 3.0 dS/m

The effluent of the WWTP falls within the middle class, slight to moderate salinity.

Salinity affects plants. Agricultural crops produce maximum yield when irrigated with freshwater. As the salinity increases, the yield decreases. Plants vary in their ability to withstand salinity levels, and some can achieve higher yields than others.

In the case of landscape plants, some species thrive in slightly to moderately saline water and will do well using treated wastewater (see Annex 2).

According to the Jordan Reclaimed Water Specifications JS 893/2006 (article 4.2.2.2) **it is prohibited to plant any edible vegetables eaten uncooked (raw)**. For the PSD site, it is therefore highly mandatory to choose purely ornamental plants, even better if these require minimal maintenance and tending.

Figure 11: Example of an ornamental plant that will not withstand TWW. (source: MIRRA. Image by: Haidar Malhas).

Irrigation practices at the PSD site must follow the health and safety measures outlined in **section 7 Health and Safety Measures**.

The PSD site has 20du of olive trees. According to the JS 893/2006 Reclaimed Water Specifications, **irrigation must be stopped two weeks before harvesting the olives**. Moreover, **all fruits which have fallen on the ground and those that touch the soil must be thrown away**.

7. Health and Safety Measures

The reuse of treated wastewater in landscape irrigation requires knowledge about the risks that are potentially associated with it.

Wastewater contains pathogens such as bacteria, viruses, and parasites that can cause disease. Parasites, such as protozoa and helminth eggs are particularly harmful since they have proven to be most difficult to treat once infected with. The presence of heavy metals in the soil at such a close proximity to people is not favorable, and their content in the influent should be minimized as much as possible.

The most important issue to remember when dealing with treated wastewater systems. Though all of the residents of PSD are adults, care must be taken to educate everyone regarding reuse activities and how to handle water. Generally speaking, exposure to treated wastewater should be minimalized.

The prevention of health risks is possible and requires attention to the following:

1. Ensuring the safe, effective operation and maintenance of all equipment and systems (e.g. the wastewater treatment plant and the irrigation system).
2. Selecting suitable crops and plants. It is highly recommended that only ornamental plants should be grown on the site, avoiding any herbs and vegetables or fruit trees.
3. Selecting and operating the appropriate irrigation system, for instance sprinkler and mist irrigation systems (those that spray water in the air) are prohibited to reduce contact with the system operator, PSD staff, and surrounding environment in general. As mentioned earlier, the Jordan Reclaimed Water

[3] 1.0 dS/m = 700 mg/l (TDS).

Specifications JS 893/2006 do not specify the kind of irrigation system to use with treated wastewater but they prohibits the use of sprinklers. It is highly recommended to use drip or subsurface irrigation techniques.

4. The control of human exposure to the treated wastewater. This entails the following:
   a. Identify the personnel in charge of the operation and maintenance of the LSI system at the PSD site. That means the agricultural labor or workers.
   b. Train the personnel in charge on the proper handling of treated wastewater during the operation and maintenance of the LSI system. **Make sure to also train seasonal labor workers.** Please consult **Annex C** for a complete list of topics that should be covered in such a training.
   c. Provide employees with appropriate protective equipment, such as impervious gloves and footwear, protective masks, hats and clothing that will reduce their risk of exposure to the effluent.
   d. Ensure that employees develop and maintain good personal hygiene, such as washing their hands after tackling the irrigation system, before eating or smoking while at work.
   e. Make sure that there are adequate freshwater supplies for human consumption to avoid consumption of reclaimed water and for hygiene purposes (e.g. for hand washing).
   f. Provide, if possible, medical assessments of the employees and labour.
   g. Install pipes, laterals, and outlets in purple color according Jordanian Reclaimed Water Reuse Standards.

8. Summary

The reuse of treated wastewater through a LIS system is a process that can be of great environmental value especially in water-stressed countries like Jordan. It can often also be of great economic value, especially when treated wastewater substitutes the expensive, limited supply of freshwater. In addition, the proper utilization of treated wastewater in LIS often results in reduced fertilizers costs. Despite the risks which area associated with pathogens and bacteria in wastewater and with the salts that might accumulate in the soil, the benefits outweigh the risks and might even block them. All that is required is adequate planning, careful execution, continuous monitoring, and preventive maintenance protocols throughout the process.

Adequate planning entails selecting the most suitable plants for the site. In general, non-food plants are the most suitable (landscape plants), which is the case at the PSD site. Preventive maintenance allows the LIS system to operate at peak efficiency, saving water and fertilizer. Routine maintenance of the various LIS components such as pumps, power units, filters, valves, and field pipe/ tubing/ emitters are required as described in this manual. Flushing the irrigation system is critical to prevent emitter plugging. A plugged irrigation system requires remedial maintenance including cleaning or replacing emitters and line purging.

Continuous monitoring of the performance of the wastewater treatment plant is also vital. LIS are able to handle a certain quality of treated wastewater, but if this quality deteriorates the LIS might not function properly.

In conclusion, harnessing the benefits of treated wastewater reuse in irrigation is a delicate procedure that requires the implementation of the proper operation maintenance procedures of the irrigation system, all the while making sure that health safety measures are followed for the well-being of the PSD occupants.

9. Annex A. Filtration unit specifications

A disc filter followed by a sand filter in series, starting with the disc filter.

Specifications of a sand filter suitable for PSD (Capacity of up to 25m^3/hr):

1. Filter diameter = 75 - 80cm
2. Filter body height= 75cm (excluding legs and support)
3. Filter inlet and outlet diameter = 4" flanged with needed screws and gaskets
4. Wall thickness = 4mm (at least)
5. Internal paint: epoxy coat.
6. External paint: thermal painting
7. The filter bottom shall be covered with at least 25 diffusers of 0.5mm slot opening
8. The filter shall be supplied with all needed fittings: Isolation valve, pressure gages, etc.
9. The filter shall have appropriate manual/automated backwash mechanism (see optional feature below)

The supplier shall include 0.5-ton media of crushed silica; average particle size: 1mm.

Optional Feature:
Automated backwash mechanism: the sand filter shall have auto backwash mechanism including a standalone 220V control panel, with the ability to control the backwash manually, based on pressure differential or time basis.
The filter shall be supplied with a disc filter set downstream to keep filtering while backwashing the sand filter.

10. Annex B. Plant species that withstand treated wastewater

Plants that are suitable for irrigation using treated wastewater and can be grown in a home garden or a public park:

1. Forest trees of various kinds (cypress, eucalyptus, Greek juniper, Casuarina *equisetifolia*, etc.), which can also be used as fences around the landscape area.
2. Fruit trees like olives and palm trees.
3. Shrubs that are usually used as fences: ligustrum sp, Thuja *orientalis*, hibiscus.
4. Trees that are planted at entrances of buildings such as the Washingtonia and the areca palm (Dypsis *lutescens*).
5. Outdoor ornamentals such as cloves and rosemary.
6. Flowering plants such as petunias, roses, cacti, hibiscus, flowering Geranium spp, Pansies, Gazanias.

11. Annex C. Agenda of training

Day	Topics
Day 1 Theoretical Training	- Opening and introduction - Wastewater production and reuse (in Jordan in general, and in PSD in particular) - Wastewater characteristics and terminology - Processes and practices at the PSD premises - Wastewater treatment - Treated wastewater reuse in landscape irrigation - Landscape irrigation system main components - Management of landscape irrigation systems - Maintenance of landscape irrigation systems - Emitter clogging and system flushing - Safety measures and practices with regard to treated wastewater - Soil salinity management and leaching - Soil Infiltration Rate - Fertigation - the incorporation fertilizers, soil amendments, or other water-soluble products through an irrigation system - The Best Management Practices Manual based (on PSD conditions) - Questions and remarks
Day 2 Practical training	- The kind of equipment that is used for treated wastewater - The filtration system - Operation and maintenance - Questions and remarks

هذا المشروع ممول من قبل الاتحاد الاوروبي والوزارة الفدرالية الألمانية للتعاون الاقتصادي والتنمية (BMZ)

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