Safe Use of Treated Wastewater in Agriculture

Jordan Case Study

Prepared for ACWUA

by

Eng. Nayef Seder (JVA)
Eng. Sameer Abdel-Jabbar(GIZ)

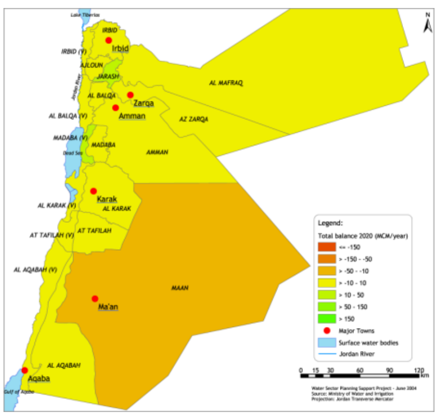
December 2011

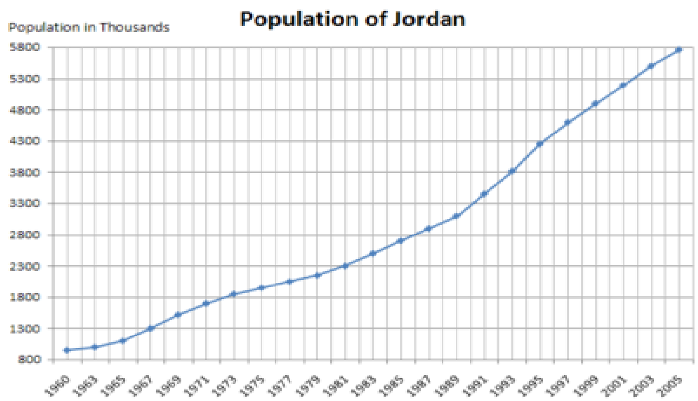
Table of Content

1 Introduction

The Hashemite Kingdom of Jordan is an arid to semi-arid country, with a land area of approximately 90,000 km^2. The population is 6 million with a recent average growth rate of about 2.2% due to natural and non-voluntary migration. About 73% of the population lives in urban areas concentrated in the northern and middle parts of Jordan.

Water resources in Jordan depend on variable rainfall and therefore are characterized by scarcity, variability, and uncertainty. The per capita share of renewable water resources is 145 m^3/capita/year and Jordan is therefore ranked fourth poorest country with regard to water resources worldwide.





Water resources depend on rainfall which varies in quantities, intensity and distribution from year to year, with most falls between the months of October and May.

The Average Annual Rainfall varies in Jordan; on High Land it is about 600 – 400 mm, Jordan Valley 300- 50 mm and Desert Area (Badia) 50 – 200 mm (91.4%).

2 Water Budget

Jordan has developed a National Water Master plan (NWMP) in 2006. It contains all relevant figures and projections for the Jordanian Water Budget and is available online (http://www.mwi.gov.jo/NWMP/INDEX.HTM). Chapter 6 deals with non-conventional water resources and addresses water reuse.

As the data is already outdated, it is currently discussed to have an update of this master plan. The following information is a short summary water resources.

2.1 Current Water Resources

Groundwater Resources

a. Renewable	Quantity	
Average annual safe yield	276 MCM	
Return flow	54 MCM	
Total Renewable groundwater abstraction	410 MCM	
b. Non-Renewable		
Annual potential	143 MCM	
Total non-renew. Groundwater abstraction	74 MCM	From Disi, Jafr and Lajoun

If this over abstraction if continued, it will cause an environmental disaster to the ground water basins.

Surface Water Resources

Average annual long term flow	713 MCM	
Average annual exploitable	535 MCM	
Current uses from Surface water	365 MCM	includes 50 MCM from peace treaty
Current storage capacity	321 MCM	

Non-conventional Water Resources

TWW from 22 waste water treatment plants	110 MCM	
Desalinated water for drinking from Abu-Zighan	10 MCM	
Desalinated water (Aqaba)	10 MCM	**Future plan**

2.2 Additional Future Water Resources

I - DISI Project: Will provide 100 MCM for Amman and South Governorate 2013
II - Additional nonrenewable GW: Will provide additional 7 MCM from Jafer and Lajoun
III - Red Sea–Dead Sea Water Conveyance Project: Will provide 570 MCM in 2022.
IV - Surface Water Resources:

- 30 MCM from Wehdeh dam
- 24 MCM storage in 2020 due to new dams (Dams yield=15 MCM)
- 5 MCM from rainwater harvesting

V - Non-Conventional Water Resources in 2022:

- 176 MCM from planned waste water treatment plants and increase in demand of existing waste water treatment plants
- 10 MCM from desalination of Red Sea water (Aqaba)
- 72 MCM desalination of brackish water (47 MCM from ZARA & Mujib and 25 from Kafrein –Hisban and Deir Alla)
- 30 MCM as stated in the peace treaty

Water Resources Development (MCM) according to NWMP

Water Resource	**2006**	**2010**	**2015**	**2020**	**2022**
Renewable GW (Abstraction for all uses	392	382	360	339	330
Desalination Aqaba	0	5	8	10	10
Desalination brackish water	10	57	82	82	82
Disi	54	59	122	122	122
Jafer	12	18	18	18	18
Lajjoun fossil water	13	14	14	14	14
Surface water without water from peace treaty	315	350	363	364	365
Resources as stated in the peace treaty	50	50	80	80	80
Red Dead Conveyance project					570
Total of Treated Wastewater	**80**	**110**	**150**	**245**	**256**
Total of Water Resources	926	1045	1197	1274	1847

Source: MWI and NWMP

3 Laws and Regulations concerning Wastewater and Water Reuse

3.1 Summary

The utilization of recycled water within Jordan has been made possible by the development and evolution of a sound legislative and legal foundation. There are several sets of standards that have paved the way. These include the first law regarding the operation of municipal sewer systems, which was first established in 1955, and the original public health standards first enacted in 1971.
Today there are several sets of standards and guidelines for wastewater, sludge, soil and crops that were derived from the work of the Water Authority of Jordan and the Ministry of Water and Irrigation. However, also other organizations are involved:

- Ministry of Water and Irrigation

- Water Authority of Jordan
- Jordan Valley Authority
- Ministry of Health
- Ministry of Agriculture
- Ministry of Environment
- Jordan Food and Drug Administration

The existing standards and laws that directly apply to wastewater reuse are

- the Water Authority of Jordan Law No.18/1988 and its amendments,
- the Jordan Standard No. 202/2007 for Industrial Wastewater Discharges,
- Jordanian Standard 893/2006 for Discharge of Treated Domestic Wastewater, and
- Jordanian Standard No. 1145/2006 regarding the use of sludge.

All of them have monitoring duties and monitoring programmes, which are partly overlapping. However, no regulation exist which defines the cooperation of data exchange and evaluation among these organisations. No institution signs responsible for overall coordination and guidance in case the public health is threatened by bad practices of reclaimed water use.

3.2 Overview of Jordanian Policies and Laws

- **Wastewater Management Policy of 1997**

The Wastewater Management Policy of 1997 institutionalizes 62 points regarding the future use and management of wastewater. It shall be considered as a water resource. The following important assertions were made a part of the national wastewater strategy by the policy:

- Wastewater shall not be disposed of; instead, it shall be a part of the water budget,
- There shall be basin-wide planning for wastewater reuse,
- Use of recycled and reclaimed water for industrial use shall be promoted,
- Fees for wastewater treatment may be collected from those who use the water,
- Any crops irrigated with wastewater or blended waters shall be monitored, and
- Ultimately, the role of the government shall be regulatory and supervisory and private operation and maintenance of utilities shall be encouraged.

- **Water Authority Law No 18/1988 amend. 16/1998, 62/2001**

This law defines the duties of the management and treatment of domestic and industrial wastewater.
The 1998 revision (Water Regulations for Connection to public sewer system) issued according to the bi law No.66 for the year 1994. The rules make it possible for any industry to obtain a connection to the sewer for that portion of their wastewater that meets the quality requirements of the revised discharge standards. The Water Authority of Jordan recognized that industries that were denied sewer connections were likely to dispose of some materials by clandestine discharges to municipal sewers from tanker trucks or hoses. Most of those concerned believed that it would be better to allow

connections even when there was some risk of toxic discharges. In this way, some revenue could be collected and large and damaging toxic shock loads that result from tankers unloading waste materials into the sewer could be reduced.

3.3 Jordanian Standards

- **Reclaimed Domestic Wastewater Standard No 893/2006**

In 1995, Jordan's Department for Standards published a comprehensive reuse standard for treated domestic wastewater principally developed by the Water Authority of Jordan and approved by the technical committee for water and wastewater at JISM. This standard was amended in 2002 to widen the reuse activities. These standards are currently applied to all municipal wastewater treatment systems. The final version of this standard was issued in year 2006. The standards establish a variable standard for wastewater quality for 7 categories of discharge or direct reuse.
The Reclaimed Domestic Wastewater standard has the following primary components:

a) Reclaimed water discharged to streams, wadis or water bodies.
b) Reclaimed water for reuse.
c) Allowable limit for properties and Criteria for use in artificial recharge for ground water.

The 2006 Standard # 893 includes the following categories of wastewater reuse standards depending on the fate of domestic wastewater after it is released from the wastewater treatment facility:

- Recycling of water for irrigation of vegetables that are normally cooked,
- Recycling of water used for tree crops, forestry and industrial processes,
- Discharges to receiving water such as wadis and catchments areas,
- Use in artificial recharge to aquifers not used for drinking purposes,
- Discharge to public parks or recreational areas,
- Use in irrigation of animal fodder.
- Use of reclaimed water for cut flowers

Quality Monitoring

The Wastewater Treatment Plant Owner Party must ensure that the reclaimed water quality complies to the standards and according to its end use. And must carry out the required laboratory tests and document results in official logbooks and present them whenever requested by the governmental monitoring parties.
The operating party must take composite samples every 2 hr for a period of 24 hrs in accordance with the frequency indicated in the standard. Monitoring parties can collect samples in any way found suitable.
The frequency of collecting samples for both the operating and monitoring parties are determined in the standard.

Collecting, preserving, transporting and analyzing samples will be as stated in the Standard Methods for the Examination of Water and Wastewater issued by APHA and the federal American Association for Water Research and Pollution Control and any of its amendments or any other approved method if it is not mentioned in the above mentioned reference.
When there is a need to define a standard value for a criterion not mentioned in this Standard then the Institution for Standards and Metrology must be contacted to take the proper action in case of epidemics the monitoring and operational parties must investigate the presence of intestinal pathogenic microorganisms that may be found in the water.

Furthermore, the standard defines the mode of monitoring and values for WWTP effluents to be discharged in water bodies and aquifers or to be reused in the allowed aspects.
The standard explicitly prohibits the direct use of reclaimed water for irrigation of crops (vegetables) which are eaten uncooked.

Evaluation Mechanism
For the purpose of evaluating the quality of reclaimed water as per the different uses mentioned in this standard according to the periods approved.
When any value violate the standards set for discharge of reclaimed water to streams, wadis or water bodies an extra-confirmatory sample must be taken. If the two samples exceeded the allowable standard limits the concerned party will be notified in order to conduct the necessary correction measures in the shortest possible time.

- **Industrial Wastewater Standard Specification No 202/2007**

This standard defines the quality for final discharge of industrial wastewater to water bodies or irrigation. Standard 202 incorporated the standard no.893/2006 for the reuse of industrial wastewater that included four categories:

- Irrigation
- Recycle in side the industrial establishment.
- Discharge to Wadis, Rivers and Catchments Areas.

The irrigation reuse standard specifies limitations on the direct use of reclaimed water to four categories as indicateed in following table:

Allowable limits per end use				
Cut Flowers	**Field Crops, Industrial Crops and Forest Trees**	**Fruit Trees, Sides of Roads outside city limits, and landscape**	**Cooked Vegetables, Parks, Playgrounds and Sides of Roads within city limits**	**Parameter**
	C	B	A	
15	300	200	30	BOD
50	500	500	100	COD
<2	-	-	<2	Do
15	300	200	50	TSS
9 – 6	9 – 6	9 – 6	9 – 6	PH
5	-	-	10	Turbidity
45	70	45	30	NO3

70	100	70	45	T-N
>1.1	-	1000	100	E.coli
≥1	≥1	≥1	≥1	Intestinal Helminthes Eggs
2	8	8	8	FOG
Unit NTU	MPN/100ml	Egg/l		

Standard 202 recognized the problem of salt in reclaimed wastewater to be used in agriculture, a limit of 2000 mg/l of total dissolved solids was specified and remain in force for industrial effluents.

- **Standards for crop monitoring**

The current crop monitoring programme for fresh fruits and vegetables bases on several international (ISO) standards. They define the mode of sample collection, preparation of samples for analysis and the analysis of chemical and microbiological parameters. The most important ones are listed below.

- Standard on Sampling of fresh fruits and vegetables No 1239/1999
- Fruits, vegetables and derived products – Decomposition of organic matter prior to analysis – Wet method, Standard No 1246/1999
- Fruits, vegetables and derived products – Decomposition of organic matter prior to analysis – Ashing method, Standard No 1247/1999
-

A guideline/ manual for a consistent crop monitoring is developed.

3.4 The future of laws and standards

Although much progress has been made in Jordan on laws and standards for wastewater reuse, the critical water situation suggests the need for further evolution of wastewater reuse standards and related law. Due to the expected rapid growth of treated wastewater supplies, it will be necessary for Jordan to expand the agricultural reuse of wastewater and to enhance industrial and domestic recycling of water in the future.

Jordan Valley Authority and German International Cooperation (GIZ) set Irrigation Water Quality guidelines, currently; this guideline will set soon into Standard with cooperation with JISM.

4 Waste Water Treatment Technology

According to the 2010 figures, out of 351 million cubic meters (MCM) used for domestic purposes, around 118 MCM reached WWTPs. This equals only about 34 % of the total domestic water consumption. A part from the fact that about 40% of dwellings are not connected to the sewer network system, administrative and technical losses are the main reasons behind the low figure of treated waste water.

4.1.1 Influents and Effluents of WWTP

Out of 351 MCM of municipal water, only 118 MCM reach sewage system. Theoretically, it means around 62% of the total amount does not reach WWTPs. A deep look into the official figures of MoWI reveals the following facts:

- Firstly, the fact that 40% of dwellings, in Jordan, are not connected yet to the sewer network system is one of the key factors contributing to the low figure of treated waste water.
- Secondly, administrative loses represented by the illegal water abstraction from the network.
- Thirdly, technical loses due to the leakage in water supply networks. These loses are estimated around 25-40% of pumped amount, according to WAJ.

Almost 73% of the actual influent is received by only one WWTP namely, As -Samra Plant. This plant is the main supplier of reclaimed water for King Talal Reservoir (KTR).

4.1.2 Existing Wastewater Treatment Plants

The following table gives an overview on applied technologies of existing and planned wastewater treatment plants in Jordan

Treatment Plant	Mechanical Treatment	Treatment Ponds	Biological Treatment	Filtration/ flocculation/ membrane	Disinfection (chlorine, ozone, UV)
As-Samra	Grid		Activated sludge		Chlorine
Aqaba		Stabilization ponds			
Aqaba – MECHANICAL TP					
Salt	Grid		Extended aeration		Chlorine
Jerash	Grid		Extended aeration		
Mafraq			Stabilization ponds		
Baqa'a			Trickling filter		
Karak			Trickling filter		
Abu-Nusir			Activated sludge		
Tafila			Trickling filter		
Ramtha		Stabilization ponds			
Ma'an		Stabilization ponds			
Madaba		Stabilization ponds			
Kufranja			Trickling filter		
Wadi Al Seer		Aerated lagoon			
Fuheis	Grid, Sedimentation		Activated sludge		Chlorine
Wadi Arab			Activated sludge		
Wadi Hassan			Activated sludge		
Wadi Musa			Activated sludge		
Irbid			Activated sludge and trickling filter		
Tel Al-Manteh	Grid, Sedimentation		Activated sludge, trickling filter, polishing ponds		UV

Source: Water Authority of Jordan, Waste-water Sector

4.1.3 Planned Future Wastewater Treatment Plants

Plant Site	Mechanical Treatment	Biological Treatment
Nauor	Grid, Sedimentation	Activated sludge
Zyzia	Grid, Sedimentation	Activated sludge
Kofur Asad	Grid, Sedimentation	Activated sludge
Al Mazar Al Shamali	Grid, Sedimentation	Activated sludge
Dair Abi Sa'id	Grid, Sedimentation	Activated sludge
Jerash West	Grid, Sedimentation	Activated sludge
North Shuna	Grid, Sedimentation	Activated sludge

Source: Adapted from Water Authority of Jordan, Waste-water Sector

Wadi Es-Sir Wastewater Treatment Plant (aerated lagoon system)

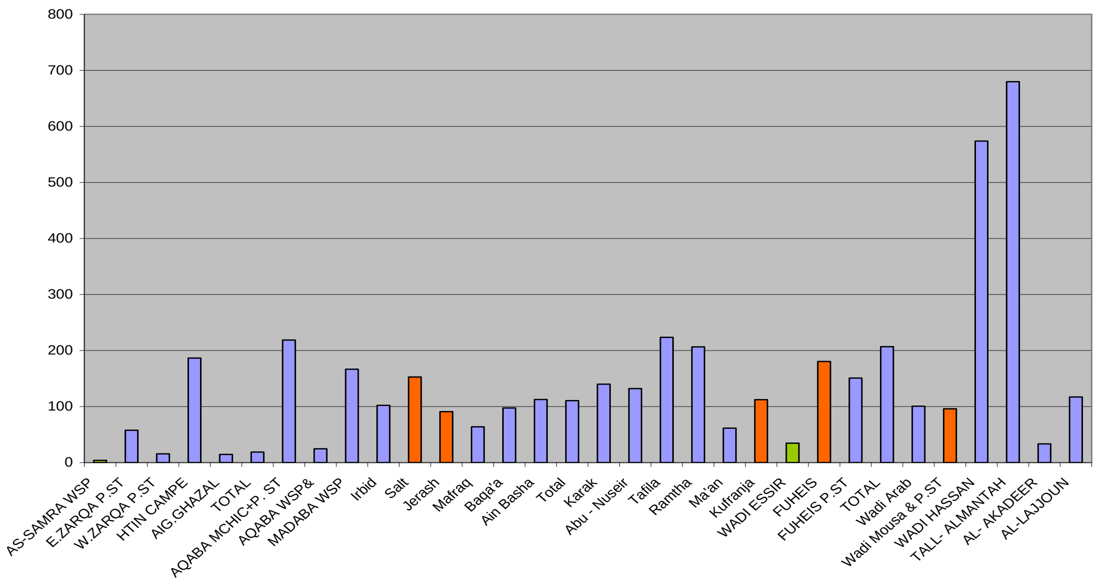
Khirbet As-Samra Treatment Plan (activated sludge system)

4.6 Costs of Wastewater Treatment:

Specific costs for wastewater treatment vary significantly between 3.9 and 680 fils/ m^3 influent. The cost strongly is determined by the treatment technology:

- Pond systems or aerated pond systems like in Wadi Es Sir, old As- Samra Ponds or Madaba have specific costs between 3.9 fils/ m^3 and 100 fils/m^3.
- Activated Sludge systems have average treatment costs of 90 to 180 fils/ m^3.
- More sophisticated systems (e.g. combined technologies and trickling filters) show specific treatment costs from 180 up to 700 fils/ m^3.

The costs also vary depending on the throughput and internal cost structure. WAJ holds records on the performance of all treatment plants in Jordan.



5 Reuse Technology

5.1 Treated Domestic Wastewater

The sewer networks in Jordan drain its load into 22 existing central Waste Water Treatment Plants (WWTP). The effluent is used for agriculture purposes inside the premises of WWTP and in their vicinities. The surplus of effluents goes down along wadis where it either dies away owing to evaporation and infiltration or reaches subsequent water bodies like dams.
Countrywide, the agricultural sector consumes around 512 MCM of water (2007). Around half of this amount (251 MCM) is consumed in Jordan Valley. Almost 56% of these 251 MCM is marginal water (brackish and reclaimed water). This means that JV cultivation consumes not more than 22% of the fresh water used in irrigation.
Three out of 22 WWTPs (Khirbet As Samra, Jerash, Baq'a) drain the biggest share of the total effluents (around 53 MCM a year) to King Talal Reservoir (KTR) where it is diluted by the annual rainfalls. Farmers in the middle JV totally depend on this resource as they don't receive any surface water from King Abdulla Canal (KAC). Therefore, this dam is considered as a vital necessity for agriculture in Jordan Valley. The recently increasing cultivation of crops in the upstream area of KTR has negative consequences on KTR water balance as it comes at expense of agriculture in JV. While in former days, farmers had to be convinced to use KTR water, now farmers face clear competition for the limited resources.

5.1.1 Irrigated area in Jordan

Cultivation in JV consumes 28% of the freshwater whereas 72% is consumed in the highland. The following table shows the amounts of irrigation water used all over the Kingdom during 2010.

Water consumption for irrigation, in Jordan

Region	Total irrigated area (dunum)	Water resources	Quantities of consumed water (MCM/ Year)
North JV	89,835	KAC (freshwater)	38
Middle-south JV	212,525	KTR, Kafrain, and Shu'aeb dams (reclaimed water)	120
		Wells (brackish water)	62
Southern Ghors	56,580	Surface (freshwater)	37
Highland	701,814	Wells (freshwater)	245
Total	**1,060,754**		**502**

Source: JVA and MoA, 2010.

5.1.2 Consumption of water at premises and vicinities of WWTP

According to agreements signed with farmers and other official entities, WAJ provides treated water either inside the plant premises or in the vicinities of the plants. The agreements guarantee provision of water in the rate $3m^3$ a day for each dunum. The total cultivated area is estimated with 14934 dunum.
Theoretically, according to the signed agreements, the total amount of water supplied to farmers should not exceed 16.02 MCM per year.
In As-Samra a lone, which makes up more than 70% of the total treated effluents, the actual consumption exceeds the supposed consumption agreed on by four times. Based on the limited available information, one must assume that the huge difference between the calculated and the actual amounts of water might be as a result of either over-irrigation or miscalculations in the cultivated irrigated areas.

By calculation, around 29% of the total effluent generated at AS-Samra is used in irrigating the cultivated areas in its premises as well as vicinity.
In addition to the total quantities of water used in agriculture, around 1.83 MCM per year is currently used by Phosphate Mines Co. for cooling purposes. This amount is coming from Aqaba Plant.

Treated water consumption in premises and vicinities of WWTP

No.	WWTP	Total cultivated areas irrigated with treated water(dunum)	Actual consumption of treated water (MCM/ Year)
1	Assamra	5103	20
2	Aqaba	2080	4.20
3	Ramtha	1206	1.18
4	Mafraq	387	0.60
5	Madaba	862	1.57
6	Ma'an	205	0.22
7	Kufranja	571	0.63
8	Salt	48	0.05
9	Baq'a	447	0.49
10	Karak	589	0.64
11	Tafila	114	0.12
12	Wadi Al-Seer	62	0.07
13	Wadi Hassan	721	0.27
14	Wadi Musa	1069	0.71
15	Al-Akader	994	1.16
Total		**14758 (Dunum)**	**31.91 (MCM/ Year)**

Source: WAJ, 2009.

5.1.3 Crop pattern irrigated with treated water

No.	WWTP	Crop pattern
1	As-Samra	Forage crops, olive trees
2	Aqaba	Date palm, fruit trees, forage crops, steppe trees.
3	Ramtha	Forage crops
4	Mafraq	Forage crops
5	Madaba	Forage crops
6	Ma'an	Forage crops
7	Kufranja	Forage crops, olive trees, steppe trees
8	Salt	Fruit trees
9	Baq'a	Nurseries, fruit trees, forage crops, olive trees
10	Karak	Forage crops, olive trees, steppe trees
11	Tafila	Forage crops
12	Wadi Al-Seer	Olive trees
13	Wadi Hassan	Fruit trees
14	Wadi Musa	Forage crops, fruit trees
15	Al-Akedar	Forage crops, olive trees

Source: WAJ, 2009.

According to Jordanian laws, reclaimed water is only used for irrigation of non edible crops such as forage crops and nurseries and trees.

5.1.4 Irrigation Technologies

Farmers in the Middle and South Jordan Valley receive reclaimed water from the King Talal Reservoir where it was diluted with rain water. The long wadi and the reservoir between the WTTP and the point of use also minimize the contamination of the water. (Natural purification) Therefore, contamination with pathogen is very limited. The main concern of the farmers however is the higher salt content of reclaimed water. This problem needs to be addressed at the source of effluents (for As-Samra treatment plant, main polluters are industries and desalination plants)

Farmers mainly use mulch (plastic cover on soil) and drip irrigation in order to avoid excessive evaporation. This practice positively influences microbiological quality of the crops as well. The use of mulch and drip irrigation is considered as very effective barriers for a microbiological contamination.

The irrigation system in Wadi Musa uses pure reclaimed water directly form the WWPT and also applies drip irrigation. In this area, it is only allowed to cultivate forage crops.

6 Actors and Stakeholders

Efficient and save reuse of treated wastewater and greywater requires the involvement and cooperation of many stakeholders. The responsibilities are mainly defined in the above mentioned laws and regulations. However, with an increasing need for water reuse some overlaps and gaps of responsibilities have been created and need to be addressed in the near future.

- **Ministry of Water and Irrigation**
- **Municipalities**
- **Water Authority of Jordan (WAJ)**
- **Ministry of Health** and **Ministry of Environment (MoEnv)**.
- **Jordan Valley Authority (JVA)**
- **Ministry of Agriculture**
- **Jordan Food and Drug Administration (JFDA)**

7 Safety Control and Risk Monitoring

Jordan is one a pioneer among Arab countries in the establishment of a Risk Monitoring System for water reuse. A long term collaboration between government, research institutions and donors have elaborated many methodologies and tools that benefit the safe reuse of water. Many important elements of a risk monitoring exist today; however, they are not used to the most efficient and effective extent. One obstacle is the communication among the above mentioned actors and stakeholders. Some tasks are partly duplicated while other relevant issues remain untouched.

Examples for existing elements/ tools:

- Frequent monitoring system of effluents from WWTP (WAJ)
- Monitoring of Soil and Groundwater in the Jordan Valley (JVA)
- Advice to farmers on wastewater reuse (JVA and various donor projects)
- Monitoring of Fresh Fruits and Vegetables from the Jordan Valley and Whole Sale Market Amman (JFDA)
- Water Quality Monitoring among Jordan of MoEnv
- Advice to households on greywater reuse for garden irrigation (various NGOs and research institutes within donor funded projects)

The German International Cooperation currently supports the MWI, WAJ and JVA in the establishment of a Safety Control and Risk Management System in the Jordan Valley. This model will be the basis for a general Risk Monitoring concept to be adjusted to other areas in Jordan.
The basis for the currently planned Risk Management Concept for Jordan is the WHO Guidelines on Wastewater and Greywater Reuse (2006). These guidelines will set into standard. A national multidisciplinary working team developed a comprehensive risk monitoring and management system for the use of treated wastewater

7. Jordanian National Plan for Risk Monitoring and Risk Managment for the Use of Treated Wastewater

In the old guidelines, WHO 1989 recommended the implementation of a rather stringent procedure depending mainly on a single barrier approach. This approach requires treating wastewater at a state-of-the-art treatment plant to render treated water of an acceptable quality for reuse purposes. In 2006 WHO-FAO-UNEP issued new guidelines for the use of treated wastewater. The new guidelines encourage the use of multiple barriers approach which is more flexible and less stringent. This approach combines treatment and post-treatment barriers compared to the old approach that relies solely on the treatment plant as the only reliable control measure. Table below shows the comparison between the old and new WHO Guidelines. The rationale behind this flexibility is based on the understanding of the socioeconomic status of developing countries and the dire need to exploit treated wastewater in dry countries. However, it is by no means acceptable to use partially treated wastewater in a way that compromises the health of people. For a rational adaptation and implementation of the new guidelines, a risk management system shall be in place in areas where treated wastewater is used for irrigation.

Comparison between the old and new WHO Guidelines

WHO Guidelines (1989)	**WHO Guidelines (2006)**
E coli ≤ 1000 MPN/ 100ml	E coli threshold varies from 1000 to 100000 MPN/100 ml depending on the set health-based target
Depends on one single approach (Wastewater Treatment Plant)	Depends on a multiple barriers approach (Control Measures)
Do not provide feasible risk-management solutions or guidance	Provide an integrated approach that combines risk assessment and risk management to control water-related diseases
Unachievable under local circumstances	Can be adopted according to the local socio-economic conditions

7.1 Types of risks associated with treated wastewater use

The use of treated wastewater is associated with three major types of risks:
Microbiological.
Chemical.
Physical.

In the context of wastewater use in agriculture, there are two groups of wastewater-related diseases; the diseases of interest are caused by:

Group 1: diseases caused by:
Viral: rotavirus (affects children under age of 3).
Bacterial: Campylobacter.
Protozoa: Amoeba, Cryptosporidium.

Group 2: diseases caused by helminthes eggs like Ascaris.

Not every hazard will end up in causing illness. Different hazards and exposures pathways will result in different diseases' burdens. The relative importance of health hazards in causing illness depends on a number of factors:

- Minimum infective dose.
- Persistence in environment.
- Ability to induce human immunity.
- Virulence.
- Latency period.

Thus, pathogens with long persistence in the environment and low minimal infective dose which elicit little or no human immunity and spend long latency period, have a higher probability of causing infection than others. Accordingly, helminthes infection poses greatest risk associated with wastewater irrigation. (Bos et al., 2010).

Chemical risks on both human and animals result from heavy metals, pesticides residues and pharmaceutical compounds. Risks of chemicals are thought to be low, except in localized areas with large industrial wastewater generation. Diseases associated with exposure to chemicals are harder to attribute to wastewater use in agriculture as it is the case in microbiological contamination.

Physical risks are the risks caused by sediments and suspensions that might clog the emitters of drip irrigation systems and/or hamper the flow of water in the irrigation network at farm level.

Public health concerns usually arise from the existence of microbiological contaminants in water and on food. Experts usually use the microbial analysis data to indicate that a hazard exists in the environment and thus assess the associated risks. The new WHO guidelines focused on the microbiological contaminants and recommended an integrated and harmonized approach for the development of health-based guidelines and standards in terms of water-and-sanitation-related microbial hazards. This approach involves the assessment of health risks prior to the setting of health-based targets and the development of guideline values, defining basic control approaches and evaluating the impact of these combined approaches on public health. These approaches combine risk assessment and risk management to control water-related diseases, see annex B. However, in this proposal, all the three types of risks were taken into consideration and assessed. The following chapters describe the approach and main results.

7.2 Microbiological Contamination: Relation between microbial indicator (E.coli) and pathogenic diseases

The presence of E.coli in a water sample will often but not always mean that other pathogens are also present. It is easier to measure E.coli concentrations and assume that this represents a group of similar pathogens than to measure concentrations of individual pathogens. According to Schwartzbord (1995), the ratio of enteric virus to fecal Coliform (E.coli) is $1:10^5$. Table below shows the possible levels of pathogens in wastewater.

Possible levels of pathogens in wastewater

Type of pathogen		Possible concentration per 100 ml in municipal wastewater
Viruses	Enteroviruses	500
Bacteria	Pathogenic E. coli	?1
	Salmonella spp.	700
	Shigella spp.	700
	Vibrio cholerae	100
Protozoa	Entamoeba histolytica	450
Helminthes	Ascaris Lumbricoides	60
	Hookworms	3,2
	Schistosoma mansoni	0.1
	Taenia saginata	1
	Trichuris trichiura	12

1 Uncertain
Source: (FAO, 1992)

7.3 Disease risk versus infection risk

It is important to differentiate between disease risk and infection risk; as the later measures the probability to ingest the pathogen, whereas the disease risk measures the possibility of ingesting enough dose of a pathogen that will manifest in a clinical disease. Not every person infected by ingestion of pathogens becomes ill. It depends on the virulence of the pathogen, age, nutritional and general health conditions of the person. A minimal infectious dose of any pathogenic disease is needed to induce illness. The minimum infectious dose for 50% of the exposed population to become infected (N50), ranges from (5.6) virus as in the case of rotavirus to more than (10,000) bacteria as in the case of salmonella. The ratio of infection to clinical disease is often as low as 100:1 (Fattal et al., 2004). WHO in 2006 guidelines, considered the disease/infection ratio for rotavirus 5:100.

7.4 A Pre-requisite for the development of risk management plan

Setting a health-based target is a pre-requisite for developing a risk management plan which uses the tolerable risk of a disease as a baseline to identify specific control measures that will reduce the risk of disease to this tolerable level and thus achieving the set health based target. Health-based target can be achieved mainly through following three steps:

- assessing the system
- identifying control measures and methods for monitoring them
- developing a management plan

7.5 Health-based target

A level of risk can be estimated for almost any exposure. In other words, there is no such thing as zero risk; only very low risks, because a level of risk can always be estimated. At first, it is important that the tolerable risk of a disease (the disability due to infection or the absence of specific disease related to that exposure) to a society to be defined to be able to calculate the tolerable risk of infection. To facilitate the comparison of different health outcomes (e.g. diarrhea compared to cancer), risks can be expressed in terms of disability adjusted life years (DALYs) which is a measure of years lost due to premature death and/ or disability caused by a disease.

DALY measures the weight of the damage incurred by a disease rather than counting the total number of cases of each disease. It accounts not only for acute health effects but also for delayed and chronic effects (morbidity and mortality). WHO has determined that a disease burden of 1×10^{-6} DALY (disability adjusted life year) per person per year from a disease caused by either a chemical or infectious agent is a tolerable risk for drinking water (WHO, 2004). The same stringent health target DALY $1x10^{-6}$ is proposed to be applied in case of using wastewater for irrigation, because people assume that their food should be as safe as their drinking water. $1x10^{-6}$ DALY means not more than 1 DALY loss per year per 1 million persons as a result of diseases arising from using treated wastewater in irrigation. To reach this stringent target, a combination of treatment and non treatment control measures should be considered and implemented. It is important to mention that WHO does not insist on this target and leaves the decisions to each country to decide, however, it necessitates and requires that authorities must ensure sound monitoring and management interventions to meet the set health-based target.

DALY loss per case of rotavirus diarrheal disease1 associated with the use of wastewater in developing countries is $2.6x10^{-2}$. This number is equivalent to 38 cases of diarrhea per year per one million people2 if the additional disease burden of $1x10^{-6}$ is adopted. In other words, the tolerable disease risk (pppy) equivalent to 10-6 DALY loss (pppy) is $3.8x10^{-6}$.

It is worth mentioning that WHO, based on DALY concept, conducted a comprehensive study for all Member States in which DALY for all possible risks of death from HIV/AIDS to tuberculosis and car accidents are calculated. The list comprises 128 death causes. When risk is described in the DALY, different health problems (cancer vs diarrhea) can be compared and risk management decisions are prioritized. Table below shows a comparison between Jordan and some other countries in terms of DALY for 2 types of microbiological risks.

[1] Rotavirus is one of the 3 index pathogens that cause diarrhea (rotavirus, campylobacter, and cryptosporidium) with highest DALY per case,
[2] WHO guidelines, 2006, chapter4

DALY per case of diarrheal disease and ascariasis in different countries.

Country	DALY per case	
	Diarrheal diseases	Ascariasis
World	8.3×10^{-3}	2.1×10^{-4}
Jordan	2.8×10^{-3}	2.1×10^{-6}
Egypt	4.5×10^{-3}	5.0×10^{-5}
Tunisia	3.3×10^{-3}	6.9×10^{-6}
Syria	2.8×10^{-3}	2.1×10^{-6}
USA	3.4×10^{-4}	0
Germany	3.3×10^{-4}	0
Australia	3.0×10^{-4}	0

Source: http://www.glocalfocal.com

Thus, the first step in any health risk assessment process is to establish the maximum tolerable additional burden of disease, – i.e., the maximum DALY loss pppy as it establishes the maximum tolerable disease and tolerable infection risks (Mara et al. 2010) as follows:

$$Tolerable\ disease\ risk\ (pppy) = \frac{Tolerable\ DALY\ loss\ (pppy)}{DALY\ loss\ per\ case\ of\ disease}$$

$$Tolerable\ infection\ risk\ (pppy) = \frac{Tolerable\ disease\ risk\ (pppy)}{Disease/infection\ ratio}$$

The difference between the two terms lies in the fact that not all persons who are subjected to infection risk would surely develop clinical disease due to different reasons, among them, the difference in the immune systems. Tolerable infection risk is very important because from this figure, we can derive the acceptable wastewater quality through quantitative microbial risk assessment (QMRA).

Establish the appropriate value for the health based target – i.e., the maximum tolerable additional burden of disease

The default value of the maximum tolerable additional burden of disease resulting from working in wastewater-irrigated fields or consuming wastewater-irrigated food as stated in the 2006 World Health Organization Guidelines for the Safe Use of Wastewater in Agriculture is 10^{-6} DALY loss pppy. As by Mara et al (2010), this reference level of risk is the same as that used in the third edition of the WHO Guidelines for Drinking-water Quality which was chosen as it is equal to the US EPA-accepted excess lifetime cancer risk from drinking 2 liters per day of fully treated drinking water containing a carcinogen (e.g., a pesticide) as its maximum permitted level for 70 years. This 70-year lifetime cancer risk of 10−5 per person is equal to an annual cancer risk of 4.6 × 10^{-3} per person. However, the USEPA-accepted maximum water-borne-cancer risk of 1.4×10^{-7} pppy is over four orders of magnitude lower than the actual average all-cancer incidence in the USA of 4.6×10^{-3} pppy during 1975–2007 and is therefore unlikely to be justifiable or cost-effective, and thus a DALY loss of 10^{-6} pppy is equally unjustifiable and cost-ineffective. However, the 2006 WHO Guidelines do allow a higher DALY loss to be chosen (as stated in 2006 WHO Guidelines, volume 2, section 4.5):

"Wastewater treatment may be considered to be of a low priority if the local incidence of diarrheal disease is high and other water-supply, sanitation and hygiene-promotion interventions are more cost-effective in controlling transmission. In such circumstances, it is recommended that, initially, a national standard is established for a locally appropriate level of tolerable additional burden of disease based on the local incidence of diarrheal disease – for example, ≤10^{-5} or ≤10^{-4} DALY [loss] per person per year."

Dr. Duncan Mara renowned international expert in the field of reuse visited Jordan during 21-30 May 2011 to assess the safety (or otherwise) of the current practices in the use of treated wastewater in the Jordan Valley. He came up with the following statement:

"A higher DALY loss of 10^{-4} pppy can be shown to be appropriate in Jordan by considering the current DALY loss due to diarrhoeal disease in the country. This is a DALY loss of 3.7 per 1000 people – i.e., a DALY loss of 0.0037 pppy. An additional DALY loss of 10^{-4} pppy due to working in wastewater-irrigated fields or consuming wastewater-irrigated food would increase this to only 0.0038 pppy, which is an epidemiologically insignificant difference (and one that would be very difficult to detect).

Using norovirus (NV) as the reference viral pathogen, the maximum tolerable additional NV disease and infection risks from working in wastewater-irrigated fields or consuming wastewater-irrigated food can be calculated as follows:

$$\text{Tolerable NV disease risk (pppy)} = \frac{\text{Tolerable DALY loss (pppy)}}{\text{DALY loss per case of NV disease}} = \frac{10^{-4}\text{pppy}}{9\times 10^{-4}} = 0.11\text{pppy}$$

$$\text{Tolerable NV infection risk (pppy)} = \frac{\text{Tolerable disease risk (pppy)}}{\text{Disease/infection ratio}} = \frac{0.11\text{pppy}}{0.8} = 0.14\text{pppy}$$

The above tolerable NV disease risk of 0.11 pppy, equivalent to one additional case of NV disease per person every nine years, is much lower than the current incidence of diarrhoeal disease in Jordan which is around 0.8 pppy – i.e., four cases of diarrhoeal disease per person every five years".

7.6 Protection measures and microbial reduction target

WHO guidelines require 6 to 7 log-unit-reduction[3] on fecal coliforms counts (E. coli is an indicator) from the source of wastewater (10^8 level of contamination in raw wastewater), and right prior to crop consumption it is 10^1 to 10^2 log-unit-reduction (acceptable level of contamination for safe food). In Jordan, Historical irrigation water quality data shows that there is no real difference between the counts of the fecal coliforms and the E.coil. A 6-7 log unit reduction can be achieved by the application of appropriate health protection measures as stated in the following table.

The available health protection measures in Jordan and their impacts on biological contamination reduction.

Control measure	Pathogen reduction (log-unit)	Notes
Wastewater treatment.	1−6	The required pathogen removal to be achieved by wastewater treatment depends on the combination of health-protection control measures selected.
Drip irrigation (low-growing crops).	2	Root crops and crops such as lettuce that grow just above, but partially in contact with, the soil.
Drip irrigation (high-growing crops).	4	Crops, such as tomatoes, the harvested parts of which are not in contact with the soil.
Spray/sprinkler drift control.	1	Use of micro-sprinklers, anemometer-controlled direction-switching sprinklers, inward-throwing sprinklers, etc.
Pathogen die-off.	0.5−2 per day	Die-off on crop surfaces that occurs between last irrigation and consumption. The log-unit-reduction achieved depends on climate (temperature, sunlight intensity), crop type, etc.
Produce washing with water.	1	Washing salad crops, vegetables and fruits with clean water.
Produce disinfection.	2	Washing salad crops, vegetables and fruits with a weak disinfectant solution and rinsing with clean water.
Produce peeling.	2	Fruit, root crops.
Produce cooking.	5−6	Immersion in boiling or close-to-boiling water until the food is cooked ensures pathogen destruction.

Source: WHO Guidelines, 2006

[3] 1 log-unit-reduction means 90% reduction in number of E. coli, 2 log equals 99% reduction, 3 log equals 99.9%

8 Future Perspectives and Challenges

- Jordan faces a high population growth and therefore an increasing demand for water. Considering the limited amounts of renewable freshwater resources in Jordan, these resources have to be protected and saved for drinking water. Therefore, the agricultural sector has to be prepared to depend more and more on marginal water resources such as treated wastewater.
- Inadequate tariffs still encourage households, industries and farmers to waste valuable freshwater resources. The low tariffs also hinder the application of reuse technologies as they are financially not attractive to households. In general, Jordanian tariffs do not cover the water production cost and even less the wastewater treatment costs. This leads to a step-by-step deterioration of the existing facilities and hinders the establishment of new treatment facilities.
- Private sector involvement is still limited in Jordan and needs to be further extended for sanitation and wastewater reuse. This, however, requires an adjustment of tariffs in order to cover the actual treatment costs for wastewater.

9 List of References

1- The Ministry of Water and Irrigation, 1999. “Wastewater Management and Reuse-Country Profile.”

2- Saleh. F. S., and R. F. Tal. 1999. “The Encyclopedia of Jordan Environmental Legislation”.

3- Saleh. F. S, and H. A. Jaber. 1992. “Evaluation of Environmental Legislation. The Higher Council for Science and Technology.”.

4- Mohammad. M., and F. J. McNeil. 1998. “Wastewater Reuse is Key to Solving Jordan’s Water Problems.” Water Environment & Technology.

5- Water Authority of Jordan. 1999. “Wastewater Annual Report”.

6- Rakad. A., and M. Samara. 1991. “Legislation- Water Bi-Laws and Regulations and Water Rights.” Water Authority of Jordan.

7- The Ministry of Water and Irrigation, Kingdom of Jordan. 1998. “The Wastewater Management Policy. “

8- The Institution for Standards and Metrology, 1996. “Jordan Standard for Sludge Use and Treatment. No. 1145.”

9- The Institution for Standards and Metrology, 1995. “ Jordan Standard for Domestic Water No. 893”

10- The Institution for Standards and Metrology, 2006. “ Jordan Standard for Domestic Water No. 893”

11- The Institution for Standards and Metrology, 1991. “Jordan Standard for Industrial Wastewater No. 202”

12- The Institution for Standards and Metrology, 2007 “Jordan Standard for Industrial Wastewater No. 202”

13- The Office of the Prime Minister, Kingdom of Jordan. “Martial Law No. 2/1988.”

14- The Official Gazette No. 3540, Kingdom of Jordan.1988. “Jordan Valley Development Law No. 19.”

15- The Official Gazette No. 3540, Kingdom of Jordan..1988. “Water Authority of Jordan Law No. 19/1988.”

16- The Official Gazette No. 4314, Kingdom of Jordan. 1998. “The Instructions for Discharging Industrial and Commercial Wastewater to the Sewer System.” Official Gazette No.4314.

15. Biswas A.K., and A. Arar. 1988. “Treatment and Reuse of Wastewater” FAO, Butterworths.
16. National Water Master Plan (2006): http://www.mwi.gov.jo/NWMP/INDEX.HTM
17. Budget of Reclaimed Water In Jordan for 2007, June, 2008, Ahmad Sobh & Sameer Abdel-Jabbar - GTZ