Proposal:

Risk Monitoring and Management Plan for the Safe Use of Treated Wastewater Upstream and Downstream King Talal Reservoir

Jordanian Interdisciplinary Working Group
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The proposal for this *Risk Monitoring and Management Plan for the Safe Use of Treated Wastewater Upstream and Downstream King Talal Reservoir* has been developed by an interdisciplinary working group consisting of:

Ministry of Water and Irrigation (MoWI),

Jordan Valley Authority (JVA),

Water Authority of Jordan (WAJ),

Ministry of Agriculture (MoA),

Ministry of Environment (MoEnv),

Ministry of Health (MoH),

Jordan Food and Drug Administration (JFDA),

National Center for Agricultural Research and Extension (NCARE),

Royal Scientific Society (RSS)

German Technical Cooperation (GTZ)

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1. Background

Jordan is one of the most water scarce countries with approximately 145 m³ of available water resources per capita per year which is extremely less than the widely recognized "water poverty line" of 500 cubic meters per capita per year, (water strategy, 2008-2022). That results in a serious overuse of the water resources. The vast growth of population and increase the per capita consumption of water is a challenge for the decision makers as the gap between the limited available water resources and the different sectors' demands is widening. Therefore, MoWI, together with other governmental institutions and donor agencies, has started augmenting the supply resources as well as managing the demands on water. Together, they are trying to overcome any risks in water shortages that might arise in the future.

The agricultural sector is the largest water consumer in Jordan, where 64% of the total water budget is being used for irrigation in 2007 (water strategy, 2008-2022). However, the farmers feel the pressure of the increasing demand on water by the domestic sector and industry. For example, farmers in the Jordan Valley are suffering from the continuous decline in freshwater resources coming from Yarmouk River through King Abdulla Canal (KAC) as more water is pumped to Amman for drinking purposes. Accordingly, farmers are forced to tap unconventional water sources such as brackish water and blended treated wastewater.

Treated wastewater quantities have been increasing due to increasing the number of domestic households being connected to the sewer system over time. This makes it an available water source all over the year. Currently, more than 110MCM of treated wastewater is produced from 24 Treatment Plants (TP) all over the Kingdom, where 79.6MCM (72%) is generated by the biggest treatment plant, Kherbit As-Samra, which is the main supplier of King Talal Reservoir (KTR), (JVA record, 2009).

Treated wastewater can be either used **directly in restricted agriculture** or **indirectly in unrestricted agriculture**. For the **indirect use**, treated wastewater is usually released in natural Wadis and stored in reservoir, where it is blended with other fresh water resources such as rainfall and springs water and then used in irrigation. In Jordan, 60.8MCM of the total quantities of generated treated wastewater is being stored in reservoirs and only used indirectly in unrestricted agriculture in the Jordan Valley, while 44.2MCM is used directly in restricted agriculture. Table (1) shows the total quantities of blended treated wastewater that is used in unrestricted agriculture in the Jordan Valley, (JVA records, 2009).

Table (1): Total quantities of blended treated wastewater used in unrestricted agriculture in the Jordan Valle. (JVA records, 2009).

Reservoir	TP supplier	Total quantity of treated wastewater (MCM)	Upstream Use (MCM)	Stored quantities (MCM)	Total quantity of stored treated wastewater (MCM)	Rainfall + Springs (MCM)	Yield (MCM)
King Talal	Kherbit As-Samra	79.6	23.9	55.7	58.0	43.2	101.2
	Baqah	3.8	1.5	2.3			
Kafrein	Wadi Es-Seir	1.2	0.3	0.9	1.4	3.6	5.0
	Fuhis	0.7	0.2	0.5			
Shueib	Salt	1.7	0.4	1.3	1.3	2.7	4.0
Total		**87.0**	**26.2**	**60.8**	**60.8**	**49.5**	**110.2**

As shown in table (1), King Talal Reservoir is the major supplier of blended treated wastewater that is used in unrestricted agriculture in the Jordan Valley. Treated wastewater flows out of Kherbit As-Samra plant (79.6MCM) down into a natural Wadi of 42Km long where it undergoes a natural purification and is mixed with other springs water until it reaches KTR (55.7MCM). There, it is blended with rainfall and run-off water (43.2MCM) and then released down to the Jordan Valley to be used in unrestricted agriculture (101.2MCM). 23.9MCM of treated wastewater is being used upstream KTR in restricted agriculture.

Therefore and based on the above mentioned facts, MoWI has updated the national water strategy for Jordan to control and manage the use of all water resources according to environmental and public health regulation with a great emphasis on encouraging the (direct and indirect) use of treated wastewater as one major resource in agriculture. The followings are sentences quoted from the water strategy 2008-2022, on the importance of wastewater reuse (Water Strategy 2008-2022):

On resource development/ Jordan Water Strategy 12, it is stated that:

“Wastewater shall not be managed as "waste". It shall be collected and treated to standards that allow its reuse in unrestricted agriculture … Appropriate wastewater treatment technologies shall be adopted with due considerations to economy in energy consumption, and quality assurance of the effluent for use in unrestricted agriculture. Consideration shall be given to blending of the treated effluent with fresher water for appropriate reuse."

On health standards/ Jordan Water Strategy 38: "Concerns for public health and the health of workers shall be a focus in the programs of reuse of treated wastewater.

Also, *on water strategy/ Jordan Water Strategy 12*, it is stated that: "Marginal quality water and brackish water sources shall be enlisted to support irrigated agriculture….

The Jordan Valley is the largest recipient of blended treated water that is used for unrestricted irrigation. Current water quality monitoring results show that the quality of irrigation water is becoming more and more acceptable, however not all potential environmental and health risks are considered yet.

As stated in *Jordan Wastewater Management Policy/ resource management 9*: "…The use of treated wastewater in irrigation shall be given the highest priority and shall be pursued with care."

On reuse of treated effluent and sludge/ Jordan Wastewater Management Policy 27 and 28, it is stated that: "…Protection of on farm workers and of crops against pollution with wastewater shall be ensured", and "Treated effluent quality should be monitored and users be alerted to any emergency causing deterioration of the quality so that they will not use such water unless corrective measures are taken".

Furthermore, it is mentioned in the Jordan *Irrigation Water Strategy/ irrigation water quality 26 that*: "Irrigation water quality shall be monitored through sampling at the sources and from the conveyance and distribution network. Farmers shall be alerted to any degradation of water quality. This is important so that they can plan the use of such water for the suitable farming purposes."

The new water strategy comes in line with the new *WHO Guidelines on Wastewater Use in Agriculture (2006)* as explained in the following section 2. The new guidelines present a flexible approach of risk assessment and risk management that can be applied under local socio-economic conditions accompanied with strict monitoring programmes in order to protect public health and environment. These guidelines are based on Stockholm Framework which is an integrated approach that combines risk assessment and risk management to control water-related diseases (see annex B). These guidelines aims at maximizing the protection of public health and the beneficial use of the important resources and were developed to be used as a basis for the development of international and national approaches to manage the health risks from hazards associated with the use of wastewater in agriculture as well as provide a framework for national decision making.

Many governmental institutions, such as JVA, WAJ, JFDA and MoEnv already do quality monitoring programmes and the available data base is valuable. However, the data often remain unused in different data bases. There is no clear procedure, when it comes to risk characterization and assessment, who should share the data with whom and how to interpret the information. Particularly, the cooperation on the operational level is weak as responsibilities are not clarified. As well as, action plans for emergency cases, that clearly define responsibilities are not available. Therefore, there is a need to form a multidisciplinary working group consists of members of all relevant institutions to cooperate in protecting health and environment when it comes to the use of treated wastewater in agriculture.

Overall goal:

The main goal of forming this committee is to develop a risk monitoring and management plan for the safe use (either direct or indirect) of treated wastewater in order to protect health and environment.

Objectives:

- Develop a risk monitoring and management plan for the delineated pilot area (Kheribt As-Samra Treatment Plant to KTR to Farms in JV to the consumers), see Annex A.
- Responsible organizations cooperate in irrigation water monitoring, crop monitoring and risk management by sharing information openly according to clear agreements and responsibilities set in a national risk monitoring plan.
- Establishing sound monitoring programmes, where needed, that enable institutions to know when and where to interfere.
- Avoid wasting the resources represented in duplication the same monitoring programme by more than one institution.
- Remove the fears of using treated wastewater in restricted and unrestricted agriculture that might hinder the widespread use of this important renewable source.
- Improve the reputation of the Jordanian agricultural products.

2. Safe Reuse of Treated Wastewater from the Perspective of WHO

In the old guidelines, **WHO 1989** recommended the implementation of rather stringent approach depending mainly on **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 treatment plant as the only reliable control measure. Table (2) shows the comparison between the old and new WHO Guidelines. The rationale for this flexibility is due to the understanding of 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 rationale adaptation and implementation of the new guidelines, a risk management system shall be in place in areas where treated wastewater is used for irrigation.

Table (2): 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

2.1 Types of risks associated with treated wastewater use

The use of treated wastewater is associated with three major types of risks:

1. Microbiological
2. Chemicals
3. Physical

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

Group 1: diseases caused by

1. Viral: rotavirus (affects children under age of 3)
2. Bacterial: Campylobacter
3. Protozoa: Ameba, Cryptosporidium

Group 2: diseases caused by helminthes eggs like Ascaris

Not every hazar`d 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 having 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)

Chemicals 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 the microbiological contaminants in water and on food, and usually experts use the microbial analysis data to indicate that a hazard exists in the environment and thus assess the associated risks. Therefore, 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 approached on public health that combines 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.

2.1.1 Microbiological Contamination

2.1.1.1 Relation between microbial indicator (E.coli) and pathogenic diseases

The presence of E coli in 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 pathogen than to measure concentration of individual pathogens. According to Schwartzbord (1995), the ratio of enteric virus to fecal coliform (E.coli) is 1:105. Table (3) shows the possible levels of pathogens in wastewater.

Table (3): 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
Helminths:	*Ascaris Lumbricoides*	60
	Hookworms	3,2
	Schistosoma mansoni	0.1
	Taenia saginata	1
	Trichuris trichiura	12

[1] Uncertain

Source: (FAO, 1992)

2.1.1.2 Disease risk versus disease infection

It is important to differentiate between disease risk and disease infection as the later measure the probability to ingest the pathogen whereas the former measure the possibility of ingesting enough dose of a pathogen that manifest in a clinical disease. Not every person infected by ingestion of pathogens becomes ill, it depends on virulence of the pathogen, age, nutritional and general health conditions status of the person. A minimal infectious dose of any pathogenic diseases is needed to induce illness. The minimum infectious dose for 50% of the exposed population to become infected ranges from few numbers of virus (5.6) 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.

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

Setting a health-based target is a pre-requisite for developing risk management plan which uses the tolerable risk of 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:

1. System assessment
2. Identifying control measures and methods for monitoring them
3. Developing a management plan

2.1.1.4 Health-based target and its implication

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, it is important that a risk tolerable of disease (the disability due to infection, or the absence of specific disease related to that exposure) to a society to be defined. To facilitate the comparison of different health outcomes (e.g. diarrhoea 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 for not only acute health effects but also 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 drinking water. $1x10^{-6}$ DALY means not more than 1 DALY loss per year per 1 million persons as a result of diseases arise 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 leave the decisions to each country to decide but 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 diarrhoeal disease[1] associated with the use of wastewater in developing countries is $2.6x10^{-2}$. This number is equivalent to 38 cases per year per one million people[2] if the additional disease burden of $1x10^{-6}$ is adopted.

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

It is worth to mention that WHO and 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 (4) shows comparison between Jordan and some other countries in terms of DALY and for 2 types of microbiological risks.

Table (4): DALY for different risks

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

From DALY, two other terms are derived; tolerable disease risk and tolerable infection risk. The difference between the two terms lies in the fact that not all persons who are subjected to disease 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). WHO guidelines require 6 to 7 log-unit-reduction[3] on fecal coliform 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 -10^2 (acceptable level of contamination for safe food).

Based on DALY $1x10^{-6}$, WHO guidelines consider the tolerable infection risk for rotavirus diarrhoeal disease is 10^{-3}. Accordingly, the required wastewater quality for unrestricted irrigation that meet the set tolerable infection risk for fecal coliform (FC) is ($\leq 10^4$ FC/100 ml)

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

which can be reached by 4 log-unit-reduction from 10^8 (FC in raw wastewater) to 10^4 by treatment plant and hence additional 2 to 3 log-unit-reduction are needed to fully meet the requirements. These 2 to 3 log-unit-reduction should be realized by post-treatment options (measures) like storage of wastewater in reservoirs, drip irrigation barrier, natural decay of pathogen (Die off) and washing and peeling of the produce. To derive the required pathogen reduction for fresh eaten crops, WHO guidelines assume that 100g of irrigated lettuce is usually consumed per person per two days. Due to the difference in food consumption habits in Jordan where people consume less fresh eaten leaf crops, we can say that there is an additional protection if the same recommendations will be applied. Therefore, Our calculation assumed that in Jordan only 10g of lettuce is usually consumed every four days comparing to 100g lettuce every other day. Thus the required pathogen reduction for fresh eaten crops will be 5 log-unit-reduction instead of 6 log-unit-reduction. Table (5) shows the comparison of the required log-unit-reduction for consuming 100g lettuce every second day and 10g every four days at the same DALY ($1X10^{-6}$).

Table (5): Derivation of required pathogen unit reduction according to different consumption habits at the same DALY ($1X10^{-6}$) for unrestricted agriculture (WHO, 2006).

	WHO (DALY $1X10^{-6}$)	**Jordan DALY ($1X10^{-6}$)**
G: g of lettuce consumed	100	10
V: volume of treated wastewater remaining on g of lettuce[(1)]	10	2
I: interval between exposure events (days)	2	4
F: number of rotavirus in 1liter	5000	5000
N_{50} : Median infectivity dose for rotavirus	6.17	6.17
α: infectivity constant for rotavirus	0.253	0.253
T: Tolerable infection risk per person per year (pppy)[(2)]	0.001	0.001
R: Risk of infection per person per exposure =(1-(1-R)^(1/(365/I)))	5.5E-06	1.1E-05
D: Dose of rotavirus per exposure event =(((1-R)^(-1/α)-1)/(N_{50}/(2^(1/α)-1)))	5.1E-05	1.0E-04
C: Dose of rotavirus per liter	5.1E-03	5.1E-02
Required pathogen unit reduction = $\log_{10}$(F) - $\log_{10}$(C)	6	5

(1) If 10ml will remain on 100g lettuce (1:10) that means 1ml will remain on 10g lettuce. 2ml was assumed as worst scenario
(2) Tolerable risk infection per person per year for rotavirus at DALY $1X10^{-6}$ is 10^{-3}. For less stringent DALY of $1X10^{-5}$, the infection risks would increase by a factor of 10 and resulting in a tolerable infection risk of 10^{-2}.

2.1.1.5 Anticipated added values of treating wastewater to different levels on the overall health conditions

For a developing country, the crucial question is what will be the added value of treating wastewater to the highest level on the overall health conditions of the society. This means that the existing background disease rate should be considered. Then assess the additional improvement on the background disease rate to be able to measure the added value of treating wastewater. According to WHO guidelines, the actual diarrhoeal disease incidence per person per year (pppy) in 2000 in developing countries ranges from 0.8 to 1.3 and 0.2 in industrialized countries in all ages (Mathers et al.,2002). Interestingly, there are developed countries with high diarrheal disease incidence include Australia (~ 0.9 pppy), (Hall et al., 2006) and the United States (~ 0.8 pppy), (Mead et al., 1999). In Jordan, actual diarrhoeal disease incidence is 0.8 episodes per person per year (Gargouri et al., 2004). Table (6) shows the impact of different treatment levels on the overall health conditions.

Table (6): The added value of treating wastewater to different levels on the overall health conditions, (Carr et al, 2004).

Parameter	Treatment levels			
Water Quality E coli /100 ml	10^7	10^5	10^3	≤2
R: Risk of diarrhoeal disease infection (pppy)	0.6[(1)]	2×10^{-3}[(2)]	2×10^{-5}[(1)]	2×10^{-7}[(1)]
A: Actual disease incidence for developing region (pppy)[(3)]	0.8	0.8	0.8	0.8
Number of cases per one million at the existing health conditions[(4)]	200,000	200,000	200,000	200,000
B: Additional burden of diarrhoeal disease (pppy) (R+A)	1.4	0.802	0.80002	0.8000002
Number of cases at additional disease burden per one million (Bx1,000,000)	1,400,000	802,000	800,020	800,000.2
Improvement (%) (B/A-1)*100	75%	0.25%	0.0025%	0.00002%

(1) Carr et al, 2004
(2) Assumed value based on the given risk values for other treatment levels
(3) WHO guidelines 2006, chapter2, table2.6
(4) assumed value based on the disease records

As shown in table (6) that treating wastewater to the level 10^3 FC/100 ml will have 0.0025% improvement on the overall background disease rate (0.8) whilst treating wastewater to the level 2 FC/100 ml will have 0.00002% improvement on the overall background disease rate. The two figures indicate that the added values of treating wastewater to high level are very insignificant and thus it is very important to consider the socio-economic conditions of the country during the planning and implementation.

In light of the above mentioned facts and in full consideration of the socio-economic situations of Jordan, the dire need to exploit every source of treated wastewater and the availability of both treatment and post-treatment barriers (like drip irrigation and high rate of natural die-off) that drastically minimize biological health risk, the committee believe that even a health based target of 1×10^{-5} DALY is acceptable and does not impose serious risk or additional disease burden on population provided that post treatment measures are enforced. Table (7) shows the difference in acceptable irrigation water quality in accordance with the set health-based target.

Table (7): The difference in acceptable irrigation water quality in accordance with the set health target, (Mara D.D, 2008).

DALY (pppy)	$1x10^{-6}$	$1x10^{-5}$
DALY loss per case of diarrhoeal disease(1)	$2.6X10^{-2}$	$2.6X10^{-2}$
Number of additional rotavirus diarrhoeal cases[4] in a city of one million people	38	380
Additional Tolerable disease risk (pppy)(2)	$1x10^{-4}$	$1x10^{-3}$
Additional Tolerable infection risk (pppy)(2)	$1x10^{-3}$	$1x10^{-2}$
Water Quality (E. coli /100ml)	≤10000 (10^4)	≤100000 (10^5)

(1) WHO guidelines 2006, chapter4, table4.2.
(2) WHO guidelines 2006, chapter4, p.60.

Table (7) shows that when adopting a disease burden of **$1x10^{-5}$**, The additional tolerable disease risk will be ($1x10^{-3}$)pppy. This figure ($1x10^{-3}$) is 2 orders of magnitude lower than the actual incidence of diarrheal disease in Jordan (0.8)pppy, and thus there is some level of inherent protection against disease outbreaks.

The committee proposes two DALY targets to be applied in unrestricted agriculture; $1x10^{-5}$ DALY for field workers and $1x10^{-6}$ DALY for consumers. The application of $1x10^{-5}$ DALY for field workers means acceptance of using partially treated wastewater (≤10^5 FC/100 ml) with only 3 log-unit-reduction through treatment process. This means 3 log-unit-reduction by treatment process (10^8 FC/100 ml to 10^5 FC/100 ml) is enough to protect field workers, but this requires additional 3 to 4 log-unit-reduction by post-treatment measures before crop consumption to meet the $1x10^{-6}$ DALY for consumers.

[4] Current global incidence of rotavirus diarrhoeal diseases is 0.1-1

2.1.1.6 Protection measures

Table (8) lists the health protection control measures available in Jordan and their impacts on biological contamination reduction, (WHO, 2006).

Table (8): The available health protection measures in Jordan and their impacts on biological contamination reduction, (WHO, 2006).

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 fruit with clean water.
Produce disinfection	2	Washing salad crops, vegetables and fruit 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.

2.1.1.7 Assessment of existing health protection barriers upstream and downstream of KTR.

The following diagram shows that the available hazard barriers vary from one group to another, and at the same time it is clear that the barriers at consumers level is more abundant and more effective in reducing prospects of biological contamination. Bearing in mind availability of all these barriers, chances of epidemic spread of disease associated with the use of treated wastewater for agriculture is very low or even does not exist.

At local community level:

Treatment Plant	**Water Storage in Reservoirs**	**Access to safe drinking water and sanitation**	**Access to health care centers**

At field workers and farmer level:

Treatment Plant	**Water Storage in Reservoirs**	**Access to safe drinking water**	**Access to health care centers**

At consumer level:

Treatment Plant	**Water Storage in Reservoirs**	**Application techniques (Drip irrigation)**	**Natural Die off**	**Food Hygiene Practices**

Tracking the contamination levels of pathogens along the food production chain, starting from treatment plant, passing across the different barriers and ending at consumer's table, is the first required step in risk assessment and management. According to WHO Guidelines, the required pathogens reduction in order to achieve the health-based target for safe use of treated wastewater in agriculture is 6 to 7 log-unit-reduction for consumers and 2 to 3 log-unit-reduction for fieldworkers. In other words, since bio-contamination level in raw wastewater estimates (10^8 FC/100 ml), 6 to 7 log-unit-reduction is needed to reach level 10^2-10^1 on the final produce, depending on the produce irrigated with such water. 7 log-unit-reduction is required for root crops, whereas 6 log-unit-reduction is enough in case of other eaten fresh crops. To make traceability of bio-contamination levels simple and understandable, the food production chain is divided into separated stages as follows:

Stage 1: From wastewater treatment plant to farm:

1. Treatment Plant

Depending on potential efficacy of WWTP reduction in biological contamination varies between 2 to 6 log-unit-reduction. For instance, in As-Samra Plant (after rehabilitation), which is the main source of irrigation water, the recent results show that the efficiency of the plant improved significantly leading to 6 log reduction units from 10^7-10^8 FC/100 ml to 10^2 FC/100 ml. As is the case, this barrier (As-Samra treatment plant) can alone bring in the required pathogens reduction to meet the health-based target set in WHO Guidelines. Due to re-contamination, effluent of treatment plant ends in KTR, at relatively elevated level of biological contamination in an average range 10^3-10^4 ($\leq 10^3$ -10^4 FC/100 ml). The reason for this sharp rise is the recontamination due to illegal practices along Wadi Al Zarqa', throughout effluent flow from As-Samra to King Talal Reservoir (KTR). Figure (1) shows the treated wastewater flow system.

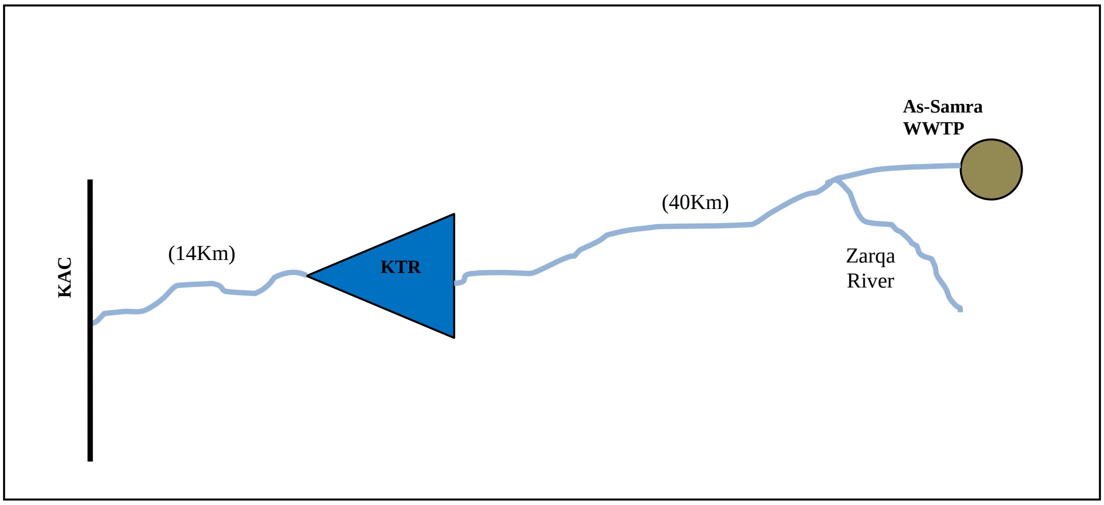

Figure (1): Flow of treated wastewater from the source (WWTP) into Zarqa River then into KTR until it ends into King Abdulla Canal

2. **Storage in the Reservoir (Post-treatment barrier)**

Retention period (withholding) of irrigation water in KTR adds at least 1 log-unit-reduction in pathogens level and thus the bio-contamination of water leaving KTR to downstream becomes 10^1 to 10^2 (≤10^1 -10^2 FC/100 ml). Later, water exposes to rise in bio-contamination level reaching 10^3-10^4 (≤10^3 -10^4 FC/100 ml) due to trash disposal practices from the local communities living near the canal.

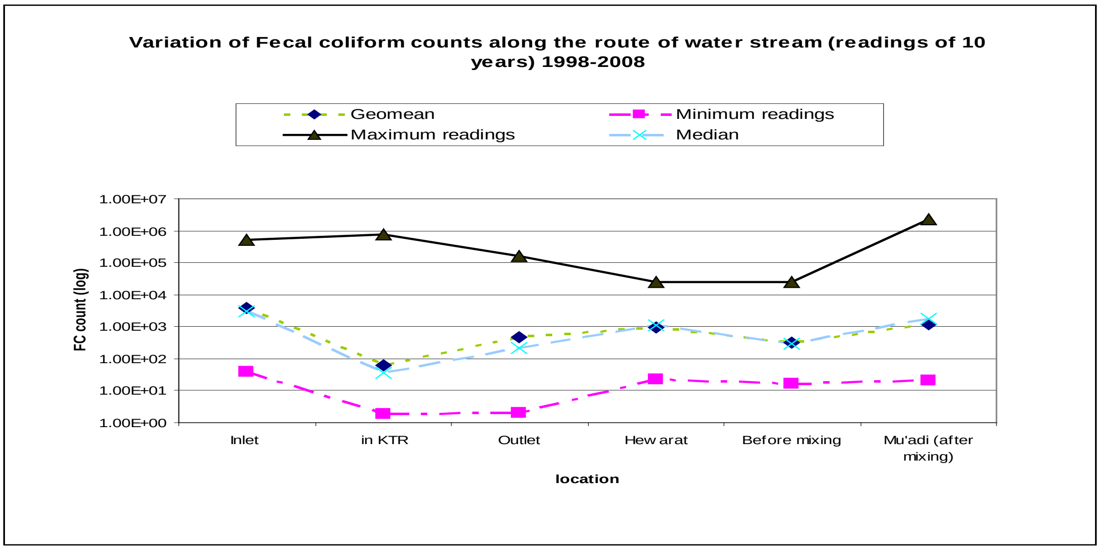

Figure 2: Variation in biological contamination level across the route of irrigation water stream (JVA, 1998-2008).

Figure (2) shows the results of 10 years monitoring for irrigation water quality along the route of treated wastewater just before water enters into KTR and prior it reaches the farms in the Jordan Valley (JVA, 1998-2008). The geometric means for fecal coliform counts for all locations are in the range10^1 to 10^3 with the lowest figure when treated wastewater is stored in KTR and the highest before it enters into KTR. The impact of KTR on water quality is obvious.

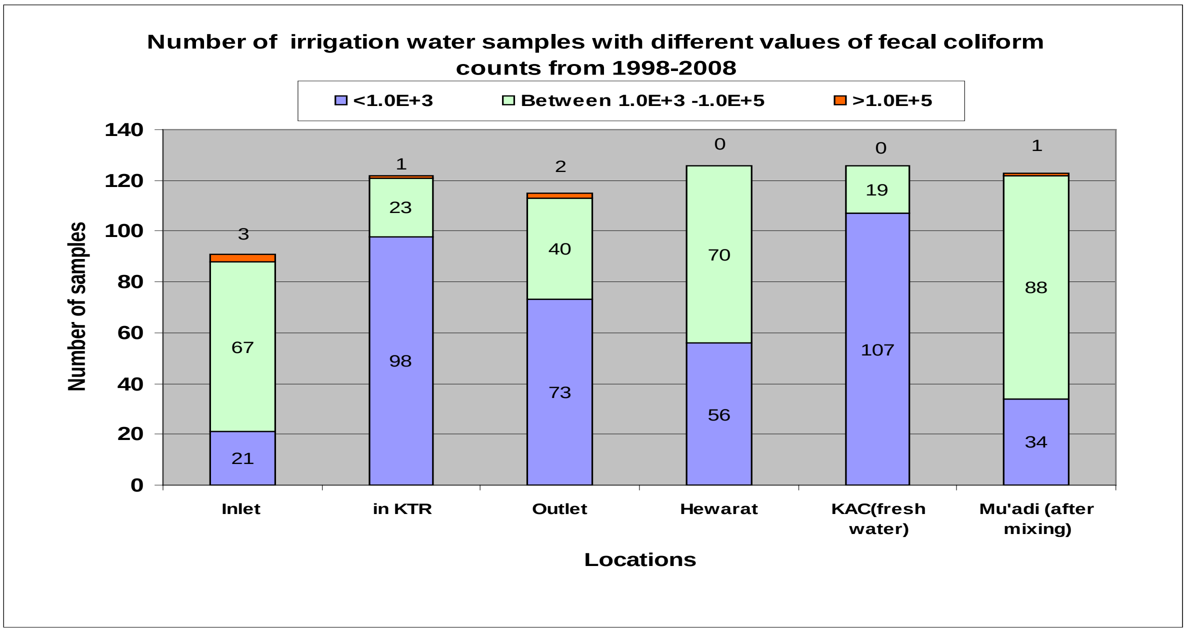

Figure 3: Number of water samples with values of fecal coliform less than 10^3, between 10^3 and 10^5 and higher than 10^5 (JVA, 1998-2008).

Figure (3) shows number of samples with different fecal coliform counts. It is obvious that number of samples exceeds 10^5 is very low and it ranges from 0 to 3 out of an average 120 readings. As for samples between 10^3 and 10^5 the figure shows high numbers and in all locations which provide an evidence that the limit proposed in old WHO guidelines ($\leq 10^3$ FC/100 ml) is frequently exceeded (JVA, 1998-2008).

It is worth to mention that results of intestinal nematodes are always in compliance with the suggested values of the new WHO guidelines.

Stage 2: On-farm:

Owing to disparities in risk of contamination on different crops produced on blended treated wastewater, the crops have been categorized into three distinctive categories according to WHO Guidelines:

- Vegetable crops: comprise wide range of crops like tomato, cucumber, eggplant, squash, etc. and require 6 log-unit-reduction.
- Leaf crops: which are fresh eaten, comprise lettuce, parsley, rocket and etc and require 6 log-unit-reduction.
- Root crops: which are fresh eaten, comprise carrot, green onion, radish and etc and require 7 log-unit-reduction.

On-farm level, additional pathogens reduction barriers take place. These barriers include:

1. **Drip irrigation system barrier (post-treatment barrier)** which, according to WHO Guidelines, can bring in an additional 2 to 4 log-unit-reduction depending on nature of the crops. The (2) log-unit-reduction can be achieved for low-growing crops (leaf crops), whereas (4) log-unit-reduction is reported for high-growing crops (other vegetable crops). Such reduction is not possible for root crops due to their growth nature under soil surface that keep them in direct contact with soil and irrigation water as long as they remain in the soil. In Jordan, drip irrigation is the common irrigation system and in the Jordan Valley 90% of farmers use drip irrigation. This should be taken into consideration when setting the appropriate the health-based target for farmers and farm workers ($1x10^{-5}$ instead of 10^{-6}). The exposure of both farmers and farm workers to low-quality irrigation water from direct contact is far less in case of drip irrigation compared to surface irrigation provided that certain wrong practices like using irrigation water for washing are avoided.

   Still, there is a very wrong and bad practice in Jordan Valley, the use of unfermented manure which poses high risk of cross-contamination; therefore, efforts should be excreted in this field either to prohibit use of unfermented manure or to secure good management practices for fresh manure uses.

2. **Natural pathogens die-off (Post-treatment barrier)** can play significant role in bringing in significant reduction to these pathogens as result of desiccation, sun radiation, high temperature which could reach 2 log-unit-reduction per day from last irrigation to harvest time. The climatic conditions in Jordan (high temperatures and abundant sunshine) favor high decay of pathogens; however, in this assessment the contribution of this barrier was assessed to be only 1 log-unit-reduction to be in the safe side. Natural die-off for root crops has been ignored due to its growth nature.

3. **Other barriers like**
   - Use of mulch: it is very common practice in the Jordan Valley
   - Use of pond : almost all farmers in the Jordan Valley use pond to store irrigation water
   - Use of sand filter: many farmers in the Jordan Valley are using it.

Studies conducted by WHO revealed a significant effect of all these on-farm measures on pathogen removal. For examples WHO reported pathogen removal based on a review of several studies for slow sand filters range is 0 to 3 log-unit-reduction. In Jordan there are no available studies of the impacts of these measure on pathogen removal and that is why it was not considered in this assessment despite that the committee believe it has a significant impacts

It deserves to mention that certain harvested crops will be subjected to recontamination risk in case farmers wash their harvest with treated wastewater. Such practice is common in case of leaf crops and root crops where some farmers use it either to maintain fresh looking for leaf crops (moistening crops to prevent withering) or to get rid of mud and soil particles on root crops before sending it to market. As is the case, such scenario, if happens, should be taken into account. This scenario has been considered in this interpretation.

Stage 3: From farm to market:

The movement of produces along marketing chain, from farm to consumer, provides further possibility for additional natural pathogens die-off but at the same time recontamination due to improper handling does exist. WHO guidelines, points out that reduction in pathogens resulted from die-off can reach 0.5 to 2 log-unit-reduction per day and consider it a reliable barrier. In this assessment only 1 log-unit-reduction has been considered as a result of this barrier.

Stage 4: From market to consumer:

At consumers level a considerable barriers exist and should not be overlooked. While the risk remains exist in case of eating fresh leaf and root crops without washing and / or peeling, the risk on cooked-eaten types vanish after cooking. Apparently, consumers themselves can play important role in pathogens reduction through implementing certain health-protection measures before eating. The following **post-treatment barriers** can bring in significant reduction in biological contamination as follows:

1. Washing: 1 log-unit-reduction.
2. Washing with disinfectant: 2 log-unit-reduction.
3. Peeling: 2 log-unit-reduction.
4. Cooking: 5 to 6 log-unit-reduction.

In general, one can say that the hygiene conditions for Jordanian people are relatively high due to good and effective hygiene education. As is the case, realizing 1 to 2 log-unit-reduction for leaf and root crops as result of washing and peeling is very likely to happen.

At stages 2 and 3, a state crop monitoring programme for fresh vegetables is conducted by JFDA, where samples are taken directly from farms and Amman whole sale market as a last step in the monitoring process along the chain of food production. This programme has been initiated since 2004 and the collected samples undergo for chemical and biological tests. Results of four consecutive years confirmed that risk of biological contamination is very minimal. Few numbers of samples were reported to have higher number of acceptable level of pathogens. The reasons of this contamination could be either

- Spreading fresh manure on the soil surface without proper incorporation into the soil
- Or the use of irrigation water in washing harvested leaf and root crops

2.1.1.8 Helminth Eggs

Helminth eggs that are considered in these guidelines are the human intestinal nematodes (e.g Ascaris, Trichuris,..). The guidelines' recommendation is that wastewater used in agriculture should contain ≤1 human intestinal nematode egg per liter. This is the same as was recommended in the 1989 guidelines (WHO, 1989) but with one important difference; when the children under the age of 15 are exposed (by working or playing in wastewater-irrigated fields) additional measures are needed, such as regular de-worming (by their parents or at school). Also, washing fresh vegetables with weak detergent and rinsing them thoroughly with drinking water, when health data indicate that helminthes infections are prevalent (WHO, 2006). The required helminthes eggs reduction to achieve the target of≤ 1 egg per liter depends on the number of eggs in the raw wastewater. For example if there are 10^3 eggs per liter in the raw wastewater, the required reduction is 3 log units. The required reduction can be achieved by following the same protection measures mentioned above (mainly by treatment and washing). In Jordan, the existing monitoring programmes focused on Helminth eggs as one of the important parameters that shall be analyzed on regular basis for both the direct and indirect use of treated wastewater. All irrigation water quality records showed a quality of ≤1 human intestinal nematode egg per liter, which is a good indicator for having a good irrigation water quality.

2.2.1 Chemical and physical risks

Industrial wastewater discharges into sanitary sewers or drains is the largest source of chemical contamination, although households may also contribute. Therefore, the hazard to public health can be reduced by limiting the intrusion of industrial wastewater into municipal wastewater. There are limited evidences on the direct health impact of chemical pollutants on public health; however, chronic diseases associated with the exposure to chemicals usually occur only after many years of exposure.

It is only the high concentration of chemical constituents that need to be addressed in treated wastewater-irrigated areas and these can be divided into:

1. Heavy metals like Cd, Cr, Co, Mo, Ni, Zn, Cu, Mn, Pb, As, Se, Hg
2. Nutrients like N, P, K , Ca, Mg, which only pose risks in high concentration represented by suppressing other nutrients, affect plant growth and affect aquatic life (including ground water contamination).
3. Salts and specific ions like Cl, Na, B
4. Persistent organic pollutants (POPs) like pesticides, and pharmaceutical compounds.

To avoid the potential negative impacts of these chemicals compounds in developing countries, multi-barriers approach would provide an effective management measures which include

1- Wastewater treatment plant: engineering-based technology

2- Farm-based measures which include soil-based treatment and plant-based treatment

2.2.1.1 Heavy Metals

All of potentially toxic metals are naturally present in the environment in trace amounts and are ingested with food, water and air. Human bodies have the ability to deal with these low levels. Hamilton et al. (2005) classified phytotoxic metals in wastewater into four groups based on their retention in soil, translocation in plants, phytotxicity and potential risk to the food chain (human and animal risks).The following table lists the four different groups

Table (9): Metal bio-availability grouping

Group	Metal	Soil adsorption	Phytotoxicity	Food chain risk
1	Ag, Cr, Sn,Ti,Y, Zr	Low solubility and long retention in soil	Low	Little risk because they are not taken up to any extent by plants
2	As, Hg, Pb	Strongly adsorbed by soil colloids	Plant roots may absorb them but not translocate to shoots; generally not phytotoxic except at very high concentration	Pose minimal risks to the human food chain
3	B, Cu, Mn, Mo, Ni, Zn	Less strongly absorbed by soil than group 1 & 2	Readily taken up by plants and phytotoxic at concentrations that pose little risk to human health	Conceptually the "soil-plant barrier" protects the food chain from these elements
4	Cd, Co, Mo, Se	Least of all metals	pose human and/or animal health risks at plant tissue concentrations that are not generally phytotoxic	Bioaccumulation thorough the soil-plant-animal food chain

Source: Hamilton et al. (2005)

Jordan is not an industrialized country which is confirmed by low levels of heavy metals exist in blended treated wastewater. In addition soils are characterized by alkalinity nature which fix heavy metals and render their absorption by the plants. The committee believes that risks associated with chemicals in the treated wastewater especially those arising from heavy metals are very low based on the following facts:

1. The results of water quality analysis show that the levels of heavy metals are within the acceptable levels
2. The "soil-plant barrier" protects the food chain from these elements

Mitigation measures (if needed) include

- Soil-based treatment like addition of gypsum, lime and phosphate materials. These amendments immobilize heavy metals
- Plant-based treatments through the so-called phyto-remediation by planting certain plant species. These plants act as hyper-accumulator for heavy metals. Crop choice

and crop selection contributes effectively in reducing human health risks. Leafy specious tend to accumulate certain metals like Cd in greater amounts than non-leafy species. As a rule of thumb, leafy parts accumulate 10 times than seeds and fruits.

Another important aspect related to irrigation with treated wastewater where heavy metal contamination is of big concern is to estimate the total accumulative loading in the soil. Depending on concentration of heavy metals in irrigation water, total applied irrigation quantities, chemical properties of the soil (mainly cation exchange capacity), the time required to reach loading limit can be calculated.

Table (10): Estimated length of time for treated wastewater irrigated areas in Jordan Valley to reach metal limits

Metal	Recommended Max. Concentration (mg L^{-1})[a]	Actual concentration in KTR water (mg L^{-1})[b]	Annual input (kg ha^{-1}) [c]	Loading limit (kg ha^{-1})	Estimated time (years)
Cd	0.01	0.005	0.04	10	250
Cu	0.2	0.01	0.08	250	3125
Pb	5	0.01	0.08	1000	12500

a: based on Ayers and Westcot (1985)
b: JVA reports (average values)
c: based on irrigation application at 800cm/ha/year

Table 10 shows two important facts

1- Metal concentration in treated wastewater used for irrigation in the Jordan Valley is below the recommended maximum concentration limits
2- The estimated length of time for the selected metal to reach its limits is very ling ranging from 250 years for Cadmium to more than 12000 years for lead

2.2.1.2 Excessive Nutrients

Treated wastewater might contain high levels of N, P and K depending on technology of treatment. Plants needs these nutrients, however high levels of these nutrients might lead to imbalances of nutrients in soil and affect plant growth. Salts represented by Cl, Na, and other major cations like Ca, Mg are needed by plants, however high levels of these salts affect plant growth negatively depending on crop types as there salt tolerant crops and salt sensitive crops. As a rule of thumb, if salinity of treated wastewater is less than 2 dS/m (unit for measuring salinity), it is of reasonable quality that suits most crops except the very high sensitive crops like strawberries. To overcome these negative effects associated with excessive nutrients and salts farmers need to have

- Information on nutrients in treated wastewater
- Guidelines for optimization of fertilization.

In Jordan, JVA started since 2 years providing farmers with monthly water quality information sheets in which farmers can find information on nutrients levels as well as salinity. In addition to this, GTZ, JVA have developed agronomic guidelines for the safe and efficient use of treated wastewater which give details on farm-based measures that can be used to mitigate the negative impacts of salinity and excessive nutrients. Recently software was developed that calculate both irrigation and fertilization requirements which consider soil status of nutrients, water quality information, crop information and other factors.

2.2.1.3 Organic Compounds

Exposure of farmers, consumers and crops to organic is much higher thorough direct pesticides application than via irrigation water. With changes in lifestyle and increase in living standards, more and more contaminants are being added to wastewater, including endocrine disruptor compounds, hormones, residual pharmaceuticals, pesticides and industrial chemicals. These substances tend to be present at very low concentrations even in treated wastewater and may have adverse physiological effects on in animals and humans. Possible health effects have been related mainly to aquatic life (Young et al.,2004) but not positively in humans, although there are many indications of possible adverse effects (Bouwer,2005; Colborn et al.,1993). Many of the chemicals might face rapid microbial degradation or adsorption by the soil organic matter and are unlikely to enter the plant tissue through the root (Change et al.,2002).

The key removal mechanisms for most organic substances are adsorption and biodegradation in soils and sediments (WHO, 2006b). Removal efficiencies are greater in soils rich in silt, clay and organic matter.

It remains, therefore, crucial to support pollution preventing policies to limit the adverse effects of organic contaminants.

Chemical and physical risks were assessed also within the pilot area (see annex F), and the main conclusion was that risk is very minimal and it can be even limited more by following good agricultural practices on farm level.

3. Steps for development a Risk Management Plan

Risk Management System as defined by the new WHO guidelines is the systematic evaluation of the wastewater use system, the identification of hazards and hazardous events, the assessment of risks and the development and implementation of preventative strategies to manage the risks. The development of risk management system should consider the following:

- Boundary identification for the entire system.
- Boundaries identification for each involved stakeholder.
- Risk identification: list all risks associated with the use of treated wastewater from the point of source until consumer table (biological, chemical, physical).
- Risk assessment for all risks in terms of frequency and consequences (human health impact, soil degradation, ground water pollution) to end up with risk quantification which in turn allows risk prioritization.
- Appraisal of existing monitoring programmes to assess their efficiency and if there is a need to further develop new programmes (i.e. soil, water and ground water monitoring programmes).
- Assessment of the existing risk management measures (hazard barriers like treatment plant, drip irrigation, natural die-off and hygiene practices etc.).
- Propose further risk management measures to curb risks occurrence.
- Identification the role of each institution in either monitoring and/or management actions.
- Selection of leading institution to organize and coordinate the entire system
- System documentation and present it to decision makers for approval.

A multidisciplinary working group consists of members of all relevant institutions, was formed to develop a risk monitoring and management plan for the safe use of treated wastewater upstream and downstream KTR. The following sections highlight the tasks of the committee and the methodology they followed and the recommendations.

4. Members of the Committee

Organization	Function	Name
Ministry of Water and Irrigation	National Water Master Plan Directorate	Eng. Hadeel Smadi
Water Authority of Jordan	Water Quality Department	Eng. Suzan Kilani Eng. Ahmad Uleimat
Jordan Valley Authority	Water Resources Directorate	Eng. Nayef Seder Eng. Fuad Hanna
Ministry of Agriculture	Forestry Directorate	Eng. Ali Abu Hamoor Dr. Wael Rashdan
Ministry of Environment	Inspection Directorate	Eng. Adnan Zawahreh
Ministry of Health	Environmental Health Directorate	Eng. Mohammad Abadi Eng. Areej Mer'i
Jordan Food and Drug Administration	Food Control Directorate	Dr. Yousef Tawalbeh Eng. Lina Sinnokrot
National Centre for Agricultural Research and Extension	Research Department	Dr. Naem Mazahreh Eng. Mohammed Ayesh
Royal Scientific Society	Environmental Research Center	Eng. Rana Arda Eng. Tharwa Qotaish
GTZ-Water Programme	Use of Marginal Water	Eng. Sameer Abdel-Jabbar Eng. Ahmad Soboh Eng. Mai Al-Dergham

5. Tasks of the Committee

The committee conducted series of meetings during 2009 and 2010. Throughout these meeting, a risk monitoring and management plan for the safe use of treated wastewater upstream and downstream KTR was developed through the following tasks:

1. Review the mandate of each relevant institution and identify responsibilities.
2. Undertake a hazard assessment and a risk characterization for the pilot area.
3. Field visit to the pilot area.
4. Assess the existing control measures and propose new ones where needed.
5. Assess the existing monitoring system, Identify overlaps and gaps, and propose new monitoring system where needed.
6. Develop a risk management plan.
7. A study tour to Egypt.
8. Document the system.

The following standards, regulations and guidelines were used as references to fulfill the above mentioned tasks. Also to show the need for updating them according to the new WHO guidelines:

Standard/ regulations/ guidelines	Issued by	Area of use
JS 202/2007	JISM	Industrial wastewater effluents
JS 893/2006	JISM	The reuse of treated domestic wastewater
JS 1145/2006	JISM	The safe use of bio-solids
Regulation no. 18/1998	WAJ according to the wastewater by-law no. 66/1994	Industrial wastewater quality to be connected to the sewer system
Irrigation Water quality Guidelines	JVA	Indirect use of treated wastewater
Guidelines for Reclaimed water Irrigation in the Jordan Valley	JVA	The good agricultural practices in dealing with blended treated wastewater
Guidelines for a State Crop Monitoring system for Fresh Vegetables	JFDA	Methodology for safe sampling and analyses of fresh vegetables
WHO Guidelines on Wastewater Use in Agriculture	WHO	Safe use of treated wastewater in agriculture

6. Methodology

The Risk Monitoring and Management Plan was developed mainly in two phases:

Phase one: reviewing the mandate of each relevant institution as stated in the official gazette. Accordingly, responsibilities were delineated and existing monitoring programmes were determined (see annex C: Legal Basis and annex D: existing monitoring programmes).

Phase two: developing a risk matrix upstream and downstream KTR, which went through different steps (see annex F):

1- Risk characterization
   a. identify affected targets along the pilot area
   b. identify hazard sources and types along the pilot area

2- Risk assessment
   a. rate the identified risks and define their health and environmental consequences
      (A semi-quantitative risk matrix approach was used as shown in Figure (4) in annex E).

3- Identify existing control measures and monitoring programmes and reassessing risks accordingly

4- Propose a risk management plan that control and mitigate to a large extent the negative impact of the identified risks.

7. New duties and tasks of involved institution in light of proposed risk management plan

According to the new risk management plan, the following is the new duties of each institution to be implemented as shown in annex F

7.1 Ministry of Agriculture (MoA)

Upstream KTR

1. Develop a standard on fish farming and livestock **in cooperation with NCARE.**
2. Prohibit the use of treated wastewater for fish farming until a standard is developed.
3. Prohibit the cultivation without the use of Drip irrigation and mulch.

Downstream KTR

1. Develop a standard on fish farming and livestock **in cooperation with NCARE.**
2. Prohibit the use of treated wastewater for fish farming until a standard is developed.
3. Prohibit the cultivation without the use of Drip irrigation and mulch.

7.2 NCARE in cooperation with Ministry of Agriculture (MoA) and Farmers

Upstream KTR

1. Conduct intensive awareness programmes for farmers on the following aspects:
    - a- on the proper way of disposing the solid waste at farm level.
    - b- on farmers' personal hygiene and product safety.
    - c- on chemical and physical clogging problems and on using filters.
    - d- on soil salinization.
    - e- on best irrigation practices with an emphasis on the sue of drip irrigation and mulch.
    - f- on crop cultivation issues.
    - g- to not graze animals nearby the water flow.
2. Help MoEnv in intensifying the implementation of its programme on promoting the use of compost at farm level.

Downstream KTR

1. Conduct intensive awareness programmes for farmers on the following aspects:
    - a- on the proper way of disposing the solid waste at farm level.
    - b- on farmers' personal hygiene and product safety.
    - c- on fencing irrigation water ponds.
    - d- on chemical and physical clogging problems and on using filters.
    - e- on soil salinization.
    - f- on using mulch and drip irrigation instead of surface.
    - g- to not graze animals nearby the water flow.
2. Help MoEnv in intensifying the implementation of its programme on promoting the use of compost.

7.3 Ministry of Environment (MoEnv)

Upstream KTR

1. Strengthening the coordination with the Environmental Police to intensify their deployment in the pilot area as well as supervision programmes
2. Enforcement of enacted regulations that govern the use of treated wastewater along the Wadi with regard to illegal dumping of sewage and mining as well as punishments for violators **in cooperation with Ministry of Interior, MoH, Ministry of Municipalities, Natural Resources Authority (NRA)**
3. Conduct awareness programmes for the public on the pros and cons of using treated wastewater **in cooperation with Ministry of Education and JVA**
4. Design one sign that prohibits all wrong practices such as grazing animals nearby the Wadi, and throwing waste along the Wadi, **in cooperation with MoA, JVA and WAJ**
5. Enforcing the use of compost instead of fresh manure

Downstream KTR

1. Strengthening the coordination with the Environmental Police to intensify their deployment in the pilot area as well as supervision programmes
2. Conduct awareness programmes for the public on the pros and cons of using treated water **in cooperation with Ministry of Education and JVA**
3. Enforcement of enacted regulations that govern the use of treated wastewater along the Wadi with regard to illegal dumping of sewage and mining as well as punishments for violators **in cooperation with Ministry of Interior, MoH, Ministry of Municipalities, Natural Resources Authority (NRA)**
4. Design one sign that prohibits all wrong practices such as grazing animals nearby, swimming and throwing waste in the canal, **in cooperation with JVA**
5. Enforcing the use of compost instead of fresh manure

7.4 Jordan Valley Authority (JVA)

Downstream KTR

1. Locate fences where appropriate along the Canal
2. Put warning signs prohibit the swimming and the use of Canal water for domestic purposes **in cooperation with MoEnv.**
3. Rehabilitation of the screening system at Telal Al-Thahab
4. Raise the awareness of JVA staff on the proper hygienic practices during their daily work. Provide ditch riders with safety clothes

7.5 Water Authority of Jordan (WAJ)

Upstream KTR

1. Delineate groundwater protection zone to cover all groundwater wells used for drinking purposes and raise the awareness of people on the groundwater protection practices **in cooperation with MoEnv, MoH and Ministry of Interior.**

Downstream KTR

1. Delineate groundwater protection zone to cover all groundwater wells used for drinking purposes and raise the awareness of people on groundwater protection practices **in cooperation with MoEnv, MoH and Ministry of Interior.**

7.6 Jordan Food and Drug Administration (JFDA)

Upstream KTR

1. Conduct continuous awareness programmes on the good hygiene practices in dealing with fresh eaten crops at household level.

Downstream KTR

1. Conduct continuous awareness programmes on the good hygiene practices in dealing with fresh eaten crops at household level.
2. Scaling up the existing fresh vegetables monitoring programme to cover at first priority the area upstream KTR.

8. Recommendations:

1. A permanent committee to be established in order to make periodic review and adjustment (if needed) and to develop plans for other areas. This committee shall be linked directly to the Prime Ministry
2. Transforming the irrigation water quality guidelines into a national standard in light of the new WHO guidelines and the outcomes of this work
3. Regulations related to crop pattern upstream KTR should be reviewed according to the results of this work
4. This plan can be standardized and set as a governmental monitoring system and to be scaled up to other areas where treated wastewater is used for irrigation.
5. JVA should be the only source for monitoring the quality of irrigation water downstream KTR.
6. Get into contact with the media in order to promote this plan and market the local agricultural produce.

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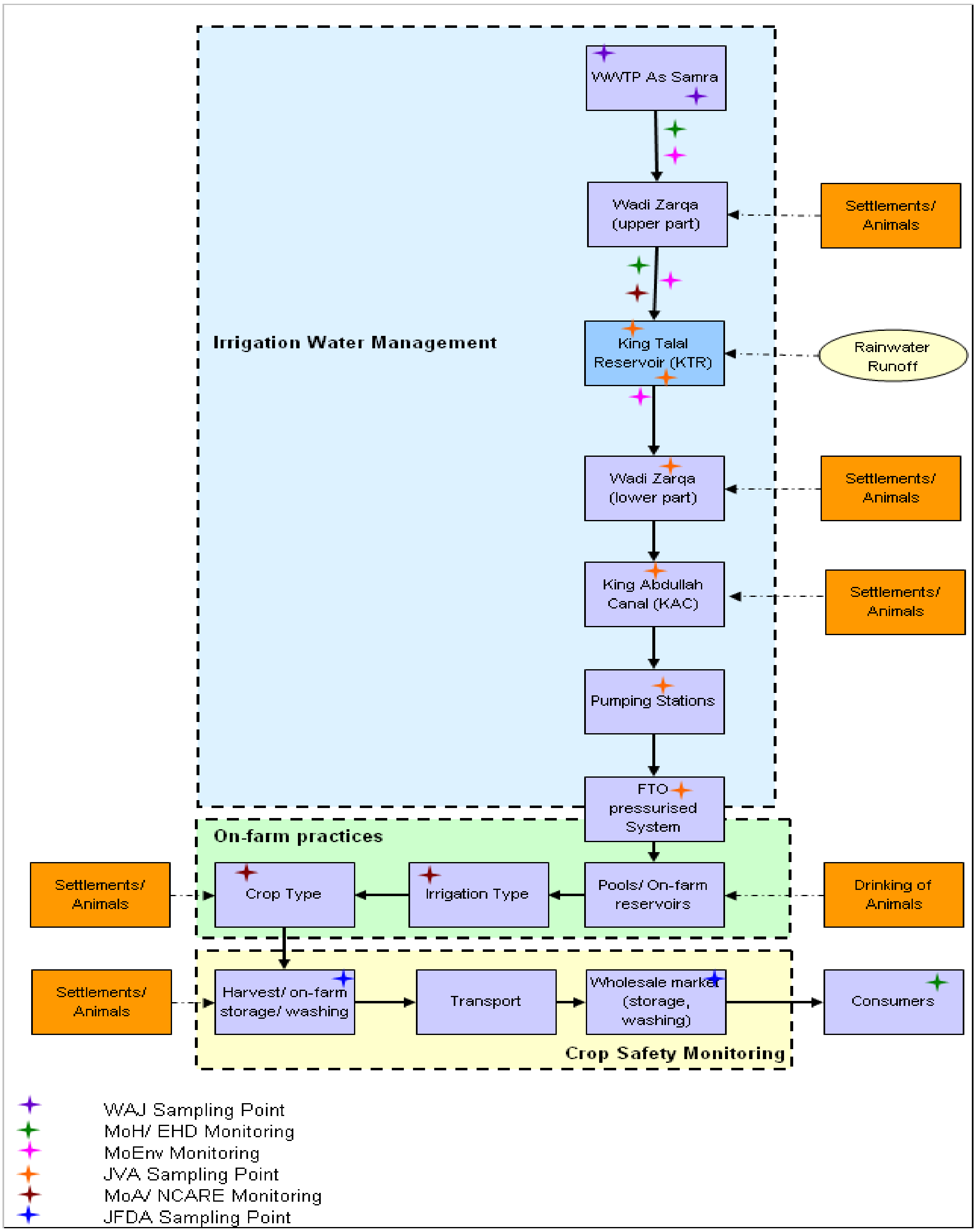
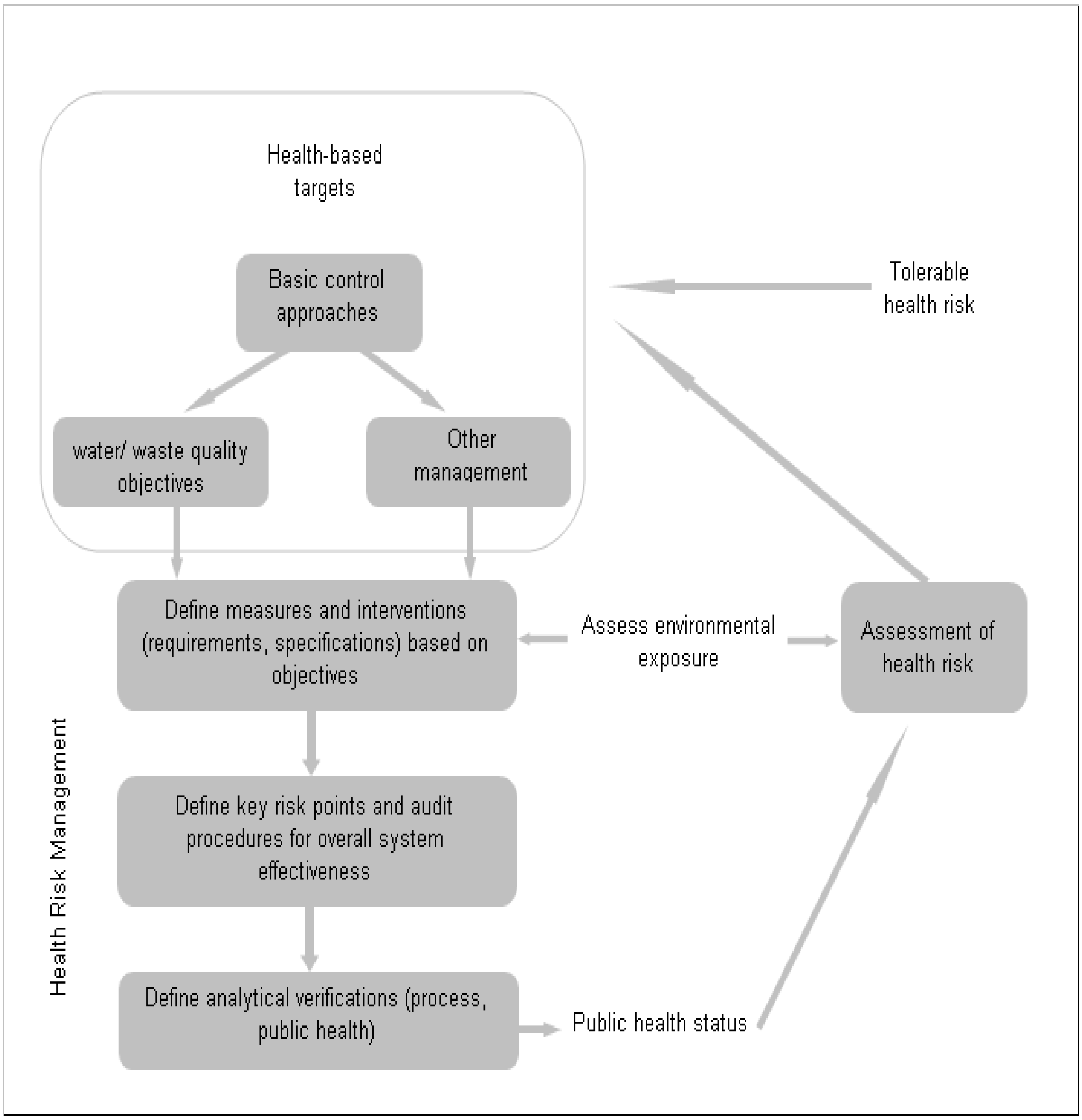
Annex A: Pilot area flow chart and the points of the existing monitoring programme



Annex B: Stockholm Framework[5]

Stockholm Framework is used for developing harmonized guidelines for the management of water-related infectious disease (WHO, 2006)



[5] Guidelines for the Safe Use of Wastewater, Excreta and Greywater, Volume 2, Wastewater Use in Agriculture, Chapter 2, WHO, 2006

Annex C: Legal Basis of Relevant Institutions

See attached power point document: Legal Basis Arabic

Annex D: Existing monitoring programmes and responsible institution within the pilot area

As an outcome of the committee meetings, the following is the existing monitoring programmes exist along the pilot area (annex A: shows the places of the existing monitoring programmes along the area). Some of these programmes are efficiently implemented while others need improvement and more sufficient coordination among the relevant institutions:

Responsible Institution	Monitoring Programme	Location
WAJ	Water	Inlet and outlet of As-Samra TP
MoH	Water	TP Outlet
MoEnv	Water	TP Outlet, KTR outlet, connecting point between ZR and TP effluent
JVA	Water	from KTR inlet to farm gates
JVA	Soil (non-obligatory)	Jordan Valley (JV) farms
MoH	Crops (Pattern)	Upstream KTR
MoA	Crops (pesticides residues)	Amman Wholesale Market (AWSM)
JFDA	Crops (biological & chemicals)	JV and AWSM
NCARE	Soil and Water	Research and studies

As shown in the above table that there is no sufficient existence for MoA as well as MoEnv in the area. The coming section is addressing the new duties and monitoring programmes that should be in place to improve the environmental and health status in the pilot area.

Annex E: Semi-quantitative Risk Matrix Approach

This approach was used to predict how often hazards or specified events may occur (likelihood) and the magnitude of their consequences)

		Severity or Consequence				
		Insignificant or no impact Rating:1	Minor compliance impact Rating:2	Moderate aesthetic impact Rating: 3	Major regulatory impact Rating: 4	Catastrophic public health impact Rating: 5
Likelihood or Frequency	Almost certain/ once a day - Rating: 5	5	10	15	20	25
	Likely / once a week - Rating: 4	4	8	12	16	20
	Moderate/ once a month - Rating: 3	3	6	9	12	15
	Unlikely / once a year - Rating: 2	2	4	6	8	10
	Rare/ once every 5 years - Rating: 1	1	2	3	4	5
Risk Score		<6	6-9		10-15	>15
Risk Rating		Low	Medium		High	Very high

Figure 4: Semi-quantitative risk matrix approach (WHO, 2009)

Annex F: Risk Matrix

See attached excel documents: Risk Matrix Upstream KTR and Risk Matrix Downstream KTR