# Decentralized Wastewater Management in Jordan

**A Compendium for Designers, Authorities and Practitioners**

**Developed in the context of the project**

'Decentralized Wastewater Management for Adaptation to Climate Change in Jordan'

**(ACC-Project) and the project**

"Assistance to Jordanian regions in the development of decentralized structures in wastewater management" within the framework of the Bund-Länder-Program (BLP)


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## Abbreviations

| | |
|---|---|
| ABR | Anaerobic Baffled Reactor |
| ACC | Decentralized Wastewater Management for Adaptation to Climate Change in Jordan |
| AIC | Average Incremental Cost |
| AM | Adaptive Management |
| B/C | Benefit Cost ratio |
| BCA | Benefit Cost Analysis |
| BLT | Build–Lease and Transfer |
| BM | Business Model |
| BOD | Biological Oxygen Demand |
| BOOT | Build-Own-Operate and Transfer |
| BORDA | Bremen Overseas Research and Development Association |
| BOT | Build-Operate-Transfer |
| CAPEX | Capital Expenditures |
| CapManEx | Capital Maintenance |
| CBA | Cost-benefit analysis |
| CDM | Clean Development Mechanism |
| CEA | Cost-effectiveness analysis |
| CoC | Cost of Capital |
| COD | Chemical Oxygen Demand |
| CW | Constructed wetland |
| CWWTP | Centralized WW Treatment Plant |
| DBFO | Design-Build-Finance and Operate |
| DBO | Design-Build and Operate |
| DCMF | Design–Construct–Manage–Finance |
| DEWATS | Decentralized Wastewater Treatment System |
| DOS | Department of Statistics |
| dS/m | Deci Siemens per meter |
| DWW | Decentralized Wastewater |
| DWWM | Decentralized Wastewater Management |
| DWWMS | Decentralized Wastewater Management System |
| DWWS | Decentralized Wastewater System |
| DWWTP | Decentralized Wastewater Treatment Plant |
| ExpDS | Expenditure on Direct Support |
| GIZ | German Development Cooperation (Deutsche Gesellschaft für Internationale Zusammenarbeit) |
| GWW | Generated WW |
| HRT | Hydraulic Retention Time |

| | |
|---|---|
| IPCC | Intergovernmental Panel on Climate Change |
| IRR | Internal Rate of Return |
| IWK | Indah Water Konsortium |
| IWRM | Integrated Water Resource Management |
| JFDA | Jordan Food and Drug Administration |
| JOD | Jordanian Dinar |
| JSMO | Jordanian Standards and Metrology Organization |
| JV | Jordan Valley |
| JVA | Jordan Valley Authority |
| KAC | King Abdulla Canal |
| KTR | King Talal Reservoir |
| MCA | Multi Criteria Analysis |
| MCM | million cubic meters |
| MED | Mediterranean region |
| MENA | Middle East North Africa |
| MMA | Ministry of Municipal Affairs |
| MoA | Ministry of Agriculture |
| MoEnv | Ministry of Environment |
| MoH | Ministry of Health |
| MoMun | Ministry of Municipalities |
| MPA/100ml | Most Probable Number per 100 milliliters |
| MWI | Jordan Ministry of Water and Irrigation |
| NICE | National Implementation Committee for Effective Decentralized Wastewater Management |
| O&M | Operation and Maintenance |
| ONAS | Office National de l'Assainissement (République Tunisienne) |
| OPEX | Operational Investment |
| PE | Population Equivalent |
| PPP | Private Public Partnership |
| PS | Private sector |
| PSP | Private sector participation |
| RSCN | Royal Society for the Conservation of Nature |
| RSS | Royal Scientific Society |
| SDB | Sludge Drying Beds |
| SDRB | Sludge Drying Reed Bed |
| SI | Sustainability Index |
| SS | Suspended Solids |
| SSP | Sanitation Safety planning |
| SSPs | Sanitation Safety Plans |

| | |
|---|---|
| **SWIM** | **Sustainable Water Integrated Management** |
| **ToR** | **Terms of Reference** |
| **TSS** | **Total Suspended Solids** |
| **TWW** | **Treated WW** |
| **UASB** | **Up flow Anaerobic Sludge Blanket reactor** |
| **UFC/100ml** | **Colony Forming Unit per 100 milliliters** |
| **VFCW** | **Vertical-Flow Constructed Wetland** |
| **WAJ** | **Water Authority of Jordan** |
| **WHO** | **World Health Organization** |
| **WSIA** | **Water Service Industrial Act** |
| **WUA** | **Water User Association** |
| **WW** | **Wastewater** |
| **WWTP** | **Wastewater treatment plant** |
| **YWC** | **Yarmouk Water Company** |

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## Preamble

The Jordan Ministry of Water and Irrigation (MWI) in close cooperation with the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH is implementing pilot projects demonstrating that decentralized wastewater management (DWWM) is a viable and necessary action for adaptation to climate change. The project entitled: "Decentralized wastewater management for adaptation to climate change in Jordan (ACC)" has a multi-level approach that follows both soft and hard tracks. Capacity development for strengthening the Jordanian capacities on DWWM and providing the relevant demanded support for strategizing adaptation to climate change specifically through DWWM remains the core of soft track activities. Likewise, demonstration projects that show the feasibility and sustainability of DWWM alternatives form the core of hard track activities.

This background report provides contextual as well as historical information that helps to understand the existing environment for wastewater management in Jordan. It also helps to position wastewater and treated wastewater use in the wider frame of adaption to climate change. Accordingly, the document is divided into two main parts. The first part starts presenting global climate change and shows its impacts on the water sector together with witnessed and foreseen impacts on relevant sectors including agriculture, health, and economy. Moreover, the concept of adaptation to climate change and increased resilience of agricultural and water systems is then presented with a particular interest in adaptation of water systems through the integrated water resources management (IWRM) approach. The latter introduces the evolving concepts of decentralization as well as integration, which were presented as the main guiding beliefs of IWRM. In doing so, the document highlights the main relevant issues that govern adaptation of water and wastewater systems as well as water and wastewater infrastructures to climate change. The second part starts to zoom in on wastewater management at regional scale and further at local Jordanian scale. A detailed discussion of how wastewater management was developed over the past decades in the kingdom and the governing regulatory frame is introduced. An overview is given on how the already developed policies, strategies and regulations related to wastewater management are implemented. The recently developed policies are presented including the decentralized wastewater management policy and the way forward is being suggested.

## Executive Summary

### Summary of Part A – Decentralised Wastewater Management in the light of Adaptation to Climate Change

Part A discusses decentralizes wastewater management and adaptation to climate change in a very broad way. It is divided into two parts. The first part addresses climate change on a global scale and shows the impacts on the water sector together with other relevant sectors including agriculture, health and economy. Looking at these interlinked sectors the issue of adaptation and resilience is discussed from the point of Integrated Water Resource Management (IWRM).

The second part focuses on wastewater management on the regional (MENA) and national (Jordan) scale. It goes back to the development and implementation of water and wastewater laws and regulations as well as policies in the Kingdom of Jordan and reveals the opportunities and challenges for implementation.

**Impact of Climate Change**

The impacts of climate change relevant to the water sector in general and the DWWM are related to the variables/ phenomena: temperature, precipitation, specific climate variability like El-Nino, droughts, floods.

In principle there are two mechanisms to cope with the adverse effects of climate change: resilience and adaptation:

- Resilience can be defined as the ability of a system to continue functioning or rapidly return to functioning during and after a climate-related disturbance.
- Adaptation refers to the ability of a system to adjust to future disturbance released by climate change.

For Jordan, the major disturbance is the continuous decrease of water resources. Beyond this physical impact, more challenges exist: The Jordanian institutions are often lacking the in-house capacity of expertise needed to engage with the added complexity associated with climate change. This is a challenge, since IWRM, which has employed a variety of tools to cope with climate change, require functioning institutions. Furthermore, the competition between different uses of water need to be mitigated – that is the core promise of IWRM. Resolving those inherent, inter-sectorial institutional conflicts is of utmost importance for successful climate change adaptation.

For the water and sanitation sector, the challenge goes further: The previous mentioned institutional clutter impedes the collection of the required information and data for planning of water infrastructure. The downscaling of global climate models does not match the level of detail required for local planning and it probably will never be able to do that. Climate change, as a 'long-onset' phenomena, does not catalyse actions of politicians. In addition, the marketing and pricing of water and water services is a sensitive topic. Prices are often set politically. Consequently, the water prices do not indicate the relative scarcity and value in use, e. g. in Jordan treated wastewater for irrigation is 10 fils/m$^3$ while the cost of treatment is up to 600 fils/m$^3$.

Conventional sewage networks and centralized wastewater treatment represent still the dominant paradigm. But this approach does not serve small and scattered communities. With our advanced scientific understanding and drivers, such as limited water resources and rising energy cost, other alternatives appear. To recognize wastewater as a resource, induce the necessary paradigm shift makes the 'invisible sanitation' visible again.

But it requires a high level of community (beneficiaries) involvement to encourage citizens to dare the mind-shift. The resistance is strong and existing practice examples are rare. Instead unmet practices (leaking cesspools, informal disposal) are continued and damages the environment.

**Status of Wastewater Management in Jordan**

Jordan is extremely water-scarce and due to high population growth and economic development the situation exacerbates. In addition, the ongoing political unrests in Syria and its related exodus cause additional pressure. Domestic, agriculture and industrial uses are competing. Farmers irrigate less than 10% of the total agricultural land. This land required around 60% of the total national water usage. At the same time agriculture only contributed 3-4% of the GDP in 2013. This is a dilemma. Furthermore, the climate change policy issued in 2016 clearly states that the water sector will be the most impacted sector.

Nevertheless, Jordan is one of the few countries with water scarcity which has managed its freshwater resources relatively well: The country has 97% freshwater network coverage. The country promotes improved water demand behaviour. It works on water reallocation and the use of reclaimed water for irrigation. Furthermore, it promotes desalination as an additional freshwater source. But like many other countries Jordan is challenged by the fact that a large number of institutions are involved[1]. The National Water Strategy explicitly promoted the use of treated wastewater, especially to substitute other water sources except for drinking water. For communities up to 5,000 inhabitants the Decentralized Wastewater Management Policy (DWWMP) is in place and is on the way to be taken into practice.

One major concern in the use of reclaimed water are the standards and norms. Standards are essential to determine the water quality needed different uses. The Jordanian standard JS 893, defines five categories for irrigation:

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[1]The most relevant institutions are: The Ministry of Water and Irrigation (MWI), The Water Authority of Jordan (WAJ) and the Jordan Valley Authority (JVA) which are incorporated within the MWI, The Ministry of Environment (MoE), The Ministry of Health (MoH), The Ministry of Agriculture (MoA), Jordan Standards and Metrology Organization (JSMO), Jordan Food and Drug Administration (JFDA), Ministry of Municipal Affairs (MMA)

1. Prohibited: irrigation of vegetable crops which are eaten raw (cucumbers, etc.)
2. Category A: irrigation of vegetables eaten cooked
3. Category B: irrigation of plenteous trees, green areas and roadsides outside the cities
4. Category C: irrigation of industrial crops, field crops and forestry
5. Additional category: irrigation of cut flowers

The Jordanian standard JS 1766/2014 (guideline) links the usage of irrigation water to the respective UN guidelines from the WHO (2006) and the FAO.

**Policy implementation and impact**

Jordan made considerable achievements regarding wastewater services, approximately 64% of the population is connected to the WWMS. As stated above, the reuse of reclaimed water is possible and proposed in different policies. A rigid regulation exists, Ghneim concluded therefore in 2010 that some standards are unnecessarily stringent. Some WWTP don't match the standard due to overloaded capacity. Nevertheless, (too) many institutions with overlapping responsibilities are involved and coordination is weak. The policies encourage reallocation of water for irrigation, but the low prices for freshwater don't have a steering effect. At last, the financial resources for rigorous monitoring are not there. These appear as the prevailing barriers.

### Summary of Part B – Domestic Wastewater Reuse

Due to the limited water resources in Jordan, it has become more unequivocal that the scale-up of wastewater reuse is an inevitable choice for Jordan. There is no limitation on the treated wastewater use in any water-based development activities, if the water quality is up to the standard regulating this use. The quality of the water allowed to be used for non-agricultural uses would be, most likely, higher than the quality of the water used for irrigation. Consequently, these non-agricultural uses must entail extremely high treatment technologies in order to meet the related standards. They are assumed to be higher than the already strict standards applicable to irrigation uses in Jordan.

This raises the question why an expensive investment in non-agricultural reclaimed wastewater use should be done? The decision makers must be aware of the returned gains that could be achieved from this investment before deciding on the scenarios of the treated wastewater use. In this deliberate process the use of treated wastewater of DWWTPs for irrigation remains the most feasible option. This promotes a suitable, context specific standard. The removal of nutrients/ ions like nitrate and phosphate from the treated effluent is counterproductive. In the reuse case of "irrigation", such nutrients are naturally needed for growth and productivity of plants/ crops. Moreover, the treated wastewater is a carrier media for these nutrients. On realizing the fact that more than 95% of the water absorbed by plant is lost into atmosphere in form of vapor through evapotranspiration process, it turns out that the wastewater reuse in irrigation is considered as an effective measure to protect water resources from being polluted by the nutrients contained in wastewater.

Therefore, the existing Jordan standard for reuse has negative implications: First, the treatment of wastewater above the actual ‘quality’ needed for irrigation represents a financial burden that may impede the implementation plans for the scale up of the decentralized sanitation services. Second, the strict standard deprives Jordan of making full use of the close-to-nature treatment technologies which are affordable and very effective under the specific context. The significance of wastewater reuse for irrigation emerges from the high assimilative capacity of the reuse system. This ensures the degradation of the pollutants contained in the wastewater. Therefore, the wastewater reuse is an opportunity for environmental protection rather than a burden.

In principle the purpose of a wastewater treatment plant is to decrease the pollutants loaded in treated effluent prior to its discharge. The treatment plant has a certain level of efficiency in accomplishing this task. Nevertheless, the pollutants will always be there at a certain residual concentration. In the case of irrigation, the reuse system itself offers a reliable measure for diminishing the remaining pollutant loads in the treated effluent. The significance of reusing wastewater becomes obvious if the quality of the treated effluent varies and if this variation cannot be controlled by the operator.

Then, the wastewater reuse for irrigation complements the role of treatment plant in minimizing the pollution on the environment. That is why wastewater reuse for irrigation is an additional post-treatment measure. It is especially suitable for the decentralized approach. The reuse of wastewater is associated with certain risks. Those risks have shaped the public misperception of the wastewater reuse and have triggered scepticism over the safety of this practice in irrigation. In order to have accurate judgement of such risks they must be compared with the risk of a prohibition of wastewater reuse. Such a comparison allows decision-makers to determine which scenario has the lower risk and is easier to manage. The risk assessment should come up with effective measures and good practices for a good risk management.

For this, a comprehensive monitoring is essential. It should cover the complete waste-water treatment process and in addition also post treatment use: the irrigated crops, the technical, agricultural infrastructure, the soil, and nearby natural water resources. The monitoring program provides the information needed for continuous re-evaluation and re-assessment of the reusing practice. This information can be used to make the necessary adjustments to ensure a reliable operation of reuse system.

Beyond the technical treatment and irrigation process an additional requirement is the easy access to a functioning drainage system, i. e. a wadi. In practice the reuse system of a fixed-size irrigation project cannot assimilate the treated wastewater supply at constant rate all the time over the year. Consequently, there will be always a surplus exceeding the actual irrigation needs during the times of the non-peak irrigation demand.

Considering the public concerns on the safety of wastewater reuse practice, it might be suggested to restrict the types of crops to those, which to not interfere with the human food chain, e. g. forest trees.

## Summary of Part C – Business Models for Decentralized Wastewater Management in Jordan

The GIZ ACC-Project is supporting its Jordanian partners in creating an enabling environment for scaling-up of DWWM alongside to centralised management. This includes the identification of feasible business models (BM) for the O&M of DWWTPs and reuse systems.

This consultancy sets out to investigate and present possible approaches to introducing sustainable BM for DWWM in Jordan, with a focus on small towns and rural settlements. The lack of sustainable BM is the principal institutional barrier to the provision of sanitation services in areas that cannot be connected to centralised, large-scale WWTPs. DWWTPs in small towns and villages are disadvantaged by their inherent inefficiencies due to their small size, limited scope and dispersed populations with the result that the revenues necessary to properly finance the systems results in tariffs that are considered unacceptably high.

This study discusses and seeks to answer some of the key questions related to the sustainability of DWWM, including

i. Who shall own assets of DWWM (e.g. collection, treatment, reuse infrastructure)?
ii. Who shall operate the assets (e.g. public institutions like WAJ or municipalities, or the semi-public like subordinated water companies, or the private sector)?
iii. Who shall pay for DWWM (e.g. customers served with sanitation, endusers of the treated water, national bodies responsible for protection of water resources, the environment and public health)?
iv. Who shall secure steady financing of DWWM under uncertain cost-recovery (e.g. MWI or WAJ, governorates or municipalities)?
v. Who shall supervise and monitor DWWM (e.g. effluent quality, review of standards, capacity development, environment protection)?

The objective of this study is to recommend appropriate BM options for DWWM and suggest policy measures needed to enhance the institutional, administrative and financial requirements of DWWM to achieve long-term sustainability.

In a decentralised approach, the **ownership of DWWM** assets should be on local level and – if possible – with the local operator, be it a private company, a local association (Cooperatives), municipality, municipal enterprises, etc. This makes even more sense when products of wastewater treatment (irrigation water, compost, etc.) are supposed to be used locally (for reasons of economic efficiency).

However, required Jordanian pre- and **framework conditions** are not yet fully in place: institutional arrangements are still unclear, WAJ's willingness to accept accountability for small-scale solutions is still underdeveloped, and existing tariffs and subsidies are insufficient to generate private interest.

General considerations in this study conclude that the "polluter-pays-principle" should apply as far as practicable, while state subsidies should be minimised, provided fees are within the range of affordability constraints. O&M costs shall be covered by user (household) fees, gate fees (wastewater delivered by trucks) and charges for products (irrigation water etc.). Innovative financing models should be considered, such as CO2 compensation schemes that are becoming more relevant following the Paris Climate Agreement. Although not considered a major issue in this study, future opportunities should consider higher charges for trade effluents for commercial and industrial users to reflect the higher costs of treatment they impose.

Additional assumptions and input data for the Business Model Analysis are:

- The location of the DWWTP is supposed to be in a Wadi near Rasoon village, acting as a representative example with data available from earlier studies and being located in an area identified as a “hot spot” by WAJ earlier.
- The sewer system and the WWTP are expected to be operated by a private sector operator although the analysis is equally as valid if it was owned and operated by a local community / municipality.
- Performance and environmental compliances to be monitored by MoEnv & MoH.
- Subscribers shall pay service fees to the operator.

**The treatment technology selected** for the business model analysis is a 2-Stage Vertical Flow Constructed Wetland meeting Jordanian Standard JS893/2006 and relevant Irrigation Water Quality Standard. According to the Consultant’s experiences, this treatment technology features the lowest CAPEX and OPEX, making the consideration of all other kinds of potential technologies less viable and hence represents the “best case option” in terms of technology.

**The Business Model Analysis** considered 3 principal treatment and reuse options:

- **Option 1: Constructed wetland only**
- **Option 2: Constructed wetland with effluent sales** to irrigation or other use where the treated water has a commercial value (there is no difference economically whether the operator uses the water directly or whether it is sold)
- **Option 3: Biomass option** that is subject to financial support through carbon credits / **$CO_2$ compensation schemes.**

The principal **outcomes** of the **Business Model Analysis** can be summarised as follows:

- The least attractive option is Option 1 with no external revenues from irrigation and/or carbon credits. Irrigation revenues and carbon credits lower required tariffs but not by much (approx. 25% to 35%). However, prices for CO2 compensations are likely to increase in the foreseeable future potentially making this option more viable. This option relies upon required certifications, agreed payment methods etc. for longer term sustainability.
- The carbon credits option is marginally most viable, but if irrigation tariff

increased, that may be preferable. Irrigation revenue may be more assured in the longer term.

- In all cases calculated tariffs are above current wastewater charges (from between 30% to over 100% over current tariff levels) but below estimated affordability ceilings[2].
- Full cost recovery (including capital expenditure), however, results in tariffs that exceed affordability ceilings[3].

One outcome from the final workshop presenting the BM study refers to the willingness to pay, respectively political willingness to raise tariffs, which is still required. This issue includes the "economies of density": densely populated cities must cross-subsidize DWWM as it is not feasible that rural residents pay more than urban dwellers.

The Consultant suggests policy measures that need to be taken to enhance the institutional, administrative and financial background for DWWM to achieve long-term sustainability

**Recommended** are a number of clarifications, legal actions and improvement of framework conditions (policy measures) to make small-scale sanitation in Jordan a viable business: based on full cost recovery, clear responsibilities and transparent share of tasks, such as:

- Promoting DWWM in rural communities regardless of the population size of <5,000 PE. The selection shall be based on community characteristics, topography, groundwater and health vulnerability, volume of WW, quality of WW, land availability, investment costs and operation and maintenance requirements due to economies of scale, scope and density .
- Agglomeration of rural communities into one DWWM scheme, if possible. Viable business models for small towns and rural sanitation depend on the scale: rural communities, which may form an agglomeration where WW collection and treatment is economically justified, or remote communes where local solutions have to be provided.
- Develop and adopt technology certification procedures and O&M operation certifications, taking results of the current activities (such as the ongoing NICE project) into considerations.
- It is required to improve and amend legislation. In particular, this applies to the establishment, management and supervision of sanitation service providers, municipal associations, WW user associations, etc.
- Wider implementation of fiscal incentives to promote potential business models.

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[2]The analysis suggests that an increase in tariffs of 200% over current levels may still be within affordability constraints.
[3]For the definition of affordability, see chapter 14.3.2 Affordability and willingness to pay

- Adopting reliable remote monitoring systems for key parameters
- Sale / reuse of treated effluent to be encouraged where it is viable
- Further considerations on $CO^2$ compensation schemes in conjunction with wastewater treatment (expected to become more viable over the next years as $CO^2$ compensation prices are increasing).

### Summary of Part D – Social acceptance as a priority for sustainable decentralized wastewater systems

***Challenges and Reticence:*** In all cases, the implementation of DWWTP is a challenge in Jordan. Different issues hamper the acceptance of DWWTPs:

***Location:*** The site selection is critical due to two points. (i) The topography determines the gravity flow and the high-energy costs for pumping water. Consequently, the DWWTP has to be located below the connected settlements. (ii) Surrounding landowners are concerned about the value losses of their land. This concern is most important for Jordan.

***Health and wellness:*** People are afraid of bad smells coming from the DWWTP. Well-designed operated and maintained plants don't smell nowadays. But a successful application is lacking in Jordan. Furthermore, the improved health-related safety for people (reduced environmental impact, e.g. no groundwater contamination) of well-operating DWWTPs are not well understood. It is uncommon for the population to know the advantages of reusing treated wastewater for irrigation and its benefits for such an arid country as Jordan.

**Culture and religion:** Cultural and religious traditions bring a high interest regarding cleanness, which easily causes reluctance of the people to become involved in DWWM-Systems.

**Economic and financial aspects:** For the rural population using leaking cesspits, which rarely need to be emptied, a new DWWTP causes connection costs and a monthly fee. The reuse of the wastewater for irrigation is no advantage for people who do not work in agriculture.

**Choice of technology:** The choice of the most appropriate technology is a very site depending, multi-criteria selection. Economic feasibility, ecologic sustainability and social acceptance must be weighted and compared. A common pitfall is the preference for high-tech solutions which are difficult to operate for the local community.

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[4]Several potential economies exist:

- Scale relates to size of operation where fixed costs can be spread over a larger group,
- Scope relates operations that include more than one service, e.g. water plus wastewater, where costs can be shared, and
- Density where more densely populated areas incur lower costs per unit of network than more sparsely populated areas

Experiences from other countries: Short case studies for DWWM form other countries are provided in chapter Experiences in DWWM projects page 262.

***Recommendations:*** Local, public acceptance is a key issue for successful implementation of DWWM. To achieve this, public awareness and public participation are essential. The experience shows that the constructive involvement of eminent groups or persons of the local communities is critical for positive acceptance.

## Summary of Part E – Orientation Guidelines developed based on the Experiences of the ACC Project

The orientation guideline documents and discusses lessons learnt and best practices developed from the ACC Project between 2014 and 2019. The primary objective of this document is to guide national and local policymakers, planners and experts of the MWI and WAJ in creating an environment for the upscaling of the DWWM approach.

### Project Background and Approach

The ACC Project started in 2014 with a conceptual study which lead to the agreement to set up a decentralized wastewater treatment and to reuse pilot area in the Rehab district to demonstrate the viability of this approach. A detailed feasibility study lead to a selection of four concepts and a Multi-Criteria Analysis (MCA) was used to determine strengths and weaknesses. The project conducted technical studies and field visits. It created public awareness and assessed the capacity development needs. Everything was accompanied by a participatory stakeholder management. Due to many constraints, which are explained above and at different points in this compendium, the location was changed to the Feynan Ecolodge in the Dana Biosphere Reserve in the south of Jordan. Although the Ecolodge was in a biosphere reserve, it did not have proper wastewater treatment nor wastewater reuse. The ACC project constructed a sustainable low-maintenance and 'close-to-nature' system.

### Challenges of DWWM in Jordan

The change of site showed that the challenges are numerous. A commitment of the stakeholders and the will for cooperation among the partners and politics was lacking. Consequently, many institutions in charge were not supportive to foster the pilot project. One reason being that investments (CAPEX) for public infrastructure in rural communities are low and have low visibility for the politicians who need to support such measures. Furthermore, there is no feasible O&M-model (OPEX) nor a business model which the private sector requires. Beyond this, regulation is not supportive. Rules and standards, relevant for DWWM and reuse do not match the needs and requirements; e.g. obligatory nitrogen and phosphorus removal do not make sense if the reclaimed water will be used for irrigation, where these substances then will be added for fertilisation. Since there are not enough cases of DWWM, expertise is not available. As shown above, social acceptance is lacking heavily.

## Orientation Guidelines for Implementing and Upscaling the DWWM in Jordan

For the successful implementation of DWWM, it is essential to understand and respect the cultural habits and behaviour. The trust of all stakeholders in a reliable DWWM technology is an essential ingredient for a successful introduction and upscaling. To reduce the administrative effort, public responsibilities and confusing regulations should be reduced and a well organised institutional framework should be set. The definition and perception of DWWM currently implies that treatment and reuse are located far away from origin of the wastewater. This is not necessarily the case and this perception should be changed.

DWWM needs a specific environment to be suitable and feasible. Topography and the purchaser of the reclaimed wastewater must suit, and other issues are relevant. The technical analysis and design should be done in two steps: a pre-design including the technical options and necessary safeguards and, based on these outcomes, the detailed final design should be done. It is very important that the reuse options determine the needed quality of the reclaimed wastewater. Therefore, the DWWMS design has to start at "the end of the pipe."

The financing is a critical aspect for DWWM since the willingness to pay for such public services in Jordan is limited. The WHO (2000) has identified seven key principals, such as maximizing the willingness to pay and clear financial responsibilities. This also pertains the operation and maintenance (O&M), and its related costs. This is crucial for long term acceptance and must be an integral part of the design of the DWWTP from the beginning. O&M should be oriented towards the available capacity of the operator.

Strict monitoring and quality control of O&M of DWWTPs are essential to protect the environment and water resources. The specific Jordan standards (JS893/2006) were designed for large scale systems and are too stringent for small scale WWTPs and increase the investment costs. At the Feynan demonstration project, a 100% recirculation of the wastewater was required, increasing the system capacity in order to meet class C of JS893/2006 for the parameter nitrogen. In specific settings of DWWTPs, this might be unnecessary. Regulations and standards should reflect this.

DWWM has a high potential. It offers large opportunities regarding the reuse of the scarce water resources. It is a cost-effective public service for wastewater treatment with the goal to protect human health and combat environmental pollution. To successfully introduce this technology, it is essential to build well-functioning practical cases. With those, it might be possible to overcome constraints such as social acceptance, lacking political support and unclear responsibilities. It will be possible to build a suitable standard. Engineers and technicians can learn the required skills for construction and operation. To mitigate these constrains, a long breath is needed.

# Part A

# Decentralized Wastewater Management in the light of Adaptation to Climate Change

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## 1. Introduction

The Jordan Ministry of Water and Irrigation (MWI) in close cooperation with the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH is implementing pilot projects demonstrating that decentralized wastewater management (DWWM) is a viable and necessary action for adaptation to climate change. The project entitled: "Decentralized wastewater management for adaptation to climate change in Jordan (ACC)" has a multi-level approach that follows both soft and hard tracks. Capacity development for strengthening the Jordanian capacities on DWWM and providing the relevant demanded support for strategizing adaptation to climate change specifically through DWWM remains the core of soft track activities. Likewise, demonstration projects that show the feasibility and sustainability of DWWM alternatives form the core of hard track activities.

This background report provides contextual as well as historical information that helps to understand the existing environment for wastewater management in Jordan. It also helps to position wastewater and treated wastewater use in the wider frame of adaption to climate change. Accordingly, the document is divided into two main parts. The first part starts presenting global climate change and shows its impacts on the water sector together with witnessed and foreseen impacts on relevant sectors including agriculture, health, and economy. Moreover, the concept of adaptation to climate change and increased resilience of agricultural and water systems is then presented with a particular interest in adaptation of water systems through the integrated water resources management (IWRM) approach. The latter introduces the evolving concepts of decentralization as well as integration, which were presented as the main guiding beliefs of IWRM. In doing so, the document highlights the main relevant issues that govern adaptation of water and wastewater systems as well as water and wastewater infrastructures to climate change. The second part starts to zoom in on wastewater management at regional scale and further at local Jordanian scale. A detailed discussion of how wastewater management was developed over the past decades in the kingdom and the governing regulatory frame is introduced. An overview is given on how the already developed policies, strategies and regulations related to wastewater management are implemented. The recently developed policies are presented including the decentralized wastewater management policy and the way forward is being suggested.

The background document deals with wastewater management at two levels. The first level discusses the integrated approach in which wastewater treatment and reuse are indispensably connected in view of the approved policies in Jordan. This approach gives some flexibility to the required treated wastewater standards, provided that better control measures are taking place at the agricultural fields. This would imply the necessity to revisit and upgrade the enacted regulations, but also define responsibilities of different governmental authorities to guarantee optimum adaptation through improved management alternatives. The second level discusses wastewater treatment technologies that might be suitable and sustainable in view of the existing Jordanian environment and the predicted impacts of climate change. In both cases (treatment and reuse), challenges are presented, and the way forward is suggested.

## 2. Observed and projected Climate Change impacts

Global climatic warming is a reality and the human influence has been a dominant cause (IPCC, 2013). As an example, on human influence, the agricultural sector was held responsible for about 10% of Green House Gases (GHGs) in 2008 in Spain. Half of these agricultural emissions were originated from livestock (especially pig manure management) as compared to crop systems (Ministerio de Medio Ambiente y Medio Rural y Marino, 2009b). It is furthermore projected that as the planet warms, climate and weather variability will increase (Thornton et al., 2014). Changes in the frequency and severity of extreme weather events and in weather patterns' variability will have significant consequences on human and natural systems. Explicitly, increasing frequencies of heat, drought and flooding events are projected for the rest of this century, and these are expected to have many adverse effects (IPCC, 2012). Observed and projected changes of five climate extremes are summarized in Table 1 as presented by IPCC (2012). Apparently, reported climate extremes have either direct or indirect links with water availability and distribution. As in global climatic warming, changes in some extremes are results of anthropogenic influences, although attribution of single extreme events to these influences remains challenging (IPCC, 2012). Concurrently, there is considerable uncertainty regarding projected changes in extremes to the end of the current century. However, low confidence in projections of changes in extremes does not mean that such changes are unlikely. In fact, there are evidences that low-probability, high-impact changes in extremes will occur (Thornton et al., 2014).

Many semi-arid regions such as the Mediterranean basin, will suffer a significant decline in water availability due to climate change. Climate change in the Middle East and North Africa (MENA) region caused more infrequent and reduced total annual precipitation (MWI, 2016a). It was estimated over the past decades that MENA region experienced a warming of about 0.2 degrees per decade. Moreover, the number of heat extremes and days with extremely high temperatures has increased . Some models estimated that mean and maximum temperatures over Jordan, for instance, will be 2-4 degrees higher and precipitation will be 15-20% lower by the end of the century (MWI, 2016a).

Climate change impacts may include water resources decreases, coastal regression, loss of biodiversity and natural ecosystems, increased soil erosion processes and loss of lives and goods resulting from the intensification of extreme weather events like floods, wildfires and heat waves (Vargas-Amelin and Pindado, 2014). Impacts are expected to be diverse and heterogeneous affecting water demand for irrigation, shortening of vegetative cycles, increase in plagues and exotic species, direct repercussions on the agricultural production, or impacts on products quality (European Environment Agency, 2012; Masters and Norgrove, 2010). In areas where precipitation may become more intense but less frequent, there is potential to increase flash floods and runoff, and as a result increase soil erosion, diminish soil moisture and increase the risk of agricultural drought (Dai, 2011). In fact, global aridity has increased substantially since the 1970s as noticed recently over Africa, southern Europe, East and South Asia, and eastern Australia (Thornton et al., 2014). Accordingly, the percentage of global land defined as dry areas has increased from 17% in the 1950s to about 27% in the 2000s (Dai, 2011). Interestingly, only in the case of drought, a significant proportion of population gets affected (Raleigh & Jordan, 2010) and consequently the process of desertification might represent one of the greatest impacts related to climate change. According to the National Action Program to Combat Desertification in Spain (Ministerio de Medio Ambiente y Medio Rural y Marino, 2008b), a considerable area is already severely affected by desertification processes. A previous governmental report in Spain expected a general reduction of water resources and increased demand for irrigation systems. The report predicted a reduction in inputs of up to 50% in semi-arid regions with increase in inter-annual variability (Ministerio de Medio Ambiente, 2005). It should be noted that desertification causes are diverse and complex, but usually include forest fires, loss of vegetative cover, erosion, the continuous loss of fertile agricultural land and salinization processes (Millennium Ecosystem Assessment, 2005). The projections of climate change would exacerbate these impacts, especially in the Mediterranean region. Extreme events may also have considerable impacts on the energy sector, and due to declining water flows, a lower hydroelectric production is expected (Ministerio de Medio Ambiente y Medio Rural y Marino, 2009a). On the other hand, behavioral changes associated with climate change, such as changes in demand for heating and cooling, will also impact energy, and consequently water use (Olmstead, 2014). The following sub-sections will highlight the foreseen climate change impacts as well as extreme events' impacts on agriculture, water, market prices and human vulnerability.

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[5]Jordan's 3rd National Communications, http://unfccc.int/national_reports/non-annex_i_natcom/items/2979.php

[6]Rahman et al. (2015): Declining rainfall and regional variability changes in Jordan, Water Res. Res., 51(5): 3828-3835

[7]Abdulla (2015): 21st century projections for precipitation and temperature change in Jordan, Report to MWI

Table 1 Summary of observed and projected changes of five extremes at a global scale (Adopted from table 3.1, IPCC, 2012)

| Variable/phenomena | Observed changes since 1950 | Attribution of observed changes | Projected changes up to 2100 |
|---|---|---|---|
| **Temperature** | Very likely decrease in number of unusually cold days and nights. Very likely increase in number of unusually warm days and nights. Medium confidence in increase in length or number of warm spells or heat waves in many regions. Low or medium confidence in trends in temperature extremes in some sub-regions either due to lack of observations or varying signals within sub-regions | Likely anthropogenic influence on trends in warm/cold days/ nights globally. No attribution of trends at a regional scale with a few exceptions | Virtually certain decrease in frequency and magnitude of unusually cold days and nights. Virtually certain increase in frequency and magnitude of unusually warm days and nights. Very likely increase in length, frequency, and/or intensity of warm spells or heat waves over most land areas |
| **Precipitation** | Likely statistically significant increases in the number of heavy precipitation events in more regions than those with statistically significant decreases, but strong regional and sub-regional variations in the trends | Medium confidence that anthropogenic influences have contributed to intensification of extreme precipitation at the global scale | Likely increase in frequency of heavy precipitation events or increase in proportion of total rainfall from heavy falls over many areas of the globe, in particular in the high latitudes and tropical regions, and in winter in the northern midlatitudes |
| **El Niño and other modes of variability** | Medium confidence in past trends towards more frequent central equatorial Pacific El Niño-Southern Oscillation (ENSO) events. Insufficient evidence for more specific statements on ENSO trends | Anthropogenic influence on trends in North Atlantic Oscillation (NAO) is about as likely as not. No attribution of changes in ENSO | Low confidence in projections of changes in behavior of ENSO and other modes of variability because of insufficient agreement of model projections |
| **Droughts** | Medium confidence that some regions of the world have experienced more intense and longer droughts, in particular in southern Europe and West Africa, but opposite trends also exist | Medium confidence that anthropogenic influence has contributed to some observed changes in drought at the level of single regions due to inconsistent or insufficient evidence | Medium confidence in projected increase in duration and intensity of droughts in some regions of the world, including southern Europe and Mediterranean region, central Europe, central North America, Central America and Mexico, northeast Brazil and southern Africa. Overall low confidence elsewhere because of insufficient agreement of projections |
| **Floods** | Limited to medium evidence available to asses climate-driven observed changes in the magnitude and frequency of floods at regional scale. There is low agreement in this evidence, and so low confidence at the global scale regarding even the sign of these changes. High confidence in trend towards earlier occurrence of spring peak river flows in snow melt – and glacier- fed rivers | Low confidence that anthropogenic warming has affected the magnitude or frequency of floods. Medium to high confidence in anthropogenic influence on changes in some components of the water cycle (precipitation, snow melt) affecting floods | Low confidence in global projections of changes in flood magnitude and frequency because of insufficient evidence. Medium confidence that projected increases in heavy precipitation would contribute to rain-generated local flooding in some catchments or regions. Very likely earlier spring peak flows in snow melt and glacier-fed rivers |

* likelihood assessment: virtually certain, 99-100%; very likely, 90-100%; likely, 60-100%; more likely than not, 50-100%; about as likely as not, 33-66%; unlikely, 0-33%; very unlikely, 0-10%; and exceptionally unlikely, 0-1%

### 2.1 Impacts on agriculture

Increase in maximum temperatures (as climate or weather) can lead to severe yield reductions and reproductive failure in many crops. In maize, each degree-day spent above 30°C can reduce yield by 1.7% under drought conditions (Lobell et al., 2011). Impacts of temperature extremes may also be felt at night, with rice yields reduced by 90% when night temperatures arrived 32°C compared with 27°C (Mohammed & Tarpley, 2009). Both intra and inter seasonal changes in temperature and precipitation have been shown to influence cereal yields in Tanzania (Rowhani et al., 2011). Another example comes from Uganda where farm sizes have decreased over the last 2–3 decades (Fermont et al., 2008; Seeley et al., 2010a) and yields have stagnated at levels well below attainable yields due to – among other factors- changes in rainfall patterns and persistent droughts (Abera-Kalibata et al., 2008; Beuving, 2010; Taylor et al., 2011; Wairegi et al., 2010). Prolonged droughts exacerbate the water stress situation and often lead to loss of an entire season's crop in some localities in Uganda. Moreover, a large proportion of the cropping and range land area of sub-Saharan Africa is projected to see a decrease in growing season length, and most of Africa in the southern latitudes may see losses of at least 20 percent (Thornton et al., 2014). Moreover, climate variability and extreme events were reported to influence yield quality. Protein content of wheat grains has been shown to respond to changes in the mean and variability of temperature and rainfall (Porter & Semenov, 2005); specifically, high-temperature extremes during grain filling can affect the protein content of wheat grains (Hurkman et al., 2009).

Climate change and climate variability, moreover, have impact on most domesticated livestock species since their temperature comfort zones remain between 10°C and 30°C. At temperatures below 10°C, maintenance requirements for food may increase by up to 50%, and at temperatures above 30°C, animals reduce their feed intake by 3–5% per each additional degree of temperature (NRC, 1981). In the recent past, the pastoral lands of East Africa have experienced droughts about one year in five, and it was generally possible to maintain relatively constant cattle herd sizes; however, increases in drought frequency from one year in five to one year in three would set herd sizes on a rapid and unrecoverable decline (Thornton & Herrero, 2009). In Kenya, some 1.8 million extra cattle could be lost by 2030 due to increased drought frequency with estimated value US $630 million for lost animals and foregone production (Ericksen et al., 2012). Moreover, species composition of grasslands is a key determinant of livestock productivity in both temperate and tropical regions. Obviously, as temperature, rainfall patterns and CO2 levels change, composition of mixed grasslands will change and will impact livestock productivity (IPCC, 2007). The overall effects of changes in temperature and rainfall and their variability on species composition and grassland quality, however, are still far from clear and remain to be elucidated (IPCC, 2007). It should be noted that timing of climate variability might be just as important as its magnitude in affecting grasslands species and livestock productivity (Craine et al., 2012).

Notwithstanding the expected impact on composition and survival of livestock, changes in climate variability and in the frequency of extreme events might have substantial impacts on the prevalence and distribution of pests, weeds, and livestock diseases. For example, in the past, combinations of drought followed by high rainfall have led to widespread of outbreaks of diseases such as Rift Valley fever and blue- tongue in East Africa and of African horse sickness in South Africa (Baylis & Githeko, 2006). Future increases in the frequency of extreme weather events could allow the expansion of Rift Valley fever northwards into Europe (Martin et al., 2008). However, the effects of future changes in climate variability on pests, weeds and diseases are not well understood (Gornall et al., 2010).

### 2.2 Impacts on water

Climate change is shifting global weather patterns in a way that is predicted to impact both natural and anthropogenic systems such as freshwater resources and sanitation systems, respectively. Projections from the Intergovernmental Panel on Climate Change (IPCC) for the late 21st century (2081–2100) show a probability of 90–100% for an increase in the frequency, intensity, and/or amount of heavy precipitation events over most of the mid-latitude land masses and wet tropical regions, a 66–100% probability for increases in intensity and/or duration of drought on a regional to global scale, a 90–100% probability of increased incidence and/or magnitude of extreme high sea level, and a 50–100% probability for an increase in intense tropical cyclone activity in the Western North Pacific and North Atlantic (IPCC, 2013). The occurrence of these extreme weather and climate events leads to an increase in fluvial erosion, salinization of coastal aquifers, reduction in water availability, and wind damage to structures in areas not accustomed to such events (IPCC, 2013, 2014a, 2008). The effects of these climate-related events could leave water and sanitation systems non-functioning, and hence exposing the population to various health risks (e.g., waterborne illnesses due to lack of safe water (IPCC, 2014a)). These risks impact both rural and urban populations in high-income countries, and low- and middle-income countries as will be discussed later.

When discussing weather extremes' impacts on water supply and water quality, every sector of the economy will be affected through impacts on health, agriculture, industry, transport, energy supply, non-market ecosystem services, fisheries, forestry, and recreation (Olmstead, 2014). It is likely that climate change will increase conflicts among different economic sectors, since it will result in situations with higher demands and reduced availability of water resources (Vargas-Amelin and Pindado, 2014). The negative effects of climate change on freshwater systems, in terms of changes in quantity and distribution, are expected to outweigh the benefits of overall increases in global precipitation due to a warming planet. Several parts of the tropics and subtropics, including parts of Central-West Asia, North Africa, Asia and North America, are likely to be particularly affected by reduced freshwater availability (Rosegrant et al., 2009). It is expected that more than half the world's population will live in countries with severe water constraints by 2050 (Rockstrom et al., 2009). Steven Chu, U.S. Secretary of Energy has suggested that diminished freshwater supplies in some regions might be an even more serious global problem than rising sea levels as the climate changes (Gertner, 2007).

Diseases such as malaria, dengue and cholera, are all highly affected by changes in seasonal distribution of precipitation, including changes in flood and drought patterns (McMichael & Kovats, 2000; Costello et al., 2009). Although changes in malaria vectors will occur due to the gradual increase in temperature, the incidence of disease is also quite sensitive to changes in precipitation. If changes in climate variability lead to changes in spatial and temporal variation in vegetation and water distribution, we could see more epidemics as the vector moves to new areas (McMichael et al., 2006). Both malaria and dengue fever have associations with La Niña and El Niño cycles (McMichael et al., 2006). Human displacement from areas subjected to extreme events, especially floods, could become more frequent with an increase in climate variability. This also often has negative consequences for human health, not least because of crowded conditions with poor sanitation. Diarrhoeal disease is regularly a problem in such situations (Haines et al., 2006). In general, increased water scarcity will have an impact on sanitation and health (Few, 2007).

### 2.3 Economic burden of climate change

Although results are indicative, Willenbockel (2012) presented one of the few studies that modelled climate shocks and their impacts on commodity prices in different regions of the world. They estimated that a drought in North America in 2030 of a similar scale to the historical drought of 1988 would have a dramatic temporary impact on world market export prices for maize and a strong impact on world market price for wheat. These impacts would feed through to domestic consumer prices, with particularly profound effects in parts of sub-Saharan Africa. For instance, Nigeria depends almost entirely on imports of wheat, and under such a condition, the average domestic price for wheat in the country would spike by 50% above the baseline 2030 price, with substantial impacts on households.

While there is considerable regional variation, the relative economic burden of climate extremes as a proportion of GDP is substantially higher in developing countries than it is in developed countries – up to 8% in the most extreme cases. A strong upward trend in overall losses due to climate extremes is indicated since 1980 (Munich Re, 2011), although how these will play out during the course of the current century is highly uncertain; and as yet, there is no evidence to link this trend to anthropogenic climate change (Bouwer, 2011). In terms of wastewater infrastructure systems, lower flows, due to reduced water supply and consumption, will result in less dilution capacity for spills, which authorities will need to address through more intensive treatment techniques or efforts to reduce discharges and pollution, which would result in additional economic burden. In terms of investments, it is expected that flood protection infrastructure will demand increased assists, as well as those needed to minimize water scarcity and droughts impacts or to improve and expand monitoring networks and early warning systems. In relation to environmental issues, declining biodiversity and environmental services of ecosystems will represent a real loss although it might be difficult to assign them a market value. Increased saltwater intrusion into coastal aquifers, loss of wetlands and associated species, in addition to necessary measures for ecosystems restoration, will involve also significant costs (Vargas-Amelin and Pindado, 2014).

### 2.4 Human vulnerability to climate change

Human vulnerability to climate change can be evaluated in terms of a range of different outcomes such as food security or household income. Thus, areas vulnerable to disasters are not necessarily the same as those whose food availability -as calorific value- is likely to be negatively affected by changes in climate variability. This is better clarified in Table 2, in which several points can be made. First, almost 5.4 billion people, or just fewer than 90 per cent of the global population in 2000, live in places that produce at least some crop and livestock calories. The selected 14 crops in Table 2 account for 70 per cent of all calories produced while livestock accounts for 30 per cent. Second, it is noteworthy that developing countries account for 78 per cent of the global population and produces only 40 per cent of the demanded calories. Conversely, developed countries account for 22 per cent of the people and produces 60 per cent of the calories. Third, the relationship between rainfall variability and the average prevalence of underweight children seems not to be straightforward: in the developed regions, the value of the food insecurity proxy increases as rainfall variability increases, whereas in developing countries, it increases up to a rainfall coefficient of variance (CV) of 30 per cent and then falls slightly for further increases in rainfall CV. A possible explanation for this is that in the higher CV regions, most food is brought in via imports or food aid, for example. Fourth, nearly eight times as many people live in areas of high rainfall variability (with a CV of 30 per cent or more) in the developing countries as they do in the developed countries (407 million compared with 54 million); yet, these areas of high rainfall variability in developing countries account for only 3 per cent of all the calories produced, and they also tend to be areas with relatively high child malnutrition. Clearly, many such areas may be targets for the provision of food aid and social safety nets. Sub-Saharan Africa is already by far the largest recipient of food aid: average annual shipments amount to about 2 per cent of all food consumed. Under many scenarios, the number of food-insecure people in sub-Saharan Africa by 2020 is still likely to be at least 500 million (USDA, 2010), and this is a challenge that will clearly not be made any easier by increases in rainfall and temperature variability.

In any case, and since most population of the globe are living in food insecure countries, extreme climatic events that might affect the main food producing countries would leave them most vulnerable, insecure and least resilient in face of the impacts of climate change and climate variability.

Table 2 Proportion of total calorie availability per person per day from livestock products and from 14 food crops in developing and developed countries, by rainfall variability class

| CV †of annual rainfall (%) | Mean annual rainfall† (mm) | Human population ‡ (million) | Children underweight § (%) | Proportion of calories from 14 main crops** (%) | Proportion of calories from livestock †† (%) |
|---|---|---|---|---|---|
| **(a) Developing countries*** | | | | | |
| **<15%** | 2739 | 211 | 16 | 1.8 | 0.2 |
| **15-20%** | 1738 | 1318 | 17 | 10.3 | 0.6 |
| **20-25%** | 1118 | 1498 | 20 | 7.7 | 11.4 |
| **25-30%** | 657 | 808 | 22 | 3.0 | 2.9 |
| **30-35%** | 428 | 242 | 20 | 0.7 | 0.1 |
| **>35%** | 226 | 165 | 19 | 1.1 | 0.1 |
| **Total** | | 4241 | | 24.6 | 15.2 |
| **(b) Developed countries*** | | | | | |
| **<15%** | 1938 | 17 | <1 | 0.1 | 0.1 |
| **15-20%** | 1094 | 323 | <1 | 4.6 | 7.0 |
| **20-25%** | 662 | 527 | 2 | 17.0 | 2.6 |
| **25-30%** | 469 | 221 | 2 | 18.3 | 3.4 |
| **30-35%** | 355 | 42 | 3 | 4.7 | 1.4 |
| **>35%** | 230 | 12 | 5 | 0.5 | 0.6 |
| **Total** | | 1142 | | 45.2 | 15.1 |

* 'Developing countries' defined here as the countries of the Americas between Mexico in the north and Brazil, Paraguay, Bolivia and Peru in the south, all of Africa, and Asia up to 45oN excluding Japan. 'Developed countries' comprise the remainder. † Mean rainfall and coefficient of variation of annual rainfall estimates simulated using methods in Jones and Thornton (2013). ‡ From gridded population of the world version 3 (CIESIN Center for International Earth Science Information Network Columbia University and Centro Internacional de Agricultura Tropical (CIAT), 2005a).

§ Global subnational prevalence of child malnutrition v1, online at: beta.sedac.ciesin.columbia.edu/data/set/povmap-global-subnational-prevalence-child-malnutrition.

** Yields and harvested areas from Spatial Production Allocation Model (SPAM) 2000 (You et al., 2012). Crops included: banana and plantain, barely, beans cassava, groundnut, maize, other pulses, potato, rice, sorghum, soybean, sweet potato and yam, wheat.

†† From Herrero et al., (2013)

The overall summary of section 2 is presented in Table 3 and Figure 1. Impacts as seen on main three themes relevant to water systems. The most significant climate change impacts are shown in Table 1, while Figure 1 grouped the expected impacts into main themes associated with water systems. As a conclusion, global models should be sufficient and adequate in order to respond and establish actions to face climate change impacts. Comprehensive plans must be ascertained in order to adapt and increase resilience of countries to climate change impacts even when local models are not shown to be accurate.

## 3. Resilience and adaptation to climate change: global perspective

Resilience can be defined as the ability of a system to continue functioning or rapidly return to function during and after a climate-related disturbance. This includes all aspects of functionality without a compromise. For water systems as an example, this would mean no compromise of quality, quantity, waste containment, continuity, or reliability. Resilience describes qualities that a system already has, and differs from adaptation or adaptive capacity, which describes how much a system can be adapted for future disturbances as shown in Figure 2 (Lu et al., 2017). Adaptive capacity was defined as the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities (associated with changes in climate), or to cope with the consequences. Adaptive capacity describes what can be (but has not been) done to increase resilience. Most systems are not completely resilient and adaptive measures are needed in order to improve system's robustness in the face of climate change. Once all measures are taken, the system becomes resilient as shown in Figure 2 Relationship between resilience and adaptive capacity (lower bar).

To support and track efforts, a five-step climate adaptation process Figure 3 was created, which includes: 1) identifying and assessing vulnerabilities/ risks; 2) planning; 3) implementing strategies; 4) monitoring and evaluating; and 5) revising and sharing lessons learnt (Bierbaum et al., 2014; Intergovernmental Panel on Climate Change, 2014; Moser and Ekstrom, 2010).

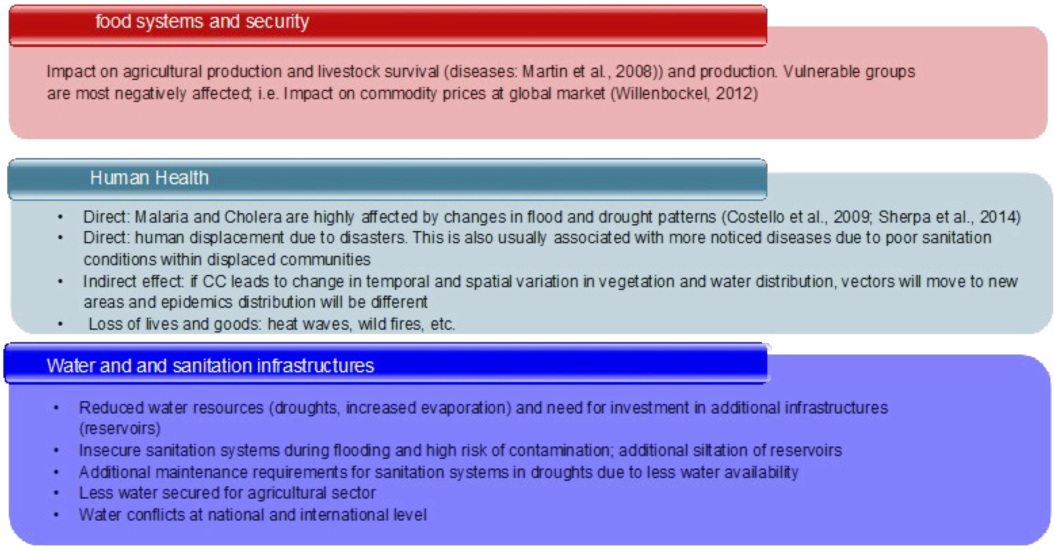


Figure 1. Impacts as seen on main three themes relevant to water systems

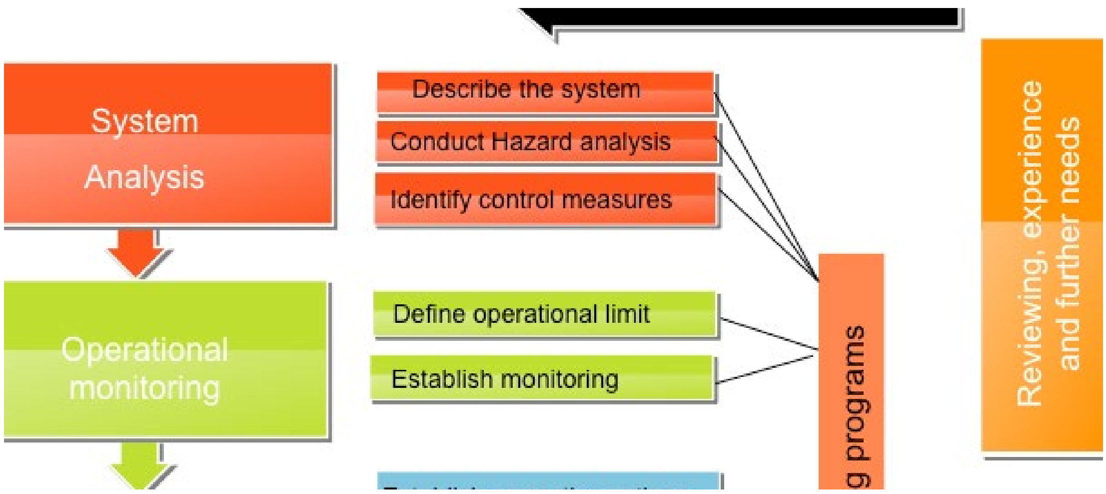


Figure 2 Relationship between resilience and adaptive capacity

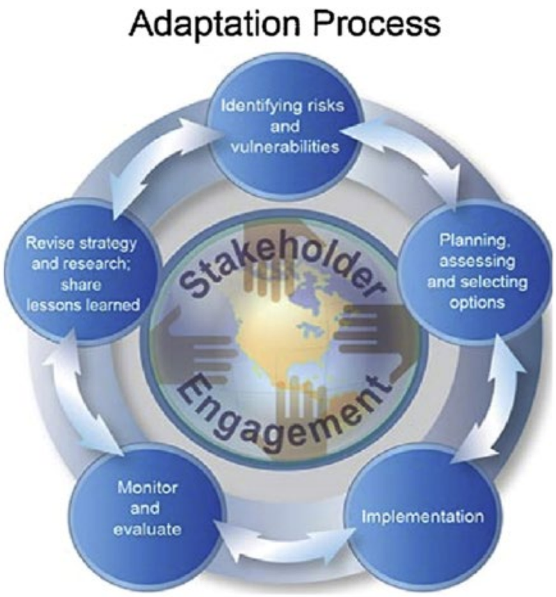


Figure 3 Basic adaptation process cycle per the 2014 US National Climate Assessment (Nordgren et al., 2016)

### 3.1 Adaptation process and the faced challenges

Adaptation to climate change is a nexus, and not a single isolated issue. Its boundaries are not defined by any single type of intervention, area of action, or group of actors (Aylett, 2015). Strong adaptation measures require crosscutting actions across multiple sectors carried out by a variety of actors (Aylett, 2015). The importance of integrating climate change adaptation measures is well explored in different sectors such as spatial planning (Hamin and Gurran, 2009; Carter et al., 2015), energy (Neumann and Price, 2009; Williamson et al., 2009; Hammer et al., 2011), transportation (Trilling, 2002; Mehrotra et al., 2011b), water (Muller, 2007; O'Hara and Georgakakos, 2008), equity (Dodman and Satterthwaite, 2008; Hardoy and Pandiellea 2009), and health (Patz et al., 2005; Haines et al., 2006; Ebi and Semenza, 2008). More holistic assessments imply that cross-system impacts of both climate change itself and adaptation strategies require a coordinated policy response across multiple sectors (Kirshen et al., 2008; Dovers and Hezri, 2010; Lawrence et al., 2015; Aylett, 2015), but also within each sector (Azhoni et al., 2017). In other words, we are faced with the challenge of mainstreaming responses to climate change both within and across existing urban systems.

Looking at institutional structures that are being put in place to address climate change planning, it is clear that staffs tasked with the climate portfolio are working from a marginal position within local governments. Adaptation and mitigation planning are driven by individuals or small, newly formed units that have been in existence for under a decade. The majority of climate planning teams are located in environmental agencies that, typically, have fewer resources and more limited jurisdictions than large bureaus such as planning, transportation, or water. These observations confirm that planning for adaptation to climate change is working from a position of relative institutional weakness (Carmin et al., 2012a, b; Aylett, 2013). A weak institutional structure means that adaptation plans and strategies framed will fail to be adequately implemented (Azhoni et al., 2017). However, increases in climate change variability, which are largely unpredictable in the short and long term, will force institutions (social patterns including organizations) to be more proactive and flexible (Gupta et al., 2010). A key aspect in this regard is to understand the factors and circumstances that strengthen the ties and cooperation between various institutions and sectors for information diffusion and knowledge exchange (Popp et al., 2013) that ultimately enhance adaptive capacity. Deep understanding of socio-economic and cultural factors (Azhoni et al., 2017) that shape decision makers' perceptions of risks (Liu et al., 2016; Smith et al., 2014), willingness to act (Adger et al., 2009; Gifford et al., 2011; Grothmann et al., 2013) or to prioritize actions is a necessity. In any case, adaptation requires the exchange of knowledge and experience (Brown et al., 2013a,b; Adger et al., 2005; Lejano and Ingram, 2008; Ziervogel and Downing, 2004; Azhoni et al., 2017) through networks at various scales (Adger et al., 2005; Juhola and Westerhoff, 2011). The role of social networks to enhance the adaptive capacity of individuals (Benson et al., 2015), farmers (Aulong et al., 2012), communities (Brown et al., 2010; Ampaire et al., 2017), non-profit organizations (Steinberg, 2009) and societies (Clarvis and Allan, 2014; Dow et al., 2013; Lejano and Ingram, 2008; McAllister et al., 2014; Pasquini et al., 2015) is widely recognized. Knowledge deficits at various levels can be identified –so far- as a major barrier to implementing climate change adaptation measures. This, likewise, can be owed to the disconnection between researchers, policy makers, practitioners and local communities. For example, more than ninety percent of the research that is conducted in India on climate change is not going to help adaptation for community because the most important stakeholders are not included in the planning phase (Azhoni et al., 2017). In other words, few climatologists perceive their role as not only producing new knowledge, but also relating it to society and providing an expanded variety of alternative applications (Wilke and Morton, 2015). If truth to be told, a greater and more effective communication is needed between scientists and decision makers, and between natural and social scientists. Currently, a failure to incorporate learning from the decision and social sciences into climate-related sciences has resulted in severe underutilization of climate information in supporting decision-making process (Weaver et al., 2013). Changes in variability are often more important for communities than changes in mean quantities; yet, the focus of modelling studies is often on the latter. Additionally, studies focusing on quantifying uncertainty in impacts are important if we are after minimizing errors in decisions taken to enhance adaptive capacity (Challinor et al., 2013; Vermeulen et al., 2013).

Meanwhile, and although adaptation efforts are transitioning from awareness raising to strategizing adaptation (Mimura et al., 2014), few cases demonstrate that adaptation is occurring (Moser and Boykoff, 2013). Findings reveal that existing services and resources are meeting the early phases of adaptation efforts such as conducting vulnerability assessments and creating adaptation plans but are failing to meet the needs associated with implementing, monitoring, and evaluating adaptation activities (Nordgren et al., 2016). Unfortunately, and as mentioned earlier, most governmental sectors lack the in-house capacity or expertise needed to engage with the added complexity associated with climate change (Bierbaum et al., 2013). Moreover, economic hardships have led to reductions in the basic resources (financial and human capital) that governments need in order to face challenges created by climate change (Zimmerman and Faris, 2011). In some cases, adaptation planning has been integrated into sectoral plans with collaboration across sectors coordinated by a dedicated climate planning team and a citywide adaptation strategy (Aylett, 2015). In others, planning and action proceed in a limited and isolated fashion (Pramova et al., 2015; Chesterman and Neely, 2015). Other countries have yet to clearly assign responsibility for adaptation planning and depend heavily on private consultants or the support of international non-profit organizations and networks (Carmin et al., 2012a, b; Aylett, 2014).

### 3.2 Adaptation of agricultural and food systems to climate change

What might vulnerable communities who are partially or wholly dependent on natural resources for their livelihoods do in response to substantially increased climate variability? A pool of methods was already suggested elsewhere in order to increase resilience of agricultural production systems in the face of climate change, particularly under the 'climate-smart agriculture' preface (e.g. FAO, 2010; Thornton et al., 2013). Options range from increasing the efficiency of crop and livestock systems via various mechanisms related to soil and nutrient management, water harvesting and retention, improving ecosystem management and biodiversity, diversification of on-farm activities (Proper handling of cultivation techniques and timing of growing season, tillage, irrigation and fertilization), use of weather forecasts and early warning systems, and methods for managing risk such as index-based insurance and risk transfer products (Barnett et al., 2008; Anton et al., 2012). As an example, and in terms of timing of growing season onset, Crespo et al. (2011) demonstrated that it may be possible to adapt to projected climate shifts to at least the 2050s in maize production systems in parts of southern Africa by changing planting dates. Farmers in northern Burkina Faso have additionally adopted many techniques intended to increase crop yield and reduce yield variability (Barbier et al., 2009). However, it should be noted that the drivers of these shifts were not climate variability but growing land scarcity and new market opportunities. Regarding dry lands cultivation options, farmers have already been substantially changing their practices and fundamental changes have occurred when critical thresholds in temperature and/or rainfall are reached (Gornall et al., 2010). Changes in the nature and timing of the growing season induced smallholders to grow shorter duration and/or more heat- and drought-tolerant varieties and crops (Hellin et al., 2012). While improved water harvesting and storage techniques may be able to reduce farmers' dependence on rainfall, they are not likely to be sufficient to significantly reduce vulnerability to drought (Barbier et al., 2009).

Another stratum considers institutional change as critical demand for enhancing resilience in dry land pastoral and agricultural systems. Governments, for instance, will need to invest in smallholder agricultural production, particularly in downstream activities such as storage, trace, processing and retailing; implementing and scaling up options that help producers to be more resilient to climate volatility, such as the now widespread use of smallholder crop insurance schemes in India and certain other countries; and establishing safety net programs for the most vulnerable households (Lipper, 2011). A second example was reported by Codjoe & Owusu (2011) in Ghana and showed that Food security could be enhanced by increasing farm-based storage facilities; improving the transportation system, especially feeder roads that link food production areas and major markets; providing farmers with early warning systems; extending credit to farmers; and the use of supplementary irrigation. Some cultural practices, particularly those that prohibit the consumption of certain foods, may reduce the resilience of some individuals and ethnic groups to food system disruptions (Thornton et al., 2014) and should be taken into consideration while planning adaptation programs. Emphasis should be given to integrating the required different types of knowledge (including indigenous knowledge and beliefs) and bringing different stakeholder groups together. Considerable innovation in participatory action research will be needed (Ziervogel & Opere, 2010). Limited predictive capability should not constrain adaptive responses, and creativity is required to arrive at actionable answers in response to questions from a wide range of decision makers concerning the appropriate adaptation of biological and food systems. Moreover, it is necessary to implement tools within agricultural policies, especially framed under the common agricultural policy (CAP), to strengthen the sector's adaptation capacity to climate change (Vargas-Amelin and Pindado, 2014). Concurrently, it is of utmost importance to link risk to decision-making profiles of farmers and their attitudes to investments and technology adoption (Thornton et al., 2014). Although some work has been done on this (Solano et al., 2000), more in-depth studies are needed since increasing adoption rates of key practices is a significant challenge and targeting options to risk management profiles is essential.

## 3.3 Adaptation of water and sanitation systems to climate change

Based on the discussion presented in section 2 of this report, it is reasonable to expect that frequency, duration, and intensity of floods and droughts will be increasing. Consequently, an appropriate response would be to ensure that future water management and water infrastructures are planned and designed to better manage those assumed increased risks. Simply put, the projected increases in climate variability will likely require more robust water systems to deal with both the rapidly expanding water management requirements of growing populations and predicted increased risks associated with climate change (Stahkiv, 2011).

### 3.3.1 General approach for adaptation of water systems to climate change

Integrated Water Resources Management (IWRM) has evolved with its core principles of adaptation to climate change (Stakhiv, 2003) and has employed a variety of tools, in different combinations, to reduce vulnerability, enhance system resiliency and robustness, and provide reliable delivery of water-related services. These tools consist of many technological innovations, engineering design changes, multi-objective watershed planning, public participation, regulatory arrangements, financial instruments, and policy incentives (Kabat et al., 2003). However, well-functioning institutions are needed to effectively administer this broad array of fairly complex, dispersed and expensive combinations of management measures. Therefore, tackling the central issue of ''governance'' is a key prerequisite for any strategy that intends to effectively deal with climate change adaptation (GWP, 2009, 2010). The formal foundation of the IWRM can be traced back to 1977 United Nations Water Conference (Biswas, 2004). IWRM is geared towards decentralizing institutions around major river basins, or a particular watershed scale and joining together various elements of water resources planning. It strives to integrated management across multiple scales while incorporating a multitude of stakeholders' interests (Engle et al., 2011). Improved governance, through IWRM is the principal means for resolving competition among multi-sectorial demands on a fixed water resources base. Each water-dependent sector (environment, water supply, sanitation, agriculture, hydropower, navigation) so far designs its own set of management principles, rules and incentives that are maximized, and often in conflict with one another. Resolving those inherent, inter-sectorial institutional conflicts is of utmost importance for successful climate change adaptation (Stahkiv, 2011).

Another concept that has evolved for dealing with uncertainties is the adaptive management (AM), which has its roots in resilience theory (Holling, 1978), and is primarily concerned with the management of uncertainty through formalized experimentation and processed-based learning (Huitema et al., 2009). In other words, AM is a decision process that ''promotes flexible decision-making that can be adjusted in the face of uncertainties as outcomes from management actions and when other events become better understood'' (National Research Council, 2004). It is a continuous process of adjustment and flexible adaptation that attempts to deal with the increasingly rapid changes in our societies, economies, and technological changes (Stahkiv, 2011).

Notwithstanding the previous two concepts, the U.S. has followed for the past 50 years a path of what could be termed ''autonomous adaptation'' to climate variability and change, which has proved to be reasonably effective with respect to water resources management (Stahkiv, 2011). Autonomous adaptation refers to actions undertaken by affected people without planned interventions (Forsyth and Evans, 2013). Autonomous adaptation in the U.S. and the European Union has incorporated many of the principles associated with IWRM, adaptive management (AM), and sustainable development (Loucks et al., 2000). These approaches, and associated changes in evaluation and normative decision rules for water resources management, comprise the conceptual foundations of an evolving pragmatic approach to dealing with climate change uncertainties (Stahkiv, 2011).

### 3.3.2 Institutional layout for adaptation of water resources to climate change

Aside from inspiring examples like the ones of Vancouver, Copenhagen, or Durban, studies showed that minimum actions took place in order to adapt urban systems to face the impacts of climate change (Aylett, 2014; Carmin et al., 2012b). Water so far tends to be managed without the demanded coordination between different institutions at the local and regional level. This introduces two complications; first, the downscaling of global predictions to the local and regional level is unreliable, and hence segregated actions might result in increased economic burden (Haddad and Merritt, 2001; Olmstead, 2014). Second, the information required to develop water management data inputs to integrated assessment models seeking to model adaptation lies with separate local water management institutions, which poses challenges for thorough and consistent data collection. Bureaucratic processes delay or render data and information inaccessible, which hinders or at least delays adaptation planning (Azhoni et al., 2017). Additionally, ambiguities in the responsibilities between different institutions were commonly cited as resulting in institutional bottlenecks (Azhoni et al., 2017), not mentioning the ambiguities in responsibilities within the same institution. Simultaneously, and since climate change, like drought, is a slowly evolving uncertain phenomenon; it is not serving to catalyze actions in a politicized world that has profound difficulties in dealing with highly uncertain actions and programs that require huge investments upfront to avoid unknown risks (Stakhiv, 2011). Issues like deteriorating infrastructure has meant that water institutions are occupied with addressing current deficiencies rather than future concerns (Azhoni et al., 2017).

Moreover, water marketing has proven to be an extremely sensitive issue and render sustainable water management complicated and challenging. De facto, some water management institutions may have role in limiting the expansion of water marketing as the case in American West (Libecap, 2011), which reduced the potential to flexibly respond to climate-change-related hydrological uncertainty. Such water institutions were basically emerged to enable agriculture and settlement of the arid region in west USA (Olmstead, 2014). Some researchers were even more sceptical about the ability of existing institutions to foster the more robust water markets that would aid in climate adaptation, since historic water allocations are locked in (Libecap, 2011). As an example, the sharp differences in marginal water values across sectors are products of historic water rights allocations, inefficient pricing, and subsidized irrigation projects (Wahl, 1989). For better elucidation, farmers in Arizona's Pima County, for instance, pay $27 per acre-foot, and water customers in the nearby City of Tucson pay $479 to $3267 per acre-foot (Brewer et al., 2008). In Texas' Rio Grande Valley, the value of water in agriculture has been estimated at $300 to $2,300 per acre- foot, and in urban uses at $6,500 to $21,000 per acre-foot (Griffin and Boadu, 1992). Another example from Jordan is related to treated wastewater use in agricultural irrigation. The government of Jordan decided to provide effluents of wastewater treatment plants with very low price as incentive for farmers to utilize this water source for irrigation. Treated wastewater use in agricultural irrigation became a well-established practice in Jordan, however, the government of Jordan is facing high resistance to adjust treated wastewater tariff. Noteworthy, the current tariff of treated wastewater is 10fils/m3 while cost of treatment might be up to 600 fils/m3. While these are just two examples, and these water prices and values are for different commodities (raw water vs. treated, piped water), current water prices do not generally equate marginal water values across users (Olmstead, 2014). Recent attempts were made to better control irrigation water in some American states as presented in California's Water Conservation Act of 2009. The act requires that all large agricultural water suppliers (such as irrigation districts) measure water delivered to farms and adopt some form of volumetric pricing (Olmstead, 2014). However, this is still insufficient to increase resilience of water systems to face climate change impacts. It is worth mentioning that in nearly all markets for goods and services, scarce resources are allocated through prices, which transmit information about relative scarcity and value in use. However, in the case of water, prices are administratively determined, through mechanisms that are often political and rarely take economic value into account. Water prices, therefore, do not respond automatically to short-term and long-term changes in supply (Olmstead, 2014). The fact that aridity and price levels may be negatively correlated in the U.S. (Bell and Griffin, 2011) and in other countries like Jordan is not an encouraging sign.

Notwithstanding that water pricing has a major role in managing the finite water resources, there are also other responsive non-price water demand management policies and programs that might be effective. These programs fall into the following main categories: (1) voluntary adoption of water-conserving technologies like the adoption of contemporary models of "double flush" toilets (Bennear et al., 2012); (2) mandatory water use restrictions, which may limit the total quantity of water that can be used or restrict particular water uses; i.e. limit landscape irrigation and car washing. However, empirical evidence regarding the effects of these actions on water conservation is mixed (Schultz et al., 1997); (3) social comparison and information policies. For instance, economists have explored the impact of providing households with information on their water consumption relative to their neighbours and estimated the impacts of such social comparisons on water use. Ferraro and Price (2013) showed that social comparison messages had a greater influence on behaviour (reducing water demand) than simple pro-social messages about the need to conserve water during a dry summer, or technical information on how water conservation could be accomplished; (4) mixed non-price conservation programs. For instance, landscape education programs coupled with water restriction programs were shown to reduce water use (Corral, 1997). It should be noted that these demand management policies have primarily targeted residential customers and so little is known about their potential impact on water consumption for other sectors (Olmstead, 2014). In fact, the relationships between sectors have created conflicts, particularly in the high presence of the agricultural sector as a major water consumer in many countries. Only in severe drought episodes, large volumes of irrigation water are reallocated for human consumption (Vargas-Amelin and Pindado, 2014), although significant empirical evidence that the availability of irrigation provides a buffer against the economic risk from agricultural productivity losses associated with periodic drought (Hansen et al., 2011). It should be noted that water reallocation would require a broad infrastructural network to store and redirect water resource, providing security and also cushioning during long periods of drought. In fact, Jordan Ministry of Water and Irrigation has developed its own water reallocation policy that prioritizes water uses by different sector and has a clear plan to reduce fresh water use for irrigation purposes, while substituting irrigation needs with non-conventional water resources particularly reclaimed water. Similarly, examples can be shown from many other water scarce countries, which successfully manage their water resources. In cases of desalination and reuse, the energy and infrastructure development costs are considerable, and the potential environmental impacts should be evaluated. However, these additional resources, readily available in places can become a guarantee for supply as well as significant release of pressure on heavily exploited river flows and ground water aquifers (Vargas-Amelin and Pindado, 2014). In any case, and given the ubiquity of these water conservation policies, understanding the forms that such policies are likely to take under increased scarcity or hydrological variability is important, particularly since they have a significant cost-effectiveness disadvantage relative to increasing water prices to reduce demand (Mansur and Olmstead, 2012).

Given the complexity of the institutional layout demanded for water to achieve adaptation to climate change, practical steps were reported by several researchers and can be divided into several levels as part of an overall strategy to deal with uncertainties of climate change. The first level can make use of the so-called ‘‘no regrets’’ actions -actions that address climate change at no cost or even to the benefit of achieving other development priorities (Pielke, 2005)- that is efficiently use scarce resources to achieve multiple goals (Aylett, 2015). The second level is an intra-agency strategy – one that any agency, such as the Ministry of Water and Irrigation can initiate as part of their own set of discretionary actions, within the authorities they possess. The third level might be science coordination initiatives that would address the issue of a new family of hydrologic techniques for risk, reliability, and uncertainty analysis that could be used to model emerging aspects of climate uncertainty. This would include the development of probability distributions, which are compatible with the uncertainties of climate change and give more weight to the uncertainties of hydrologic extremes. This coordination was already underway (Brekke et al., 2009). Finally, the fourth level of engagement would be policy driven, and deal with changing the basic decision rules and evaluation procedures and criteria – such as methods for determining expected annual damages and associated optimized decision rules such as ‘‘maximize net benefits’’ or ‘‘minimize risk cost’’- that need to be revised for compatibility with the nature of risks and uncertainties posed by climate change (Stakhiv, 2011).

Finally, the ideal environment for successful, cost- effective adaptation is characterized by water management policies and institutions that are resilient and robust to uncertainty (Olmstead, 2014). Reported adaptive institutional responses could involve, in addition to legal changes to water rights regimes and water pricing, price structure changes; implementation or expansion of water banking; leasing and marketing; and changes in investment in and operation of water infrastructure including dams, reservoirs and conveyance infrastructure (Loomis et al., 2003). Moreover, negotiated ad-hoc water transfers might be an additional adaptive response. In fact, in the last decade, two trends clearly attached to counter political choices have been consolidated regarding water transfer: an uncompromising defense of water transfers from the 'surplus' basins to the 'deficit' ones, and an opposite trend that rejected transfers and focused instead on desalination and other measures that promoted the use of non-conventional resources (Vargas-Amelin and Pindado, 2014). Maladaptive responses to climate change in the water sector could include local, regional, or national "grabs" for water from shared surface- and groundwater resources to which property rights are poorly defined, as well as water pollution export to downstream jurisdictions (Olmstead, 2014). Empirical analyses of water pollution spillovers in trans-boundary settings have found that countries, and even states and counties, free- ride in water quality. Pollution levels are higher near international borders (Bernauer and Kuhn, 2010; Sigman, 2002) as well as near subnational borders within countries (Lipscomb and Mobarak, 2008). A recent study of global trans-boundary river basins identifies those "at risk" due to the combination of: (1) expected future increases in hydrological variability due to climate change; and (2) weakness (or absence) of treaties and other institutions to manage water allocation (DeStefano et al., 2010). Economic theory would suggest that if resources dwindle or become less predictable over time, and they are essentially open access, the incentive to over-exploit them would increase, rather than decrease (Olmstead, 2014).

### 3.3.3 Adaptation of water and sanitation infrastructures to climate change

#### 3.3.3.1 Adaptation of water infrastructures to climate change

It is unfortunate to mention that many critical municipal agencies – including those responsible for water, wastewater, health, and building codes – remain on the margins of urban adaptation efforts (Aylett, 2015). While the international community is promoting the highly uncertain climate change projections of the IPCC and devising numerous methods for regional vulnerability assessments (Kundzewicz and Stakhiv, 2010), they are not simultaneously promoting a framework of planning and design methods for a new generation of more robust, reliable, and resilient water resources infrastructure that would more effectively deal with those highly uncertain increased risks. Instead, there is a persistent focus on what is termed the ''soft path'' to climate adaptation (e.g., Gleick, 2002), which advocates that economic growth and development can be decoupled from water resources development, emphasizing such generic strategies as water conservation, water use efficiencies in agriculture, and ''learning to live with floods and droughts" (Stahkiv, 2011). For most developing countries, demand management (the ''soft path'') is a necessary but insufficient condition for growth, development, and adaptation to climate change (Stahkiv, 2011). In fact, the suite of decision rules and evaluation principles used for investment justification has to be strengthened. They need to be aligned to be more compatible with the implications of a highly uncertain future climate trajectory, so that the hydrologic effects of that uncertainty are correctly reflected in the design of water infrastructure (Stahkiv, 2011). The following essential five categories to adapt to climate variability and change have to be considered by water managers and water managing strategies:

1. Planning new investments, or for capacity expansion (reservoirs, irrigation systems, levees, water supply, wastewater treatment)
2. Operation, monitoring, and regulation of existing systems to accommodate new uses or conditions (e.g., ecology, climate change, population growth)
3. Maintenance and major rehabilitation of existing systems (e.g., dams, irrigation systems, canals, pumps, etc.)
4. Modifications in processes and demands (water conservation, pricing, regulation, legislation) for existing systems and water users
5. Introducing new efficient technologies (desalting, biotechnology, drip irrigation, wastewater reuse, recycling, solar energy)

The magnitude and direction of climate adaptation through water infrastructure investments and changes in infrastructure operation, are critical, because a main purpose of conventional water resources infrastructure is smoothing in the variability of water supply, either storing water in preparation for intra-annual dry seasons or periodic droughts, or maintaining sufficient storage capacity to absorb excess flows during rainy seasons or periodic floods. Another main purpose would consider climate variability and extreme weather conditions through selecting more resilient and feasible water and wastewater infrastructures within the allocated annual budget. Actually, adaptation to climate-related changes in the frequency and severity of weather extremes related to water resources (drought and flood) may be more difficult than adaptation to changes in mean temperature and precipitation (Hansen et al., 2011; Reilly, 1999). It is worth mentioning that water supply and flood management adaptation costs are among the top three categories of estimated adaptation costs for developing countries (Narain et al., 2011) partly due to high population growth. Relevant costs for municipal water infrastructure may include: construction or enhancement of flood barriers, or green infrastructure, to protect existing facilities (e.g., low-lying water or wastewater treatment plants); creation or enhancement of infrastructure for natural or artificial groundwater recharge and storage; increased reservoir storage capacity (raising dams, removing sediment from reservoirs, lowering water intakes); and increased resilience of wastewater infrastructures (California Department of Water Resources, 2008; European Environ- ment Agency, 2007; U.S. Environmental Protection Agency, 2012). The most significant empirical work to date on the likely extent and cost of such measures in industrialized countries develops engineering cost estimates of adaptive infrastructure investments, and then considers how much these costs could be reduced if water prices increase to reflect growing scarcity, reducing demand and thus reducing the magnitude of needed infrastructure investments (Hughes et al., 2010).

In any case, one should note that the extremes and changes we are experiencing are still within the ‘‘norms’’ of natural historical climate variability – albeit based on relatively short, century-long historical records. The existing water resources infrastructure was designed to accommodate such variability. When discussing practical decision-making methods for adaptation, it should be noted that there have been very few failures of water management infrastructures (where the infrastructure failed before its design capacity was exceeded). In the past, standard engineering practices accounted for those structural failure uncertainties by explicitly designing project redundancy for numerous features. Hence, ''levee freeboard'' was added to account for a ''standard project flood,'' which was calculated to accommodate the uncertainties associated with hydrologic variability that is inherent in a relatively short hydrologic record. One could do away with these ''safety factors,'' which compensated for a lack of information about climate variability and deals with the unknowns, if one knew more about and could better predict future climate patterns. Unfortunately, the current generation of General Circulation Models (GCMs) cannot provide an adequate foundation for the design of hydraulic infrastructure such as dams, irrigation systems, levees, and culverts (Dessai and van der Sluijs, 2007; Dessai et al., 2009). Hence, there must be a practical fallback position that planners and designers can count on, in this interim period, as the water profession awaits improvements in GCM forecasting skill. These improvements, however, are not expected to materialize in the next two decades (WUCA, 2009; Stahkiv, 2011). Hence, in any given region or location, planners and designers have to determine a broad set of related planning (appropriate scale / size of a project that maximizes public services) and hydraulic design (structural safety) issues that are always dependent on the frequencies of hydrologic and precipitation phenomena. In either case, water resources management is essentially bounded by how the extremes – floods and droughts – are defined and characterized, along with a diverse array of methods, evaluation procedures, and standards for reducing risks to society.

It should be recognized that water management systems are not designed to deliver services or protect against the full range of expected extreme events under what is understood to be contemporary climate variability. They are designed to minimize the combination of risks and costs of a wide range of hazards to society, while maximizing benefits. This benefit-risk-cost balance is constantly being adjusted by societies – either as new climate and hydrologic information comes in, or new urban and land use patterns create increased exposure to a larger set of environmental risks. That is why flood protection standards for flood and drought infrastructure reliability have evolved to a level of about a 100-year return period – they approximate that the 100 years is historically determined risk-cost optimum period for our systems. The scale or appropriate ''level of protection'' or reliability of a project is the first consideration of an analysis – focusing on a balance between enhancing public safety, maximizing economic productivity, and reducing economic damages. The second consideration is the physical integrity of the structure – that is, the safety and reliability of the structure itself, which is a correlated aspect of engineering design (Stahkiv, 2011). For example, since the destructive Mississippi River floods of 1993, there has been a movement to increase the flood protection standards of major urban areas in the floodplains to about a 500-year level of flood protection (Interagency Floodplain Management Review Committee, 1994). One can view this pragmatic response to flood risk uncertainty as increasing flood protection robustness and resiliency. However, societal decisions to change flood frequency analytical methods, or devise new norms for flood protection or benefit-cost procedures – usually go through a complex and lengthy process of approvals at all levels of government. As long as there is considerable controversy associated with the science of climate change and the utility of GCMs as the basis for analysis, governments will find it difficult to promote alternative procedures (Stahkiv, 2011).

#### 3.3.3.2 Adaptation of sanitation infrastructures to climate change

Notwithstanding that sanitation infrastructure is vulnerable to climate-related threats, the impact of climate change on sanitation and its adaptive capacity has received little attention (Howard et al., 2010). Overloading of the sewer network for instance, can cause damage to the sewer system and to the treatment facilities, leading to system failure (Sherpa et al., 2014). A study was conducted in Bangladesh in order to rank local communities' perception regarding adverse impacts of flooding in flood affected areas and results revealed that water borne diseases and contamination of water by sewage were placed third and fourth, respectively, in the priority order (Rashid et al., 2007). Decentralized sewers systems can localize the impact of flooding and might reduce the negative impacts of climate change on sanitation systems. Such sewer networks can be constructed to cover shorter distances and can be connected to decentralized treatment systems, thereby decreasing the risk of damage and controlling the spread of contaminants compared with centralized systems having long networks. Additional important gain is that intermediate storage facility in place (e.g. septic tank in free solids sewer networks) may allow households to continue using toilets even in the case of a breakdown of the sewer network and of the decentralized treatment facilities in such systems (Sherpa et al., 2014). Other precautions that might assist preventing flood water intrusion, wash out and flotation of the sewer network include structural modifications, such as anchoring sewer lines to the ground, sealing manhole slabs, and placing non-return valves. Moreover, raising the plinth of pits (in free solids sewer system) has shown to be an effective measure to withstand high flood levels. They can also be coated with cement and mud/sand to prevent erosion by water waves during floods (Morshed & Sobhan, 2010). Designing smaller and shallower pits can reduce the risk of collapse and also expose a lower volume of faeces to floods. Compacting soil around pits can likewise help protect the structure. Alternatively, pour flush toilets can be connected to a biogas reactor as the reactor dome can be made structurally resistant to flood damages. Secure and watertight lids on the dome openings or constructing the dome to have these openings above the ground can prevent floodwater intrusion (Sherpa et al., 2014).

In low water availability areas, decentralized treatment systems with simplified or solids- free sewers can be likewise more suitable (Sherpa et al., 2014). In such drought conditions or reduced water availability, there will be less water for flushing and cleaning and per capita water share would reduce gradually in future due to predicted decrease in rainfall. Therefore, the user interface in the single pit system, using a pour flush toilet, and the pour flush system with twin pits might be appropriately selected and well maintained to reduce problems like clogging. Waterless systems with alternating pits and single pit systems that use dry toilets are better options for drought conditions because there are reduced risks of groundwater contamination and the pits dry faster, facilitating easy emptying (Sherpa et al., 2014). Although such systems might be technically the most suitable and cost effective under drought conditions, public acceptance in some regions might be a barrier against proper implementation. For instance, high resistivity for waterless wastewater treatment systems was reported in Ajloun-Jordan due to social reasons. Even when considering any other technology, decentralized wastewater treatment systems faced high opposition of the community in Jordan particularly when considering site selection of the treatment plant. Rural communities in Jordan wish to have conventional sewerage system, however, a treatment plant in their neighborhood is not accepted. Therefore, it is very important that community participation, that considers the social structure and social relations in the targeted area, be ensured during the sanitation planning process when developing a sustainable sanitation alternative with higher resilience to climate change (Sherpa et., 2014). Capacity enhancement and closing the knowledge gap about sanitation systems, technologies, and climate change trends will enable households, communities, and nations to build sanitation systems that have higher resilience and that can be more easily adapted to climate change impacts (WHO, 2009). As a matter of fact, local communities have experience with and knowledge on how to cope with climatic variability and extreme weather events (UNFCCC, 2007; Adelekan, 2010; Jabeen et al., 2010) and their knowledge shall be incorporated in the process of sanitation planning.

In summary, resilience of sanitation technologies suggested in a region or in a community to different climate-related events must be defined (Charles et al., 2010). In a recent study, expert assessment was conducted to obtain opinions on the resilience of five sanitation technologies to the following six climate-related hazards: drought, decreased inter-annual precipitation, flood, super-storm flood, wind damage, and saline intrusion (Luh et al., 2017). As shown in Figure 4, drought and decreased inter-annual precipitation showed large ranges in resilience between different sanitation technologies, indicating that the selection of technology is important for drought-prone areas. Pit latrines and composting toilets are the most resilient technologies in areas with decreased water availability, as these two technologies do not require water. For floods and super storm floods, most sanitation technologies were scored similarly, except compositing toilets, which were scored as the most resilient technology for areas that experience floodwaters (Luh et al., 2017). No sanitation technology scored higher than 5.0 across all hazards, suggesting that the resilience of sanitation technologies is highly dependent on the climate-related hazard and thus a technology that is resilient to one hazard may not be resilient for another hazard. As such, careful selection and consideration of additional adaptation measures should occur prior to the selection of a sanitation technology (Luh et al., 2017).

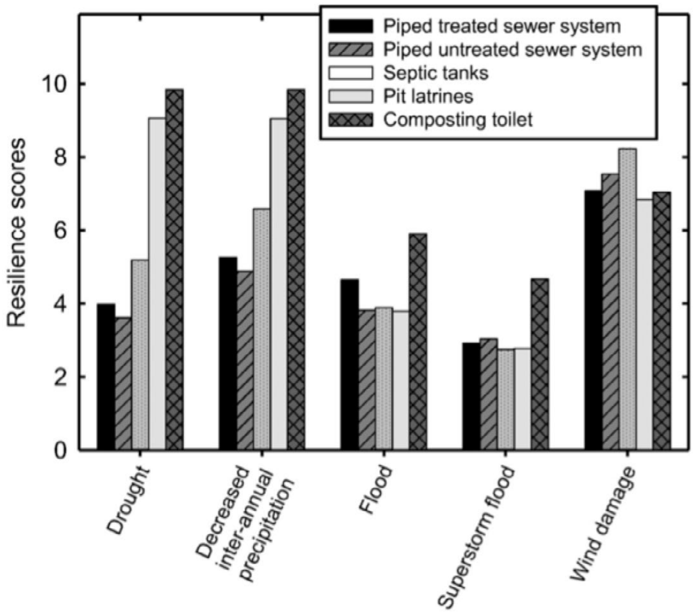


Figure 4 Resilience scores for sanitation technologies as shown by Luh et al., (2017)

Additionally, special attention should be paid to sludge management options since the collection and transportation of sludge could be challenging. Particularly in larger cities, the disposal points may be located on the outskirts (Ingallinella et al., 2002) and may not be accessible. Indoor installations might be necessary to increase resilience of sludge treatment technologies to climate change. Covered solar sludge drying beds were found to be more efficient in terms of sludge drying and protection (Salihoglu et al., 2007). Moreover, the total amount of sludge to be eventually disposed was found to be 40% less as compared with open sludge drying beds. This would additionally result in reduced handling and transportation costs. Other adaptation measures related to sludge management alternatives would be implementing technologies that have the capacity to store sludge or/and select wastewater treatment technologies that have the advantage of producing less sludge per kilogram of COD removed. As a matter of fact, up to 90% less excess sludge production was noticed under anaerobic treatment conditions as compared to aerobic treatment conditions depending on the type of treated wastewater (van Lier et al., 2008). Excess sludge can be thenceforth treated and stored in the treatment plant using sludge drying reed beds, which has the capacity to store sludge up to 10 years (Nielsen and Willoughby, 2005). Sludge drying reed beds in Jordan were found to produce sludge that is comparable to high quality compost specified by the EPA (Halalsheh et al., 2015). Reed beds' sludge had a nitrogen content of 7% and an organic content of 40% when tested after 3 years of storage (Halalsheh et al., 2015).

In conclusion, it is highly believed that the main principle governing adaptation to climate change when considering sanitation schemes is "Go Smaller", which actually reflects the decentralization concept proposed earlier by the IWRM. The second main principle in adaptation of sanitation systems to climate change is "integration", which is demanded for each sector and between sectors during projects' planning and implementation. Wastewater shall be managed at basin level and taking into account that water is a finite resource. Priority shall be given for managing all water resources without demanding water transfer between basins provided that this is a feasible option. Sanitation systems can be as small as house onsite treatment units and as big as systems covering the whole basin. Size and technology have to be selected based on the prevailing socio-economic conditions, resilience of sanitation technologies to predicted climate change and climate extremes, and the existing institutional setup. Adaptation of sanitation systems and their management has to take into account both soft and hard routes. The latter needs special attention since selection of acceptable resilient systems has to follow pre-set criteria. Moreover, many associated matters like technology's design criteria, existing guidelines, building codes, and acceptable effluent quality from wastewater treatment plants has to be carefully judged and deliberated. For instance, strict effluent standards in Jordan does not consider the size of the treatment plant and, consequently, discourage small wastewater treatment systems due to the resulting high investment costs. The soft path would also be extremely important, as wastewater management options and technologies that are most resilient to climate change necessitate intensive and extensive parallel capacity building programs.

Zooming into regional and local scales reveals additional complications that need to be carefully considered on top of climate change impacts and the consequent demanded adaptation actions. However, all challenges emphasize the inevitability of adopting the main two pillars of adapting water and wastewater systems to climate change; which are "Go smaller" and "integration" lying under the concept of integrated water resources management. When it comes to sanitation services, our communities are faced with a major challenge inherited from historical perception of wastewater management as will be discussed later. A paradigm shift is indeed due and is urgently demanded in order to meet the agreed SDC 6 targets related to sanitation services provision and protection of freshwater resources from contamination. The following sections will discuss in more details challenges facing sanitation at regional level and will present the evolution of the modern sanitation systems. The report will then discuss wastewater valorization in the region with a focus on Jordan as a case study since the country has a rich experience in integrated wastewater management and had developed policies and strategies to optimize its very limited water resources.

Table 3 Summary of significant climate change impacts

| Impacts (General) | Source |
|---|---|
| Water resources decrease (droughts) and consequent impacts on water and sanitation infrastructures | Vargas-Amlin and Pindado (2014); Thronton et al., (2014) |
| Loss of biodiversity and natural ecosystems (Temperature). Timing of climate variability may be as important as its magnitude | Vargas-Amlin and Pindado (2014); Craine et al., (2012) |
| Increased soil erosion processes (floods) | Vargas-Amlin and Pindado (2014) |
| Loss of lives and goods (wildfires, heat waves and floods) | Vargas-Amlin and Pindado (2014) |
| Severe yield reductions and reproductive failure in many crops (Increase in maximum temperature –as climate or weather-: i.e. each degree day spent above 30$^{o}$C can reduce yield by 1.7% under drought conditions. Many other examples exist | Lobell et al., (2011); other examples Mohammed and Tarpley, 2009) |
| Climate variability and extreme events can also be important to yield quality; i.e., high-temperature extremes during grain filling can affect protein content of wheat grain | Hurkman et al., (2009); other examples (Rowhani et al., 2011); Gornall et al., (2010) |
| Change in livestock productivity due to grassland reduction and variability in species and composition | (IPCC, 2007; Ericksen et al., (2012) |

# 4. Zooming in: Setting the policy framework for wastewater management

## 4.1 Regional Climate change impacts among other complications and the established responses

Climate change will threaten water and food security in MENA region due to the projected decrease in available freshwater resources for agricultural and food production (Almazroui 2012). Climate models project changes in the region's temperature, rainfall and sea level, which will have impacts on both availability and use of water resources (Sipkin 2012). Projections suggest 20% decrease in rainfall in the region over the next 50 years, while 40% reduction was predicted for some locations according to most global climate models (Meslemain 2008). The climate risk index, that classifies countries according to their exposure to climate change risks, has classified Iraq as the fifth most vulnerable country in the world in terms of decreased water, availability of food, extreme temperature conditions, and associated health problems (GEO-6, 2016). Recent droughts have aggravated water crisis in Iraq and many studies warn that the Tigris and Euphrates might dry up by 2040 (Rowling, 2014). Coupled with poor water quality, these stresses have displaced people from their livelihoods to seek for access to better drinking water (Rowling, 2014). Other counties in the region were also rated as highly vulnerable, while Yemen was rated as extremely vulnerable. Climate change impacts will lead not only to a reduction in the quantity of water resources, but also will have an impact on water quality and is expected to increase the variability and frequency of extreme events (Glass 2010).

As a matter of fact, the region is already facing major water challenges mainly due to scarcity, growing population, urbanization, and other industrial/development needs. Coupled with the fragile arid environment and its low resilience in the face of different activities, decision makers are left with major responsibilities to achieve safe and dependable water and food supplies in the future. Fresh water scarcity means greater risks for a community's ability to grow and create jobs (AFED 2014). Likewise, current regional political unrests combined with increased stress on economy have exerted serious threats to sustainable development. The situation has resulted in two major governing priority themes, namely water-energy-food, and peace-security-environment nexuses for the region (UNEP 2016). However, such priorities should not be examined in isolation from social, economic and institutional priorities, if the scope of impact of suggested solutions is called to have long and lasting effects.

On the demand side, a reduced per capita water share was observed in many countries in the region, partly as a result of the recent increase in the cross-border influx of refugees. The political unrest has recently arisen in several countries, including Iraq, Syria and Yemen, which resulted in a direct impact on water supply and sanitation services. Overexploitation of groundwater resources throughout the region was also observed and has resulted in deterioration of water quality, seawater intrusion, depletion and salinization of aquifers, and rising pumping costs. Depletion of non-renewable groundwater has been, moreover, observed with the expansion of agriculture. An increase of about 82% in the region's total blue water withdrawals for agriculture, and domestic use between 2000 and 2012 was noticed. The agricultural sector in almost all countries in the region is by far the largest consumer of water resources (Abuzeid 2014) leaving little amounts for domestic and industrial sectors. All aforementioned challenges called for urgent responses in order to reduce the gap between water supply and water demand.

As mentioned earlier, "Integrated resources management" is one of the best approaches that can help us make the best use of water resources in an era of water scarcity and climate change. The approach entails coordinating land and water management, recognizing water quantity and water quality linkages, improving techniques to manage demand and conserve water and learning through adaptive management experiments. In this regard, reallocating water towards domestic and industrial sectors -rather than agriculture- may be a critical and provocative way to adjust to water scarcity and enhance water availability. Although sector water reallocation may not have been announced as a policy in many countries, the highest priority given to the domestic water use have resulted in water reallocation from the agricultural sector (Abuzeid and Elrawady 2014). For instance, Iraq, Jordan and Qatar have witnessed significant sector water reallocation. Furthermore, Jordan has established a stand-alone reallocation policy and a substitution policy in 2016. The trend of reallocating fresh water for domestic use and allocating non-conventional water, such as treated wastewater and agricultural drainage, to agriculture is likely to be part of future water management in the whole region (Abuzeid 2014). Potential volume of non-conventional water resources in MENA region is estimated at 1.27 billion cubic meters of treated wastewater (Abuzeid and Elrawady 2014). This is on top of the other non-conventional resources such as agricultural drainage and desalinated brackish and seawater. Obviously, wastewater contributes as a renewable water resource for agricultural expansion (Abuzeid, 2014).

### 4.2 Valorization of wastewater resources in the region

Full valorization of wastewater in agriculture requires integrated planning and likewise is critical to meet countries' obligations to many Sustainable Development Goals (SDGs), particularly SDG6 on water and sanitation. Notwithstanding that some countries of the region have relatively a good match between collected and treated wastewater, there is still a high demand outside large cities and in newly urbanized areas to receive better services. Wastewater in such areas is still discharged directly into the environment and only partly used for irrigation purposes, though unsafely. In many cases, wastewater and excess irrigation water infiltrates to reach the groundwater causing chemical and microbiological contamination. For instance, elevated nitrate concentration and pathogenic contamination were both reported for some springs in north Jordan (Ajloun) due to domestic wastewater leaking from upstream nonpoint sources, principally cesspools. Contamination had resulted in closure of some drinking water springs, while it exerted additional treatment burden in some other cases. Obviously, serving rural scattered communities and rapidly expanded urban areas is crucial to protect scarce water resources and provide non-conventional water source for agricultural irrigation.

### 4.2.1 Constraints of sanitation services provision and full valorization of wastewater

Conventional sewerage network and centralized wastewater treatment options are so far the dominant sanitation paradigm. Notwithstanding that this conventional centralized wastewater management scheme is generally no option for small-scattered communities and rapidly expanded peri-urban areas, it should be noted that utilizing fresh water to flush excreta to a sewerage network is not the zenith of scientific achievements particularly in water scarce countries. This historical practice was re-initiated more than 150 years ago when very little was known about fundamentals of water physics and chemistry and when practically applied microbiology was still not discovered. Minimizing fatal diseases breakouts in the nineteenth century was the main concern, and hence, wastewater was shipped as far as possible away from communities by utilizing existing Roman sewer networks found in major European cities. In fact, bad smell was blamed by that time to be the cause of diseases as presented to the British parliament by the Chair of the Health Board on 1849. The Chair Edwin Chadwick stated that miasma was the main cause of death and the decision was made to transport all sewage outside the Victorian city of London and discharge it in the Themes River. The concept spread in other European cities and this paradigm became dominant with time resulting in complete division between citizens-consumers at one-hand and service providers at the other hand. Sanitation services became invisible and comfortable at the consumers side and associated risks disappeared from the world-life within served communities. Moreover, water availability was not a concern in most European countries and consequently, shipping faecal matter by water and through sewerage networks did not present a barrier in applying the paradigm. However, the financial burden associated with this paradigm had restricted service provision, not only at regional level, but also at global level. Currently, 60% of the global population is not provided with sanitation services (Rachel et al. 2013), while almost 80% of the collected wastewater is discharged to the environment without treatment. Apparently, wastewater shipping is not necessarily what would be done today if countries had the chance to start again. Current advanced understanding of chemistry, physics and microbiology of wastewater, which was gained during the previous century, coupled with some other factors like limited resources and energy costs encourage us to find alternatives to wastewater management. One alternative is to link sanitation management to cities' economic development (Kone, 2010) through resource conservation and recovery, which is a complete shift in the perceived sanitation paradigm since it deals with waste as a resource that has to be utilized. The new sanitation paradigm brings wastewater into the forefront again and made the invisible sanitation services visible again (van Vielt et al., 2010). Consequently, all recently proposed sanitation alternatives require high level of community (the beneficiaries) involvement. The new paradigm calls for decentralization and sustainability and proposes better management for the limited resources by taking into account different pillars of decentralized sustainable sanitation principles including stakeholders' participation, technical feasibility, economic feasibility and legal and institutional arrangements. The proposed paradigm can be best implemented in non-serviced areas, be it peri-urban, rural, or otherwise. Main differences between 'old' and 'new' paradigms are shown in Table 4.

Table 4 Paradigm shifts addressing water and sanitation infrastructure (van Vielt et al., 2010)

| Old paradigm | New paradigm |
|---|---|
| **Slow implementation** | Rapid implementation |
| **Prescriptive technologies** | Adaptive solutions |
| **High social acceptance** | Low social acceptance |
| **One water quality type fits all** | Provision of water quality based on use |
| **Low priority on energy efficiency** | High priority for energy efficiency |
| **“Siloed” health, economic, engineering** | Integrated systems approach |
| **Financing via taxes, subsidies, tariffs** | Innovative financing and business models |
| **Centralized energy provider** | Distributed energy systems |
| **Less priority on resource conservation** | High priority on resource conservation |

Notwithstanding the substantial benefits of the new paradigm, it is still beyond the required implementation level due to many reasons including the discouraging institutional environment and the lack of enforcement. Currently, opposite to central wastewater management systems, wastewater in small communities is not usually managed by the government. In general, they depend on house on-site sanitation systems, consisting mainly of cesspools, which are handled by self-organized private stakeholder upon demand. For instance, septage accumulating in the cesspools in Jordan is either transferred to wastewater treatment plants, special treatment plants, or in the absence of proper control, directly discharged –though illegally- into the environment. Moreover, and in many instances where law enforcement is weak, households do not find a necessity to discharge septage since wastewater infiltrates into the soil and cesspools would rarely become full enough to present a nuisance to the inhabitants. In other cases, household may find it more convenient to close the cesspool when it becomes full and excavate another one, particularly when land space is available.

Challenges faced by the small communities and peri-urban areas in getting access to sanitation services are manifold and can be summarized as follows:

1. Diseconomy of scale of sewer networks in less densely populated areas render conventional (and sometimes non-conventional) wastewater collection systems not feasible.
2. Innovation challenges related to the new sanitation paradigm, in which a multi-stakeholders approach has to be followed. Consequently, high level of community (the beneficiaries) involvement is required. It should be noted that social acceptance to decentralized sanitation is not generally achievable in the short-term and requires specialized and long-term customized programs oriented and designed for different case.

3. Most governmental authorities do not plan or invest in non-conventional sanitation alternatives; for instance, proper fecal sludge management options. Obviously, by investing in fecal sludge management, authorities/utilities may end up treating lesser volumes of wastewater per capita, while avoiding investment required to provide sewer connections to all (Reymond et al., 2016). However, public sector thus far lacks capacities and incentives needed for proper planning and management of fecal sludge generated by small communities. Additionally, low-tech small-scale wastewater treatment plants or on-site treatment systems are not as noticeable as large-scale systems, which make the latter more appealing to decision makers. Existing environments tend to encourage high technology and still follow the top-bottom approach that has been so far implemented in centralized wastewater treatment systems.
4. Many clusters in rural communities and peri-urban areas are informal. Such clusters are not recognized by authorities and hence, provisions of services for such neighbourhoods are unthinkable.
5. Non-conventional sustainable sanitation services would require the development of different and lenient regulations as compared to centralized sanitation services in order to allow for sustainable business models. Consequently, different institutional arrangements might be required.

Addressing the above listed challenges requires - creating an adequately enabling environment in which proper institutional arrangements and societal engagement are prioritized. Moreover, technical feasibility and economic feasibility are also main concerns. The Kingdom of Jordan presents a good example in MENA region with respect to sanitation services provision and treated wastewater use. Jordan had made impressive progress with respect to creation of an enabling environment for - conventional centralized and to lesser extent for non-conventional decentralized sanitation services. Although experience in sustainable decentralized sanitation services is still limited, Jordan has stepped forward and developed its own policy framework for decentralized sustainable sanitation that are planned for communities with less than 5000 inhabitants. Obviously, the main motivation of Jordan for the development of such policy was groundwater protection in view of the very limited freshwater resources. Moreover, achieving SDG 6 and the consequent international obligation was another main motivation behind the development of such policy. The following sections will further present and discuss Jordan's experience with respect to the enabling environment created for sanitation services provisions and use of wastewater.

#### 4.2.2 Zooming further: current Status of Wastewater management in Jordan

As many countries in the region, the water sector in Jordan is characterized by water scarcity issues exacerbated by the increasing water demand due to high population growth and economic development needs (Ministry of Water and Irrigation, 2016). Challenges related to high population growth have been recently aggravated by an influx of refugees particularly those resulted from the ongoing political unrest in the region with around 650,000 reported Syrian refugees and 750,000 Syrian residents. Furthermore, water scarcity challenges are exacerbated by climate change and the associated augmented drought conditions. In fact, the average annual per capita water share does not currently exceed 100m3, which is far below the global threshold of severe water scarcity reported at 500m3/capita/ year. Moreover, the competition among domestic, agriculture, and industrial sectors present a serious water sustainability challenge. Only 5% of land receives enough rainfall to support rain-fed cultivation. While farmers irrigate less than 10% of the total agricultural land, agricultural water requirements represented around 60% of total national water needs, which is estimated to be 700MCM (million $m^3$) while at the same time, agricultural sector contributed only 3-4% to GDP in 2013 (Ministry of Water and Irrigation, 2016). Some measures have been applied for rational use of irrigation water, for instance, drip irrigation technologies; however, Jordan's system of subsidies influences the use of irrigation water, which necessitates strict rationing to allocate the remaining water resources. Appropriate water pricing can be used for optimizing cropping patterns and water distribution, which can substantially increase agricultural production and conserve water (Olmstead, 2014; Ministry of Water and Irrigation, 2016).

Notwithstanding the severe water shortage; Jordan is one of few countries in the world to have managed its freshwater resources relatively well. The country has 97% water network coverage; one of the highest coverages in the region. Moreover, Jordan is currently thriving to improve water availability by influencing water demand behavior, optimizing water transfer and allocations, reusing reclaimed water in irrigation, and providing additional fresh water source by desalination. The Government of Jordan (GOJ) has recently developed and adopted several policies in face of confronts associated with water shortage. Among the issued guiding documents, many are addressing wastewater management including substitution policy, reallocation policy, decentralized wastewater management policy, National Water Strategy 2016-2025, Wastewater master plan and climate change policy. The Ministry of Water and Irrigation (MWI) is currently developing action plans based on these policies in order to optimize management of scarce water resources.

Use of wastewater in agriculture is a well-established practice in Jordan since decades and has been identified as a priority as will be described later. The country has managed to provide 63% of its population (totaling 9 million inhabitants) with sewerage network. All collected wastewater is being treated in 31 wastewater treatment plants distributed all over the country in addition to two treatment plants serving Syrian refugees camps. Most of the treated wastewater is used mainly for agricultural production after mixing with fresh water resources. The rest of the population is served by house onsite management systems consisting mainly of cesspools. The Government's strategy and emphasis on wastewater collection and treatment is relatively comprehensive: the 31 wastewater treatment plants are expected to treat 240 MCM/year by 2025 contributing to around 16% of the total water budget. As a minimum, secondary biological treatment is applied and about 70% of the collected wastewater goes beyond and undergoes tertiary treatment.

Adaptation to climate change in Jordan locates wastewater precisely in the water cycle. Keeping in mind that **wastewater is a renewable and increasing water resource;** wastewater should be optimally utilized to enhance food security.

Although Jordan is a pioneer in using reclaimed water for agricultural crops production, the country is still facing some challenges that can be categorized into two sets. The first set of challenges is related to demanded increase in wastewater collection and treatment. This also entails the lack of (economically viable) services offered for scattered communities in rural areas and for rapidly expanding peri-urban areas. The lack of such services presents a real barrier against the full utilization of the wastewater and, perhaps more importantly, prevention of potential groundwater pollution. The unaffordable investment costs of the conventional wastewater collection systems and even infeasibility of implementation in most cases hindered the expansion of sanitation services to such communities. The only foreseen solution would be the implementation of the new paradigm that presents decentralized sustainable sanitation options as the core approach. The second set of challenges is related to the capacity attributes of the new paradigm. Lack of socio-cultural acceptance, absence of legal framework and related institutional arrangements are among the main associated challenges. Another challenge that is linked indirectly to the limited valorization of wastewater in rural communities and peri- urban areas is the limited science-policy interface. Any new wastewater-related innovative technology generally takes long time before being practically adopted. Demonstration projects as well as high level of communication and coordination are required to boost the application of such new concepts.

Increasing sanitation coverage is expensive, and the shift in water sector expenditures from water supply to sanitation in Jordan in the period 2011–2013 was a significant step towards increasing coverage (Ministry of Water and Irrigation, 2016). The Wastewater Master Plan published through the ISSP (2014) provided a snapshot of the sanitation and wastewater treatment in Jordan and presented the investments needed for wastewater collection. The following sections present Jordan experience in terms of wastewater management practices and existing polices and what might be recommended for further development of the sector.

#### 4.2.3 Wastewater Management Policies, Laws and institutional arrangements in Jordan

Prior to addressing wastewater management laws, policies, and reuse standards, it would be helpful to present the main governmental institutions that have to deal with wastewater management in Jordan. The governmental entities which are directly or indirectly involved in the field of wastewater management and reuse are as follows (ACWUA, 2011):

- The Ministry of Water and Irrigation (MWI)
- The Water Authority of Jordan (WAJ) and the Jordan Valley Authority (JVA) which are incorporated within the MWI
- The Ministry of Environment (MoE)
- The Ministry of Health (MoH)
- The Ministry of Agriculture (MoA)
- Jordan Standards and Metrology Organization (JSMO)
- Jordan Food and Drug Administration (JFDA)
- Ministry of Municipal Affairs (MMA)

Summaries of the current related policies, strategies, standards and plans are presented in annex 1. However, the following subsections discuss the main related regulatory frames of wastewater management in Jordan in addition to their evolution.

#### 4.2.3.1 Polices Related to Wastewater Management and Use

Jordan adopted its first official wastewater use policy in 1978 (Haddadin and Shteiwi, 2006). Wherein, wastewater was to be collected from the municipal sector and treated in wastewater treatment plants (WWTPs) to an acceptable degree. Reclaimed water then flows to King Talal Dam where it would be diluted with freshwater and the mixed water would progress from the dam to the Jordan Valley to be used for irrigation (Ghneim, 2010).

In 1998, a new policy called the 'Wastewater Management Policy' was approved by the Cabinet (Ghneim, 2010). This policy had been the official governmental policy dealing with wastewater management and reuse between 1998 and 2008. Many important affirmations (Nazzal, et al., 2000) were stated in that policy such as:

1. Wastewater shall be considered as a part of the Jordanian water budget.
2. The major towns and cities in Jordan should have adequate systems for wastewater collection and treatment in order to protect public health and the environment.
3. The priority of use should be assigned to agricultural irrigation.
4. The quality of the treated effluent should be monitored, and the users must be alerted to any emergency which causes deterioration in the effluent quality so that they do not use the water unless remedial actions are taken.
5. Crops to be irrigated with reclaimed water or a mixture of reclaimed water and freshwater shall be chosen to accommodate the irrigation water, type of the soil and its chemistry, and reuse economics.
6. Crops irrigated with reclaimed water or mixed water should be monitored.
7. Sludge that results from wastewater treatment processes would be processed so that it could be used as a soil conditioner and a fertilizer. Care shall be practiced in order to comply with the regulations concerning the protection of public health and the environment.
8. Utilization of reclaimed and recycled water for industrial purposes shall be promoted.

Jordan's Water Strategy for 2008- 2022 which was titled "Water for Life" (MWI, 2009) dedicated a separate chapter to wastewater. Several goals were set in this strategy for wastewater, including:

1. Public health and environment shall be protected from all pollutants especially in the peripheries of WWTPs;
2. Treated wastewater shall comply with national standards and monitored in a periodic manner; and
3. The operation of all WWTPs shall be in accordance with international standards and manpower shall be trained in a way that ensures adequate operation.

Approaches were specified in the strategy in order to achieve the goals related to wastewater by the year 2022. Some of the key approaches are listed below:

1. An environmental impact assessment for each sanitation project shall be done. Any project of this sort shall not be executed unless it has been ascertained that there will be no negative environmental impacts as a result of its execution.
2. The process of wastewater treatment will be directed to the production of water that is appropriate for reuse in irrigation according to the WHO (1989) and Food and Agriculture Organization (FAO) Guidelines as a minimum. The use of treated wastewater for other purposes shall be subject to appropriate specifications.
3. Regular monitoring of treated wastewater quality will be performed at each WWTP.
4. Farmers will be encouraged to use modern and efficient irrigation technologies. Proper procedures shall be taken to protect the health of farm workers and prevent the contamination of crops with treated wastewater.
5. Public awareness about the danger of exposure to untreated wastewater and the significant value of treated wastewater for different end uses will be raised using different methods.
6. Public and farmers awareness programs will be designed and executed to encourage the use of treated wastewater and provide information about irrigation methods and produce handling. Such programs will be focused on ways to protect the farmers' health and the surrounding environment.

A recent water strategy (2016-2025) was approved by the Cabinet and focuses on wastewater treatment and use as a component within integrated water resources management. Jordan will gradually substitute freshwater use in irrigation with wastewater wherever feasible. Water and wastewater pricing will be reconsidered according to water allocation models. This is of utmost importance if right massages have to be conveyed regarding scarcity of water resources. Moreover, centralized and decentralized wastewater treatment and reuse will be improved with special focus on centralized systems to assist irrigation water provision for large agricultural projects. The strategy also does not encourage wastewater collection systems for communities with population not exceeding 5000 inhabitants. Apparently, such communities can be served with other sustainable wastewater management and in accordance with Decentralized Wastewater Management policy published on 2016.

The reallocation policy was issued in 2016 and is based on the fact that water resources are limited and accordingly, priority is to be given for domestic water uses while other economic sectors will be prioritized based on their contribution to the GDP. The main aim is to redistribute water flexibly between sectors and governorates by introducing both conveyance systems for water and wastewater. A conveyance system for treated wastewater to the Jordan valley intends to maximize the use of treated wastewater for irrigation and free fresh water for domestic uses. The policy states clearly the following:

- Wastewater shall be treated and fully utilized for industrial, agricultural, cooling and other uses except for drinking purposes. This means that reclaimed water shall be used as much as possible in order to save fresh water for domestic uses.
- The quality of treated wastewater from all municipal and industrial wastewater treatment plants shall meet national standards and shall be monitored regularly.
- Wastewater standards shall be revised and amended to meet direct and indirect water reuse for the production of high value crops in cooperation with all stakeholders.
- Fresh water allocated for irrigation purposes shall be reduced and replaced by treated wastewater. Thus, irrigated agriculture can be expanded only where treated wastewater is available.
- The role of private sector shall be enhanced and expanded with regard to treated wastewater use.

The water substitution policy issued in 2016 details the intention of the government of Jordan to use reclaimed water in irrigation and other economic activities. It calls for expanding the collection and treatment of wastewater to be used for economic development and encourages both centralized and decentralized wastewater management. The policy clearly states, among others, the following:

- MWI targets augmentation of treated wastewater to amount for 240MCM by the year 2025 through developing new facilities.
- Areas irrigated with groundwater in the highlands shall be substituted with either treated wastewater or surface water. A water users association shall be established in the highlands with the aim of monitoring groundwater and treated wastewater use with the possibility of blending.
- A robust mechanism to price treated wastewater that takes into consideration fairness, cost recovery and economic activities support shall be explored, and consensus has to be obtained. A dynamic and sustainable economic development plan has to be developed for efficient use of wastewater.
- Farmers shall be encouraged to choose cropping patterns that result in highest revenues and best irrigation practices. This point has to be coordinated with the MOA and Water Users Associations.
- A national plan shall be developed for operation and maintenance of wastewater treatment plants taking into account private sector participation. Moreover, private sector and community-based organizations as well as non-governmental organizations shall be encouraged to participate in reuse plans and reuse processes.

The climate change policy issued in 2016 clearly states that the water sector will be the most impacted sector and Jordan's resilience to climate change shall be strengthened based on IWRM principles. Climate change policy builds on, among others, substitution policy 2016, water strategy 2016 and reallocation policy 2016. Climate change adaptation measures in the water sector embraced both soft and hard solutions as shown in Figure 5. Wastewater management was explicitly stated in both hard and soft solutions proposed for adaptation to climate change.

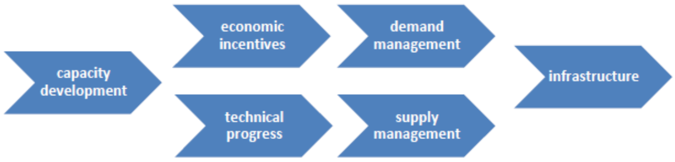


Figure 5 Continuum of soft and hard solutions in the water sector for adaptation to climate change (adopted from climate change policy, 2016)

The policy calls for coordination and integration with other sectors specifically with the Ministry of Environment, Ministry of Agriculture, Ministry of Energy and Mineral Resources, Ministry of planning and International Cooperation, and the Ministry of Municipal Affairs.

Finally, the decentralized wastewater management policy which was originally developed with the aim of groundwater protection from non-point contamination sources like cesspits, was issued in 2016. Augmentation of water resources was another main aim in view of the fact that wastewater is an increasing water resource. The policy document estimated an additional reclaimed water amount of 64 MCM per year coming from decentralized sanitation services. It was also estimated that agricultural benefits would be around 679 JOD per dunum for greenhouse and 173 JOD per dunum for fruit trees. Additional benefits were calculated from savings made by utilizing nutrients in reclaimed water and substituting fertilizers. These savings were expected to amount for 1000 to 3000 JOD per year (Decentralized wastewater management policy, 2016). Moreover, avoided annual costs of cesspits cleaning were calculated to be 20,039 JOD per 500 PE. The policy also recommends deciding on the most cost-effective wastewater management solutions using "Assessment of Local Lowest-Cost Wastewater Solutions" (ALLOWS) decision-support tool that was developed for the MWI.

The policy emphasized the following:

- Communities' participation has to be strengthened particularly during the planning phase. Capacity building at different levels is indispensable for successful decentralized wastewater management.
- Legal considerations include revisiting both standards for effluent quality of decentralized wastewater treatment plants and the conditions requested for environmental impact assessments of decentralized wastewater projects. Standards must take into consideration a balanced judgment of implementing cost-effective treatment systems without jeopardizing human health and environmental issues. The policy had drafted standards for effluent qualities from wastewater treatment plants with design flow equivalent ranges of 50-500 PE and 501-5000 PE. Conditions for the required environmental impact assessments were also grouped according to the size of served community.
- Provision of funds that will enable national and local authorities and communities to conduct wastewater projects is vital.
- The role of private sector in decentralized wastewater management was introduced through the introduction of different operation and maintenance services contract options.

A recent Water Management Initiative (WMI) project that is funded by USAID aims at establishing action plans for all recent developed policies. It is expected that action plans will be ready through the year 2018. Moreover, there is a tendency to merge some implementation plans together given that there is much intersections between policies. For instance, water reallocation policy intersects with water substitution policy and decentralized wastewater management policy. Apparently, integrating these polices and establishing one action plan would facilitate implementation and follow up.

#### 4.2.3.2 Laws Related to Wastewater Management and Use

The Municipality Law No. 29/1955, which was introduced in 1955, was the first law related to wastewater management in Jordan (Ghneim, 2010). Under this law, the governmental authorities of Amman, the capital of Jordan, and other municipalities were made responsible for construction, operation, and management of sewers (Ghneim 2010; ACWUA 2011). The recent municipality law No.41/2015 states that the municipality council has the responsibility of preparing programs and following up their implementation to achieve sustainable development with the participation of local communities, and managing all local facilities, services and projects entrusted to them through their employees or in partnership with other municipalities or any other competent authority or through the establishment of municipal owned companies either alone or in cooperation with the private sector and local community institutions. The prior consent of the minister is requested. Moreover, the municipality council shall coordinate with the concerned authorities to establish sewerage networks and set up, manage and control water cycles. The Buildings Rural and Urban Planning Law No. 79/1966 was adopted by the government of Jordan in 1966 (Nazzal, et al, 2000). This law enabled governmental agencies to regulate the disposition, collection, and discharge of wastewater which might cause inconvenience or damage (Nazzal, et al., 2000).

The Public Health Law No.27/2008 article 51 provides a public health framework for the control of wastewater. According to this law, the MoH was granted the authority to regulate and monitor the quality of the treated wastewater. The Jordan valley Authority (JVA) law No. 3/2001 assigns planning and implementing infrastructure projects in the JV to the authority. Thus, JVA presided over the construction and management of wastewater systems in JV.

The Decentralization law No 49/2015 article 3A assigned the Ministry of interior affairs to take the necessary measures to maintain public health, safety and environment. The law assigned the ministry the formation of oversight and inspection committees and the authority of temporary closure of shops, facilities and sites infringing and custody of assets until the referral of violations to the competent court. The Water Authority of Jordan (WAJ) was founded in 1983 according to the temporary Law No.34/1983. WAJ responsibilities and duties were later defined by the Water Authority Law No.18/1988, which stated that WAJ is in charge of implementing policies related to the provision of domestic and municipal water and wastewater disposal services. Its responsibilities include the design, construction, and operation of these services, as well as supervising and regulating the construction of public and private wells, licensing well-drilling rigs and drillers, and issuing permits to engineers and licensed professionals to perform water and wastewater-related activities (ISSP, 2012 and ACUWA, 2011). The WAJ law was amended in 2001. Article 28 was introduced to allow for private sector participation in water and wastewater service delivery through the assignment of any of WAJ's duties or projects to any other body from the public or private sector or to a company owned totally or partially by WAJ. This amendment enabled WAJ to corporatize utilities and enter into build-operate-transfer (BOT) contract arrangements and other private-sector participation (PSP) options (ISSP, 2012).

The year 1988 also witnessed issuing the Jordan Valley Development Law No. 19/1988, which was replaced by law No. 3/ 2001. Article 38 of law No. 3/2011 states that it is not permitted to contaminate the Jordan Valley water or cause its contamination by introducing any material from any source to the valley. The law generally mandated JVA to undertake all works related to the development, utilization, protection and conservation of the water resources in the Jordan Valley. JVA's other responsibilities include (ISSP, 2012):

1. Raising the efficiency of agricultural water use;
2. Studying, designing, implementing, operating and maintaining irrigation projects, all major dams and water harvesting structures; and
3. Defending Jordan's rights to trans-boundary waters.

In 1992, the Ministry of Water and Irrigation (MWI) was formed according to the by-law No. 54/1992 so as to merge water resources management in Jordan under one organization (Nazzal, et al., 2000). The regulation of wastewater treatment and reuse was amidst the duties of the MWI (Nazzal, et al., 2000).

In 1996, the Ministry of Health (MoH) discerned that water flowing in the Zarqa River from Al-Soukhneh Bridge area to King Talal Dam was polluted with treated wastewater discharged from As Samra WWTP and suspected that vegetables irrigated with this water could also be contaminated. It was also discerned to the MoH that these vegetables can be harmful to the health of those who consume it. Consequently, these vegetables became a health hazard according to the definition stated in the Public Health Law which required their destruction and taking the necessary procedures to prevent their transport to locations where they might be consumed. Consequently, the Minister of Health approved the destruction of all vegetables irrigated with water flowing in the Zarqa River within the aforementioned limits and also prohibited the use of Zarqa River water in any further irrigation of all types of vegetables until further notice. Based on this decision, use of the Zarqa River Water was limited to the irrigation of fodders, field crops, and trees on the condition of ceasing irrigation two weeks prior to the harvest.

In 2002, the Agriculture Law No.44/2002 was issued and later replaced by Law No. 13/2015. According to article 3A of the recent law, the Ministry of Agriculture (MoA) has the responsibility of organizing and developing the agricultural sector in cooperation with the relevant authorities- whenever such cooperation is called for. The target is to achieve several objectives such as the sustainability of utilizing natural agricultural resources without damaging the environment, and consequently, the provision of protected environment, livestock, and plants. Article 3B of the same law states that the MoA is to accomplish the objectives of offering basic agricultural services in areas where the private sector either does not provide such services or provides them with a lack of competency and efficiency. Such services include performing laboratory analyses in domains related to agricultural production. Studies, research, and observations related to soil salinity are among the activities related to this law.

Article 15C of the Agriculture Law No.13/2015 states that the Minister of Agriculture issues the regulations which specify the conditions according to which treated wastewater, saline water, and brackish water can be used in the irrigation of crops. The Minister specifies by means of these regulations the types of crops which are allowed to be irrigated by each of the aforementioned types of water. According to article 15D of this law, the use of wastewater or treated wastewater for the purpose of washing plants and agricultural products is prohibited. Anyone who violates article 15D is penalized with a fine of 500 Jordanian Dinars for each ton that has been washed with wastewater or treated wastewater and the violator is also required to destroy these plants and products.

Article 15E of the Agriculture Law No. 13/2015 states that anyone who uses wastewater or treated wastewater for the irrigation of crops in violation of the regulations issued according to paragraph C of article 15 is penalized with a fine of 300 Jordanian dinars for each Donum (=1000m2) or part of it that was irrigated, and the violator is required to remove the planted crops and destroy them under the supervision of the MoA. In the event that the violator refuses or delays the removal and destruction of crops, the administrative governor has to order the destruction of crops on the expense of the violator and under the supervision of the MoA.

In 2006, the Environment Protection Law No.52/2006 was issued. Article 4 of this law states that in order to achieve the objectives of environment protection and improvement of its various elements in a sustainable manner, the Ministry of Environment (MoE) in cooperation and coordination with the relevant authorities handles several tasks such as:

1. Monitoring, measurement, and follow up of the elements and components of the environment through specific centers accredited and certified by the MoE according to the adopted standards.
2. Issuance of the necessary environmental regulations for the protection of the environment and its elements, the conditions according to which agricultural projects can be established and related services which must be abided by and included in the prior conditions to issue or renew permits for these projects according to the stated legal standards.

In 2008, the Public Health Law No. 47/2008 was issued. Article 18B of this law states that in the event of a disease outbreak or the occurrence of infections with this disease, the MoH has to take the necessary measures to prevent spreading of the disease such as monitoring public and private water resources, planted crops, and foodstuffs or other sources that may form possible means of carrying the infection. It is specified in article 21A of the same law that in order to prevent the outbreak of a disease which may result from wastewater, senior staff members from the MoH have the right to commission the authorities responsible of sanitation to take the necessary procedures to protect the public health during the time period specified by the former.

Article 51A of the Public Health Law No. 47/2008 states that the MoH, in coordination with the relevant authorities, handles the monitoring of wastewater, sewer networks, interior plumbing, and WWTPs according to its own legislations to ensure their compliance with health conditions. The MoH also has the responsibility of taking the appropriate procedures to prevent any damage to public health. Article 51B of the Public Health Law No.47/2008 states that if the MoH discerned that wastewater, sewer networks, plumbing, or WWTPs pose or may pose a threat to public health, then the ministry has to take all the necessary procedures to prevent the occurrence of the anticipated health risk.

In 2008, the Food and Drug Administration Law No.41/2008 was issued. According to article 5 of this law, the Jordan Food and Drug Administration (JFDA) handles the task of monitoring the quality and validity of food in accordance with the adopted technical rules and legislations.

#### 4.2.3.3 Standards Related to Wastewater Management and Use

Water quality laws, treated wastewater regulations, standards for treated wastewater discharge into streams and water bodies, and standards for reclaimed water use in irrigation that are currently enforced in Jordan, have been drafted based on the principles and regulations set by the WHO or on the stricter principles established by the State of California in the United States (Ulimat, 2012). The national organization in charge of issuing such standards in Jordan is the Jordan Institute for Standards and Metrology (JSMO).

The reuse of wastewater for agricultural irrigation in Jordan was initially carried out according to the Health Guidelines for the Use of Wastewater in Agriculture and Aquaculture established by the WHO in 1989 (Ghneim, 2010). The use of the 1989 WHO guidelines continued until the first Jordanian wastewater use standards were adopted in 1995. The Jordanian Standards JS 893/1995 was established by the WAJ and was approved by a technical committee for water and wastewater at JSMO (ACWUA, 2011). The direct use of reclaimed water for irrigation of vegetable crops eaten raw such as cucumber, tomato, and lettuce were forbidden under the Jordanian Standards JS 893/1995 (McCornick, et al., 2004). Sprinkler irrigation as well as the irrigation of crops during a period of 14 days prior to harvest were also forbidden (McCornick, et al., 2004). Standards for the discharge of reclaimed water into wadis (streams) and water bodies, aquaculture, and groundwater recharge were addressed in the Jordanian Standards JS 893/1995 as well.

The Jordanian Standards JS 893/1995 were replaced by the Reclaimed Domestic Wastewater Standards JS 893/2002 (ACWUA, 2011). The reasons for why the Jordanian Standards JS 893/1995 were amended and revised in 2002 can be summarized as follows:

1. The reuse activities covered within the Jordanian Standards JS 893/1995 needed to be expanded (ACWUA, 2011).
2. Jordanian vegetables and fruits export market was hampered by the new tough regulations introduced by some import countries such as the Gulf Countries, which enforced prohibition on the process of importation (McCornick, et al., 2004). Consequently, it became necessary to develop new standards which would ensure enhanced safety to both farmers and consumers (Ghneim, 2010).

The Jordanian Standards JS 893/2002 was divided into two main groups which were the standards and guidelines. The Jordanian Standards JS 893/2002 also addressed groundwater recharge and the discharge of reclaimed water into streams, wadis, and areas of water storage. There were three categories of irrigation in the Jordanian Standards JS 893/2002. These categories were termed A, B, and C. Category A stood for the irrigation of vegetables eaten cooked, parking areas, sides of roads inside cities, and playgrounds. Category B referred to the irrigation of plenteous trees, green areas, and roadsides outside the cities. Category C referred to the irrigation of industrial crops, field crops, and forestry. Similar to the Jordanian Standards JS 983/1995, the direct use of wastewater in irrigation for vegetables eaten raw was also prohibited in the JS 893/2002 (MEDAWARE, 2005). Use of wastewater through sprinkler irrigation was only allowed for golf courses and limited to nighttime. In that case, the sprinklers must not be accessible for use throughout the day and they must be of the movable type (MEDAWARE, 2005). Same as in JS 893/1995, irrigation must be ceased two weeks before the harvest when reclaimed water is used for the irrigation of fruit trees.

The current standards governing the wastewater use in Jordan were introduced in 2006 (ACWUA, 2011). The current standards - Jordanian Standards JS 893/2006, also include two main groups which are the standards group and the guidelines group. The standards group includes those standards with which the effluent produced by WWTPs must comply (Ulimat, 2012). The guidelines group, on the other hand, is only taken for guidance purposes.

The Jordanian Standards JS 893/2006 also addresses the discharge of reclaimed water into streams and water bodies, groundwater recharge, and irrigation. Similar to the JS 893/2002, there are three categories for irrigation termed A, B, and C. However, the JS 893/2006 also has an additional irrigation category which is the irrigation of cut flowers.

According to the quality monitoring component in the Jordanian Standards JS 893/2006, the entity which owns the WWTP and the regulatory entity must make sure that the quality of the treated effluent conforms to the standards corresponding to its end use (Ulimat, 2012). Laboratory tests must be performed by both the monitoring and operating entities according to the sampling frequency specified in the Jordanian Standards JS 893/2006 (Ulimat, 2012). As for the evaluation component of the Jordanian standards JS 893/2006, it is specified that if any tested value doesn't comply with the standards stated for the discharge of the treated effluent into streams and water bodies, then an extra-confirmatory sample must be collected (ACWUA, 2011). If the two samples exceed the limits allowed by the standards, then the concerned party will be informed so as to carry out correction measures as soon as possible (ACWUA, 2011). The enacted standards are currently under revision at JSMO and the new standards are expected to be issued by the end of 2019.

Recently, Jordanian standards JS 1766/2014 was issued as a guideline (non-obligatory) determining usage of irrigation water, including treated wastewater, in line with WHO guidelines (2006) and FAO guidelines. The issued guidelines deal with irrigation water in general according to its quality regardless of its source. In the presented guidelines, level of irrigation use restriction is determined by irrigation water quality, soil properties, crop sensitivity, on-farm protection measures and irrigation management. It also includes a section which can be used as a guideline for selecting crops to be irrigated with different water qualities in terms of salinity and other parameters. The salinity is a major concern in irrigation water.

In Jordan, the currently adopted program for monitoring crops irrigated with reclaimed water is based on several international standards (ACWUA, 2011). These standards define methods need to be followed for sample collection, preparation, and analysis. The most important standards are (ACWUA, 2011):

1. Standard for Sampling Fresh Fruits and Vegetables No. 1239/1999.
2. Fruits, Vegetables, and Derived Products – Decomposition of Organic Matter prior to Analysis – Wet method, Standard No. 1246/1999.
3. Fruits, Vegetables, and Derived Products – Decomposition of Organic Matter prior to Analysis – Ashing Method, Standard No. 1247/1999.

It deserves mentioning here that the monitoring program for crops irrigated with reclaimed water in the Jordan Valley is no longer implemented due to financial constraints.

#### 4.2.4. Policy Implementation and the Impact

Considerable achievements have been made in Jordan thus far with respect to implementation of developed wastewater management policies and standards. It will be indeed difficult to present progress that has been made on 2016 policies due to the fact that their implementation plans are under development, however, implementation of earlier developed wastewater policies can still be discussed. Jordan has managed to serve 64% of the population with collection and treatment systems and most of treated wastewater is being used mostly after mixing with surface water for irrigated agriculture. Most of constructed wastewater treatment plants are considered as centralized management systems except for few treatment plants for fecal sludge management. The latter receives fecal sludge discharged from cesspits in newly developed areas and in rural communities, which are not connected to sewer systems. Moreover, reuse directorate at the WAJ is responsible for managing the process of treated wastewater use in vicinities of treatment plants except As-Samra WWTP which is managed by JVA . Farmers planning to use treated wastewater have to apply at the directorate. Based on the area, reuse directorate establish an agreement with farmers and allocate a certain amount of water. The agreement is so far granted only for the cultivation of fodders and/or fruit trees. Water meters and valves are installed within the wastewater treatment plant and controlled by the WAJ staff. Treated effluent is carried by water lines to the adjacent farms and is being used directly for irrigation.

It is worth mentioning that although Jordanian regulations and standards (viz. regulations and conditions for the use of treated wastewater, brackish and saline water- issued by minister of agriculture based on agriculture law no 13/2015, article 15C and Jordanian standards 893/2006) allow irrigating vegetables eaten cooked with treated wastewater (i.e. direct use scheme for vegetables eaten cooked), WAJ has so far limited the direct use of treated wastewater to fodder crops, olive trees and forests trees. Financial returns would be significantly higher if farmers are granted licenses within the limits of the current standards to irrigate vegetables as well (Majdalawi, 2003).

#### 4.2.4.1 Challenges

A national water reuse coordination committee (NWRCC) was formed as per the cabinet letter 57/11/6826 dated 21/5/2003 under the supervision of the secretary general of the WAJ. Other members of the committee represented the Royal Court, Ministry of Environment, Ministry of Health, Ministry of agriculture, Jordan Valley Authority, National Center for Agricultural Research and Technology Transfer, Royal Scientific Society, Farmers Union, Universities and Private sector. The main task of the committee is to coordinate with the reuse directorate (previously known as wastewater reuse unit) in order to eliminate overlapping between the ministries. However, the committee was not active and hardly any improvement was noticed.

As mentioned earlier, violation of the regulations related to the reuse of treated wastewater is controlled with the destruction of the crops in question together with a fine. Nevertheless, the Jordanian standards for wastewater use are not being fully implemented. Despite the fact that there are monitoring programs put in place to ensure the compliance with the regulations in terms of the water quality and the type of irrigated crops, farmers do not always conform to these conditions.

The lack of implementation of the standards can be attributed to several challenges such as (Ghneim, 2010):

1. Certain treatment plants are currently being overloaded. Thus, the quality of the produced effluent doesn’t always conform to the Jordanian Standards JS 893/2006. Currently many of these wastewater treatment plants are under upgrading processes;
2. The Jordanian Standards for the discharge and use of treated wastewater are unnecessarily stringent. As a consequence, they are not always met;
3. The fact that there is relatively a large number of stakeholders involved such as the MoA, MWI, JVA, WAJ, MoE, and MoH may have caused an overlap of responsibilities and a lack of coordination (ACWUA, 2011) at some points. A clear coordination set up does not exist, which result in loss of resources in view of multiplication of some tasks that exist between different stakeholders;

4. Some farmers use treated wastewater discharged into streams for unrestricted irrigation prior to the process of mixing the treated effluent with freshwater in reservoirs. This irrigation practice is considered illegal and violates the Jordanian Standards JS 893/2006. Not mentioning lack of irrigation water alternative, farmers probably follow this practice due to the lack of knowledge on their behalf, or due to the fact that they do not have other water alternative;
5. The lack of financial resources can impede the rigorous monitoring intended to discover certain violations in view of the high number of small farms; and

6. The reuse of treated wastewater for irrigation is subject to competition from freshwater resources such as groundwater even though fresh water resources are scarce. This is due to the fact that the fees for using freshwater in irrigation are low and thus, farmers who happen to have access to freshwater have no incentive for using reclaimed water.

In addition to what has been discussed, there are some issues related to optimum utilization of quantity of treated wastewater rather than its quality. Firstly, lack of clear policy for crop patterns is a challenge facing optimum utilization of this water source. In general crop patterns have to be established by the MoA based on different factors. Although the MoA took some attempts in guiding farmers to establish crop patterns, it is believed that those attempts were not comprehensive enough. Marketing, for instance, was absent in the adopted approach, which resulted in losing the trust of the farmers. The farmers did not agree with the proposed cropping patterns. Secondly, existing extremely low irrigation water tariffs did not support optimum utilization of water quantity.

Several solutions could have been employed in order to enhance the implementation of wastewater polices and reuse standards. Among them, the following can be of priority:

1. Standards revision might be a necessary step. More lenient standards are recommended particularly when it comes to acceptable concentrations of nitrogen and phosphorus in the effluents of wastewater treatment plants. Moreover, acceptable microbiological contamination has to be considered in a wider frame where risk management rather than risk prevention guide reclaimed water use. Accordingly, the development of an implementation plan for the developed standards JS1766/2014 has to be considered and is further discussed in section 5 of this report.
2. Coordination plans should be established between different stakeholders. For instance, monitoring programs can be shared between different regulatory bodies. Authorities might utilize the capacities of each governmental body for partial monitoring while data from different monitoring bodies can still be compiled and shared between them in order to maximize utilization of limited financial resources. Coordinated decisions can then be made.
3. Public awareness campaigns should be intensified in order to appreciate reclaimed water value. Special training programs should be directed to farmers aiming at introducing best agricultural practices that can be

implemented to optimize water use but also quality of product and marketing of harvests.

4. Water and reclaimed water pricing shall be revised and tariffs have to reflect and send clear massages to consumers about scarcity of the utilized commodity.

With respect to treatment of collected wastewater, WAJ had made impressive steps for improving and upgrading the existing wastewater water treatment plants. Moreover, the WAJ has plans for constructing additional treatment facilities whenever is needed. Most of upgraded and new plants operate mainly by activated sludge systems that are by far considered most flexible when it comes to process operation for optimized effluent quality. The WAJ operation team has built considerable experience in such systems, which are considered by them the most preferable technology. Although the technology with its different modifications is known to be effective in producing high quality effluent, energy demand and excess sludge production are main drawbacks. For instance, and until late 2009, most of collected wastewater was treated using stabilization ponds technology, which is known to have high capacity for sludge storage and sludge stabilization, not mentioning its minimum energy demand. Sludge can be stored in the ponds for periods of 10 years and higher. During storage, sludge is stabilized and digested due to the very high sludge retention times. However, and since lower effluent quality is produced using such systems, most treatment plants utilizing stabilization ponds were converted into activated sludge systems. The resultant is indeed higher quality effluents, but also considerable amounts of sludge that has to be accordingly managed. It is estimated that 300 tons of sludge (dry basis) is produced daily from the 31 WWTPs in Jordan for the year 2016 assuming that per capita sludge production is 53 g/d and that 63% of the population are connected to treatment plants (USAID, 2014). Keeping in mind that biosolids use for agricultural production is so far prohibited by the Ministry of Agriculture (Annex I), the WAJ is currently facing challenges with sludge management. Produced sludge is either stored at the WWTPs or mixed with the influent of large treatment plants. Indeed, a pragmatic solution would be to work jointly will all relevant stakeholders in order to allow for better utilization of biosolids and improve the perception of the different stakeholders with respect to biosolids being a resource rather than a useless by product of wastewater treatment plants. This has also to encourage WAJ for better selection of wastewater treatment technologies for the unserved population or whenever expansion of the existing treatment plants is considered. Sludge production shall be an important criterion for technology selection. As a matter of fact, a combination of anaerobic technology followed by aerobic technology would always maximize effluent quality and minimize sludge production. Moreover, co-composting of sludge with food waste (when feasible) might be a good option that might support efforts in utilizing such resource.

#### 4.2.4.2 Impact

When considering the direct use of reclaimed water, most farmers apply furrow or border irrigation. This is basically due to the fact that irrigation is limited so far to fodder crops, olive trees or other fruit trees. Only farms utilizing effluent of Wadi Musa WWTP (see Table 5) apply drip irrigation systems as part of a project funded by the USAID to serve Petra City and surrounding villages (Addison, 2005).

Drip irrigation systems are more efficient but expensive compared with furrow or border irrigation systems. Additionally, drip irrigation systems have to be replaced on regular basis averaged 5 years. When farmers are only allowed for fodder and fruit trees irrigation, which does not create as much income as other cultivation products (Majdalawi, 2003), they are discouraged to invest in more efficient water systems. Accordingly, shifting to higher value crops that have better financial returns to farmers is a win-win situation that will result in applying more efficient irrigation water systems and probably better acceptance for higher water tariffs. Current water tariffs do not exceed 40fils/m3 (0.056$US/m3), which hinder water conservation in such farms, and consequently more efficient irrigation water systems are not encouraged. Other discouraging factor can be related to farmers demand to maximize their financial incomes. In fact, management of direct treated wastewater use, which takes into account maximizing the net benefits and minimizing associated risks, is possible as proposed by WHO (2006) guidelines and adapted recently by JSMO through its publication JS 1766/ 2014. This will be further elaborated in the following section.

In the Jordan Valley, farmers mainly follow indirect use via means such as drip irrigation systems with plastic covers in order to avoid excessive evaporation as shown in Figure 6. This practice positively influences the microbiological safety of the crops as well since there is no contact between irrigation water and planted crops. As described earlier, the indirect use of treated wastewater for irrigation is currently taking place mostly in the middle and southern Jordan Valley (ACWUA, 2011 and Carr, et al., 2011). The indirect use is for unrestricted irrigation (Ammary, 2007). Nevertheless, supply of fresh water to Jordan Valley Authority (JVA) is increasingly declining because of the reduced stream flow in the Yarmouk River and side wadis and reduced rainfall in the Jordan River watershed (ISSP, 2012). The types of crops which are irrigated with blended treated wastewater in the middle and southern Jordan Valley include vegetables, grapes, citrus, bananas, and certain types of stone fruits (Ammary, 2007). According to JVA and Ministry of Agriculture (2010), 212,525 Donum (1Donum = 0.1ha) of land in the Middle and Southern Jordan Valley were indirectly irrigated with reclaimed water during the year 2010. There are some violations to the reuse standards JS 893/2006 which occur alongside streams located downstream of WWTPs where farmers use the reclaimed water discharged in these streams for unrestricted crop irrigation prior to the process of blending reclaimed water with freshwater in the dam (Ghneim, 2010).

On the other hand, around 23.82% of the treated wastewater produced at treatment plants was directly used for irrigation in 2013 (WAJ, 2013). Table 5 shows details pertaining to the direct use of treated wastewater for irrigation at or near each WWTP such as the type of irrigated crops and the planted area. As seen in Table 5, the overall amount of treated effluent produced by WWTPs in the year 2012 was 118 MCM and the overall area irrigated with treated effluent at the WWTPs was 14266 Donum that same year (WAJ, 2012), which represents around 6% of the total land irrigated either directly or indirectly with treated wastewater. Table 5 also shows the number of agreements between farmers and the water authority of Jordan. These agreements specify the conditions according to which treated wastewater is directly used for irrigation near WWTPs.

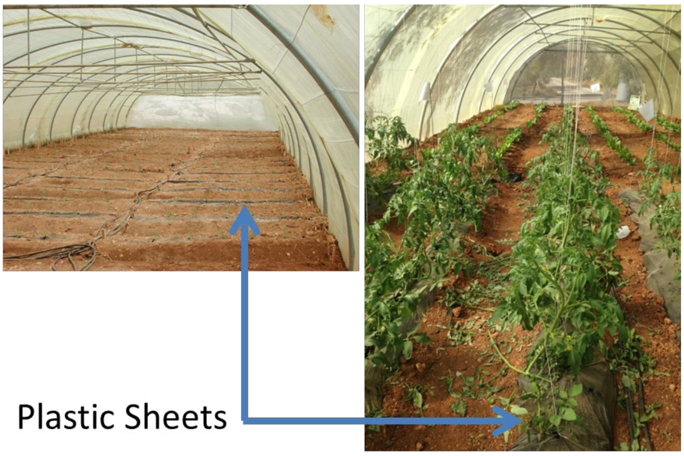


Figure 6 General irrigation system and scheme in the Jordan Valley with blended water through drip irrigation

Table 5 Use of treated effluent at or near wastewater treatment plants

| WWTP | Effluent Quantity (MCM/yr)[a] | Amount of Reused Effluent (directly and indirectly) (MCM/yr)[a] | Irrigated Area at or near WWTPs (Dunum)[a] | Type of Irrigated Crops[a] | No. of Agreements with Farmers[b] | % of Direct Reuse of Treated Wastewater[b] | Destination of Excess Effluent[a] | % of Direct and Indirect Reuse of Treated Effluent[a] |
|---|---|---|---|---|---|---|---|---|
| As Samra | 87 | 87 | 3990 | Fodder and Olive Trees | 34 | 15 | King Talal Dam | 100 |
| Al-Fuheis | 0.8 | 0.8 | 30 | Fodder | 1 | 4 | Wadi Shu'aib Dam | 100 |
| Al-Ramtha | 1.4 | 1.4 | 1302 | Fodder | 22 | 100 | - | 100 |
| Madaba | 1.8 | 1.8 | 1213 | Fodder and Olive Trees | 27 | 100 | - | 100 |
| Al-Baq'a | 4.1 | 4.1 | 437 | Nurseries and a Polo Field | 15 | 13.6 | King Talal Dam | 100 |
| Kufranja | 0.9 | 0.9 | 812 | Forest Trees | 10 | 100 | - | 100 |
| Al-Karak | 0.7 | 0.7 | 609 | Fodder and Forest Trees | 8 | 100 | - | 100 |
| Al-Mafraq | 0.6 | 0.6 | 660 | Fodder | 18 | 100 | - | 100 |
| Al-Salt | 2.2 | 2.2 | 100 | Olive and Fruit Trees | 5 | 4.4 | Wadi Shu'aib Dam | 100 |
| Ma'an | 0.8 | 0.4 | 357 | Fodder | 9 | 47 | Stream | 47 |
| Al-Ekeider | 1.0 | 0.961 | 1069 | Olive and Fruit Trees | 17 | 100 | - | 100 |
| Al-Sharee'a[c] | 0.1 | 0.1 | 181 | Olive and Fruit Trees | 16 | 100 | - | 100 |
| Wadi Al-Seer | 1.2 | 1.2 | 62 | Olive Trees | 1 | 4.3 | Al-Kafrain Dam | 100 |
| Wadi Hassan | 0.4 | 0.4 | 721 | Olive and Fruit Trees | 1 | 100 | - | 100 |
| Wadi Mousa | 0.9 | 0.9 | 1069 | Fodder and Olive Trees | 38 | 100 | - | 100 |
| Abu Nuseir | 0.9 | 0.18 | 75 | Ornamentals | 1 | 20 | Bereen Stream | 22 |

[a] Source: WAJ (2012), [b] Source: (WAJ, 2013) [c] Desalination Treatment Plant

Table 5 (Continued). Use of Treated Effluent at or near Wastewater Treatment Plants

| WWTP | Effluent Quantity (MCM/yr)[a] | Amount of Reused Effluent (directly and indirectly) (MCM/yr)[a] | Irrigated Area at or near WWTPs (Dunum)[a] | Type of Irrigated Crops[a] | No. of Agreements with Farmers[b] | % of Direct Reuse of Treated Wastewater[b] | Destination of Excess Effluent[a] | % of Direct and Indirect Reuse of Treated Effluent[a] |
|---|---|---|---|---|---|---|---|---|
| Al-Aqaba/Natural Plant | 2.0 | 2.0 | 1580 | Palm Trees, Windbreaks, and Green Areas | 4 | 100 | - | 100 |
| Al-Aqaba/Mechanical Plant | 2.6 | 2.6 | - | Green Areas [c] | 1 | 100 | - | 100 |
| Al-Tafileh | 0.5 | - | - | - | None | 0 | Ghor Fifa | 0 |
| Al-Lajoon | 0.3 | - | - | - | None | 0 | Al-Lajoon Stream | 0 |
| Wadi Al-Arab | 3.7 | - | - | - | None | 0 | Jordan River | 0 |
| Al-Talibeyeh | 0.1 | 0.1 | - | Forest Trees and Ornamentals | None | 100 | - | 100 |
| Tal Al-Mantah | 0.1 | 0 | - | Fodder | None | 0 | - | 0 |
| Al-Mi'rad | 0.3 | 0.3 | - | - | 1 | 0 | King Talal Dam | 100 |
| Central Irbid | 3.0 | - | - | - | None | 0 | Jordan River | 0 |
| Jarash | 1.2 | 1.2 | - | - | None | 0 | King Talal Dam | 100 |
| Wadi Shalala[b] | 0.8[b] | - | - | - | None[b] | 0[b] | Jordan River[b] | 0[b] |

[a] Source: WAJ (2012), [b] Source: (WAJ, 2013), [c] The effluent is also used for industrial purposes.

## 5. Final Discussion

Climate change is a fact and all global models predict a change in temperature and extreme weather conditions including increased floods and droughts events. Changes are already witnessing all over the globe and almost all countries are affected. Impacts of extreme weather events distressing one region are not necessarily limited at that region and their impacts might be noticed at other geographic locations particularly when considering impacts on agricultural commodities exports. Moreover, there is clear evidence that developing countries will be most affected by climate change as a result of their high vulnerability and low resilience in the face of extreme changes. Apparently, the water sector will be the main sector that is directly impacted by climate change, and therefore, proper planning is indispensable to accommodate expected changes. When addressing impacts on the water sector, all economic development activities including health, agriculture, and energy become a concern.

Adaptation to climate change and increased resilience of water systems had been the topic under discussion at international, regional and local scales since decades. Many concepts had evolved with IWRM as being the most developed approach. De facto, the concept calls for decentralization in which water is managed at basin level. The concept also calls for integration, be it within water sector or across different sectors. Both decentralization and integration would additionally necessitate direct consideration of the system governing water management including existing regulations, socio-economic structure, technological innovations and engineering design changes, and prevailing culture. Deep understanding of socio-economic and cultural factors that shape decision maker's perceptions of risks, willingness to act, or to prioritize actions is crucial. Improved governance is the principle means for resolving competition among multi-sectorial demands on a fixed water resources base.

Notwithstanding the complexity of adaptation to climate change in the water sector through IWRM, practical steps can still be advised with a special interest in intra-agency strategy; a one that any agency like the Ministry of Water and Irrigation can initiate as part of their own set of discretionary actions, within the authorities they possess. Adaptation to climate change in the water sector in Jordan followed mainly a soft track and to a lesser extent a hard track. Soft track consists of exchange of knowledge and experience through networks at various scales. Capacity development of the governmental sector to improve in-house capacity or expertise needed to engage with the added complexity associated with climate change is a focus of the MWI, which had published the climate change policy for a resilient water sector on 2016. Coupled with other guiding governmental documents (annex I), adaptation to climate change include maximizing use of non-conventional water resources mainly for agricultural irrigation. Expanding sanitation services for better protection of ground water and maximum reuse would imply government interest in wastewater treatment and reuse as a measure for adaptation to climate change. This very particular topic is covered through different policies and the water strategy as shown in annex I. The established policies are comprehensive and have dealt with adaptation to climate change at different levels. One of the main related policies is the decentralized sanitation policy that is specifically targeting settlements with less than 5000PE. The policy touched on different subject matters related to decentralized sanitation services and proposed different operation and maintenance business models that might be adopted for sustainable service provision. The policy also proposed new effluent standards for decentralized wastewater treatment systems depending on the size of served population. The MWI is currently developing the action plans for the policies and defining the timelines and future planned projects together with their demanded budgets.

Although Jordan is one of the few countries in MENA region who is well managing its wastewater, there is still –as it is always the case- a room for improvement. Integrated wastewater management as a component within the IWRM is highly believed to be the way forward. This would imply both maximizing reclaimed water use in agriculture as specified by the different policies in action and the JS1766/2014; and expanding sanitation services for the unserved. It is however, difficult to separate both topics and the only reason for presenting them in this form is to facilitate discussion of some related details in the following sections.

### 5.1 Treated wastewater use for agricultural production

As mentioned earlier, safe wastewater use in agriculture had been so far "guided" by the World Health Organization (WHO) guidelines (WHO 1989), which stipulated quality parameter limits for effluents of wastewater treatment plants (WWTPs). Although the guidelines tackled health risks related to pathogens existing in wastewater, end of pipe technologies were always deemed as the basis for safe water use. Explicitly, maximum permissible values were set to determine the quality of treated water that can be used for agricultural irrigation. There is a main drawback in such approach; explicitly, there is evidence for effluent contamination or regrowth of pathogens downstream of WWTPs, or in effluents stored before being reused in agricultural production. Therefore, setting strict quality parameters are not merely sufficient to guarantee safe water reuse downstream of the treatment plant. Concurrently, other quality parameters defined by the enacted standards like nutrients existing in wastewater has to be revisited. Such nutrients are important for agricultural production throughout stages of plants growth and have to be maintained in the effluent rather than removed. Since crops do not require the addition of these nutrients all over the growth period, it is highly recommended to implement treatment technologies that are flexible and would respond to such demand. This specific point will be better elucidated in the following subsection.

Above issues demanded a dramatic shift in the ways how wastewater use in agriculture should be better controlled. WHO guidelines published in 2006 was a result of such demands. A clear shift in wastewater management approach was observed in the 2006 guidelines (WHO 2006), including the need to involve different stakeholders in determining the risks and risk mitigation strategies. The guidelines addressed WWTP effluent quality in conjunction with agricultural practices aiming at safe reuse of different wastewater qualities. Figure 7 shows how WHO shifted its borderline from the downstream of treatment plant towards agricultural fields and further along the rest of the food chain. Farming practices are of utmost importance in this integrated approach; in which minimally treated wastewater was not excluded from being safely used in agriculture. It should be noted that other farming practices that may have an impact on produce is to be furthermore considered. For instance, pesticides application may result in non-communicable diseases, as it is the case for organochlorine pesticides, which are known to be carcinogenic. Such group of pesticides was shown to accumulate in soil and easily enter food chain (Batarseh and Tarawneh, 2013). Consequently, it is indispensable to consider best farming practices in combination with other practices related to treated wastewater use as presented by the WHO guidelines (2006). Another relevant example is related to produce contamination by pathogens present in unprocessed manure that is used as fertilizer. In fact, agricultural irrigation using fresh water does not mean a produce complying with imposed standards since water quality is not the only determinant of the produce quality. Accordingly, it is believed that agricultural use of wastewater should be considered in a comprehensive perspective into which water quality is one element. Other input variables are as important as water such as fertilizers quality and pesticides application.

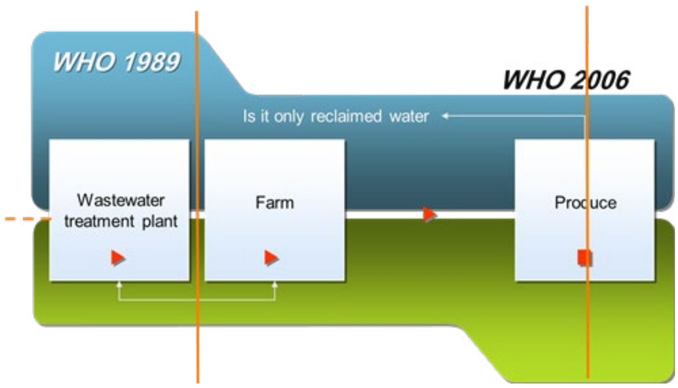


Figure 7 Paradigm shift in sanitation approach from end of pipe technology (WHO, 1989) to integrated management approach (WHO, 2006)

In response to the WHO guidelines (2006), JSMO had issued Jordanian standards JS1766/2014 that introduced such integrated approach, which presented the necessary control on irrigation water and did not exclude treated wastewater as an irrigation water source. In fact, for the specific case of Jordan with high quality WWTP's effluent, some other surface water irrigation sources have much lower quality and were not controlled by the regulator. Consequently, it was crucial to consider all irrigation water rather than focusing on the treated wastewater quality. Notwithstanding required integrity of the full system proposed by WHO guidelines (2006) and approved by the local Jordanian standards, the absence of detailed management plan limits its applicability. Obviously, management plans are expected to vary from country to country, as well as within the same country, depending on different variables. Emphasis should be given to the role of coordination between different stakeholders when developing applicable management plan, but also at implementation stage. Plans can be established for the whole sanitation chain or can be progressively developed according to existing conditions. Moreover, management plans can be designed to deal with acute conditions when raw sewage is used for agricultural production (e.g. focus on risk management of microbial hazards); while more comprehensive plan can be developed when wastewater is well treated (the case of Jordan), in which good agricultural practices may deal with additional chemical hazards.

The management plans proposed to accomplish JS1766/2014 are known as sanitation safety plans (SSPs). The SSPs prioritize risks and utilize limited resources to target highest risk allowing for progressive improvement. A manual has been developed recently to provide step-by-step guidance to assist the implementation of the WHO guidelines (2006) for the Safe Use of Wastewater, Excreta and Greywater in agriculture (WHO, 2015). Development of a framework that can enhance the understanding of the system and facilitate precise development of detailed SSPs, is considered a step prior to the Sanitation Safety Planning (SSP). The framework should provide the institutional conceptual structure needed for the SSP and serve as informative tool for relevant authorities. Following is a description of SSP and a proposal for the demanded institutional framework required for the implementation of the JS1766/2014.

### 5.1.1 Sanitation Safety Planning (SSP)

Development of SSPs is modelled after the Stockholm framework for preventive risk assessment and management. It follows almost the same approach used in the development of Water Safety Plan (WSP) (Davison et al., 2005). Similar to WSP, SSPs also comprises three main components: system analysis and design, operational monitoring and management plans as shown in Figure 8. Each of these components as well as the supporting programs needed, are briefly introduced in the following subsections.

### 5.1.2 System Analysis

System analysis consists of the three consecutive steps:

1. **System description**, which covers the whole chain (from the toilet to the farm and then to the table) and can be best represented by flow chart that carefully delineates the system;
2. **Hazard analysis** in which identification of all potential hazards (biological, chemical, physical, and radiological agents that have the potential to cause harm), their sources, possible hazardous events and an assessment of risk presented by each (Davison et al., 2005) are presented; and
3. **Control measures**, which are steps needed along the chain in order to ensure that health-based targets are met. They are actions or activities that have to be applied to minimize hazards. For instance, at the farm level, applying drip irrigation system would present a barrier to microbial hazard transfer. Alternatively, other barriers (control measures) can be applied as shown in Figure 9. Control measures and frequency of monitoring should reflect likelihood and consequences of the loss of control. In any system, there may be many hazards and potentially a large number of control measures. It is therefore important to rank the hazards in order to establish priorities (Davison et al., 2005).

### 5.1.3 Operational Monitoring

It is important to define the operational limits that lead to the safe practices. Operational limits should not necessarily mean concentration of hazard, but rather a gauge of control measure performance that can explain the objective of monitoring. Performance monitoring relies on establishing 'what', 'how', 'when' and 'who' principles (Davison et al., 2005). The objective of monitoring is to monitor the efficacy of control measures in timely manner to prevent

wastewater from being used unsafely in agriculture. A monitoring program should be established, and records of all monitoring shall be maintained and communicated among all stakeholders.

### 5.1.4 Management and Communication

When monitoring indicates a deviation from the established operational limit, there is a need for corrective action in order to restore operation and ensure safety of wastewater use in agriculture. Clear descriptions of actions to be taken during such situation should be provided. Moreover, appropriate documentation and reporting has to be established.

### 5.1.5 Supporting Programs

Supporting programs comprise all activities that ensure process control such as standard operating procedures, hygienic practices, and raising awareness among the communities. Accordingly, supporting programs are not directly part of SSP; however, they are extremely important in maintaining the operating environment and ensuring proper control.

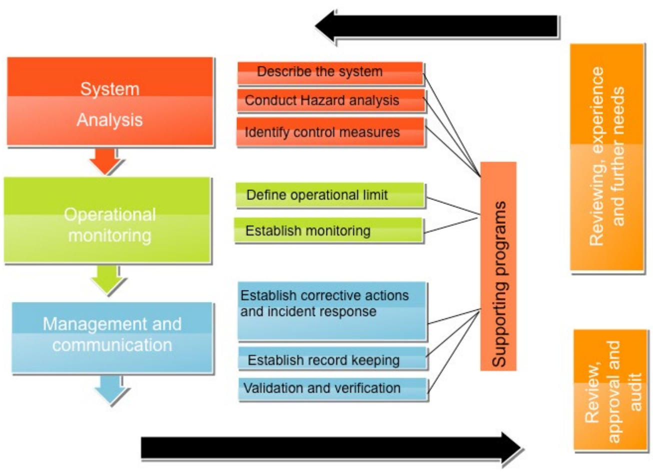


Figure 8 Components of SSPs (adapted from Davison et al., 2005)

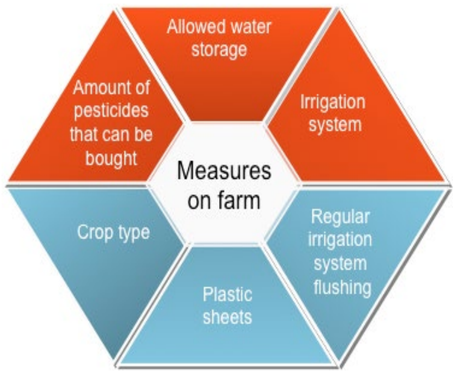


Figure 9 Examples of control measures (barriers) that can be implemented at farm level

A previous study conducted by a consortium consisting of the University of Jordan and German Jordanian University has identified hazards based on Jordanian experience (Halalsheh et al., 2018). The study showed that pesticide-residues and pathogenic contamination originated from either wastewater or manure fertilizers are the hazards that can be of primary concern. Hazards related to pathogens are so far controlled as shown in Figure 10. The figure identifies priority hazards together with their sources and the applied control measures. The process of controlling the pesticide-residues is not clear so far and the role of MoA in such control seems absent –indicated as question mark in Figure 10-. Control measures are currently applied and assured by WAJ and MoH. Limitation of the crop types is the only control measure that is applied thus far at the farm. Although the approach is successful in controlling pathogens at the effluent of WWTP, it is still limited downstream since pathogenic contamination might appear due to manure application. Moreover, and referring to the results of the conduced experiments within the study, it was clear that health protection can still be achieved even with less restrictions on irrigation water quality. This is particularly true for irrigating vegetables that can be eaten raw. Higher revenues expected from the vegetables eaten-raw makes a strong case to improve the flexibility in the treated wastewater use options (Majdalawi, 2003). Based on this analogy and the results from the conducted experiments, the pan outlined in Figure 11 had been proposed.

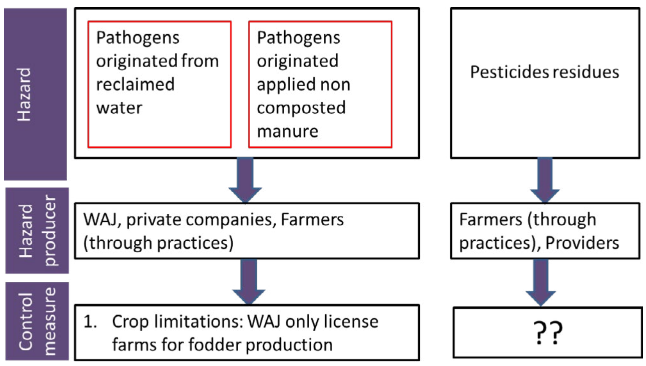


Figure 10 Current hazard management of direct wastewater use in Jordan

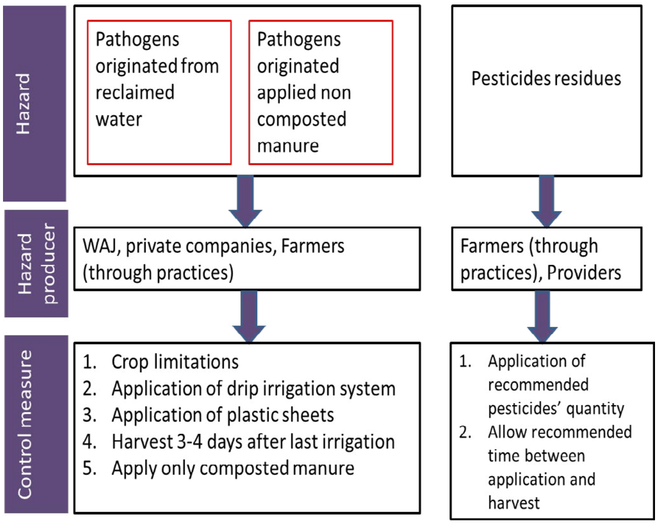

Figure 11 Proposed control measures for priority hazards

### 5.1.5 Proposed Framework for Implementation of SSPs

As mentioned earlier and shown in annex I, laws of the Ministry of Health (MoH), MoA, Water Authority of Jordan (WAJ), and MoE are controlling reclaimed water use for different purposes. Obviously, there are some overlaps between different bodies. Coordinated actions need to be established and better definitions and distribution of tasks are warranted. For instance, dialectic still exists between MoA and MoH about the responsibility for controlling and assuring quality of irrigated crops. Although MoA is monitoring imported crops for pesticides residues, reluctance exists for controlling local non-processed food. At the same time, MoH argues that crop quality control is part of the MoA mandate. As a matter of fact, the following articles are included in MoA's law No. 13/2015:

- Article 5B, states that the MoA contributes with competent authority in preparation and application of sanitary and phytosanitary measures to ensure prevention and transmission of disease or harm to humans through plant and animal and agricultural inputs without prejudice to any relevant authorities to examine food.
- Article 7B, states that the MoA should take sanitary and phytosanitary measures necessary to achieve proper protection of human and animal health in Jordan against the risks arising from additives or contaminants, toxins or disease-causing organisms in agricultural products or agricultural production inputs.
- Article 8, states that the MoA shall perform procedures according to the instructions issued by the Minister, which are necessary to ensure conformity of agricultural products and agricultural inputs with health and technical conditions, including sampling, inspection and control procedures.

As for MoH, the following related articles in amended law of food control for year 2003 are included. The amendment is read together with law No. 79 for year 2001:

- Article 2 defines food as any material intended for human consumption whether raw material or semi-processed or manufactured, including drinks, pickles and condiments, chewing gum and any substance used in food manufacturing, processing and treatment except for cosmetics, tobacco, drugs and drinking water.

- Article 3 states that: Subjected to the provisions of Agriculture Law in force, the institution is the only agency authorized to oversee health and food control, including suitability for human consumption in all stages of trading, whether locally produced or imported in coordination with any official related entity if the Director-General sees the need for such coordination.
- Article 11 A, states that the MoH takes in accordance with instructions issued by the Minister, necessary measures to ensure that the food and health conditions are met or health measures, including sampling, inspection and control procedures are implemented.

There are certainly overlaps in responsibilities assigned for each ministry, which requires careful coordination between both for adequate control of produce. In addition to existing overlap and lack of coordination, it is expected that lack of capacities at both ministries are behind reluctance to take decision on responsibilities to control locally produced crops. Institutional, infrastructure and human capacities at both ministries require improvement. A six years program was implemented earlier by the GIZ targeting indirect treated wastewater use in the Jordan Valley with a component focusing on strengthening the capacity of JFDA for crops monitoring. Moreover, and through Jordanian component of WHO/UNDP/GEF project on adaptation to climate change, additional capacities of Jordan Food and Drug Administration (JFDA) was built for measuring pathogenic contamination of crops. On the other hand, MoA has the capacity to monitor pesticides residuals in crops, whether imported or locally produced.

#### 5.1.2.1 Scenario Analysis

Obviously, implementation of JS 1766/2014 would require additional efforts to establish a clear set up where full agricultural process rather than reclaimed water quality is controlled. Accordingly, the following two scenarios have been suggested:

Scenario I:

This scenario proposes establishing a unit at MoH, which has the following responsibilities:

1. Issuing licenses to the farmers applying for direct treated wastewater use.
2. Control and monitor the produce with respect to pesticide-residues and pathogenic contamination. Capacity of JFDA should be built accordingly. Samples have to be collected from farms directly since number of WWTPs is limited, even when considering the ones planned for near future.
3. Take corrective actions if tested samples fail to meet produce quality according to recognized standards

Licensing the use of treated wastewater in unrestricted irrigation would require the users to be trained and certified for good agricultural practices recommended by MoA. The MoA should also approve amounts and sources of applied fertilizers and pesticides. WAJ has to provide data related to irrigation water quality to MoA and MoH on a yearly basis. With respect to un-composted manure, Jordan currently has around 5000 composters. Controlling such a high number of composters presents a challenge to MoA. One solution can be to establish associations and make the associations responsible for quality control of the end product. This will automatically put wastewater use for agricultural production in a wider context where responsibilities of MoA has to be activated for controlling all inputs to agricultural fields including fertilizers, pesticides, and irrigation water quality.

Scenario II:

Responsibilities are shared between an established unit at the MoA and another established unit at the JFDA. The unit at the MoA shall be established under direct responsibility of assistant secretary general for plant wealth (referring to organizational chart of MoA). The unit shall have the following responsibilities:

1. Issuing licenses for farmers applying for reclaimed water use, whether direct or indirect is are intended. Licensing should be done based on the best agricultural practices and training certificates to the farmers.
2. Control and monitor the produce with respect to pesticide-residues. Samples have to be collected directly from farms.
3. Control and monitor the agricultural practices at the farm and approve their compatibility for licensing purposes.
4. Take corrective actions if tested samples fail to meet produce quality according to recognized standards or when agricultural practices do not meet licensed practices.

Table 6 Advantages and disadvantages foreseen for location of suggested established unit(s) responsible for reclaimed water use management

| | Advantages | Disadvantages |
|---|---|---|
| **Scenario I** | • Responsibilities of monitoring and control are concentrated in one unit | • Needs significant capacity building of JFDA<br>• Limits the role of MoA |
| **Scenario II** | • Capacities of both JFDA and MoA are utilized<br>• Fits better into legal role assigned for each ministry | • Needs higher level of coordination between MoA and MoH<br>• Samples has to be collected twice from each farm (resources loss) |

In both scenarios, activation of MoA's role through the agricultural extension unit, in raising awareness between farmers on good agricultural practices is crucial. MoA can establish training programs necessary for proper implementation of JS 1766/2014. A second possibility would be certifying the private sector to perform necessary training programs. Advantages and disadvantages of both scenarios are shown in Table 6. While first scenario concentrates responsibility in one unit located at JFDA, it limits the role of MoA according to its law No. 44/2002. On the other hand, distributing responsibilities between JFDA and MoH would utilize resources and capacities available at each body. However, it also has some limitations related to higher level of required coordination and some limited duplication.

### 5.2 Decentralized sanitation services

Notwithstanding the developed decentralized wastewater management policy that was issued on 2016, it is advisable to redefine decentralization within the frame of IWRM by considering a well-defined and agreed unit -say basin level- for managing all water resources including wastewater resource. This might be important since the current definition is based on PE, which is so far debatable and does not really have a clear justification. However, and until then, the policies of the MWI will be guiding the following discussion. The approved policies do not encourage sewerage networks for communities with population not exceeding 5000PE. Although serving scattered communities with conventional sewerage network within the existing regulations is not economically feasible, any future consideration or updates for the policy should not exclude sewerage networks provision provided that non-conventional sewers are allowed and regulated. In any case, discouraging sewerage networks will limit the main choices of decentralized sanitation services by either onsite treatment systems or by fecal sludge management systems.

Obviously, sanitation systems that are closer to communities would necessitate the involvement of such communities in the early stages of planning and all over the process. Social acceptance is a key when decentralized sanitation is considered. Moreover, onsite treatment systems shall demand the application of more lenient regulations (be it standards or instructions enforced by different governmental institutions). In fact, the Jordanian standards JS1766/2014 might serve as a starting point. The implementation of such standards would require the development of SSPs with the involvement of all stakeholders. A dialogue has to start in Jordan were the required enabling environment for such service provision is discussed. The development of successful business models for operation and maintenance of such services has to be developed. At the same time, technologies that might be of choice have to be defined considering their resilience in the face of weather extreme events. Those systems have to be developed with close consultation of different stakeholders and based on well-defined criteria. These criteria have to be developed for each onsite treatment systems and for fecal sludge management systems. It is of utmost importance to consider simplicity, robustness, resilience, sludge production, operation and maintenance requirements into account. Systems that minimize sludge production in the case of onsite wastewater treatment systems shall be selected. Moreover, simple technologies that are known for their robustness and resilience in the face of climate change have to be considered. For instance, anaerobic baffled reactors followed by constructed wetlands are known to have such advantages. On the other hand, and with respect to fecal sludge management, sludge drying reed beds are also known for robustness and ability to store and stabilize sludge. At the same time sludge drying reed beds are known for their resilience to extreme weather conditions particularly heavy rainfalls. For these specific reasons, the ACC project and within its hard track activities is demonstrating the feasibility of such technologies for wastewater treatment and for fecal sludge management. For practical reasons, secondary sludge produced at Wadi Hassan WWTP was assumed to have the same characteristics of fecal sludge produced by cesspools. In both cases, wastewater is being subject to treatment and easily biodegradable organic matter is already consumed, which might justify such approach. Experience gained after operating such systems will be used and exchanges with different stakeholders. Other soft track activities are also planned in order to support the concept of decentralized sanitation and reuse being one important adaptation measure for climate change.

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# Part B

# Domestic Wastewater Reuse in the Context of Decentralized Wastewater Management in Jordan for Climate Change Adaptation

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With inputs from Dr Ismail Al Baz, Jens Götzenberger and Hesham Asalamat

## 1. Introduction

Jordan lies in the eastern part of the Mediterranean region and extends along Jordan Rift Valley from the south of Syria to the north of Saudi Arabia. It covers a land area of approximately 90,000 km². It is almost a landlocked country with only one-point access to seawater, confined to the Gulf of Aqaba in the south.

The diverse topographic and geomorphologic features control the water drainage pattern system whose drainage system consists of two main flow patterns:

The first drainage system drains water towards the Jordan Valley through deeply incised wadis and rivers dissecting the Jordan Valley-Dead Sea escarpments to ultimately discharge into the Dead Sea. This explains the presence of all constructed dams on the eastern side of the valley. The second drains water through shallow streams and washes, which flow eastwards from the western highlands towards the internal desert depressions and mudflats.

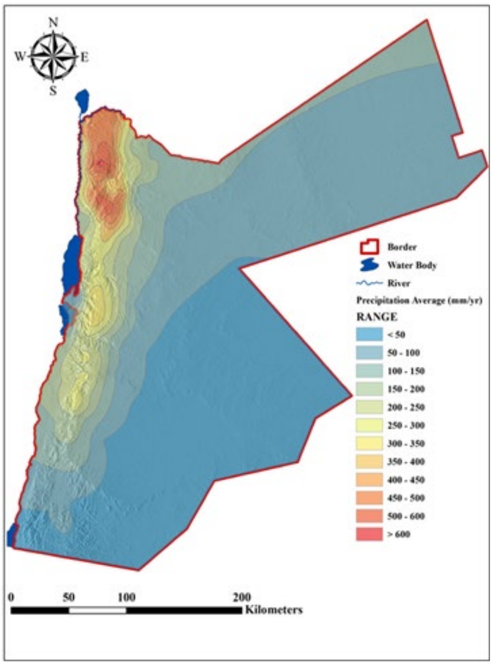


Figure 12 Jordan's precipitation map

The climate ranges from Mediterranean to arid. The Rift Valley and the desert, east of the highlands, belong to semi-arid to arid climate while the Mediterranean climate dominates most of the mountainous highlands adjacent to the Jordan Valley.

Jordan's water resources extremely rely on the rain for its water system replenishment. The long-term annual total rainfall amount (1937-2014) is estimated at 8.2 billion m3 of which about 92.6% is lost to evaporation; 2.4% flows as runoff and 5% ends up in recharging the groundwater.

Jordan is not only subject to periodic droughts that extend for some few years in duration but also the rainfall is spatially uneven in distribution. Figure (1), showing the geographic rainfall distribution, indicates that the annual rainfall ranges from less than 50 mm in the desert regions to about 600 mm in the western mountainous highlands along the Jordan Valley-Dead Sea-Wadi Arab depression.

According to precipitation distribution, the land is classified to various categories as shown in figure (2); it is obvious that more than 90% of Jordan's land area receives less than 200 mm/year whereas the relatively high annual precipitation, i.e. more than 300 mm rainfall, is confined to only 4% of Jordan's land area.

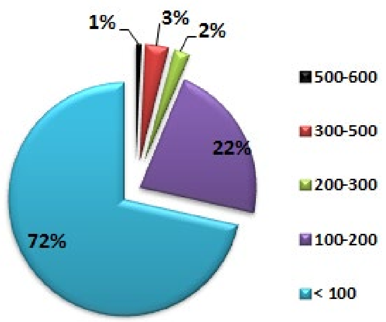

Figure 13 Jordan's land categories Vs annual rainfall

In terms of water resources, Jordan is ranked among the most water-scarce countries in the world. The water problem is aggravated by the fact that most of Jordan's water resources are shared with neighboring countries and thus it forms a limitation on management and utilization of these resources. Moreover, due to political instability in the region, Jordan has hosted influxes of refugees from the neighbouring Arab countries; an additional factor that is undoubtedly increasing the pressure on water resources and wastewater-related infrastructure. According to Jordanian Department of Statistics' records, the estimated population of Jordan in 2015 is around 9.53 Million; of which around 6.58 million is the Jordanian population while the rest (2.95 million) is non-Jordanian; around half of them, i.e. 1.3 million, is Syrian refugees. In other words, the Jordanian and non-Jordanian population in 2015 constitute around 69% and 31% of the total population respectively. More than 90% of the population is concentrated in the northwest quadrant of the country where the rainfall is relatively the highest and most of the water resources are located. The average population growth rate (2004-2011) is estimated at 2.2 %. The trend of indigenous growth rate in Jordan during the duration (2004-2011) showed gradual slowdown. However, this may be offset by the influx of refugees from neighbouring countries because of the political instability sweeping the Arab region.

Owing to the fact that only around 63% of Jordan's population is currently served with the public sewer network, there is a promising potential for Jordan to scale up sanitation services through the adoption of the decentralized approach in wastewater management as a complementary to the centralized wastewater collection, treatment and reuse. This is particularly true for the northern governorates, where around 28% of Jordan population lives and only around 45 percent of its population is served with sewer network. Not to mention that these governorates host most of the Syrian refugees, while the wastewater infrastructure is not designed to serve such large number of population. Moreover, the expansion of the existing public sewer system ending in centralized treatment plants is not only hindered by the financial limitations but also the topography as well as fragmentation of the settlements makes any plan for this expansion, most probably, infeasible and beyond Jordan's capacities. All above-mentioned facts underline the importance of adopting decentralized sanitation to bridge the current gaps in sanitation services.

Apart from water scarcity, Jordan encounters ever-increasing demand on energy that constitutes an additional burden on the budget. To better realize the severity of the complex problem, it is enough here to mention that the water sector alone consumes no less than 15% of the total electricity incurred by the energy sector.

## 2. Water Status Quo of Jordan

Jordan faces chronic water scarcity due to the very limited water resources amid ever-increasing water demand. The per capita annual share of water for all uses has declined from 3600 m3 in 1946 to less than 150 m3 in present and would even remain subject to further decrease in future unless water supply is increased correspondingly to the mounting demand – a very challenging mission indeed.

According to Jordan's Water Budget (2016/ 2017), the total water consumption is estimated at around 1044 million cubic meter (MCM) whilst the total available renewable resources, surface and groundwater resources together, are estimated to be only 700 MCM; of which around 136 MCM is treated wastewater. The deficit in water, around 344 MCM in 2016, has been covered through over-abstraction of the highland aquifers beyond its safe yield capacity (around 275 MCM) and through exploitation of fossil water.

The competition between different sectors on the limited freshwater quantities is ever increasing. According to the water budget (2016), as shown in the table (1), agriculture is the largest consumer; constituting around 53% of the 2016 overall water budget compared to only around 47% for all other sectors: the municipal and industry. It deserves mentioning that the municipal water supply is subject to water losses, technical and administrative losses, no less than 52%.

Table 7 Water consumption by different sectors (2016)

<table>
<tr><th>Sector</th><th colspan="2">Water Consumption (MCM)</th><th colspan="2">%</th></tr>
<tr><td>Municipal</td><td colspan="2">457</td><td colspan="2">44</td></tr>
<tr><td rowspan="2">Agriculture</td><td>Freshwater</td><td>421</td><td>40</td><td rowspan="2">53</td></tr>
<tr><td>Treated wastewater</td><td>134</td><td>13</td></tr>
<tr><td>Industry</td><td colspan="2">32</td><td colspan="2">3</td></tr>
<tr><td>Total</td><td colspan="2">1044</td><td colspan="2">100</td></tr>
</table>

Source: 2016-Water Budget (MWI)

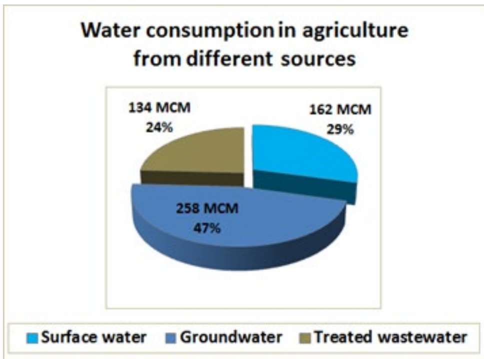


Figure 14 Water consumption in agriculture from different sources (based on the 2016-Water Budget)

including; groundwater, surface and treated wastewater. The figure (3) shows the contribution of these different resources to sustain agriculture's water needs. Though the treated wastewater generated countrywide is already used in irrigation, the agriculture still forms an extremely continued pressure on the groundwater which in turns provides around 47% of the agriculture's total water consumption while the surface water and treated wastewater contribute 29% and 24% of agriculture water needs respectively.

The total amount of treated wastewater generated countrywide in 2016 is estimated at around 151 MCM of which around 134 MCM was used for irrigation; more than 65% of this amount is used in the Jordan Valley for unrestricted irrigation while the rest (less than 35%) is used in forage crops cultivation, i.e. the alfalfa, in the areas around the centralized treatment plants.

## 3. The Jordanian Experience in Wastewater Reuse

The wastewater reuse in Jordan includes the direct and indirect use of treated wastewater for irrigation. Both terms are intentionally used to distinguish between the two ways of this reuse. The direct reuse refers to the use of a treated effluent which generated from a treatment plant without being mixed with any other sort of waters. While when the treated wastewater blends with other waters before being used, then the reuse is known as an indirect use. Consequently, the treated wastewater is used indirectly in the Jordan Valley and directly in the areas around treatment plants. This section provides an overview on the direct and indirect reuse of treated wastewater for irrigation in Jordan.

The history of wastewater reuse for irrigation in Jordan dates back to the eighties of the past century; immediately following the operation of As-Samra Wastewater Treatment Plant in 1985. The treated effluent has been used for indirect irrigation in the Jordan Valley after being mixed with other waters from runoff during rainfall in winter and some springs that drain in the King Talal Reservoir (KTR). In view of the increase in the amount of wastewater collected and treated in many treatment plants, the reuse practice has been further expanded to include the direct use of treated wastewater in irrigation in the vicinity of centralized wastewater treatment plants. It deserves mentioning here that according to the Water Budget (2016) almost 90 percent of the treated wastewater generated is used in irrigation.

### 3.1 The Indirect Wastewater Reuse for Irrigation

The Jordan Valley is considered as the «vegetables basket» of Jordan; the unique prevailing warm climate in the Jordan Valley allows the off-season crop production in winter. The extremely hot weather in summer puts an end to the vegetables season and consequently becomes favorable for implementing soil solarization in preparation for next season.

The cultivable area in the Middle and Northern Jordan Valley is estimated at around 30,000 hectares while the total irrigated area is around 25,150 hectare. Historically the Jordan Valley had the main surface freshwater resource; that's attributable to the Jordan River whose annual flow, downstream of Tiberius Lake where Yarmouk River converges with Jordan River, was no less than 1.2 billion cubic meter (BCM). That's why the freshwater was the only source abundantly available to farmers who used to apply in their fields. After the diversion of the Jordan River in early 60s by the Israeli side and the consequent water shortage amid increasing demand on water, the need emerged to exploit all water resources available, including unconventional waters, to cope with this shortage in water. Since early eighties of past century, treated wastewater has been used for irrigation in the Jordan Valley to be the first agricultural area where water reuse is practiced in irrigation. The importance of the wastewater reuse in the Jordan Valley stems from the fact that the practice underlies a free-up of freshwater for other uses in need of high-water quality. To stand on how the reuse cycle is going in the Jordan Valley, the following explanatory diagram depicts this cycle. The reuse cycle, depicted in the diagram, starts from the Yarmouk River in the North of the Jordan Valley. Fraction of the freshwater flowing into the King Abdulla Canal (KAC) is pumped out to the Zai Drinking Water Treatment Plant to be treated before being pumped to Amman for drinking. In 2014, around 70 MCM of freshwater was pumped for drinking purposes. The other fraction is still used in the Northern Jordan Valley for irrigation. Most of the wastewater generated in Amman and Zarqa drains into sewer network system and ends at the As-Samra WWTP. The treated effluent of As-Samra takes its way through Wadi Al Zarqa to its destination - the King Talal Reservoir (KTR), the second largest reservoir in Jordan with a full storage capacity of 75 MCM. In the KTR, the treated wastewater blends with other waters (from springs and rain run-off). The "blended treated wastewater" is then released to the Jordan Valley to be used for irrigation. In 2014, around 114 MCM of the "blended treated wastewater" was released from KTR down to the Jordan Valley to be used in the unrestricted irrigation.

Before 2008, around 49% and 51% of the total irrigated area in the Jordan Valley was already irrigated with the "blended treated wastewater" and the freshwater respectively. Within 6 years later, this area witnessed an expansion in use of the "blended treated wastewater" coupled with a corresponding decline in freshwater use. Currently, no less than 60% of the irrigated area is irrigated with the "blended treated wastewater" and less than 31% is still irrigated with freshwater. The rest 9% is still alternately irrigated with both waters; the freshwater and the "blended treated wastewater". It should be stressed that the whole Jordan Valley is envisioned to be, within few years to come, completely irrigated with the "blended wastewater"; the objective that would most likely be achieved in near future in light of the increasing treated wastewater amount from As-Samra WWTP in addition to the utilization of the joined effluent of the three wastewater treatment plants in the north Jordan Valley, i.e. the Central Irbid, the Shalaleh and Wadi Arab WWTPs.

The special significance of wastewater reuse practice in the Jordan Valley lies in the substitution of freshwater with sufficient "blended treated wastewater". In so doing, the sustainability of agriculture and the free-up of freshwater for drinking are both secured in the Jordan Valley.

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To get a close insight into the success factors for the sustainable agricultural use of treated wastewater in the Jordan Valley, it would be necessary here to shed the light on the grounds that have made the reuse a strategic, practical and sound solution. Unlike any other areas in Jordan, the Jordan Valley is blessed with the following spatial features and the existing infrastructures that make the large-scale wastewater reuse a success story of Jordan.

### 3.1.1 Topography

Though the Jordan Valley, where the reuse being immensely practiced, is located far away from the generation point of the treated wastewater, it is still true that the treated effluent in its way to the King Talal Reservoir (KTR) is flowing in a natural wadi, i.e. Seil Al-Zarqa for a distance of no less than 45 km, fully by gravitational force with no need for pumping. Furthermore, the existing around 400-meters-difference in elevation between the KTR and the Jordan Valley ensure also the conveyance of irrigation water from the KTR into the downstream by gravity. In the strict sense, the existence of such natural wadi with continuous downward slope, from the location of the treatment plant until the site of water reuse, represents an ideal model for cost-effectiveness in operation of irrigation water supply and it plays a very crucial role in the feasibility of water reuse schemes, in particular for a country already overloaded with high energy bill, like Jordan. Not to mention that a natural wadi obviates the need for a constructed conveyor in form of either a pipe or a concrete canal.

### 3.1.2 The confined irrigable area

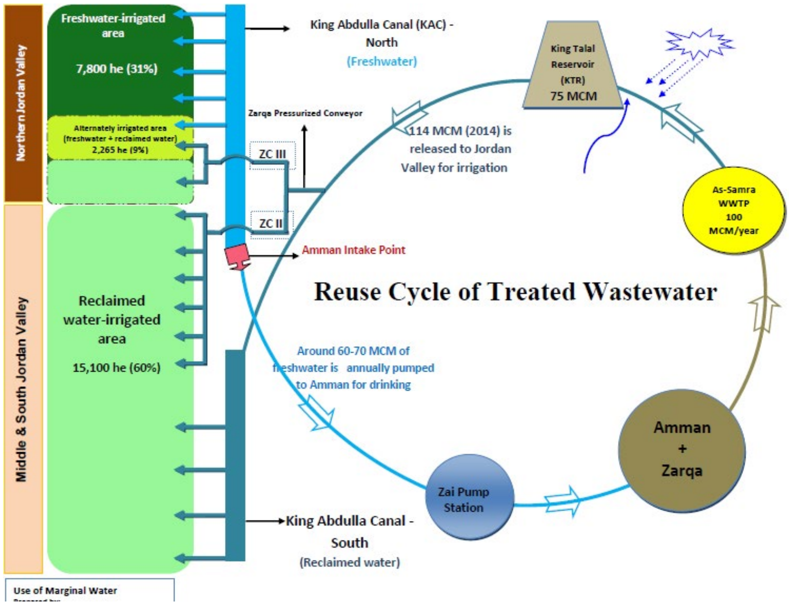


Figure 15 Reuse Cycle of Treated Wastewater

Unlike any other agricultural area in Jordan, the cultivable area of the Jordan Valley is geographically confined to a narrow strip bordered by the Jordan River in the west and mountainous heights in the east. That's why the irrigable area in the Jordan Valley is limited in size and almost in-expandable. Administratively, the irrigable area is divided into smaller plots known as farm units which are spatially contiguous. From feasibility perspective, the spatial contiguity of farm units is of high importance because, on one hand, this makes the implementation of any expansion plans of wastewater reuse in further areas of the Jordan Valley very possible and achievable within future vision and, on the other hand, that makes any investments in irrigation infrastructure to be more cost-effective and very feasible.

### 3.1.3 Sustainability of agriculture

It goes without saying that the success of wastewater reuse schemes for irrigation is always reliant on the sustainability of agriculture which is the end-consumer of treated wastewater. The cultivable area in the Jordan Valley in particular is protected by law from risk of shrinking in size that might be resulting from changing the use of farmlands for non-agricultural uses, the urban expansion and the fragmentation of farmland holdings due to the obligations imposed by the inheritance system. That's why the sustainability of agriculture in the Jordan Valley fosters the sustainability of wastewater reuse and vice versa.

### 3.1.4 Lack of sufficient alternative water for irrigation

The already limited freshwater in the Jordan Valley is not only insufficient to fulfil the agriculture needs but also it has been diverted for drinking uses. Consequently, around 60 - 70 MCM of the freshwater is annually pumped out of the King Abdulla Canal for drinking. This freshwater could not have been allocated for drinking unless the treated wastewater had been reused as alternative irrigation water. Currently, no less than 60% of the irrigated area in the Jordan Valley is using the “blended” treated wastewater and the expansion in this reuse will be continuing in light of the increasing quantities of the treated wastewater generated from AsSamra WWTP. Moreover, additional quantities, around 15 MCM, are expected to be collected from the joined-effluent of Irbid-Ashalala-Dogara treatment plants to be used in the north Jordan Valley in near future.

Given to the fact that around 65% of the country-wide generated treated wastewater amount is exploited in the Jordan Valley for irrigation and thus the availability of treated wastewater in such a bulky quantity, the reuse practice has been feasible and cost-effective.

### 3.1.5 Existence of adequate infrastructures for water management

The Jordan Valley is equipped with unique irrigation scheme, infrastructures and other facilities which all are advantageous to monitor, to supply and to manage water resources throughout the Jordan Valley. Of course, as was mentioned before, the contiguity of the irrigable area made such costly infrastructures very feasible to implement in spite of the high investments. The key infrastructures include the following:

a. The King Talal Reservoir (KTR) is very important for proper management of irrigation water supply in accordance with the irrigation water demands over the year. That gives the operators such a high flexibility for scheduling water supply and thereby maximizing the efficiency use of the irrigation water; with this dam, it is possible to store the surplus water in excess of irrigation demands during certain times to meet the demand during the peak periods.
b. The King Abdullah Canal (KAC) constitutes the backbone of irrigation network system in the Jordan Valley. It extends along the Jordan Valley from the far north toward the south with a length of 110 Km. It is thus the largest irrigation canal system and most importantly it operates by gravitational force. The KAC is divided into two parts; the North-KAC and the South-KAC which carries the freshwater and the blended treated wastewater respectively. The two parts of the canal are connected through a siphon that only allows the flow of water in one direction; the surplus freshwater in the North-KAC, if any, could flow to the South-KAC and not vice versa.
c. The Zarqa Pressurized Conveyor System enables the scale up of wastewater reuse in other irrigated areas in the northern Jordan Valley.

d. The irrigation water pump stations, which located alongside the whole KAC in the Jordan Valley, provide the farm units with irrigation water through the distribution networks, by means of pumping or in some cases by gravity. Because water is supplied intermittently, the irrigation water supply is stored in a farm pond to be flexibly used and managed by farmer.

e. The Control Centre allows the operation staff to remotely monitor and manage all water resources of the Jordan Valley, for all uses.

### 3.2 The Direct Wastewater Reuse for Irrigation

The MoWI has made a remarkable progress towards the scale up of sanitation services across Jordan. In this regard, the public sewer network has been expanded to collect the wastewater generated from the densely populated areas across Jordan. So far, 34 centralized wastewater treatment plants were constructed to cope with the increasing wastewater amount. The availability of treated wastewater has encouraged farmers to start cultivating forage crops like alfalfa in the areas around these treatment plants. Currently, around 35% of the treated wastewater exploited countrywide is used there in irrigation. It deserves mentioning that the demand on treated wastewater by the farmers is on increase due to the profitability of forage crops cultivation. The adequate lands around the treatment plants even allow the farmers to enlarge their farms in proportion to the increased generation of treated wastewater. It deserves mentioning here that the direct wastewater reuse came as a result of the availability of treated wastewater following the operation of these treatment plants; there were no irrigation projects in these areas before. This explains why no substitution of freshwater was made as a result of the reuse practice in these areas.

There are specific success factors which together facilitate the expansion of the direct wastewater reuse in the areas around the centralized wastewater treatment plants. These factors can be summarized as follows:

i. The availability of treated wastewater in a quality suitable for cultivation of forage crops, and in a quantity sufficient for feasible-scale cultivation

ii. The standard 893/2006 allows the direct use of treated wastewater for irrigation of class C-crops, i.e. forage crops. The high profitability of cultivating the forage crops maintains an increased demand on the treated wastewater by farmers

iii. The availability of lands in sufficient size allows for maximum utilization of the treated wastewater amount generated from these treatment plants. The surplus water is easily managed by discharge into existing wadis. Moreover, the irrigated lands are allocated exclusively for irrigation purposes and thus it supports the sustainability of wastewater reuse project.

iv. The lack of access to any other conventional water by farmers for irrigation use in the area, i.e. no alternative irrigation water in the area.

# 4. Wastewater Reuse in the Decentralized Sanitation Context

## 4.1 Function of Reuse Systems in the Integrated Wastewater Management

The special quality of wastewater entails applying a functionally interlinked cascade of successive systems that operate synergistically and complementarily to manage wastewater from the point of generation to the point of use or disposal. These systems include (i) the collection/ transport of wastewater, (ii) the treatment of wastewater and (iii) the safe system for disposal of treated wastewater in the environment, i.e. a reuse system.

The necessity for integration of the three systems in the wastewater management arises from the fact that the three systems are equally important; these systems are functioning in complementarity and serving jointly the ultimate objective of wastewater management, i.e. the protection of environment and the public health. The table (2) summarizes the significance of the three systems in the whole wastewater management.

Table 8 The wastewater management systems and their respective functions

| The wastewater management systems | Functions | |
|---|---|---|
| **Wastewater collection/ transport system** | (i)<br>(ii)<br>(iii)<br>(iv) | Minimize the exposure of communities' residents to pathogens<br>Minimize the potential pollution risk to water resources<br>Allows for treatment of the collected wastewater on one site<br>Allows for wastewater reuse at economic scale |
| **Wastewater treatment system** | (i)<br>(ii)<br>(iii) | Maintain the pollution loads discharged to the environment within the assimilative capacity of receiving ecosystems<br>Reduce the counts of pathogens in wastewater<br>Allows for safer reuse of wastewater |
| **Reuse system** | (i)<br>(ii)<br>(iii)<br>(iv)<br>(v)<br>(vi) | Minimize the exposure to pathogens<br>Reduce the counts of pathogens on the irrigated crop<br>Minimize the potential pollution with excessive nutrients and biodegradable organic matters<br>Allow for high resilience against substandard water quality<br>Allow for adoption of modest treatment technologies<br>Guarantee a safe disposal of wastewater into the environment in productive or profitably manner |

It should be realized that one of the safest ways for disposal of wastewater to the environment is the reuse of this water in agriculture for irrigation. Especially in arid and semi-arid areas where the hot and dry weather conditions usually dominate, the assimilative capacity of the reuse system for polluting loads of wastewater is effective to clean away these pollutants. It deserves recalling here that the reuse system comprises all components involved in the cultivation process as well as the prevailing weather conditions that collectively interact to dissipate the pollution and reduce the associated risks to an environmentally acceptable level. The reuse system exhibits various mechanisms in assimilating pollution loads. These mechanisms include the following:

1. Dispersion of pollutants in the environment over a larger area, i.e. the irrigated fields.
2. Biodegradation/ mineralization of organic molecules by the microflora and fauna in soil.
3. Assimilation of nutrients by the wastewater-irrigated crops/ plants as well as the intrinsic micro-flora and fauna of the soil.
4. Incorporation of humus in soil and thereby improving soil structure and increasing soil fertility.
5. Adsorption of heavy metals and excessive phosphorus in alkaline soils.
6. Provision of effective barriers against the pathogens contained in wastewater (health protection measure)

In order to recognize the centric role of reuse system in the wastewater management, it is important to shed the light on the components of this system and how each component is contributing to proper management of wastewater. The reuse system involves the following components:

i. The treated wastewater which has to be dissipated/ and used in a productive manner in cultivation; and this is the ultimate function of the reuse system in the sanitation chain.
ii. The cultivated crops, in its all kinds, whose function is to (i) transpire the treated wastewater and to (ii) assimilate nutrients loaded in the water. It deserves mentioning here that despite of the huge water amount used by plants, only small part of this amount remains in the plant to supply growth. As a rule of thumb, more than 95% of water taken up by plants is lost to the atmosphere whereas less than 5% is retained in the plant tissues for cell expansion and plant growth. Most of constituents which are deemed as pollutants are actually essential nutrients for growth of plants. The nitrogen and phosphorus ions in particular which stand a big concerns due to its polluting potential for water bodies are indeed assimilated by plants and other intrinsic micro flora and fauna of the soil. The two nutrients together with potassium are needed by plants in large quantities and thus they are called as macronutrients. Other nutrients available in the water are also required by the plants but in lesser amounts and thus they are known as micronutrients.
iii. The irrigated soil doesn't only act as a sink for the wastewater and various organic and inorganic loads but also serves as a hosting ecosystem for unlimited biological activities which are performed by many living organisms, i.e. the crops grown as well as the inherently diverse micro-fauna and micro-flora. All these organisms take care of dissipation of the irrigation water and its contents of nutrients, organic matter and any other degradable macromolecules.
iv. The soil's fine particles provide a huge surface for the absorption of heavy metals, if any, in the treated wastewater. This is true especially in the alkaline soil like almost all the Jordanian soils.
v. The elements of irrigation system including, the on-farm pond, the filtration system and the irrigation networks, are all of high importance in reducing the risks posed by the water-borne pathogens and other

suspended particles. The following table shows some examples of how irrigation system is very helpful in reduction of these risks.

vi. The prevailing weather conditions are also functioning as additional barrier against the disease-causing pathogens by the effect of natural die-off. According to the WHO 2006, the pathogens' natural die-off can reach 0.5-1 log-unit-reduction and 1-2 log-unit-reductions a day in the cloudy wet cold day and in the sunny dry hot day respectively. In this sense, through only the practice of stopping irrigation for 2-3 days before harvest, the risk of common pathogens, if any, can easily be avoided.

Table 9 The main elements of irrigation system and their contribution in risk reduction

| Component of irrigation system | Significance of irrigation system component in risk reduction |
|---|---|
| **On-farm water irrigation pond** | • Provides retention time for further suspended solids settling and pathogens' natural die-off |
| **Sand filtration system** | • Further interception of suspended solids contained in water<br>• Provides a barrier for pathogens reduction; up to 3 log-unit-reductions in pathogens counts |
| **Drip irrigation** | • Provides a barrier for pathogens reduction; around 2-4 log-unit-reductions |

Source: The National Plan for Risk Monitoring and Management System for the Use of Treated Wastewater in Irrigation.

Due to its unequivocally high assimilative capacity, the reuse system should be deemed as an irreplaceable unique post-treatment system that is capable of dissipating the effluent as well as its pollutants contents to the environment safely and productively. This new perception of assimilative capacity of reuse system has very important implications. It provides more flexibility to the regulatory entities for setting a reasonable and more realistic standard for domestic wastewater management. Thus, it allows for adopting more affordable close-to-nature treatment technologies with least maintenance and operation.

### 4.2 Quantities of Wastewater Untapped

The population of Jordan is estimated at around 9.53 million according to the last census in 2015. According to the figures officially announced by MWI, currently only 63% of Jordan population is served by public sewer network. The total treated effluent generated countrywide from all centralized treatment plants is estimated at 151 MCM. That means the daily per capita share of wastewater is around 70 litre. On assuming the same daily per capita share of wastewater (around 70 litre), the wastewater annually generated by the rest 37% of the population unserved by sewer sanitation, i.e. 3.53 million, is supposed to be in the order of 90.2 MCM in the then time. This quantity represents the wastewater potentially uncollected and thereby being untapped so far. The Table 10 shows the potential amount of wastewater which would be collected when different percentages of the population, 3.53 million, were being served by sewer system.

Table 10 The potential amounts of wastewater under various collection scenarios

| Connection to sewer system (%) | Population served by sewer system (in million) | The potential collected amount of wastewater (MCM) |
|---|---|---|
| **10%** | 0.353 | 9.02 |
| **25%** | 0.883 | 22.6 |
| **50%** | 1.77 | 45.2 |
| **75%** | 2.65 | 67.7 |
| **100%** | 3.53 | 90.2 |

Irrespective of the potential contribution of wastewater reuse in the development of water resources, it should be borne in mind that the potential amounts of the untapped wastewater has been posing a continued risk to the environment including the public health and the precious water resources, and therefore it needs to be managed in line with the financial capability of Jordan. Here comes the importance of the decentralized sanitation approach in offering a reliable option for residential areas which will be unlikely served in the short or long-term with centralized sanitation.

### 4.3 Flexibility in Gradual Scale up of Decentralized Sanitation

Given the advantage of the decentralized wastewater management approach in provision of sanitation service at small-scale, this approach gives the MWI a high flexibility in expanding the sanitation services gradually and through phases. It is obvious that the financial resources are too limited to accomplish large-scale sanitation projects, as is the case of the centralized approach. On contrast, the decentralized sanitation approach, due to its small scales, allows the decision-makers for setting national targets for scaling up sanitation services that are achievable and in line with the annually financial budget available. It deserves mentioning here that the treatment cost per cubic meter is probably lower in a large-scale centralized wastewater treatment plants compared to decentralized wastewater treatment plants. But taking into consideration the cost for long sewer system as well as the operation and maintenance cost in centralized sanitation, the decentralized wastewater management might become more cost-effective. Moreover, even for decentralized wastewater management, there would even be no reason to rule out the close-to-nature treatment technologies and hence to insist on implementation of costly unaffordable high-technologies just to meet such unreasonably strict standard. This is especially true when it comes to nutrients limits in the effluent intended to be used in irrigation, i.e. the nitrate and phosphate in particular. The regulators might be otherwise just to take no action and wait on the hope that adequate budget for the centralized sanitation and such a desired unaffordable treatment technology would be available one day. Meanwhile, the pollution by raw wastewater from the existing cesspits will continue in threatening the environment and water resources. In the contrary, as the reuse system in irrigation provide a safety factor for offsetting the substandard quality of treated wastewater, this fact offers the regulators more flexibility to adopt more realistic standard that pave the way for more feasibly cost-effective treatment technologies.

### 4.4 Options of Wastewater Reuse in the Context of Decentralized Sanitation

In principle, the treated wastewater can be used in any water-demanding development activities and for unlimited purposes. The quality of water remains the key determining factor for any of these uses and here comes the importance of deciding on the suitable treatment technology to be adopted. The desire for having the wastewater treated up to an ambitious level and thus the preference for specific treatment technologies should not make the regulatory entities overlook the socio-economic situation of the country. The regulatory entities have to be aware of the capital and the operation cost incurred when selecting the treatment technology to fulfil the desired standard of water quality. Not to mention the quantity of wastewater that will be treated for the reuse in terms of the scale economy. For water-scarce countries facing financial constraints like Jordan, it would be unadvisable to adopt high treatment technologies to treat the wastewater to very high standard in order to be reused for non-agricultural uses unless it proves to be a dire need. For instance, creation of new water-reliant business, like street cleaning and fish breeding just to use the high standard treated effluent from the decentralized wastewater might be unjustified. While if the water security reaches an extremely threatening point that necessitates a treatment of wastewater to such high standard for the groundwater recharge, then the adoption of the state-of-art technologies would be realistic and justified. Even in this case, the centralized wastewater may be the right and the most feasible option to be first treated up to such a high standard; simply because of its availability in economic amount. Eventually, the target level of treatment of wastewater is governed by the reuse option and most importantly the urgent priority for this option among other options. So far, the wastewater reuse in agriculture for irrigation seems to be the feasible option in the context of decentralized wastewater management for adaptation to climate change for the following reasons:

1. The advantages of treated wastewater use in irrigation over any other options lies in its magnitude and the broad potential of impacts as an adaptive measure to climate change. More elaboration on this topic is presented later in this concept paper.
2. The irrigation projects can be established easily due mainly to the affordable investment required as well as the ease of operation. This is obviously true especially due to the small-sized irrigable area required for practicing water reuse in the context of the decentralized wastewater management. On the contrary, creating new non-agricultural businesses for reuse from scratch may be unaffordable and entails more complicated operation management. Moreover, the water consumption capacity of non-agricultural business seems very limited and intermittently. The treated effluent is flowing continuously and has accordingly to be used on daily basis. For instance, wastewater reuse for non-agricultural irrigation option like street cleaning or firefighting couldn't take place on daily basis.

3. For irrigation uses, the wastewater reuse system offers synergistically natural complementarity with the treatment plant in accomplishing the safe disposal of wastewater in the environment. For instance, and unlimited to, the nutrients contained in treated wastewater are assimilated by the irrigated crops and the soil's intrinsic micro flora and fauna as well. In so doing, the reuse system largely helps diminish the risk posed by mainly nitrate and phosphorus. In the strict sense, the assimilative capacity of reuse system in irrigation is extremely higher than that of any other non-agricultural reuse systems.
4. Unlike its use in irrigation, the treated wastewater for almost all other non-agricultural uses is either explicitly prohibited or there are no standards applicable to these uses. For instance, the wastewater reuse for the groundwater recharge is prohibited when the groundwater is allocated for drinking. Surprisingly, the majority the populations who are supposedly to be served by the decentralized wastewater sanitation are concentrated in the areas that already lay on the groundwater basins used for drinking. As for the wastewater reuse for fish breeding, this option has no national standard at all so as to be implemented.
5. The wastewater reuse for irrigation uses almost entails less stringent water quality standard and this has a direct impact on reducing the cost of wastewater treatment. In this sense, a flexible standard opens the door for adoption of close-to-nature treatment technologies. In this respect, the anaerobic treatment systems in particular would also help reduce the burden of sludge management on the operator.

## 4.5 Potential Applications of Wastewater Reuse in the Context of Decentralized Sanitation

It is a fallacy to assume that the wastewater reuse must always lead to replacement of freshwater. The misperception of the purpose of wastewater reuse renders both concepts, i.e. reuse and substitution, being sometimes mixed and undistinguishable. In other words, both concepts are used alternately as if substitution of freshwater with treated wastewater goes for granted once the use of treated wastewater has been in place. This stereotyping thinking would distract attention from the functional potentials of reuse system in serving multi ends other than the freshwater substitution.

In principle, it is true that the ambitious end of wastewater reuse is to substitute the precious freshwater of the high quality with the treated wastewater with a view to preserving freshwater for the purposes in need of high-water quality. But in practice, the water substitution is not always the inevitable result of the treated wastewater availability. It is enough to recall here that the wastewater reuse for direct irrigation in the areas around the centralized wastewater treatment plants has taken place due to the availability of treated wastewater while there had been no freshwater use for irrigation on the ground.

In any case, the wastewater reuse stays a dire necessity for the completion of safe disposal of the treated effluent to the environment. That's why the wastewater reuse itself should firstly be regarded in the Jordanian context as an irreplaceable measure that functions in complementarity with treatment system of wastewater for sake of environment protection. Accordingly, in the middle of the uphill struggle to develop water resources, the decision makers are supposed to attach an importance to the scale up of wastewater reuse in the context of decentralized approaches with a view to leveraging protection of the environment and the precious water resources from the pollution stemming from the improperly managed wastewater, and thereby curbing the deterioration of the water quality of the existing resources. Under the different spatial contexts and settings of the decentralized sanitation projects, the success factors and the challenges for wastewater reuse implementation are usually very variable. That's why it seems impossible to define a fixed application for wastewater reuse to be always applicable and fit for all settings. However, there is avenue for four generic scenarios of reuse applications which are vary in its complexity and the effectiveness in its adaptive response to the climate change.

#### 4.5.1 Dissipation/ wasting of wastewater from cesspits in the areas unserved by sewer sanitation

In most of the Jordanian villages which are still unserved by sewer network, the wastewater generated from dwellings is managed through cesspits. The cesspits are constructed in such a way that allows continued infiltration of the supernatant liquid of the wastewater into the surrounding soil. The infiltrating wastewater poses a continuously serious risk on water resources and the public health. In light of the financial constraints, the sanitation services can neither be fully accomplished in all residential areas within short time nor in a single phase. When sewer sanitation is implemented in certain villages, there is an urgent need for taking actions in the meanwhile to curb the standing pollution risk posed by the cesspits in the villages unlikely to be served by sanitation soon. Though the cesspit is relatively the reasonable and the affordable option for the on-site wastewater management, but the question is how the risk from the cesspits can be minimized as much as possible. In combination with enforcement of certain specifications for the construction of the cesspits, the wastewater reuse in its simplest form would certainly serve as an interim solution until the area gets served by sewer sanitation. In this case, the on-spot wastewater reuse is recommended to dissipate the infiltrating wastewater from the cesspits. This on-spot wastewater reuse can easily be implemented by plantation of one or few trees close to the constructed cesspits. The tree should be fast growing, evergreen, and highly water consuming plant. For this task, the eucalyptus tree may be among the suitable plants for this purpose; at maturity stage when its diameter of canopy arrives 9 m, the eucalyptus tree can consume around 90 and 450 litres a day during the coldest months, i.e. December-January, and the hottest months, i.e. June-July, respectively.

#### 4.5.2 Afforestation activities

The use of treated wastewater for afforestation seems to be one of the most sustainable reuse applications for many reasons:

i. The forest area of Jordan is not only very limited but also in continued shrinkage with time. This fact explains the significance of the forests development to Jordan. Moreover, this reuse application receives political support as being a top priority in the plans of Ministry of Agriculture.

ii. The afforestation schemes are supposed to be implemented on public lands. When suitable public lands are available, this would save part of the financial budget which is to be spent for acquisition of privately-owned lands. These savings could be allocated for rehabilitation of the existing public land for afforestation prior to commencement of reuse scheme. Above all, the use of treated wastewater in afforestation seems to be the most sustainable application.

iii. The afforestation schemes can be executed in the lands around the premises of the wastewater treatment plants or even alongside the banks of the wadis used for the effluent discharge

iv. The public concerns about the reuse-associated risks seem to be an issue and thus wastewater reuse in irrigation of forest trees, by common consent, will be the safest application. And a full consensus from various actors on this option is actually guaranteed.

#### 4.5.3 Production of income-generating crops

Owing to the relatively modest quantities of the treated wastewater generated from the decentralized wastewater treatment plants, and the limitations on finding adequate lands for cultivation, there should be three main criteria serving as a basis for selection of the suitable target crops for income-generation:

i. Legally, the crop should be among the crops already approved by the regulatory standard to be irrigated with the treated wastewater of certain quality.

ii. Technically, the crops should be characterized by certain features and properties that make them capable of assimilating as much water as possible from the generated treated wastewater; fast growing properties, high production, with high assimilation capacity for nutrients, and exhibits more semi-steady water consumption pattern during the different growth stages over the year, i.e. the crops characterized by the least discrepancies in crop coefficient values during the different growth stages. The crops that fulfill these features are the perennial evergreen crops, and finally,

iii. From economic point of view, the crops selected should be among those crops whose profitability is high enough to attract farmers to invest in such kinds of irrigation projects.

Almost all these prerequisites are applicable to the alfalfa and olive trees which are commonly cultivated in Jordan. However, the alfalfa' high irrigation requirements make this crop more preferable than the olive trees. The fact that the well-established olive trees are rain-fed makes the olive trees a good choice to serve as a secondary crop in this scenario of reuse. The JS 893/2006 approves alfalfa to be a crop under Class-C, the most flexible class in terms of nitrate content, but as a matter of concern is that the alfalfa can naturally produce its nitrogen needs by nitrogen-fixation process. This may reduce the uptake of nitrate by alfalfa and thereby enhancing accumulation of nitrate in the soil profile. Under such circumstance when water percolation is to take place due to the additional water fraction added over the crop water requirement for sake of proper management of salinity, theoretically the nitrate could infiltrate gradually deeper in the soil and then may threaten the groundwater in the long terms. Given this fact, intercropping pattern involving growing alfalfa and olive trees together would be the solution for maximizing the nitrate uptake by olive trees.

It should be borne in mind that the reuse site should accommodate the maximum area of the alfalfa cultivation based on the maximum peak of irrigation demand during June and July, as well as the daily flow of treated wastewater. By irrigating the alfalfa, the surplus water will be relatively at minimum but still has to be dissipated by growing other additional crops. This topic is elaborated later in the section related to the management of the surplus water.

#### 4.5.4 Replacement of freshwater with treated wastewater in irrigation

From quick assessment for the agricultural activities in almost all residential areas and villages which are projected to be served by decentralized sanitation, the following preliminary findings can be concluded:

- The dominant crops cultivated in these villages are mainly the olive trees and to less extent the stone fruit trees. All these orchards are usually rain-fed. This crop pattern has been shaped by the hilly topography of the villages and the relatively high rainfall.
- The freshwater use in irrigation, if any, in some villages, is inclusively limited to very small scale when some springs are available, and the farmers have the access to this naturally flowing water. The water is used in irrigating some kinds of vegetables or some fruit trees in scattered small plots of lands alongside wadis.
- Some lucky households use the tap water in irrigating their small gardens occasionally. However, this is not the case in all houses; the municipal water in some villages scarcely suffices for the daily in-house routine activities.
- Barring some springs, the groundwater is not used for irrigation in these villages. The irrigation projects using groundwater exist in the area far away from the residential communities.

Based on the aforementioned findings, the potential for replacement of freshwater with treated wastewater in the decentralized wastewater management context is obviously inapplicable. However, the treated wastewater, in principle, could be used in place of freshwater under certain specific settings.

The Table 11 shows the four proposed scenarios of the wastewater reuse and their respective anticipated impacts based on the purpose envisioned for each. The scenarios have been listed in the table in the ascending order, from A to D, in accordance to the weight of the anticipated impact of each. Despite of the significant gap in the impact of these scenarios, all scenarios serve equally a common objective which is the safe disposal of wastewater, the objective that offers Jordan the minimal contribution of wastewater reuse to climate change adaptation. The weight of the impact is dependent on the application scenario of reuse itself. It is obvious that this weight is increasing exponentially in direct proportion to the complexity of the reuse system. Of course, the applicability of implementing any of these scenarios on the ground does not yield to the preferences of planners or decision makers for certain application. That's why when an ambitious reuse scenario is inapplicable in certain spatial setting, any other scenarios should be not ruled out from the plan even when its weight of impact was the most modest amongst all scenarios'. This applies for instance to the on-spot dissipation of the cesspits' raw wastewater by an evergreen perennial plant. With time, the door would be open for the possibility of replacing an existing reuse scheme with other more ambitious scenario when the local context would change in favour of this upgrade. At the beginning, surely any reuse scenario implemented on the ground, would contribute into adaptation to climate change and thus should be neither underestimated nor excluded. This is certainly true especially as the scale up of the decentralized sanitation cannot be achieved within a short time and, it could only be implemented gradually through phases over a long period.

In the conclusion, the aforementioned reuse applications share the basic function which lies in the protection of environment and water resources as well as the improvement of hygiene conditions. In spite of the certain additional gains which could be achieved from the more complex application, none of these applications should be neglected; each spatial setting has its own specific conditions that impose the most applicable application of reuse. The scenario A in particular should be urgently materialized on the ground for sake of, at least, slowing down the trend of pollution as an interim measure in synchronizing with the gradual scale-up of decentralized sanitation. In the meanwhile, this measure gives some vital breathing space to MWI until the arrival of sanitation service to the target area.

Table 11 The application scenarios of reuse in irrigation and their contribution to climate change adaptation and mitigation

| The reuse Scenarios | The purpose of irrigation scenarios | The anticipated impact contributing to climate change adaptation and mitigation |
|---|---|---|
| A | Dissipation/ wasting of raw wastewater from cesspits in the area unserved with sewer network | • Reduce pollution to environment<br>• Improve hygiene condition<br>• Support protection of water resources from pollution<br>• Reduce the cost burden on empty of the cesspits |
| B | Afforestation activities | • Strengthen the impact of Scenario A<br>• Increase green areas/ maintain biodiversity of flora and fauna<br>• Contribute to curbing soil erosion |
| C | Production of income-generating crops | • Strengthen the impact of Scenario A and B<br>• Generate income for livelihood<br>• Increase net profit by reducing fertilizers<br>• Enhance food security |
| D | Replacement of freshwater with treated wastewater in irrigation (at least partially) | • Strengthen the impact of Scenario A, B and C<br>• Sustain agriculture in target area<br>• Free up freshwater for other uses<br>• Maximize the adaptation to water scarcity |

# 5. Management of Surplus Water

It goes without saying that the irrigation demand is mainly a function of the following two variable factors:

i. The reference evapotranspiration (ETo) which varies spatially and over time all year round.
ii. The crop coefficient (Kc) which varies in value from crop to another and even during different growth stages of the same crop itself.

The crop water requirements reach its peak during June-July whereas these requirements go down during December – January. In general, the ETo values under the Jordanian context fall in the range of around 2 mm/day in coldest months to around 7 mm/day during summer months. That's why the irrigation demands for any crop show a noticeable deviation over time during the year. Because the treated effluent is generated continuously in mostly steady daily flow all year round whereas the irrigation demand is calculated based on the peak demands, it is unsurprising to expect surplus water, in excess of irrigation demand, during the months witnessing lower irrigation demands than those required during the peak demand months.

As the ETo is unalterable, the surplus water could be managed through the following options:

i. Discharge of the surplus water to wadis
ii. Use of adequate storage structure capable of storing the surplus water during the months of low-irrigation demand for sake of providing irrigation water during peak months.
iii. Use of the surplus water in supplementary irrigation for a combination of crops other than those cultivated as major crops in the reuse system.

## 5.1 Discharge of the surplus water to Wadis

In general, the discharge of the surplus water to a natural drainage system like a wadi is the most feasible and the easiest option in managing the treated effluent or the surplus. For the decentralized wastewater management in particular, the availability of the natural wadi for transport of the surplus water seems to be inevitable and thus it should be a key criterion in prioritizing which of residential communities are to be first served by sewer decentralized sanitation.

The wastewater reuse in irrigation entails a compulsorily dual use of the treated effluent which includes the irrigation use and the discharge to wadi alike at the same time. Accordingly, the quality of treated wastewater generated from the treatment plant is supposed to be compliant with the strictest standard that is applicable to the two standards for both uses. In practice, according to the JS 893/2006, the standard for discharge of treated effluent to wadi is usually the strictest standard. Thus, it is the basis used in the design of treatment plant and the so basis used in verification of the performance of treatment plant. However, when the quality of the surplus water doesn't comply with the standard applicable to discharge of the effluent to wadi and still comply with the irrigation use standard, then there still an option to keep the compliance with the standard. For this case, the land stripe that goes alongside the bed of the wadi can be planted with vigorous evergreen forest trees characterized by good adaptation to drought and high potential for water consumption as well. Among these trees species, the eucalyptus trees are famous in having these both features.

### 5.2 Storage of the surplus water

In certain spatial settings, when storage of the surplus water might be possible, the treated effluent could be used more efficiently without wasting any fraction of the water. This option gives the operator more flexibility for scheduling irrigation water supply over the year in harmony with the changing irrigation demands. In so doing, the generated treated wastewater can be fully used, and the maximum irrigable area can be determined based on the annual water budget rather than the daily flow of the effluent. In spite of the advantages of the surplus water storage, the regulatory and operational entities should be aware of the environmental consequences of this option. On the top of these concerns comes the nuisance that will certainly be arising from the smell due to stagnation of the stored water and the ensuing propagation of mosquitoes. Not to mention the difficulty in finding an adequate space for construction of the facility in addition to the high cost that may be incurred.

### 5.3 Use of the surplus water in complementary irrigation for additional crops

The use of the surplus water in irrigating additional areas cultivated with rain-fed crops seems to be the sound option for management of the surplus water. The total area that is cultivable with the major crop, i.e. alfalfa, in the reuse system is logically determined based on the peak irrigation demand during June-July. The daily surplus water is expected to start available after the peak months and continue in flowing until the peak irrigation months come again. During December - January the required irrigation water reach the lowest level of demands. Barring the peak irrigation months, the surplus water generated all the time during the rest months can be managed through its use in supplementary irrigation of certain rain-fed crops. For instance, a proper combination of the following cultivation scenarios could be the perfectly feasible options for complementary irrigation provided that adequate lands for reuse practice are available on the site or close to generation point of the treated wastewater.

#### 5.3.1.1 An existing rain-fed olive trees orchard

Given the fact that the rain-fed olive trees are abound in most of the target areas, the surplus water could be used for supplementary irrigation of those orchards. The rain-fed olive trees are characterized by vigorous root system extending deeply in the soil. At such depth, the soil has the ability to store much water for later use during non-rainy months. The advantages of this option are:

- The complementary irrigations provide the olive trees with the additional water necessary for better productivity
- The complementary irrigations will take place only when the surplus water is available and will not come at the expense of the major crops during its

peak irrigation demand.

- The surplus water will be no longer used during olive harvesting time which usually takes place during November – December. This would free up the surplus water, at least during this time, for irrigating other winter field-crops whose cultivation coincides with the olive harvesting process while the surplus water is at its peak.

#### 5.3.1.2 Cultivation of winter field-crops

The winter filed-crops, like wheat and barley, are actually rain-fed and thus prosper in the areas receiving more than 250 ml rainfall. The rest of the surplus water, in excess of supplementary irrigation of olive orchards, could then be used further in supplementary irrigation of these field-crops. The advantage of this option lies in the fact that these crops are sown during November and early December and are harvested in May. The seeds of both crops can also be sown earlier in October provided that being under irrigation. Moreover, these crops are highly tolerant to salinity and characterized by its high uptake of nutrients. That's why they are commonly used in soil reclamation to extract the excess salts in the soil.

When a flat area of soil characterized by sufficient holding capacity is available, the cultivation of these winter field-crops will be an ideal option for reuse practice with a view to managing the surplus water. Another particular advantage of these crops is that their cultivation timing coincides with the peak of the surplus water availability. All the aforementioned reasons make these crops suitable for management of the surplus water amount.

#### 5.3.1.3 Cultivation of forest trees

The surplus water could also be dissipated through its use in irrigation of forest trees either on site of the treated wastewater generation in the area around treatment plant or in the nearby sites. To maximize the benefit from water reuse, the sites which are usually prone to high soil erosion could be the favourable choices. The species of trees should have certain characteristics. It goes without saying, these trees should be evergreen perennial characterized by fast growing, vigorous root system, high consumption of water under water availability and high adaptive potential to drought.

In addition to the above-mentioned potential sites, as mentioned before, the land stripe extending on both sides of the bed of wadi, which is used for water discharge, could be a good option for cultivation of forest trees. In so doing, the following benefits can be gained from this scenario:

- The surplus water will be dissipated productively in creating additional green spaces.
- The dissipation of the surplus water at certain distance along the wadi is a good measure to offset the substandard quality of treated wastewater when its quality doesn't comply fully with the standard for the discharge to wadi.
- The green spaces around the treatment plant facility would shape a better perception among the communities and thereby improving their acceptance to decentralized wastewater management approach.

- The green coverage would be effective in reducing the soil erosion particularly in the Jordanian setting which is subjected to high erosion due to the hilly topography.

## 6. Wastewater Reuse and Climate Change

Like other regional countries, Jordan will further be under the impact of all burdens imposed by the climate change. According to Ministry of Water and Irrigation records, the precipitation has decreased by 20% over the last eight decades. The climate change manifests itself in unlimited adverse implications on environment, water resources, standard of life and even health condition of people. To cope with the shortage of water for sake of keeping up sustainable development, there is a dire need for adopting a package of adaptive measures to be applied together and in parallel in order to bring in the desired change in face of climate change.

The climate change constitutes a cosmopolitan challenge that should jointly be addressed by all signatory states to Paris Agreement. Accordingly, like all countries, Jordan, on one hand, has to contribute its share of the global obligation towards reducing CO2 emissions and this necessitates adoption of mitigation measures. According to Jordan's Third Communication Report on Climate Change submitted to the United Nations Framework Convention on Climate Change (UNFCCC), the CO2 equivalent emissions of Jordan in 2030 will be around 51.028 million tons CO2-eq and thus the National Determined Contribution (NDCs) targets will be 1.5% unconditional and 12.5% conditional reductions in CO2-eq, these percent reductions equal to 0.77 million ton CO2-eq and 6.38 million ton CO2-eq respectively. The total NDC target for CO2-eq emission reduction will be around 7.1 million tons CO2-eq. On the other hand, Jordan has no option but to adapt well to adverse impacts driven by climate change through the implementation of adaptation measures. The commitment to implementing adaptation projects opens the door for Jordan to benefit from the international funds offered by different global funds trusts, like the Global Environment Facility (GEF) Trust Fund, Special Climate Fund (SCCF), Least Developed Countries Fund (LDCF) and Adaptation Fund (AF).

In this section, the concept paper is focusing on highlighting some positive impacts of reuse for climate change adaptation, which can obviously be traced and realized.

### 6.1 Water Reuse as an Adaptive Measure

In light of the ever-escalating increase on water demand, it has become unequivocal more than ever that the scale up of wastewater reuse for water-scarce countries, like Jordan, is an inevitable choice; mainly for coping with water scarcity and then for adaptation to climate change as well. Given to its cross-cutting nature in terms of impact, the reuse contribution to climate change adaptation would be not confined to coping with water scarcity; its multi-dimensional effects and the ensuing positive impacts obviously extend to affect all different aspects of life and all development sectors. The reuse has two dimensional contributions in response to climate change: adaptive dimension and mitigation.

### 6.1.1 Synergizing efficiency of wastewater management for improvement of hygienic environment

By complementing wastewater treatment's role in disposal of wastewater into the environment safely, the reuse contributes in synergizing the hygiene conditions of communities and thereby improving the health environment, an objective that would not be achieved once the wastewater is collected and treated. In this sense, the treated wastewater of substandard quality would be posing a risk to the people, the children in particular, who are living in places close to the effluent. Therefore, this effluent, no matter what its quality, should be reused to reduce the potential exposure of people to this unsafe water. When quality of the effluent is substandard, as is in some treatment plants in Jordan, this makes the reuse practice even more important to be relied on for minimizing the risk. The magnitude of reuse contribution in this regard should be weighed differently from one setting to another; depending on the water availability for domestic use. For a water-scarce country like Jordan in particular, where the daily per capita of clean water is less than 80 litre and still even likely to decline, the improvement of sanitation services would make up for the extreme shortage of water - especially, when realizing that the transmission of the enteric diseases is projected to intensify with poor hygiene and sanitation.

### 6.1.2 Protection of the existing water resources

In parallel with exerting the continuous efforts to develop water resources, it is equally essential to keep up the existing water resources intact and protected from pollution. Given the fact that the domestic wastewater, in the areas still unserved with public sewer network, is usually managed through cesspits, the raw wastewater continues in percolation and infiltration into groundwater. The outflows of cesspits pose also a high risk to surface water. The protection of water resources should therefore occupy the top priority of any interventions for many reasons. On one hand, any remedial actions for pollution of water resources, if happened, would be more costly and even a quick resilience would not be guaranteed. Not to mention that any serious pollution would confound operator and cause cut in water supply for some time. On the other hand, the domestic wastewater - the key source of contamination - will anyhow be in need of collection and treatment in order to be eventually utilized in reducing the pressure on water resources through the reuse. In this regard, the collection and treatment of wastewater alone never obviate the necessity for complete dissipation of treated effluent in the environment. The complementary role of reuse in the wastewater management enhances protection of the water resources from the pollutants contained in the treated effluent; these pollutants remain risky, no matter what low their concentrations.

### 6.1.3 Coping with growing water needs

In light of sever water scarcity aggravated by climate change in Jordan; there is a dire need to develop the water resources to keep up the wheel of sustainable development. The collection of wastewater helps the Jordanian government in its quest to attain this ambitious task. It is unsurprising that the Jordan Water Strategy considers the wastewater as a renewable ever-increasing water resource that can be collected, treated and reused. The treated wastewater has many advantages which make it a reliable water resource to cope well with the ever-increasing demand by all sectors particularly the irrigation sector – the biggest consumer of water; it is certainly a renewable and increasing water resource. The reuse of treated wastewater gives Jordan a high resilience to cope with water scarcity and adapt to climate change through two ways. On one hand, the reuse is a supportive avenue for bridging the gap between the water supply and demand. On the other hand, it supports the reallocation of water resources among all sectors based on the priorities. Unlike any other sectors, the irrigation sector, where its needs of water can be fulfilled with a water of less quality, the treated wastewater use adds a great deal of strength for sustainability of agriculture. This is why the treated wastewater use makes the Jordan Valley almost the only agricultural area being the most sustainable and less affected by the growing water shortage. Meanwhile, there is also a potential collection of additional no less than 90 MCM of wastewater currently still untapped through decentralized sanitation.

#### 6.1.4 Strengthening food security

The agriculture in the low-income developing countries in particular, is the lifeline of economy. This is why the food security in these countries is largely revolving around sustainability of agriculture. The dependence of agriculture on water supply makes it the most affected by water scarcity and climate change. This fact explains the firm link between water reuse and food security especially in water-scarce countries where freshwater is reallocated for other sectors. Under such circumstances, the agriculture would not be sustained unless the treated wastewater was used in irrigation as alternative water. On one hand, the use of treated wastewater would support the free-up of freshwater for drinking. On the other hand, the treated wastewater serves as alternative irrigation water necessary for sustainability of agriculture. Not to mention, the very crucial role of agriculture sustainability in protecting the precious cultivable soil from the degradation and erosion.

According to the 1996 World Food Summit, food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life. From this definition, the food security entails four main dimensions which can be identified. The Table 12 shows these dimensions and how water reuse contributes into each. The significance of this contribution depends on the socio-economic situation of any communities. For the low-income countries, especially in these whose per capita income is less than two dollars a day, the water reuse even at very small-scale application presents a highly positive impact on the people' life whose livelihoods are largely dependent on reuse of wastewater for food production.

Table 12 Contribution of water reuse to various dimensions of food security

| Food security dimension | Contribution of water reuse |
|---|---|
| **1. Food availability** | • Food production is increased |
| **2. Access to food** | • The access to food is improved |
| **a. Physical access** | • Local food production and food self-sufficiency is enhanced |
| **b. Economic access** | • Income for livelihood is generated<br>• Cost of food production is minimized<br>• Farmers' net profit – due to low water price and nutrients in water - is increased<br>• Soaring price of food through more food supply is curbed |
| **3. Maximum utilization of food** | • Hygienic conditions of communities is improved<br>• Clean freshwater for domestic use is freed up |
| **4. Stability of all dimensions** | • Sustainability of agriculture is strengthened<br>• Safe disposal of treated wastewater is sustained<br>• Pressure on freshwater resources is reduced |

### 6.1.5 Remedial measure for soil erosion

The soil is naturally subject to continued erosions caused mainly by water and wind. The erosion takes place at variable rates depending on many factors such as steepness levels, the intensity and frequency of rainfall, the speed and direction of winds and the extent of vegetation availability in the area. Unlike the wind-driven erosion which mostly occurs in flat areas, water-driven soil erosion intensify in the rough areas characterized by hilly topography and particularly where stormy rains are common as is the case of arid and semi-arid regions. The wind-eroded soil could be transported into anywhere depending on direction and speed of wind, while the water carries the eroded soil from high places to lower places by gravitational force. When the rain falling rate exceeding the soil infiltration rate, the runoffs is expected to occur and continue in flowing until it ends up in the water bodies and dams - where the eroded soil loads are deposited. The sediments increase the turbidity of water for a while and hence confound the operator and may cause temporary cut in water supply. The continued accumulations of sediments at high rates over the long time may significantly reduce the storage capacity of dams. It deserves mentioning here that the eroded fraction of soil is usually coming from the top soil layer which is by far the richest in phosphorus, a key nutrient responsible for eutrophication phenomenon in water bodies. Besides engineering measures, the vegetation cover plays a crucial role in curbing the rates of soil erosion and here comes the significance of treated wastewater exploitation in increasing the vegetative cover. On the contrary to bare soil, the vegetated soil is mostly protected from erosion; the following mechanisms explain how the vegetation is working:

The vegetative cover serves as cushion that absorbs some of the kinetic energy of the falling water drops and hence prevents destruction of the surface soil structure, the first step in initiating water runoff.

- The plants' roots extending in all directions inside the soil serve as supportive network that hold the soil firmly.
- The vegetation cover stabilizes the soil through dissipation of excessive moisture by evapotranspiration.
- The vegetation improves the infiltration and the drainage characteristics of the soil
- The vegetation cover helps slow down the velocity of the flowing runoffs and thus helps soil particles in water to settle down.

The potential for increasing vegetation by utilizing treated wastewater as alternative irrigation water proves the significant of the massive application of wastewater reuse in combating soil erosion and consequently in protection of surface water bodies from the eroded sediments loaded into water bodies.

## 6.2 Water Reuse as a Mitigation Measure

The climate change mitigation measures comprise reduction of CO2 emissions directly or indirectly. The direct reduction could be achieved by reducing fertilizers production and application of most efficient production processes with minimum releasing emissions while the indirect reduction of emission could be attained by reducing fertilizers application through exploiting nutrient in irrigation water as well as sequestration of atmospheric carbon dioxide in biomass of plants. The contribution of reuse lies in the indirect reduction of CO2 emissions as follows:

### 6.2.1 Reduction of fertilizers application

It goes without saying that the fertilizer industry is considered one of the inventories responsible for carbon dioxide emissions. According to the Intergovernmental Panel on Climate Change (IPCC) reports, the fertilizers, in its life cycle, are responsible for around 1.2 % of the total emissions worldwide.

Table 13 Nutrients content (NPK) of waters used for irrigation in the Jordan Valley

| Water source | Average values (mg/l) for NPK | | |
|---|---|---|---|
| | N | P | K |
| **Freshwater from KAC-north** | 1.4 | 0.23 | 10.5 |
| **"Blended treated wastewater" from KAC-south** | 18.4 | 3.1 | 26 |

Source: (Guidelines for reclaimed water irrigation in the Jordan Valley, 2006) based on the test results from JVA and RSS Labs (2003-2005)

The Jordanian farmers resort to apply synthetic fertilizers in their farms with a view to enhancing its productivity and thereby increasing their net profit. Once dissolved in water, the synthetic fertilizer breaks down to ions, similar in the form, to those nutrients' contained in the treated wastewater. Irrespective of its source, as long as the nutrient is available in an absorbable form, it can be easily assimilated by plants. Accordingly, the exploitation of nutrients contained in the treated wastewater would either drastically reduce or even obviate the need for synthetic fertilizers application. In so doing, farmers can save considerable amounts of these fertilizers whose production is inherently coupled with a release of CO2 emission. In the strictest sense, the reuse serves as a mitigation measure to climate change. To shed the light of the importance of nutrients content in wastewater from agronomic point of view, the two waters used in irrigation in the Jordan Valley had been analyzed. The water analysis shows significant amount of nutrients contained in the "blended treated wastewater" compared with freshwater. The Table 13 presents nutrients content in these waters. The calculations of the GIZ Project "Use of Marginal Water", confirmed by on-field demo sites, showed that nutrients in the "blended treated wastewater" provide no less than (20 – 40) % of the actual crops needs.

With a view to verifying the difference between good agriculture practices (GAP) and farmer's traditional practices with regard to irrigation and fertilization, many on-farm demonstrations trials on various crops were implemented over a period of three successive years by GIZ team in cooperation with farmers. The results revealed significant differences between the farmer's practices and the GAP – see the Table 14.

At the time of demo site implementation, the traditional practices costed farmer more than JD 150 per 0.1 hectare in comparison to JD 62.8 for the GAP; the P and K fertilizers are expensive. As shown in the table, farmer's practices lead to overuse of P and K by three and seven times more, respectively.

To stand on more concrete facts on the contribution of fertilizers production in the global warming gas emission, the amount of CO2 emission associated with production of some commonly used fertilizers and the related energy consumption at factory-gate are shown in the Table 15.

Table 14 Comparison between farmer's conventional practices and good agricultural practices (GAP) for cucumber greenhouse cultivation

| Parameter | | Conventional practices | GAP | Difference |
|---|---|---|---|---|
| Appearance | | Similar | | 0 |
| Yield (ton/du) | | 14.8 | 15.3 | + 0.5 |
| Fertilizers cost (JD) | | 155.5 | 62.8 | - 92.7 |
| Fertilizers Quantities (Kg/du) | N | 57.4 | 56.6 | - 0.8 |
| | P | 13.4 | 6.3 | - 7.1 |
| | K | 40.4 | 5.6 | - 34.8 |
| Irrigation ($m^3$/du) | | 510 | 495 | - 15 |

Source: (Guidelines for reclaimed water irrigation in the Jordan Valley, 2006)

The CO2 emissions amount associated with fertilizers production varies according to the fertilizer-producing regions and this obviously depends on many factors including the manufacturing processes, the energy sources, the raw materials used, and the efficiency in reducing the CO2 emission coupled with production process. The data in the Table 15 represent the CO2 emissions coupled with fertilizer production in the main producing regions besides the energy consumed in production of common fertilizers in Europe where highly efficient production processes are applied. As the data in the table is expressed in terms of fertilizer product while fertilizers contents dissolved in treated wastewater are in form of nutrients, the former values are supposed to be expressed in terms of nutrients content in order to make the comparison possible. Accordingly, the relevant values of fertilizer have been converted from product's basis into nutrients' elementary forms - see the Table 16. It deserve mentioning here that because any elementary nutrient could be available in various compound fertilizer products, which in turn differ in the CO2 emissions released during their production, the average CO2 emissions has been calculated for each nutrient with a view to unifying a benchmarking value for comparison purpose.

Table 15 Mineral fertilizer carbon footprint (CFP) reference values (2011) and energy consumption by fertilizer production in Europe

| Fertilizer product | Nutrient content | Fertilizer production-associated $CO_2$ emission (Kg $CO_2$-eq/Kg product) [1] | | | | Energy consumption by on-site fertilizer production in Europe (MJ/Kg product) [2] |
|---|---|---|---|---|---|---|
| | | Europe | Russia | USA | China | |
| **Ammonium nitrate** | 33.5% N | 1.18 | 2.85 | 2.52 | 3.47 | 14.02 |
| **Calcium ammonium nitrate** | 27% N | 1.00 | 2.35 | 2.08 | 2.86 | 11.78 |
| **Ammonium nitrosulphate** | 26% N, 14% S | 0.82 | 1.58 | 1.44 | 2.22 | 10.61 |
| **Calcium nitrate** | 15.5% N | 0.67 | 2.03 | 1.76 | 2.20 | 7.23 |
| **Ammonium sulphate** | 21% N, 24% S | 0.57 | 0.71 | 0.69 | 1.36 | 8.07 |
| **Urea** | 46% N | 0.89 | 1.18 | 1.18 | 2.51 | 23.45 |
| **Urea ammonium nitrate** | 30% N | 0.81 | 1.65 | 1.50 | 2.37 | 13.84 |
| **Triple superphosphate** | 48% P2O5 | 0.18 | 0.25 | 0.19 | 0.26 | 0.18 |
| **Muriate of potash** | 60% K2O | 0.23 | 0.23 | 0.23 | 0.23 | 3.00 |

Source: 1 Carbon footprint analysis of mineral fertilizer production in Europe and other world regions, 2 Fertilizers Europe

From the data shown in the Table 16, the amount of CO2 emission released by fertilizer production, in the form of N, P, and K, is around 6.30 (in average), 1.05, and 0.46 Kg CO2-eq per Kg of the nutrient respectively. To estimate the potential reduction of CO2 emission attainable from the potential use of nutrients contained in the Jordanian treated wastewater, the average allowable limits of total nitrogen and phosphorus, imposed by the JS 893/2006 to be in the effluent for irrigation use, have been assumed. As for potassium, because its limit is completely omitted from the standard, it has been assumed to be 30 mg/l. So, the NPK limits used in the calculation are 70 mg/l as N, 10 mg/l as P and 30 mg/l as K.

Table 16 Adapted carbon footprint reference values of mineral fertilizer production and the related energy consumption

| Fertilizer product | Nutrient content (%) | Nutrient content (Kg nutrient/Kg product) | Average fertilizer production-associated $CO_2$ emissions | | Energy consumption of fertilizer production in Europe | |
|---|---|---|---|---|---|---|
| | | | **(Kg $CO_2$-eq/ Kg product)** | **(Kg $CO_2$-eq/ Kg nutrient)** | **(MJ/Kg product)** | **(MJ/Kg nutrient)** |
| **Ammonium nitrate** | 33.5% N | 0.335 N | 2.51 | 7.49 | 14.02 | 41.85 |
| **Calcium ammonium nitrate** | 27% | 0.27 N | 2.07 | 7.67 | 11.78 | 43.63 |
| **Ammonium nitrosulphate** | 26% N, 14% S | 0.26 N | 1.52 | 5.85 | 10.61 | 40.81 |
| **Calcium nitrate** | 15.5% N | 0.155 N | 1.67 | 10.77 | 7.23 | 46.65 |
| **Ammonium sulphate** | 21% N, 24% S | 0.21 N | 0.83 | 3.95 | 8.07 | 38.43 |
| **Urea** | 46% N | 0.46 N | 1.44 | 3.13 | 23.45 | 50.98 |
| **Urea ammonium nitrate** | 30% N | 0.30 N | 1.58 | 5.27 | 13.84 | 46.13 |
| The average values for the N nutrient | | | | **6.30** | | **44.07** |
| **Triple superphosphate** | 48% $P_2O_5$ | (0.437 X 0.48) = 0.21 P | 0.22 | 1.05 | 0.18 | 0.86 |
| **Muriate of potash** | 60% $K_2O$ | (0.830 X 0.60) = 0.498 k | 0.23 | 0.46 | 3.00 | 6.02 |

Based on this reasonable assumption, the amounts of nutrients contained in each cubic meter of an effluent of treated wastewater will be 0.07 Kg, 0.01 Kg, and 0.03 Kg of N, P, and K respectively. By exploiting the nutrients amounts in each 100 m3 of the Jordanian treated wastewater, as alternative to synthetic fertilizers, the potential reduction in the corresponding CO2-eq emission from synthetic fertilizers production will be around 46.53 Kg. The table (11) shows the potential annual reductions in CO2 emission from synthetic fertilizers production due to exploitation of nutrients amounts in the water for different scenarios of treated wastewater collection.

In comparison with the Jordan's unconditional NDCs (0.77 million metric ton CO2-eq reduction), the conditional NDCs (6.38 million metric ton CO2-eq reduction) and the total NDCs (7.1 million metric ton CO2-eq reduction) by the year 2030, the potential reductions in CO2-eq which could be attained from the full exploitation of nutrients in the untapped treated wastewater amount so far would constitutes 5.45%, 0.66% and 0.59% of these NDCs CO2-eq reductions respectively. Based on the energy demands for fertilizers production which are indicated in the Table 17, the assumed "latent" energy of the nutrients contents in the treated wastewater, which are still untapped, is equivalent to around 82 million KWh – the same energy amount required for production of the corresponding amount of nutrients in form of synthetic fertilizers under the manufacturing settings in Europe.

Table 17 The potential annual reductions in CO2 emissions associated with fertilizers production under various scenarios of exploiting nutrients in treated wastewater

| The potential scenarios for untapped wastewater collection (% of the total available, 90.2 MCM) | The potential collected amount of treated wastewater (MCM) | NPK amounts in treated wastewater (Kg) | | | The potential annual reductions in $CO_2$ emission amount when exploiting nutrients in water (Kg) | The annual energy needed for production of the same amount of nutrient (MJ) in European countries |
|---|---|---|---|---|---|---|
| | | N | P | K | | |
| **10%** | 9.02 | 631,400 | 90,200 | 270,600 | 4,197,006 | 29,532,382 |
| **25%** | 22.55 | 1,578,500 | 225,500 | 676,500 | 10,492,515 | 73,830,955 |
| **50%** | 45.10 | 3,157,000 | 451,000 | 1,353,000 | 20,985,030 | 147,661,910 |
| **75%** | 67.65 | 4,735,500 | 676,500 | 2,029,500 | 31,477,545 | 221,492,865 |
| **100%** | 90.20 | 6,314,000 | 902,000 | 2,706,000 | 41,970,060 | 295,323,820 |

It deserves mentioning here that the concentration of nutrients in any treated wastewater is largely dependent on the design/ performance of treatment plant, the treatment technologies in use, and strength of raw wastewater. As the nutrients content varies among effluents of different wastewater treatment plants; a more precise calculation of the actual $CO_2$ emission reduction has to be worked out based on the actual nutrients amount contained in the respective effluent. In addition, it should be borne in mind that the potential reduction in $CO_2$ emission amount, calculated in this concept paper as a result of exploiting the nutrients contained in treated wastewater, comprises only the $CO_2$ fraction emitted during the process of fertilizers production and hence doesn't take into account any other amount of the $CO_2$ emitted during transportation of fertilizers from factory gate in producing countries to farms in consuming countries. On considering the $CO_2$ emissions stemming from transporting fertilizers, the potential reduction of $CO_2$ emissions should certainly be higher.

### 6.2.2 Sequestration of atmospheric carbon dioxide

The atmospheric $CO^2$ is sequestered in plant biomass through photosynthesis, a bioprocess by which the carbon of the CO2 is assimilated by plant biomass to produce the simple monosaccharide sugar, glucose, which serves as the raw molecule for producing the energy (ATP) necessary for plant through respiration process. The glucose itself serves afterward as a precursor for synthesis of all micro and macro organic molecules which vary in its complexity from simple carbohydrates to more complex structural carbohydrate like cellulose. That's why the carbon constitutes the backbone of all these bioorganic molecules with no any exception. In nature, the carbon cycle is supposed to be in equilibrium; the rate at which carbon is released equal the amount being sequestered out of the atmosphere. But owing to anthropogenic activities, especially after the industrial revolution in the eighteenth century, the carbon cycle became out of this equilibrium. The continuous deforestation activities have aggravated severity of this dilemma. The wastewater reuse for irrigation plays a crucial role in mitigating $CO_2$ emissions through sequestering the $CO_2$ in plant's tissue; the carbon constitutes around 50% of the dry mass of trees. When wood from these trees is used in various wood products, the carbon is stored for the lifetime of that product. The carbon stored in wood is only released back to the atmosphere when the wood product is burnt or decays.

To recognize the significance of the $CO_2$ sequestration, it should be known that the Australian forests and wood products, for instance, actually sequester approximately 57 million metric tons of $CO_2$ which in turns offsets around 10% of the total greenhouse gases emitted in Australia. The eucalyptus tree, which is a dominant native plant in Australia and very common tree worldwide, is characterized by high adaptation to all environments, fast growing, vigorous root and high-water consumption. That's why this tree has been highly recommended in this concept paper to be used in dissipating wastewater; a tree of eucalyptus of height 8 meters with a diameter of 40 cm is capable enough of sequestering around one metric ton of $CO_2$.

As for the alfalfa, which is widely cultivated in the areas around centralized wastewater treatment plants in Jordan and is recommended in this concept paper to serve as the primary crop under decentralized wastewater management, this forage crop is a desirable sequestration crop for many reasons. On one hand, it is a perennial crop that lasts for 5-7 years generating high income and harvested 8-9 times in a year. On the other hand, the extensive root system of this perennial is well suited to store carbon and thereby enhancing the soil organic carbon.

According to an on-field research conducted in Canada, the results showed that under the continuous alfalfa rotation had an annual sequestration rate of around 1.9 metric ton $CO_2$-eq per hectare within a 34 cm soil depth. Another on-field research conducted in China showed a substantial increase in the soil organic carbon (SOC) within a 2 m soil depth estimated at 24.1 metric tons carbon per hectare over the 7-year growth period of alfalfa, while the SOC decreased by 4.2 metric carbon per hectare in the bare soil. The sequestered carbon amount under alfalfa vegetation is equivalent to 88.5 metric tons $CO_2$-eq per hectare, i.e. an annual 12.64 metric tons CO2-eq per hectare.

However, to determine the potential sequestration for various crops under Jordanian conditions, there is a need to conduct similar research by academic and research institutions.

# 7. Challenges of Wastewater Reuse in the Context of Decentralized Sanitation

Despite of the apparent advantages of wastewater reuse, certain challenges associated with this reuse are still to be addressed. The challenges at different levels can be summarized as follows:

## 7.1 The Environmental and Health Concerns

The wastewater reuse is normally associated with some risks pertaining to the relatively low quality of water. Among these risks are the water-borne pathogens, heavy metals and salinity of water. In this regard, before presenting these risks, the decision makers should be aware of the following facts:

i. The identity and severity/ weight of risks vary significantly under different contexts. For instance, and unlimited to, the risk of groundwater pollution under the shallow groundwater settings, as is the case in the European countries, sounds extremely severer than the very risk under the deep groundwater settings as is the case in Jordan. That's why an imported assessment of risks is usually misleading and thus the validity of this assessment to the local context should not be taken as an indisputable matter of fact.
ii. The risks associated with wastewater reuse should be weighted in comparison with the standing risks that would stem from either the lack of proper management of wastewater or the ban on reuse of wastewater on pretext of being risky. In this sense, the risks should be assessed qualitatively and quantitatively according to their potential damages, the consequent implications, the potentials for their management under the local condition, and the ensuing cost. Based on the assessment, these risks are then rated and prioritized with a view to deciding in favour of the least risky scenario under the Jordanian context besides proposing effective measures for minimizing risks.
iii. The intention of risk assessment is NOT to identify the risks with a view to avoiding them BUT to prioritizing the risks in order for the decision makers to decide on the least severe risks, and to enforce the proposed effective measures that make the accepted risks manageable. In this life, there is no such thing as "zero risk". When deciding not to accept a risk, other risk of another kind will always be there and must be dealt with. For instance, the use of treated wastewater in irrigation as well as the discharge of the effluent has their respective risks. This raises the question of which option of the two uses is safer so as to be adopted. Here comes the importance of the risk assessment to answer for which scenario of the two the risks are less severe and in which scenario the risks can be more manageable efficiently and cost-effectively and thus more accepted.

iv. The Jordanian experience in the direct wastewater reuse in the vicinities of wastewater treatment plants and the indirect reuse for the unrestricted irrigation in the Jordan Valley is supposed to be at least a preliminary guide for assessment of these risks under the local contexts.
v. The wastewater reuse in the context of decentralized wastewater management could be confined to the direct use of treated wastewater for restricted irrigation. In the strict sense, restricting reuse of wastewater on certain crops serves as a precautionary measure to minimize risk. That's why all the reuse applications proposed in this concept are exclusively applicable to the crops listed under the Class C in the standard 893/2006.
vi. On the other hand, there is no reliable tool for verifying the safety of the long-term use of treated wastewater in irrigation but the implementation of a comprehensive monitoring program for the water resources, the soil and the crops irrigated with treated wastewater.

#### 7.1.1 Water-Borne Pathogens

Based on the lessons learnt from the Jordanian long experience in wastewater reuse, the health concerns on the water-borne pathogens should no longer be extremely exaggerated as long as the implementation of proper agricultural good practices is enforced at farm level. Especially, the strictness of the standard 893/2006 to the maximum allowable pathogens' counts in the treated wastewater as well as the restrictions on irrigation uses are supposed to be enough to dissipate the health concerns. Moreover, the 2006-WHO Guidelines allow the use of raw wastewater for unrestricted irrigation provided that adequately effective measures for pathogen reduction are available in place. Accordingly, as long as the use of raw wastewater is allowed for unrestricted cultivation, there is no sense to be more conservative on the use of a treated wastewater for restricted irrigation. At the end, the wastewater treatment plant is only one of these measures and hence the full reliance on this measure alone could narrow the space for management of the risks emerging from any deterioration in quality of the treated effluent that could take place in any treatment plants for any unexpected reasons.

Therefore, the focus should be placed on raising the awareness of farmers regarding the good agricultural practices and the effective measures whose implementation should be respected by farmers at their fields. Then, it is the responsibility of the regulatory and operational entities to verify that farmers are fully committed to implementing these measures and practices in their farms.

#### 7.1.2 Heavy Metals

It goes without saying that the industrial wastewater constitutes the largest source of heavy metals. Although households may also contribute to the addition of heavy metals to domestic wastewater, it would be a fallacy to assume unsuitability of the municipal treated wastewater for irrigation as an irrefutable fact. All heavy metals are naturally present in the environment in trace amounts and could be ingested with food, water and air. The heavy metals include some metals which are essential micronutrients for plant like manganese and zinc. On the other hand, cobalt (Co) is a core element in the structure of vitamin-B12 (cobalamin) and thus its deficiency in the soil affect the vitamin B12 levels in the sources that provide human with this vitamin, i.e. the animal products like livestock meat.

Soil ecosystems and irrigation water could be contaminated with heavy metals through various anthropogenic activities, e.g. sewage sludge, unrestricted mining, industrial and automotive emissions and extensive use of agrochemicals and synthetic fertilizers. For instance, the primary source of zinc in the soil is the weathering rocks while the cadmium present as impurities in synthetic fertilizers.

These heavy metals are classified into four groups based on certain criteria which include (i) the retention in soil, (ii) translocation in plants, (iii) phytotoxicity and (vi) potential risk to the food chain. The Table 18.

show the four different groups of heavy metals based on the aforementioned criteria.

Table 18 Metal bio-availability grouping

| Group | Metal | Soil adsorption | Phytotoxicity | Food chain risk |
|---|---|---|---|---|
| 1st | 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 |
| 2nd | As, Hg, Pb | Strongly absorbed by soil colloids | Plant roots may absorb them but do not transport them to the shoots; generally, not phytotoxic except at very high concentrations | Pose minimal risks to human food chain |
| 3rd | B, Cu, Mn, Mo, Ni, Zn | Less strongly absorbed by soil than the 1st and 2nd groups | 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 |
| 4th | 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 through the soil-plant-animal food chain |

Source: The National Plan for Risk Monitoring and Management System for the Use of Treated Wastewater in Irrigation

The metals concentrations at which plants show phytotoxicity depends on many factors including soil texture, soil characteristics, plant species, the bioavailable metal concentrations and the duration of contamination. For instance, different soils which have the same metal concentrations show remarkably differences in the metal uptake by plant and thus the potential for metal phytotocixity. On the other hand, leafy parts tend to accumulate heavy metals around 10 times more than what seeds or fruits do. Some metals like Pb and Zn compete with others like Co and thus reduce its uptake by plant. That's why variability in the metal's bioavailability due to many interrelated factors suggests that the total metal concentrations in the soil may not be appropriate indicator for phytotoxicity.

The monitoring programs which carried out on water quality by the Royal Scientific Society (RSS) have proved that the heavy metals in the Jordanian treated wastewater, even if any, are at undetectable levels. It makes sense that the results of monitoring programs come in consistent with the fact that Jordan is not an industrial country; the heavy metals is regarded a big concern in the industrialized countries not in non-industrial countries like Jordan. Not to mention that generally industrial activities are absent in the potential locations for decentralized wastewater management implementation. Moreover, on contrary to acidic soils in the European countries, the soils in Jordan are characterized by high alkalinity. The alkaline soils play a significant role in sequestering the heavy metals, if any, and thereby deterring their absorption by plants. However, all these preliminary facts cannot obviate the necessity for implementation of comprehensive monitoring for any wastewater-irrigated crops, which consumed by either human like olive or livestock like alfalfa, to verify their quality. In addition, a monitoring program should be implemented for all fields irrigated with wastewater to observe the accumulation trends of heavy metals in the soil over the long time.

For the worst scenario, if the treated wastewater was highly polluted with heavy metals, the use of the water in irrigating forest trees would be strongly advisable; for two reasons:

i. The forest trees could serve as good bio-accumulators for the heavy metals loaded into soil and above all,
ii. These irrigated forest trees have no destructive interference in the food chain.

In conclusion, the health concern related to the heavy metals should not be a reason for banning wastewater reuse especially this use is very restricted by the Jordanian standard. The selection of proper crops is very crucial measure. And the high adsorptive capacity of soil in Jordan serves as a precautionary measure for heavy metals, if any, in the treated wastewater. Even the high concentration of heavy metals in irrigation water should be adequate impetus for its use in afforestation; this use remains by far safer than the discharge of such effluent to wadis.

#### 7.1.3 Water Salinity

The salinity should be a concern from three perspectives; the directly adverse effects on the crops productivity, adverse impact of sodium on soil structure, and the long-term salinization of soil. In order to simplify the topic, there is no way but to recall the following facts:

1. The salinity is attributed to many sources which include the soil itself, the fertilizers used, the manure usually applied and the irrigation water of all kinds. Owing to the extremely wide variability in characteristics and the quality of each individual source, the salts content varies widely even in the source itself.
2. Different plants can tolerate different levels of salinity. The tolerance of a same plant even varies according to its variety and different stages of growth.

However, the plants have normally the mechanisms to adjust to the increased salinity up to certain levels before becoming gradually affected by further increase in salinity above these levels. To illustrate the effect of irrigation water salinity on crop's potential production, the salinity tolerances for some selected crops are given in Table 19.

Table 19 The salinity tolerances for selected crops and their yield potential at different irrigation water salinity

| Crops | Yield potential (%) at different irrigation water salinity (dS/m) | | | | |
|---|---|---|---|---|---|
| | 100% | 90% | 75% | 50% | 0% |
| Barley | 5.3 | 6.7 | 8.7 | 12 | 19 |
| Wheat | 4 | 4.9 | 6.3 | 8.7 | 13 |
| Date palm | 2.7 | 4.5 | 7.3 | 12 | 21 |
| Olive | 1.8 | 2.6 | 3.7 | 5.6 | 9 |
| Alfalfa | 1.3 | 2.2 | 3.6 | 5.9 | 10 |
| Peach | 1.1 | 1.5 | 1.9 | 2.7 | 4.3 |

3. Because the salinity is a function of many interrelated factors which are interacting collectively, it is difficult or even impossible to predict or assess exactly the effects of salinity in separate from these factors; many factors influence the plant's tolerance to salinity and the long-term build-up of this salinity in soil. This fact makes the salinity a manageable task in most cases and here comes the significance of implementing comprehensively good agricultural practices for salinity management. In the strict sense, the judgement on water suitability for irrigation only from its water salinity perspective will certainly lead to wrong judgement and hence unwise decisions and more conservative attitudes on wastewater reuse in light of the water salinity.
4. The salinity management is firmly linked to irrigation management. A good irrigation management plan entails applying sufficient water to meet, on one hand, the crop water demand for ideal growth of the crop and, on the other hand, the leaching requirement necessary for maintaining the accumulating salts in the root zone of soil within the accepted levels with no harm to the crop. Leaching can be done at each irrigation, each alternate irrigation or less frequently, or at even longer intervals, as necessary to keep salinity below the threshold above which yields may be unacceptably reduced
5. The soil drainage is the key factor that determines the trend of salts accumulation and the consequent salinity build-up in soil and most importantly the efficiency of leaching. Even when freshwater of high quality is used in the fields characterized by poor drainage, the salinity build-up is also expected to emerge. On the contrary, the use of saline water in the soils characterized by well drainage system, the salinity build-up can easily be avoided as long as proper leaching for soil is sufficiently practiced at farms.
6. Under drip irrigation system, water can flexibly be applied on a daily basis and at low application rate (4–8 litres per hour per emitter). The daily replenishment of the water depleted by the crop maintains the soil moisture at the field water holding capacity; the optimal status of water availability for the crop. Then, a slight increase of the water applied above the field capacity, will certainly enhance salts leaching.

7. Given to its high-quality water, rainfall in the target area has a crucial role in leaching salts below the root zone of crops and hence prevents accumulation of salts in the soil. It is often the most efficient leaching method particularly in cases of the fields irrigated more frequently, i.e. on a daily basis.
8. A particular concern is related to the sodium content in the soil and irrigation water. The significance of sodium comes from its destructive effect to the soil structure on the long term when sodium is the predominant ion in irrigation water. The destruction of soil structure by sodium results in very poor soil infiltration to water. But as the salinity of the Jordanian treated wastewater is around 2.4 dS/m and the SAR value is in the range of 6-9 as assumed in the Jordanian standard, the sodium destructive impact on the soil is unlikely to occur. From the aforementioned discussion, the following could be concluded:

    - It turns out clearly that the fields selected for practicing reuse of treated wastewater should have good drainage characteristics to avoid the long-term salinization of soil. The good drainage capacity of soil plays a crucial role in easing and improving the efficiency of leaching. That's why, management of the salinity's short-term effects on the crop is possible to attain in good-drainage soils.
    - The salinity of the Jordanian domestic treated wastewater is normally in the order of 2.4 dS/m. In comparison with the values of water salinity shown in the table, the domestic treated wastewater proves a very high suitability to be used for irrigating the income-generating crops like olive, alfalfa, barley and wheat.
    - In the context of decentralized wastewater management, the water irrigation is supposed to be applied on daily basis. Accordingly, there are no serious risks from the reuse of treated wastewater either on the crops or the soil. However, the following practices and measures should be practiced:

        a. As the nutrients required for the plants' proper growth are available in the treated wastewater and soil, restriction on use of fertilizers might be necessary to avoid the increase in the soil-water salinity. Alternatively, foliar application of micronutrients fertilizers can be used in specific cases.
        b. Additional water fraction, equivalent to 10-20% of the crop water requirements, is supposed to be applied regularly to the fields irrigated with treated wastewater, especially during the periods of low irrigation demands.
        c. The irrigations should be continued following the days of low precipitation at the beginning of rainfall season.
        d. Soil and crop monitoring are useful tools to verify the long-term trends and changes in soil salinity.

### 7.2 The Social Acceptance

The social acceptance is normally linked to wastewater management especially when it comes to treatment technologies and the proximity of treatment plants to residential communities. The public misperception of wastewater management has been shaped by the negative experiences which arise from the operation of the centralized wastewater treatment plants over long time, i.e. the smell and the consequent drop in prices of private lands in particular. So it is important here to identify clearly from which perspective the social acceptance would be a challenge. In this regard, there are two different groups; the community and the farmers who both have different interests and concerns. Based on the long experience in working closely with communities, it turns out that the social acceptance usually relates to the acceptance of communities for the decentralized sanitation approach itself. But when it comes to wastewater reuse, the conflict would arise as a challenge due to the competition among farmers on the water. It makes sense to expect such competition in light of the profitability and gains which can be achieved from use of the water in agricultural income-generating projects. The farmers' unacceptance to use of treated wastewater is certainly expected in a particular case; when the use of treated wastewater is intended to replace the freshwater already farmers use for irrigation of their fields. This is especially certain, when the farmers have the access to the freshwater for irrigation adequately.

### 7.3 Sustainability of Reuse System

The decentralized wastewater management, as the concept suggests, requires the use of treated wastewater in the vicinities of the water generation. Consequently, this narrows down the feasible options available for the site selection. This fact complicates the task of finding a feasible site for practicing wastewater reuse within a relatively small geographical area. Based on the long experience in agriculture and water reuse, the following criteria should be considered in selection of the site:

1. The site should be exclusively allocated for irrigation. The sustainability of reuse system is very crucial in the context of decentralized wastewater management. The change of the land use would place the sustainability of reuse project at stake. Especially, when the land is privately-owned, there is no guarantee that the land use will not be changed for other non-agricultural uses. As is the case in most of rural areas, the cultivable lands are subject to continuous fragmentation and shrinking due to obligations imposed by the inheritance system. This factor is the main impetus for changing of the land uses with time, from agricultural uses to housing uses or more profitable uses; especially the price of lands in Jordan is going in rise. In light of these facts, the public lands will be the best option for ensuring sustainability of reuse. Consequently, it is advisable whenever possible to acquire sufficient land in the vicinity of the treatment plant to accommodate the irrigation project. This is highly important when public lands are not available in the target area for implementing a reuse project.
2. The reuse site(s) should be available in adequate size in order to utilize the maximum amount of the effluent and to cope with the increasing effluent amount over time up to the full capacity design of the treatment plant.

When selecting the site of reuse, it is important to take into account the amount of treated effluent at time of operation commencement as well as the increasing amount afterwards, i.e. design horizon of the wastewater treatment plant. The availability of extra cultivable area and the presence of rain-fed trees like olive or forest trees on the site of/or near the treatment plant is preferable; this helps in the management of the surplus water. In this regard, the diversity of these options provides a sufficient space of manoeuvre to the operator for proper management of the irrigation water supply and the surplus water as well.

3. The provision of irrigation water to the reuse site should be in affordable cost. The proximity of the reuse site to the treatment plant should be always given a particular priority while selecting the reuse site. Moreover, the conveyance of irrigation water to the reuse site by gravity is always the desired option. If the difference in elevation was sufficient to operate the irrigation system without or with minimal pumping, this would be an advantage for reducing the operation cost. Under such ideal condition, the low operation cost will be very attractive to the farmers to use the treated wastewater in irrigating their fields or even to invest in new irrigation project.
4. From agronomic perspective, the site should be suitable for wastewater-irrigated cultivation. Comprehensive tests for the soil characteristics have to be the basis for making a decision on its suitability for irrigation with treated wastewater. The main tests should include the soil depth, the soil texture and structure, the soil salinity, the soil tendency to salinization, and the soil drainage capacity. Then, the soil suitability should be analysed and interpreted integrally with the quality of irrigation water and characteristics of the crop intended to be cultivated. The assessment of reuse site should be approved by experienced agronomists.

### 7.4 Natural Drainage System for Emergencies

In light of the fluctuating irrigation demand during the whole season, the treatment plant should have access to a natural drainage system, i.e. wadi. This access should legally be secured; and technically functioning well. To this end, the wadi should not be located on private lands and should be capable of draining water away safely and efficiently as well. The access to a wadi plays a very crucial role, not only in wastewater reuse management in the context of decentralized wastewater management, but also in the sustainability of the entire decentralized sanitation management. The access to wadi is very important for the following reasons:

i. The surplus water can be easily managed by means of the wadi

ii. On the other hand, this access serves as an alternative measure for manoeuvring in face of the ensuing risk from a change in the use of the reuse site land to any other uses. This is a particular concern when the reuse site is private land. In this sense, the wadi will be there so that it performs the function of draining away the treated effluent.

iii. The accessible wadi can serve dual purpose at once. On one hand, it serves as a drainage system for the treated effluent. Under exceptional settings, when the decentralized wastewater treatment plant is situated in the upstream and close to a dam, being used exclusively for storage of irrigation water, the treated effluent generated from the decentralized wastewater treatment plant could be discharged to this dam. In this case, the water will be certainly used in irrigation but off-site. On the other hand, the wadi itself would serve as an alternative site for reuse. All what is needed is to cultivate the bed of the wadi with forest trees.

In conclusion, it is obvious that without a securely accessible wadi, the management of the surplus water/ or the effluent in worst scenarios will not be possible. This gives rise to the question of what the situation would be if the reuse site on private lands was changed to other non-agricultural uses and the treatment plant had no access to wadi to discharge the effluent. In this case, the collapse of the whole decentralized wastewater management project will be certain and most importantly, if that happens, the skepticism toward the feasibility of decentralized wastewater management approach under the Jordanian contexts would be fostered.

### 7.5 Legal Framework (JS 893/2006)

The Jordanian standard (JS 893/2006) for wastewater discharge and reuse is the mandatory standard that covers the scopes related to: (i) the treated effluent discharge to wadis, streams and water bodies, (ii) the effluent reuse for groundwater recharge and (iii) the effluent direct reuse for agricultural irrigation

This section seeks to shed the light on some findings concluded from the review of the standard with the aim of drawing the decision-makers' attention to the potential for introducing some improvements and amendments which are still necessary to make the standard more conducive to scale up reuse under the Jordanian context.

1. The JS 893/2006 still adopts the old WHO guidelines (1989) despite of the updated version of those guidelines, issued later, after 16 years. For irrigation reuse, the old WHO Guidelines (1989) necessitate a treatment of wastewater up to certain standard without proposing solutions for risks that would emerge from a substandard quality in an effluent for any possible reasons. While the 2006-WHO Guidelines adopt a multi-level approach for risk management based on risk assessment without compromising the health aspects. The scale up of wastewater reuse for irrigation necessitates a deep understanding of the 2006-WHO Guidelines which is supposed to be adopted in reviewing the existing JS 893/2006 for many reasons including the following:

    i. It is an updated version of the old WHO Guidelines (1989) which already adopted in drawing up the JS 893/2006.
    ii. The use of wastewater is addressed by the 2006-WHO Guidelines from new perspective and based on new findings and evidences drawn from field, scientific research and epidemiological studies.
    iii. The direct and indirect wastewater reuse in Jordan for long time has already proved the validity of these guidelines. In return, these

guidelines explain how the reuse practice has gone safe all these years with no risk management plan on place.

iv. (iv) The 2006-WHO Guidelines take into account the socio-economic situations of the countries without compromising the health issues. In this regard, the 2006-WHO Guidelines propose various effective measures which work synergistically with treatment plants for minimizing the reuse-associated risks. These measures, already mentioned earlier in this concept paper, are available and even have proven high efficacy under the Jordanian context. Accordingly, the insistence on adoption of a relatively strict standard would increase the cost of wastewater management and discards the potential of the effective protection measures available to Jordan that eventually support the safe use of treated wastewater. On the other hand, the standard neglects the assimilative capacity of reuse system for the polluting loads.

2. For irrigation uses, the JS 893/2006 doesn't take into account the unavoidable fluctuation in the irrigation demand over the year. Given the fact that the treated effluent is continuously flowing from treatment plant, there will be a need to discharge any surplus water in excess of irrigation needs while the reuse is operationalized. The dilemma of the standard JS 893/2006 mainly lies in the presence of two discrepant sets of standard, one for irrigation and another for the effluent discharge, while both uses are inseparable in the context of wastewater reuse. In this sense, whenever the effluent is used for irrigation, the effluent discharge will spontaneously be taking place during certain times of operation of the reuse system; simply, the total effluent amounts cannot be used in irrigation in all settings and hence a frequent discharge of the surplus water to wadi will be an integral part of irrigation supply management. On this understanding, the standards for both uses must be met at once. But the differences in the allowable limits of the parameters in both standards are too extreme to attain this harmony.

   As such, in order to use the effluent for irrigation, two options are available: (i) the effluent quality has to be in compliance with the standard for discharge or (ii) the total effluent amount should be completely used for irrigation with no discharge. The latter option almost cannot be materialized unless the surplus water is stored for later use during the peak irrigation demand. Thus, an adequate storage tank is supposed to be there to manage the surplus irrigation water supply. The matter would practically be impossible in most settings.

   The regulatory entities should be aware of the inseparable interdependence between both uses, i.e. the irrigation and discharge of the effluent. Thus, it is very crucial to have common standards for both uses; simply it is impossible to change the quality of the treated effluent so as to meet the standard for both uses alternately once the treatment plant is operated.

3. The standard prohibits application of sprinklers irrigation method, with an exception for irrigating golf courses. But on the ground, the very

method is currently applied in the forage crops fields in the vicinity of the Asamra WWTP. This fact exposes that the standard, which is supposed to be a national standard and thereby being mandatory country-wide, is applied differently according to location of reuse practice and the entity responsible for operation of reuse system.

4. The JS 893/2006 attaches less significance to the irrigation water quality parameters which are of more importance from the agronomic perspective while for some parameters which are actually less important, the standard entails stricter limits. In this sense, the JS 893/2006 goes very flexible to the value of TSS for Class C-crops while the crops of this class are the main target crops of the direct reuse. Not to mention that the drip irrigation is the exclusively allowed irrigation technology. The TSS is the limiting factor to the use of drip irrigation due to the clogging problems associated to high TSS.
5. The total suspended solids (TSS) limits for different irrigation categories are widely variable; the limits values range between 15 and 300 mg/l. Given to the fact that the risk of TSS almost exclusively lies in clogging of drip irrigation, there is no justification for setting different limits for the TSS for different irrigation classes; simply, the drip-irrigation is the only irrigation method allowed by the standard itself and hence should be in use in any case. The TSS has no effects on the crop itself to justify the variation in the TSS limits.
6. The nitrate limits for the discharge uses, i.e. 80 mg/l, is higher than those required for all irrigation uses, i.e. (30 – 70 mg/l). Surprisingly, the potential uptake of nitrate by plants has been neglected though the nitrate is an essential ion for growth of plants and needed in high amounts by plants. And most importantly, the permissible limit of nitrate in drinking water is 50 mg/l (WHO Guidelines)
7. Moreover, the nitrate limits for the Class-C-crops is relatively more flexible than the limits for Class-A and B-crops. The alfalfa, among the field crops under Class-C and widely cultivated around treatment plants, is capable of producing its nitrogen needs naturally by the atmospheric nitrogen-fixation process in its root system. In light of this fact, the nitrate limits in water used for alfalfa cultivation should be refined. In this case, intercropping practice would be necessary to ensure adequate assimilation of nitrate by the other crop.
8. The maximum allowable count of the E. coli for irrigation of cut-flowers is too strict, i.e. less than 1.1 MPN or CFU/100 ml. This gives rise to the question of whether the risk from the exposure of persons to wastewater-irrigated cut-flowers is higher than the risk from the consumption of the freshly eaten crops irrigated with water of lower quality in the Jordan Valley. The Table 20 shows the water quality in terms of the E. coli for the two waters used for irrigation in the Jordan Valley. Though the E. coli geometric average in the "blended treated wastewater" and the freshwater of KAC are 103 and 102 respectively, the E. coli counts are likely to exceed the geometric mean
limits. According to the Royal Scientific Society (RSS) Annual Reports,

the E. coli count in the two waters even reaches 104 and 103 respectively.
It is clear that though the cut-flowers is listed in the standard as potential crops which could be irrigated with treated wastewater, but practically the strictness of the standard for the reuse indicate to impossibility of this use!

Table 20 The average values for E. coli counts in the two waters used for unrestricted irrigation in the Jordan Valley

| Irrigation Water | E. coli (MPN/100ml) |
|---|---|
| **The "blended treated wastewater"** | $1.3 \times 10^3$ |
| **The surface freshwater** | $1.9 \times 10^2$ |

Source: The annual report of the Royal Scientific Society (2014/2015)

9. The JS 893/2006 sets no value for the E. coli count in the effluent for irrigation uses of forage crops under the Class-C, despite these crops are almost the dominant cultivation in vicinities of the treatment plants.
10. The JS 893/2006 is to serve a dual purpose; on one hand to assure the operational performance of treatment plants and on the other hand to regulate uses of treated wastewater including the irrigation uses. Apart from monitoring the water quality, the following measures are imposed by the standard:

    i. banning the use of treated wastewater for irrigating uncooked-eaten vegetables
    ii. the application of drip irrigation, which almost is not applied on the ground
    iii. restriction of sprinklers method use to only for irrigating golf courses provided that the irrigation takes place in evening
    iv. stopping irrigation two weeks prior to harvesting the fruits of fruit trees together with excluding these fallen on the ground beneath trees (as being in contact with the soil) from picking.

    Despite of the undisputable significance of the aforementioned measures imposed by the standard, an important measure which should be in place and still missing in the standard is how to verify the quality of any wastewater irrigated crop. And most importantly the verification of the long-term impact of wastewater reuse on the agricultural soils which are irrigated with treated wastewater.
11. The permissible pollution limits in the treated effluent have been drawn up on the basis of concentration in water rather than the total load of these pollutants. To simplify the idea, the following example is intended to draw the attention to the relation between the size of treatment plant, the treatment performance and the pollution load discharged by the treatment plant to environment.
    For the decentralized wastewater treatment system which supposed to be implemented in Jordan to serve up to 5,000 capita, on the assumption that the per capita daily wastewater = 70 l/d, the daily generated

treated effluent will be no more than 350 cubic meters. On the other side, a larger centralized treatment plant serving 25,000 capita, on the assumption of the same per capita daily wastewater, then the daily generated treated effluent will be 1,750 m3. On the assumption that the treatment performance of the decentralized treatment plant was only 50% of the centralized treatment plant, then the potential pollution loads discharged from the two treatment plants for main parameters will be as shown in the Table 21 and Table 22

Table 21 The daily pollution load discharged in 350 m3 of treated effluent from a treatment plant operating on a relatively relaxed standard basis

| Parameter | Water quality standard (mg/l) | The daily pollution load (Kg) discharged in ($350m^3$/day) |
|---|---|---|
| **BOD** | 60 | 21 |
| **Nitrate** | 80 | 28 |
| **Total Nitrogen** | 70 | 24.5 |
| **Phosphate** | 15 | 5.25 |

Table 22 The daily pollution load discharged in 1,750 m3 of treated effluent from a treatment plant operating on a relatively strict standard basis

| Parameter | Water quality standard (mg/l) | The daily pollution load (Kg) discharged in ($1,750m^3$/day) |
|---|---|---|
| **BOD** | 30 | 52.5 |
| **Nitrate** | 40 | 70 |
| **Total Nitrogen** | 35 | 61.3 |
| **Phosphate** | 7.5 | 13.1 |

From quick comparison between the two systems, the following conclusion can be concluded:

- Though the treatment performance of the assumed centralized plant is twice higher than the performance of the decentralized plant, the pollution load discharged by the decentralized wastewater treatment plant is only 40% of the total pollution load discharged by the centralized treatment plant.
- If the two effluents from the assumed treatment plants are used in irrigation of the same crop, the absolute amount of the surplus water in excess of the crop irrigation demand will be larger in the context of the centralized wastewater plant. Thus, the pollution load discharged in the surplus water will be also higher.
- From the environmental perspective, the pollution in terms of the total load is more sensible indication for assessment of the wastewater pollution impact on the environment and water resources. On the other side, the pollution in terms of concentration is a good indication for assessment of the treatment performance of a treatment plant.

In conclusion, the standard in its current form cannot support the scale up of the decentralized sanitation unless it was refined. As long as the JS 893/2006 remains the only standard applicable to wastewater treatment and reuse in the context of decentralized sanitation, it is strongly recommended to review the standard and to introduce necessary amendments to it. The other option would be is to develop a separate standard for the decentralized sanitation context especially the DWWM Policy itself has already adopted this option and hence proposing separate two sets of standard. And most importantly, the standard must take into account the following concerns and needs:

i. Different sizes of treatment plants
ii. The assimilative capacity of all ecosystems including the reuse system, drainage system and receiving water body
iii. The proximity of the treatment plant from water bodies, in terms of probability of pollutants to arrive at water bodies and in which amounts
iv. The socioeconomic of Jordan and the financial & technical consequences
v. The affordable treatment technologies and their perspective treatment performances.

### 7.5.1 Comments on the standard proposed in the Decentralized Wastewater Management Policy (2016)

In an attempt to facilitate reuse of treated wastewater for irrigation in the context of decentralized wastewater management, the related policy has proposed two sets of standard for the treated effluent generated from two sizes of decentralized treatment plants whose design flow falls in the range of either 51-500 capita or 501-5000 capita. On reviewing the standard proposed, the following conclusions would be noticed:

- Out of the numerous parameters imposed by the mandatory Jordanian Standard 893/2006 that regulate the quality of the treated effluent from centralized wastewater treatment plant, only 6 parameters are proposed in the standard. These parameters include the chemical oxygen demand, total suspended solids, total nitrogen, nitrate, E. coli and pH. On narrowing the number of the parameters regulating the effluent quality to 6 parameters, the proposed standard has relatively an advantage over the mandatory JS 893/2006; it would make the fulfilment of the standard somewhat possible.
- Despite the proposed standard comes to regulate decentralized treatment plants of two different range-sizes, and hence implicitly should be on the basis of pollutants loads, a same value is proposed for each parameter in the two sets of standard applicable to both sizes of treatment plants. In this sense, no consideration actually is given to the difference in size of treatment plants or pollutants loads either. This gives rise to the question of the purpose for having two values, which are equal, for each parameter in this standard as long as the philosophy behind proposing the two sets of this standard is to regulate the assumed two different sizes of treatment plants?!
- In the proposed standard, three general end-uses of the treated effluent are addressed. These uses include open discharge, infiltration trench, and

irrigation. The latter use is categorized in accordance to three irrigation methods: subsurface, drip, and open irrigation. As for the infiltration trench, it is exclusively applicable in case of the small-sized treatment plants whose design flow equivalent to the range of 50-500 capita.

- According to the standard proposed in the policy, the open discharge of effluent is only allowed provided that the discharge area is fenced. In this regard, the proposed standard goes much stricter than the JS 893/2006. The regulatory entities should be aware of the cost burden of this prerequisite; the capital cost, maintenance and undertaking measures against any vandalism that could happen.
- The standard places no clear restriction on the crops to be irrigated with the treated effluent. The lonely exceptional ban, explicitly mentioned in the standard, is relating to the crops whose harvest-part grows underneath the soil surface like carrot and potatoes. And even this ban, according to the standard, takes effect only in the case of subsurface irrigation method application. The argument of the ban on cultivation of these kinds of crops under all irrigation methods, without exception, can somewhat be understood. But, as the root-zone of soil is to be wetted by irrigation water of a given quality, the same risk stemming from this water, if any, on such kinds of crops is supposed to be always a concern, no matter what the irrigation methods is used. In light of no risk management operation plan in place, the crop restriction should be enforced as a core safety measure for wastewater reuse in the context of the decentralized sanitation. That is particularly needed as the decentralized wastewater management is still new approach and hence no mature business model effectively applied in Jordan.
- Under the drip irrigation settings, the proposed standard entails either fencing of irrigation zone or using plastic mulch in combination with drip irrigation. Surprisingly, the standard doesn't requires such a measure for the fields irrigated by surface (open) irrigation though the risks stemming from the exposure to irrigation water as well as the wet soil are relatively high in case of open irrigation compared with other methods like drip or subsurface irrigation systems. Moreover, the other option, i.e. the plastic mulch, cannot be applied in most crops like alfalfa.
- The proposed standard entails a maximum value of nitrate, 60 mg/l, for the effluent discharge, and this value is stricter than the value of nitrate came in the 893/2006 for the same use, i.e. 80 mg/l. Obviously no values of nitrate are proposed for irrigation uses. As for the total nitrogen, a same value, 70mg/l, is proposed for all end-uses in the standard applicable only to the large-sized treatment plants while for the small-sized plants, no value of total nitrogen is proposed for any end-uses except the effluent discharge.
- The standard proposed 1000 E. coli for both uses, the effluent discharge and the irrigation uses, while the allowable E. coli count is reduced to 100 E. coli only in case of open irrigation. The E. coli count for subsurface irrigation and infiltration trench as well is left unidentified. It is not understandable how limits of E. coli count have been proposed while the crops allowed to be cultivated are not identified in advance in the standard.
- The standard proposes a same value of TSS for all settings of irrigation uses

with no consideration to the unequal risk weight of TSS on the different irrigation methods. It should be realized that this risk is by far the highest under the drip irrigation method while it is almost negligible in case of surface irrigation.

- Besides the irrigation uses, the standard applicable to the small-sized treatment plants (serving 50-500 capita) allows the disposal of the effluent through "infiltration trench" provided that the maximum daily load of water allowed to be applied into soil is no more than 1 m3/10 m2. By simple calculations, this water amount is equivalent to a daily 100 mm depth of water. In other words, the allowable discharge rate of the effluent into the given infiltration trenches, in average, is around 4.2 mm per hour. In order to ensure full infiltration of the entire water depth through the soil surface, and hence avoiding ponding or run-off of water, the trenches should have the adequate infiltration capacity; equal at least or preferably slightly more than 4.2 mm/ hour. The capacity of the trenches, to perform the adequate infiltration, depends on different factors that collectively affect the infiltration process. Among these factors only selected ones will be addressed later in this section.

It should be realized that different types of soil show different ranges of infiltration rates. The Table 23 shows the basic infiltration rate for selected different types of soil.

Table 23 Basic infiltration rates for various soil types

| Soil type | Basic infiltration (mm/ hour) |
|---|---|
| **Sand** | < 30 |
| **Sandy loam** | 20 – 30 |
| **Loam** | 10 – 20 |
| **Clay loam** | 5 – 10 |
| **Clay** | 1 - 5 |

Apart from the effects of other factors, the proposed rate for discharge of the effluent, i.e. 4.2 mm/h, seems theoretically achievable in most soil types except for clay soil. But on considering other factors that affect the infiltration rate, it turns out the inaccuracy of the daily allowable discharge load proposed in the standard, i.e. 1m3/10m2. When proposing the daily allowable water load, the following key factors should be taken into account:

i. Rainfall during winter will add extra water depth and this in turns increase the total water depth that has to infiltrate across the trenches' soil surface. In this case, the depth in excess of the infiltration capacity of soil will stagnate or run off.
ii. Accumulation of the suspended solids continuously loaded onto the soil will impede the infiltration rate of such soil over time. The suspended solids contained in the effluent water would clog pores in the surface layer of the soil and this consequently slows down the infiltration rate.
iii. The soils largely predominated by sodium ions show very limited infiltration rate especially in the heavy soils.
iv. The infiltration rate of soils depends largely on speed of water percolation through the soil layers. Any slowdown in the percolation will

certainly hinder the downward movement of water and hence affecting the infiltration rate. The main factors affecting the water percolation is the structure of the different layers of soil in the underneath. Moreover, presence of a hard pan layer will certainly reduce the percolation. In light of the various factors affecting the water infiltration capacity of trenches, the maximum allowable daily water load should be reconsidered, taking into account the collective effect of all these factors on infiltration rate of water in trenches.

It should be realized that the disposal of the effluent through infiltration trench would pose higher risk, i.e. pollution of the groundwater, than its use in irrigation. This is true especially when these infiltration trenches are located above the rocky layers abounded in cracks that may deeply extend through these layers.

At least the assimilative capacity of reuse system in irrigation is high enough to serve as a measure for safe disposal of the effluent and, most importantly, in productive and profitable way.

In conclusion, both standards, the mandatory JS 893/2006 and the proposed standard in the related policy as well, **provides no solution for the given persistent alternation between the two uses** - the effluent discharge and irrigation - that take place all round the year when the surplus water is available during times of non-peak irrigation demand. This gives rise of the question which of the two uses has the priority to dictate its standard on the other at the time of treatment plant design? Moreover, both standards show **unreasonable strictness** on the parameters which **in need of flexibility and show flexibility** on the parameter**s in need of strictness!** The same applies to some unjustified requirements

## 8. Proposals and Recommendations

The following proposals and recommendations are made with an intention to motivate the decision-makers as well as the regulatory and operation entities to get in further discussion so as to come up with the decisions and actions which are enabling conducive environment for scale up of wastewater reuse in the context of the decentralized wastewater management approach:

- Due to the potential assimilative capacity of reuse systems in irrigation, the wastewater reuse should be adopted as an irreplaceable component for safe management of wastewater before being an end. This adoption has very important implications including:

  i. The wastewater treatment plant would be no longer regarded as the only measure that ensures safe management of wastewater. In contrast, the reuse system in irrigation would be equally an effective post-treatment measure rather than being a burden in need of strict standard as a prerequisite for the use of the effluent in irrigation.

ii. The assimilative capacity of the reuse system allows the regulatory entities to adopt more realistic standard by which the environment is protected, reuse is scaled up and the door is opened for adoption of the close-to-nature treatment technologies which are more affordable and thus more scalable in line with the economic situation of Jordan.
iii. The affordable decentralized sanitation allows for gradual scale up of sanitation services through phases, and in the interim, the enforcement of the simplest form of wastewater reuse, i.e. dissipation of infiltrating raw wastewater from cesspits by forest trees, could be helpful in minimizing the pollution risk in the areas unserved by sewer sanitation until the arrival of sewer sanitation.

- In the context of decentralized wastewater management, a restriction on the wastewater reuse is recommended. At the beginning, the irrigation uses could be confined to the forage crops, olive trees, winter field-crops, and forest trees. The restriction is justified by the following facts:

  i. Lack of a comprehensive risk management for wastewater reuse in place while the reuse-associated risks seem relatively higher in the context of the decentralized wastewater management; the treated wastewater is used on site of the residential communities.
  ii. The decision-makers' perspective on the wastewater reuse in the context of decentralized sanitation in particular is very conservative; The Jordanian decentralized sanitation experience is still immature and thus inadequate for the decision makers to take the risk of using the treated wastewater for irrigation of a wider range of other crops.
  iii. The significance of protecting the environment, including the water resources, and improving the hygiene conditions outweigh any other motives of wastewater reuse in the context of decentralized sanitation. This end could be achieved by the wastewater reuse for irrigation of specifically selected group of crops and forest trees which are proposed in the concept paper.

- The sustainability of wastewater reuse in the context of the decentralized sanitation is very crucial and therefore, the following elements should be secured from the outset:

  i. A barrier-free access to well-functioning wadi for management of the treated effluent, i.e. for the discharge, the irrigation use of the effluent or the surplus water.

  ii. Adequate land allocated for cultivation uses and thus for an exclusive wastewater reuse practice. The wadi itself could be an additional and/ or an alternative good site for reuse that can be cultivated with forest trees.

When reuse system scheme is inapplicable in certain spatial setting, at least the first abovementioned element, i.e. the wadi, should be secured for sake of sustainable operation of sanitation system.

- For the areas which are unlikely to be served soon by sewer sanitation, it is recommended to promote and enforce the simplest form of wastewater reuse, i.e. plantation of forest trees close to the cesspits to dissipate the infiltrating wastewater.
- The probability of pollution risk posed by the wastewater loads to the environment and water resources depends on the following factors:

    i. The total pollutant loads discharged which in turns is a function of the pollutants concentrations and the total amount of treated wastewater generated from the treatment plant
    ii. The proximity of the water bodies to the outlet of treatment plant. The proximity meant here is not the straight distance but the length of the drainage route and the probability of the effluent's arrival to the water body.
    iii. The assimilative capacity of the ecosystems for pollutant loads. The ecosystems include the reuse system and the receiving water bodies, and the wadi allocated for the effluent discharge.
    iv. And most importantly the socio-economic situation of the country. Therefore, these factors collectively are supposed to serve as the basis for setting the standard for domestic wastewater treatment and uses.
- Given the differences between the centralized and decentralized wastewater management in terms of their concepts, settings and scales, there are two options for setting an appropriate standard that is conducive to the scale up of decentralized wastewater management. Practically, this could be achieved by either adapting the existing standard (JS 893/2006) to serve the centralized and decentralized wastewater management alike. The other option would be the development of a separate standard for sake of the decentralized wastewater management; the option already adopted by the DWWM Policy. The decision makers should take into account the cons and pros of the two options, keeping in mind the possible twining and complementary between the two sanitation approaches - centralized and decentralized approaches for wastewater management. In this regard, the complexity of adapting the existing standard makes the other option seems to be easier to achieve within short time and may be more preferable.

- It is highly recommended to review the current standard (JS 893/2006) not only for sake of decentralized wastewater management in particular but for sake of the wastewater management in general.

- In case the decision is taken in favour of adapting the standard (JS 893/2006) to serve the wider use of the treated effluent for irrigation in the contexts of centralized and decentralized sanitation as well, then it is NOT recommended to adopt a pollutant-load based approach solely, as is the case in Germany, for setting such adapted standard, for many reasons:

i. The treated effluent is supposed to be used in irrigation, and most importantly, this reuse will be on the site of the decentralized sanitation setting. In contrast, under the German context the effluent is discharged to the continuously flowing rivers which thus have adequately high assimilative capacity for pollution loads. Moreover, the loads are carried far away from residential communities.
ii. The adoption of a totally load-based standard in the Jordanian context entails introducing various categories of standard quality so that the standard can be applicable to various sizes of the treated effluents. The extreme variation in size of the Jordanian treatment plants will necessitate having such a wide range of these categories. This gives rise to the question of whether the current standard JS 893/2006 would be the basic reference standard for the largest or the smallest-sized treatment plants. When the current standard is taken as a reference standard for the largest-sized treatment plant, relaxing the standard in proportion to the size of wastewater treatment plants will ends in too flexible quality of the effluent generated from the smallest-sized treatment plant as is the case of all decentralized wastewater treatment plants. In so doing, the too flexible quality will be then stuck in the unsuitability of the effluent for irrigation. On the other hand, if the current standard is adopted as the reference for the smallest-sized treatment plants, then adapting the standard for the largest-sized treatment plants will ends in extremely very strict standard that entails an advanced upgrade of the existing centralized wastewater treatment plants; the matter that would be beyond the financial reach of Jordan.
iii. The size of treatment plants in Jordan is always subject to continuous expansion in order to handle the increased wastewater amount generated from the new dwellings which get increasingly connected to the sewer networks. In such contexts, there is no possibility for adopting a standard based on the total loads in the treated effluent.

- Instead, a realistic compromise between the following recommendations sound more practical and helpful for proposing a realistic standard for the decentralized wastewater management:

    i. The standard proposed for the decentralized sanitation is recommended to be only relating to the two uses, the effluent discharge and the irrigation,

    ii. The standard for the two uses is recommended to be merged in one standard that regulates the two uses at once.

    iii. In this standard, a parameter could have four limits; a minimum, an intermediate-minimum, an intermediate-maximum and a maximum values:

- The minimum value is only applicable to the discharge of the effluent fully to uncultivated wadi and hence no reuse is practiced at all
- The intermediate-minimum value is only applicable to the discharge of the effluent into an adequately forest tress-cultivated wadi
- The intermediate-maximum value is only applicable to irrigation use provided that the surplus water in excess of irrigation demand is discharged to uncultivated wadi
- The maximum value is only applicable to irrigation use provided that the surplus water, if any, is discharged to an adequately forest trees-cultivated wadi
- An exception should be given to the TSS values due to the clogging problem associated with high TSS for the drip irrigation whose application is a must according to the JS 893/2006.

iv. Then, the decision on which of these four values should be adopted for designing a treatment plant, is taken during the planning phase of a decentralized sanitation in a specific setting. In this regard, the preliminary feasibility study should give a specific answer whether or not the spatial setting of the planned project allows for sustainable wastewater reuse in addition to what scale this reuse would be practiced. As such, the strictest value is no longer the basis for designing the treatment plant

v. Only for the wastewater reuse in the context of decentralized wastewater management, it is recommended to restrict the use of treated wastewater to the crops listed under the category C in the standard JS 893/2006.

vi. Though the proposed standard can be divided further to serve different categories based on the size of the decentralized treatment plants, this proposal is not urgently recommended under the Jordanian current context because (i) the treated effluent is going to be used in irrigation, (ii) as previously recommended, the use of the treated wastewater is restricted to certain crops (Class C) that need a similar standard quality of irrigation water, and (iii) the scale of the decentralized sanitation projects in the Jordanian context is still relatively very small and the variation in this scale is not so extreme and thus insignificant.

vii. The values of certain parameters, which came in the JS 893/2006, are recommended to be relaxed based on the assimilative capacity of reuse system. This includes in particular the dissolved nutrients (nitrate and phosphate) which are assimilable in huge amounts by plants and the soil's microorganisms. On the other hand, the big difference in the values of T-N and nitrate is not understandable and therefore the T-N values could be reduced.

viii. As the synthetic fertilizers contribute to the salinity of the soil and may contain some heavy metals while the treated wastewater is very rich in most nutrients, it is highly recommended that the standard ban the use of these fertilizers except under very particular cases when a foliar application is needed to remedy the micronutrients deficiency on the plant.

ix. It is highly recommended to implement a comprehensive monitoring program with a view to verifying the impact of the long-term of wastewater reuse on soil, the irrigated crops and forest trees, and the water resources. This is the only tool that can be reliable to monitor the pollution trend in the environment. The monitoring findings enable the institutions concerned to revaluate the effectiveness of the existing measures and hence additional measures would be enforced. On the other hand, these monitoring programs are very essential tools for the decision makers to take strategic decisions regarding wastewater reuse.

x. It is recommended to integrate the monitoring programs into the standard as being a mandatory prerequisite.

xi. It is recommended that the standard explicitly identify the institutions and the entities responsible for implementing the respective monitoring programs.

The Table 24 represents a preliminary proposal for a quality of the treated effluent to serve the effluent discharge and irrigation of only the crops under Class C in the context of decentralized wastewater management. The parameters values of the JS 893/2006 are included in the table for comparison purpose. The other parameters can be neglected because either they are not problematic characteristic of the Jordanian wastewater or their removal significantly is beyond the performance capacity of all existing treatment plants.

Table 24 The proposed standard for the effluent quality in the context of decentralized wastewater management

| Parameter | Unit | JS 893/2006 | | The proposed standard for the effluent quality in the context of Decentralized Wastewater Management | | | |
|---|---|---|---|---|---|---|---|
| | | Discharge | Irrigation of Class C-crops | Discharge to uncultivated wadi | Discharge to cultivated wadi | [2]Irrigation use + discharge of surplus to uncultivated wadi | [2]Irrigation use + Discharge of surplus to cultivated wadi |
| **BOD5** | mg/l | 60 | 300 | 70 | 80 | - | - |
| **TSS** | mg/l | 60 | 300 | 70 | 80 | 50 | 50 |
| **Nitrate** | mg/l | 80 (100 in rainy days) | 70 | 90 | 100 | 130 | 150 |
| **[1]Nitrate-N** | mg/l | 18.1 (22.6 in rainy days) | 15.8 | 20.4 | 22.6 | 29.4 | 34 |
| **T-N** | mg/l | 70 (100 in rainy days) | 100 | 50 | 60 | 70 | 80 |
| **Phosphate** | mg/l | 15 | 30 | 20 | 25 | 35 | 40 |
| **E.coli** | CFU/100 ml MPN/100 ml | 1000 | - | 1000 | 1000 | 10000 | 10000 |
| **Intestinal Helminthes** | Egg/l | ≤ 0.1 | ≤ 0.1 | ≤ 0.1 | ≤ 0.1 | ≤ 0.1 | ≤ 0.1 |

Note: 1The Nitrate-N value represents the concentration of elemental N of nitrate and thus is calculated by dividing the Nitrate value by 4.42

2Drip irrigation is assumed only in case of irrigation use and this condition doesn't apply to the discharge of surplus to cultivated wadi

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# Part C

# Business Models for Decentralized Wastewater Management in Jordan

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## 1. Introduction

On behalf of the Federal Ministry for Economic Cooperation and Development (BMZ) the Project "Decentralised Wastewater Management for Adaptation to Climate Change in Jordan" (ACC Project) started in June 2014 with the aim to strengthen the capacity of the Jordanian counterparts, especially the Ministry of Water and Irrigation (MWI), the Water Authority of Jordan (WAJ) and others in DWWM. The focus is to elaborate measures of DWWM for climate change adaptation to support the implementation of the Jordanian National DWWM Policy. The project is in the process of identifying best practice measures for DWWM in the country, incl. means how to sustainably operate DWWM systems to pave the way for scaling-up.

In places that are not connected to centralised treatment plants and / or that cannot be connected cost-efficiently, decentralised wastewater treatment plants (DWWTPs) offer an opportunity to introduce WW treatment and generate treated effluents to be used for irrigation water and others uses such, industries, cement, gardening, golf course, etc. The advantages of decentralised technologies include their capability to provide WW treatment infrastructure in remote and hilly rural communities and their responsiveness to fast-growing semi-urban settlements. DWWM can service locations that cannot be serviced by centralised systems due to technical and financial limitations.

Making DWWM a viable business that is attractive to private investors and operators is a major challenge. The absence of sustainable business models for DWWM represents probably the major barrier to the improvement of the sanitary situation on the ground in rural and / peri-urban areas.

## 2. General Assumptions and Guiding Principles for this Study

The outcomes of this study are supposed to create a better understanding on potential opportunities and chances for "making small-scale sanitation a business". This study is based on the DWWM Policy, officially acknowledged as the guiding principles for the development of Jordan's decentralised sanitation sector.

The following bullet points are summarising the Consultant's general approach and assumptions:

- The village of Rasoon in Ajloun Governorate has been selected for this study as a typically representative location, following earlier investigations made by ACC in the Sanitation for Millions (S4M) study and in agreement with the Client. Furthermore, Ajloun is considered a hot spot area by WAJ due to numerous shallow springs at risk by pollution, adding additional justification to the selection of this village.
- Real life data has been used to the largest possible extent, generated by household surveys in Rasoon carried out in earlier projects (DORSCH 2014).
- The initial investment into physical infrastructure (sewer systems, WWTPs) is expected to be financed by grants from international development agencies. Consequently, the business model only considered the financial flows subsequent to the investment including capital maintenance.
- For all calculations and considerations, a 2-stage vertical flow constructed wetland has been chosen as the standard wastewater treatment technology (refer to the section on technology selection below) which most likely comes with the lowest investment and operation costs, hence representing the "best case solution". Any other technology will not result in better financial performances of the selected business models due to their higher CAPEX and OPEX.
- Potential operators are water utilities under WAJ, private sector entities and cooperatives.

## 3. Definition of Decentralised Wastewater Treatment and Management

Decentralised WW treatment consists of a variety of approaches for collection, treatment, and dispersal/reuse of WW for individual dwellings, industrial or institutional facilities, clusters of homes or businesses, and entire communities. An evaluation of site-specific conditions is required to determine the appropriate type of treatment system for each location. These systems are a part of permanent infrastructure and can be managed as stand-alone facilities or be integrated with centralised sewage treatment systems (semi-centralised). They provide a range of treatment options from simple, passive treatment with soil dispersal, commonly referred to as septic or onsite systems, to more complex and mechanized approaches such as advanced treatment units that collect and treat waste from multiple buildings and discharge to either surface waters or the soil. They are typically installed at or near the point where the WW is generated (Capodaglio, 2017), indicatively less than 3–5 km and not served by a central sewer system connecting them to a centralised WWTP (Capodaglio, 2017)

The term "decentralised" also qualifies systems serving small portions (clusters) of an urban area according to hydrology, landscape, and local ecology considerations. Decentralised systems require more awareness, involvement, and participation from local users than centralised ones. The decision to implement a decentralised solution to WW treatment needs is usually made or discussed at the local level, and local stakeholders are usually more proactive when considering these systems.

The basic idea behind the use of centralised water treatment is that WW is transported out of the city and far away from residential sites as quickly as possible in order to reduce public health risks. To a large degree, this centralised sewage treatment approach can solve the problems of sanitation very efficiently (Zhang et al., 2014). The centralised approaches are often plagued by high capital investment cost, improper operation, and an over reliance on treatment technologies that are unaffordable in rural areas with low population densities and dispersed or scattered households. In a few EU countries (Germany, The Netherlands) demonstrative decentralised systems serving up to 1,000 people have been implemented in urban areas.

The European Committee for Standardization defines small WWTPs as systems that serve less than 50 PE. The European Commission as reported by (Berland & Cooper, 2001) defined decentralised WW treatment technologies as serving less than 5,000 PE, whereas (Gutterer, Panzerbieter, Reckerzugl, & Sasse, 2009) defined this threshold at WW flows of 1,000 $m^3$ per day or 10,000 PE respectively. According to (Gutterer et al., 2009) DWWTPs provide treatment for WW flows with close COD/BOD ratios from 1$m^3$ to 1,000$m^3$ per day and unit[8] .

In this study and according to Jordanian definitions the term 'DWWM systems' is used for DWWTPs with a capacity below 5000 PE at or near the point of WW generation that may include different plant sizes and treatment technologies, such as onsite treatment plants for individual homes, plants serving small to middle-sized clusters of homes or even entire communities. Many DWWM systems consist of multiple WWTPs serving the population of a defined area. The debate about the less than 5,000 PE refer to the size of the total community population or the size of the potential connected population or the size of the treatment plant. For example, if a community of 9,000 is connected to two WWTP of 4,500 PE each due to topographical factors, then it can be considered as two decentralised WWTPs?

Typically, approximately 60%-80% of the capital costs of a complete wastewater system relate to the collection systems associated with densely populated areas. With less densely populated areas this proportion increases and the costs of transporting wastewater long distances to a centralised treatment plant increases

[8]According to Jordan's DWWM policy, the decentralised approach to wastewater management is most appropriate for suburban and rural communities (…) where the costs of wastewater being pumped over long distances to a large centralised treatment plant outweigh the plant's potential economies of scale" ((MWI, 2016b)

the unit costs considerably to the point that they do not financially or economically viable. A more decentralised approach that overcomes this and other constraints are often more viable although each solution needs to be assessed on a case by case basis to ensure the overall optimum investment decision. A treatment system can be considered a decentralised system which should ideally fulfil the following criteria regardless of the population size and technology:

1. suitable for very diverse local conditions,
2. provide reliable and efficient treatment of domestic and process WW,
3. require only short planning and implementation phases,
4. moderate investment costs,
5. limited requirements for operation and maintenance.

The advantages of DWWM system in Jordan can also be justified by:

1. Long distance between wastewater generation and large-scale WWTP
2. Costly pumping of wastewater due to unfavourable topography
3. High CAPEX for excavation of sewer network due to harsh soil conditions
4. Limited availability of (public) land for construction of (large) centralised WWTP

## 4. Current Challenges to BM in DWWM

Aside from being financially attractive successful private sector operations require institutional, regulatory and market clarity and stability. In this regard, several barriers have been discussed and need to be overcome. The list below is a summary of concerns based on anecdotal interviews and in-country experiences:

- **Institutional responsibilities** for DWWM (< 5,000 PE), esp. with regards to WAJ, are unclear.
- **Responsibility for O&M is not defined** (refer to private operations YWC/Miy/Aqaba).
- **Regulatory framework lacking and unclear.**
- **Certification of O&M system** (education and training) is lacking.
- The government is hesitant to introduce a comprehensive and fair **Tariff system** for DWWM for the sake of political stability.
- **Private sector involvement** (design, construction, O&M) is insufficient.
- **Private sector interest** in the sector is limited since tariffs based on full cost **recovery and reasonable profits are not guaranteed.**
- **A competitive market** for O&M does not yet exist; a critical mass of DWWTP is **required** ("Decentralised treatment – centralised management").
- **Revenues** of selling the treated effluent (fresh water substitution) are believed to be **not cost-covering**, especially as the water tariff is very low (subsidized).

In addition to the institutional bottlenecks described above, successful private sector involvement in the sustainable development of water supply and sanitation services rely on:

- **Longer term assurance of financial viability** which means a degree of regulatory and financial certainty over tariffs and commitments for subsidy support where required. Even a perceived risk that such assurances may not be honoured may result in limited investor interest. This will almost certainly result in the investor confining its activities to operational activities only and an unwillingness to undertake investment in capital maintenance and expansion.
- **Consumer support** through a willingness to pay charges and support for the activities, notably with respect to the social benefits of a properly functioning wastewater system.
- **Other stakeholder commitment**, e.g. the agricultural sector and/or the agencies supporting carbon credit systems, to provide longer term assurances on revenue streams.
- **Other institutional support**, e.g. environmental protection agencies, to ensure that the operator works in partnership with them to achieve wider overall benefits.
- **Meeting minimum investor expectations,** e.g. cash flow positive, secure returns on capital and/or assured margins, etc.

# 5. Overview of Wastewater Treatment and Reuse in Jordan

## 5.1 Jordanian Water and Sanitation Policies

In recent years Jordan has developed and implemented an impressive set of water and sanitation-related policies and strategies, as briefly described below:

**Jordan's Water Strategy,** Water for life (2008-2022) (MWI, 2009) stresses the need to encourage private sector participation in MWI activities. The MWI shall encourage and expand the private sector's role in the distribution of retail water, WW, treated effluent and irrigation water. Emphasis shall be placed on the social benefits in conjunction with private investment. Furthermore, DWWTPs shall be explored for new urban settlements. The MWI shall issue specifications and minimum standards for the use of septic tanks in rural areas. Particular attention shall be paid to the protection of underlying aquifers. Furthermore, the MWI shall establish innovative approaches to WW treatment for small municipal systems. Design criteria, performance specifications and guidelines for such systems shall be adopted and generalized. Despite these policy goals and activities many have not met the expected targets and deadlines.

**The National Water Strategy 2016-2030** (MWI, 2016c) addresses the need to expand the sanitation services to cover the upcoming forecasted service demand and to rehabilitate the existing infrastructure of WW collection networks and irrigation water networks (MWI, 2016c). Decentralised systems also will be used where appropriate. The management of both centralised and decentralised systems will be enhanced. The sanitation strategy will consider health, hygiene and the environment in the development of waste and WW treatment in urban centres and small towns WW treatment capacity will be expanded to cover all of Jordan as per the National Strategic Wastewater Master Plan (NWMP) (ISSP, 2014). This policy resulted in the decentralised WW National Implementation and National Plan for Operation and Maintenance of WW treatment proposed (MWI, 2015).For localities with fewer than 5,000 inhabitants, construction of WW collection and treatment systems is not proposed unless the localities are in close proximity to existing treatment and collection facilities or face exceptional circumstances based on sanitation and health considerations.

**The Water Substitution and Reuse Policy** (MWI, 2016e) is intended to direct the water sector towards more efficient use of water resources. Treated WW shall be reused for irrigation and other activities freeing up fresh water to be utilised for municipal uses. It also provides for using the treated WW in other economic activities. It calls for expanding collection and treatment of WW, updating and development of standards and practices for substituting fresh water used in irrigation by treated WW. Surface water utilisation for municipal uses shall be enhanced to decrease the demands on groundwater. Treated WW specifications and standards shall be enhanced to ensure safe reuse and to generate high economic return products for treated WW. DWWM can contribute to achieve these objectives by utilizing treated effluent in different economic activities that generate income. However, the current specifications and standards to treat and dispose WW in small-scale WWTPs are incompatible with the substitution goals. Specific standards and requirements for small scale WWTPs in a country suffering from water scarcity are needed. The policy indicates that the MWI will adopt and implement a National Plan for Operation and Maintenance of WWTP aiming at achieving efficiency. The plan includes best available models including private sector participation.

**The Water Reallocation Policy** (MWI, 2016d) states that the quality of treated WW from all municipal and industrial WWTPs shall meet national standards, be monitored regularly, and reviewed periodically. WW standards shall be revised and amended to meet direct and indirect water reuse for the production of high value crops. All concerned governmental ministries, agencies and bodies dealing with environment and irrigation issues are to be consulted and be part of the decisions related to effluent quality. The WW standard is not consistent and needs to be revised by various stakeholders such as MoA, JSMO, MWI, JVA, RSS and MoH. This reallocation policy is intended to serve as a vehicle to set action plans for redistributing the water flexibly between sectors and governorates. It intends to employ a conveyance system for water connecting the southern and northern regions and another conveyance system for treated WW in the Jordan Valley to maximize the use of treated WW for irrigation and free the expensive used fresh water to be used for domestic purposes.

**The Climate Change Policy** for a Resilient Water Sector (MWI, 2016a) stresses the need of water substitution, which aims at substituting freshwater with treated WW and possibly other non-conventional water sources, avoiding negative impacts on water and soil quality, and which also refers to the principles of IWRM. On the adaptation measures for climate change the level of WW collection, treatment and re-use of treated WW in agriculture and industrial sector shall be increased when and where it is technically possible. The policy prioritises selected solutions, with WW reuse as an efficient and cost-effective measure. DWWM can contribute to achieving the goals of this policy with respect to water substitution and environmental protection.

**The Decentralised Wastewater Management Policy** (DWWM Policy, MWI. 2016b) offers an opportunity to introduce WW treatment and generate irrigation water in places that are not yet connected to centralised WWTPs. The advantages of decentralised technologies include their capability to provide WW treatment infrastructure in remote and hilly rural communities and their suitability for fast-growing semi-urban settlements (MWI, 2016b) (MWI & NICE, 2015). A decentralised approach to WW management is generally most appropriate for suburban and rural communities, particularly towards the upper edge of catchments, where the costs of WW pumping over long distances to large centralised treatments plants outweigh the plant's potential economies of scale. The DWWM Policy refers to WWTPs with a capacity of up to 5,000 Population Equivalent (PE). One of the major environmental concerns related to current WW treatment and disposal practices is the contamination of surface and groundwater resources; a critical issue for the Ministry of Environment (MoEnv), MWI, and other agencies.

This policy also stresses the need to expand WW management by implementing the practice of recycling and reusing water beyond the existing conventional WW service system. Reuse is considered essential for economic viability. For reuse of treated effluent originating from a WWTP with a capacity of up to 5,000 PE, reuse shall be performed following the quality parameters for treated effluent as suggested in the DWWM Policy "Regulatory specifications and programs for treated domestic WW from treatment plants with a capacity of up to 5,000 population equivalents". Furthermore, a group of several different neighbouring WWTPs with a design capacity of up to 5,000 PE each is considered a DWWM cluster.

## 5.2 Status of Wastewater Treatment and Reuse

Jordan is a country facing high levels of water scarcity. On a per capita basis, Jordan has one of the lowest levels of water resources in the world: freshwater availability per capita is below 100m$^3$/capita/annum, expected to drop to 90 m$^3$/capita in 2025. This situation has led to Jordan developing a water substitution and reuse policy whereby the government emphasises increasing the amounts of treated wastewater and considers this treated wastewater as a potential water source as well as a source of revenue.

Currently Jordan uses three different types of wastewater treatment plants: Waste Stabilisation Ponds (WSP), Activated Sludge (AS) and Trickling Filter (TF). AS systems have the highest efficiency of removal of BOD (above 95%), followed by TS (92.5%-95.7%) and WSP (74%-81%). Similar results are obtained in reduction of Chemical Oxygen Demand (COD)(Abdulla, Alfarra, Abu Qdais, & Sonneveld, 2016). Jordan has developed a National Strategic Wastewater Master Plan which aims to ensure that all localities with more than 5000 residents are served by a wastewater collection and treatment plan by 2035. In larger urban areas, Jordan currently disposes over 33 operational public Wastewater Treatment Plants (WWTP), 7 private WWTP's and more than 40 small scale private industrial WWTP's. The current systems serve some 6.7 million people, and in terms of the 2035 strategy, an additional 1.3 million people will be served

Ensuring supply and reuse of treated wastewater is therefore central to Jordan's water security strategy. In addition, the national water security strategy includes elements such as increasing the efficiency of distribution and conservation of existing resources and exploration of new sources such as through rainwater harvesting and desalination.

The characteristics of wastewater in Jordan are different to that of most countries for two main reasons. The first is that the average salinity of municipal water is relatively high: Total Dissolved Salts (TDS) is some 580 ppm on average, while average per capita domestic water consumption is low (80 l/capita/day). The result of this situation is high salinity and heavy organic loading of influent into wastewater treatment facilities. Wastewater treated in waste stabilisation ponds is subject to high evaporation rates, further increasing salinity. Also, the high organic loads can lead to biological overloading of treatment facilities against a background of relatively low water flow. In 2005, nine wastewater treatment plants became biologically overloaded, one of the factors leading to the upgrade of wastewater treatment facilities in the country and stimulating the development of new wastewater treatment facilities

The National Strategic Wastewater Master Plan was developed in 2013, and wastewater treatment plant construction and/or upgrades were subdivided into three categories: immediate implementation (2013-2015), medium term implementation (2016-2025), and long-term implementation (2026-2035). Top priority was accorded to areas with wastewater collection systems experiencing overflows, sewers were overloaded, or wastewater treatment plant design capacity was exceeded or was close to design capacity. Second order priority was accorded to those areas for which the wastewater treatment plant would reach its maximum supply capacity between 2016 and 2025, those areas which were served by collection tanks but did not suffer from overflows, and areas with significant potential of polluting groundwater or surface water resources. Third order priority status was given to those areas which did not meet the criteria for priority I or II status (ISSP, 2014)

The national target for WW services as stated in the Water Sector Strategy (2016-2025) is to increase the number of people connected to sewer networks to 80% by the year 2025. Since the WW coverage in 2018 does not exceeds 66%, it seems unrealistic to reach the target within 6 years due to many limitations, including limited available funds allocated to the WW sector. Consequently, the MWI set a new timeframe to coincide with SDG6 targets that by the end of 2030 it is intended to reach 80% of population connected via a sewer system to centralised or decentralised systems.

## 5.3 Utilization of Recycled Water

Agriculture is an important economic activity in Jordan. Treated wastewater is be a valuable source for irrigation in the agricultural sector, freeing up fresh water resources that are needed for the rapidly growing urban populations. The irrigated areas using treated wastewater is increasing. With a fast growing population and expansion of the irrigated areas to meet the food demand the pressure on water resources in Jordan remains of imminent importance (Myszograj, Qteishat, Sadecka, Jędrczak, & Suchowska-Kisielewicz, 2014). The reuse of reclaimed wastewater are controlled by comprehensive environmental plan, which will take into consideration safety actions relative to quality standard of released reclaimed wastewater. This requires examination of physical-chemical and environmental properties of applications on soil, plants, and construction processes

The use of recycled water within Jordan has been made possible by the development and evolution of a sound legal framework. Reuse of WW is regulated by several sets of standards: including one governing the discharge of toxic materials to sewers and others that established standards for reuse of WW and the processing and use of sludge (refer to Annex 2 for more details).

The main source of irrigation water in Jordan Valley is the treated wastewater generated from As-Samra WWTP, which treats about 72% of generated wastewater in Jordan. TWW effluents discharged to Zarqa River end in King Talal Dam (KTD). The treated effluent from As-Samra WWTP to Zarqa River increased from about 61 mcm in 2007 to about 110 mcm in 2015 (MWI, 2016). Water from KTD is released to King Abdullah Canal (KAC) where it gets mixed with fresh water and used for unrestricted irrigation in the middle and southern parts of the Jordan Valley.

An evaluation of reclaimed domestic wastewater showed that of the 34 public wastewater treatment facilities, treated wastewater from 9 facilities did not fully comply with the Jordanian standard for ambient water quality[9].

During the early 1990’s, MWI started to encourage farmers to use the effluent to irrigate the lands around the WWTP’s but restricting the reuse to fodder crops because the discharged effluent’s poor quality. One of the aims for this course of action by MWI was to prevent the effluent from some of the smaller WWTP’s to flow into Wadis which would have polluted other surface and ground water sources. Steps toward reusing treated wastewater started by delivering the effluent to farmers’ lands adjacent to the WWTP’s free of charge. As public acceptance was achieved, the next step was to recover cost of delivery of the effluent. During the mid-nineties, more WWTP’s were constructed, while the old ones were expanded and rehabilitated through introducing mechanical methods which rendered the effluent quality in full compliance with local and international standards for reuse without restriction.

[9]These WWTP’s did comply with regulations for most parameters, but six exceeded the levels for hydro-carbonates, five exceeded the norms for chemical oxygen demand, and four exceeded the norm for phosphates (MoEnv, 2019)

### 5.4 Industrial wastewater discharge

The regulation on industrial discharge to the public sewer collection lines is only loosely enforced in Jordan. Industrial effluent from various types of industries with varying industrial wastewater strengths are currently being discharged into public sewer systems without supervision and monitoring, and eventually treated by municipal WWTP using standard technologies that are not supposed to treat industrial sewerage. Treated effluent from the municipal WWTP maybe therefore be unfit for agricultural purposes.

## 6. Population Context and Demand for DWWM and Reuse

Jordan policies and strategies prior to 2016 were based on a total population of 6.6 million including the Strategic Wastewater Master Plan's (SWMP)(ISSP, 2014), After conducting a population census in 2015, an unexpected, much higher population size was determined. The most recent population statistics suggest that the population of Jordan is 10.45 million. The Department of Statistics (DOS) expects the population to increase to 12.1 million by 2025, 14.37 million by 2030 and to 15.17 million persons by 2035 (refer to Table 30 in Annex 1).

### 6.1 Domestic Water Supply and Wastewater Generation

Domestic water used by different types of customers including residents, small industries, commercial, governmental institutions, and tourists is supplied through the public water network, which is managed by WAJ. Public water supply significantly increased over the past decades in both absolute and relative terms, rising from 376 mcm in the year 2013 to 470 mcm in 2017. These figures represent about 41% and 45% of the total water offtake, respectively, and were mostly due to the growth in municipal consumption, especially in the urban areas of Greater Amman, Irbid and Aqaba (MWI, 2017).

Table 31 in Annex 1 shows municipal supply in Jordan in l/c/d. The recent per-capita water supply for the year 2017 is about 125 l/c/d, significantly lower than that of neighbouring countries. Ajloun and Jerash governorates receive the lowest per-capita water supply. At governorate level, per capita consumption varies, partly reflecting significant variations in administrative losses due to the technical and socio economic particularities found in each governorate. Illegal use is high in Mafraq, Ma'an, and, until recently, in Madaba governorate. Other factors include variations in living standards, degree of urbanisation and local technical conditions. Table 31 shows) that the per-capita water supply is decreasing over time which appears to be driven by a combination of limited water resources and increasing population.

The effects of global warming, higher temperatures and more variable precipitation, is reducing the amount of water available for agricultural and household purposes in Jordan. This may probably force many Jordanian farmers out of business, posing an extra challenge to policy makers (Jiries, Shatanawi, AlMomani, & Al-Atrash, 2011).

### 6.2 Wastewater Generation and Collection

Based on current trends, water availability is expected to drop to 90 $m^3$/capita in 2025.[10] This situation has led to Jordan developing a water substitution and reuse policy whereby the government emphasises increasing the amounts of treated wastewater and considers this treated wastewater as a potential water source as well as a source of revenue. Jordan uses three different types of wastewater treatment plants: Waste Stabilisation Ponds (WSP), Activated Sludge (AS) and Trickling Filter (TF)[11] . Decentralised systems constructed so far are using SBR and constructed wetland (CW) technologies.

The WW generated was estimated assuming that 70-80% of the water supplied will become WW (Alfarra, Kemp-Benedict, Hötzl, Sader, & Sonneveld, 2011). A daily water supply/use of 120 l/c/d for Amman, 100 l/c/d for main cities and 80 l/c/d for other urban and rural areas (MWI, 2016d) has been adopted for preliminary calculation with a return flows to sewer system of 80%, 75% and 70%, respectively (ISSP, 2014)[12].

The forecasted total amount of WW generated from population will increase from 279 mcm in 2018 to 371 mcm in 2030 and to 411 mcm in the year 2035 based on the population forecast and constant per capita water supply over the next period (2020-2030) (MWI & UNICEF, 2019). Therefore, additional treated WW is around 92 mcm and increasing annually by about 7.6 mcm. The collected and non-collected generated WW for the year 2018 by governorate are shown in Table 33 (Annex 1). This table highlights the need to invest to increase WW connection and coverage sewered communities. The potential WW quantities that can be collected and treated in communities with less than 5,000 PE is a very low portion of the total generated WW.

### 6.3 Financing of wastewater infrastructure

The projected wastewater collection and treatment expansion are assumed to achieve 80% coverage by the year 2030 as proposed in the water strategy ((MWI, 2016c) page 9).

The required capital investment costs to achieve the SGD target of 80% of population to be connected to sewer systems and wastewater treatment facilities are estimated with JD 1,913 million for the period 2020-2030. About JD 489 million are required in the already connected communities, this amount is needed to connect the people who are not connected and the future population growth. About JD 1.124 million are required to coverage the non-served communities with

[10]Ministry of Water and Irrigation / UNICEF (2019): Developing Jordan's Roadmap to achieve Sustainable Development Goal 6.2, This is only the case of water availability remains constant, i.e. disregarding the effects of climate change

[11]AS systems have the highest efficiency of removal of BOD (above 95%), followed by TS (92.5% - 95.7%) and WSP (74%-81%).(Abdulla et al., 2016). Similar results are obtained in reduction of Chemical Oxygen Demand (COD).

[12]The Consultant considers the "supply water to waste water rate" of 80% realistic, given the high exfiltration rates of the sewer systems as mentioned in earlier reports already (such as DORSCH 2014).

sewer and wastewater facilities., and about JD 697 million are required to served communities with more than 5,000 PE and about JD 428 million for communities with less than 5,000 PE (MWI & UNICEF, 2019)

Government together with international development agencies finance much of the WW collection and treatment capital expenditure. However, customer contributions from initial connection fees subsequent water bills recover about 55% of the total cost. The initial connection fees are paid only by customers whose houses are connected to the water supply networks. Consequently, non-water connected consumers that use the wastewater system effectively do not pay. This is exacerbated by those consumers that purchase water from other suppliers who effectively contribute less to the wastewater system than they would do if they purchased all of their water from the public utility (Albakkar, 2014).

The coverage of public sewer and sanitation services is lower than the water coverage. Many WW treatment facilities are either overloaded or are employing inefficient technologies as shown in (Table 34 in Annex 1). The total WW treated in 33 WWTPs is approximately 150 mcm in 2018 and is being reused primarily for irrigation purposes in the Jordan Valley (JV). About 90% of treated WW is used in agriculture, nearly 80% are used in JV blended with fresh surface water and 20% are directly used near WWTPs. The treated WW represents about 14% of the water budget. Although only 66% of the population is connected to public sewer systems, the proportion with "improved sanitation"[13] exceeds 88%, with one third of the population using septic tanks and cesspits[14] .

### 6.4 Sanitation in Rural Areas

In most of rural areas residents are using cesspits to discharge the WW from their houses. Since most of these cesspits are not watertight, there is a large inflow of untreated WW to the groundwater. In addition, un-emptied cesspits cause spillage of WW to land and streets (Al-Mefleh, AlAyyash, Khaled, & Fatima, 2019). A recent survey conducted by (Al-Mefleh et al., 2019) in Mafraq Governorate showed that 12.1% of homes are connected to the sewer system and that the remaining 87.9% of homes use a collection tank. The study found that 41.2% of collection tanks are used for more than ten years, 36.9% are used between 6 and 10 years, and 21.9% are used for less than 5 years. As for how often the collection tanks are pumped, no one reported pumping the collection tank daily, 1.0% of respondents reported pumping weekly, 14.0% reported pumping monthly, and 85.0% reported pumping when necessary.

[13]Improved sanitation is a term used to categorize types or levels of sanitation for monitoring purposes. The term was coined by the Joint Monitoring Program (JMP) for Water Supply and Sanitation of UNICEF and WHO in 2002. The use of a flush toilets and septic tanks / collection tanks qualifies for improved sanitation already, no matter if connected to a sewer system or not.

[14]A septic tank is a collection tank designed to mechanically treat wastewater and the effluent is not allowed to soak away. Usually collection tanks are made by concrete. It requires regular emptying when it is full. A cesspit is an underground dig hole serviced as collection tank which does not treat wastewater and retains it for collection. Emptying frequencies depend on the size of the cesspool. Often cesspits allow wastewater to seep into the soil.

Of the respondents, 83.5% said that the collection tanks do not cause any environmental problems; whereas 16.5% said that the tanks cause many problems (such as flooding, odours, pollution, and contamination of groundwater). Building a new sewer will reduce the costs associated with drilling cesspits and pumping waste, as well as environmental problems associated with cesspits was expected by 16.5% of respondents (Al-Mefleh et al., 2019).

The construction of a sewerage network will reduce health risks caused by spillages from cesspits and the emptying activities as well as the treated effluent providing an additional water source that can safely be used in various forms for agriculture or other uses.

### 6.5 Targeted Communities with less than 5,000 inhabitants

Since about 66% of population are connected to a sewer and sanitation system, the target is to reach another 14% of population during the period 2020-2030 to reach the 80% of population with coverage of sanitation system.

### 6.6 Influent Wastewater Quality of WWTPs in Jordan

Information on domestic WW quality and data on the chemical analysis of treated effluents were obtained from MWI open files stored in NWIS (MWI, 2019). For domestic WW characteristics in Jordan, only those WWTPs receiving domestic WW were considered. The specific ranges for raw WW qualities that refer among others to the most important quality parameters, i.e. Biological Oxygen Demand (BOD5), Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), and Total Nitrogen (TN) are presented in Table 25.

Table 25: The chemical characteristics of domestic WW influents in Jordan for the year 2016

| Parameter | Avg. TEMP | PH | TD- | $BOD_5$ | COD | DO | $NH_3$ | $NH_4$ | TS | TSS |
|---|---|---|---|---|---|---|---|---|---|---|
| **JAN** | 16 | 7.48 | 1141 | 772 | 1512 | 0.53 | 63.0 | 85 | 1687 | 743 |
| **FEB** | 15 | 7.43 | 999 | 826 | 1348 | 0.53 | 64.9 | 104 | 1544 | 671 |
| **MAR** | 19 | 7.52 | 1051 | 772 | 1409 | 0.53 | 65.7 | 132 | 1592 | 828 |
| **APR** | 21 | 7.54 | 1429 | 768 | 1536 | 0.53 | 67.1 | 121 | 1449 | 755 |
| **MAY** | 23 | 7.49 | 1304 | 826 | 1418 | 0.42 | 61.4 | 130 | 1570 | 812 |
| **JUNE** | 24 | 7.55 | 1249 | 820 | 1533 | 0.42 | 68.1 | 100 | 1554 | 829 |
| **JUL** | 26 | 7.56 | 1027 | 760 | 1463 | 0.56 | 63.9 | 139 | 1494 | 801 |
| **AUG** | 26 | 7.51 | 1067 | 814 | 1478 | 0.93 | 65.6 | 89 | 1476 | 995 |
| **SEP** | 25 | 7.45 | 1092 | 794 | 1375 | 0.80 | 64.9 | 110 | 1412 | 726 |
| **NOV** | 24 | 7.60 | 1086 | 717 | 1352 | 0.93 | 71.2 | 119 | 1768 | 760 |
| **OCT** | 25 | 7.47 | 1036 | 744 | 1424 | 0.88 | 64.3 | 109 | 1674 | 748 |
| **DEC** | 21 | 7.47 | 1001 | 815 | 1615 | 0.93 | 70.0 | 123 | 1522 | 680 |
| **Avg.** | **22** | **7.51** | **1123** | **786** | **1455** | **0.67** | **65.8** | **113** | **1562** | **779** |
| **Min** | **15** | **7.43** | **999** | **717** | **1348** | **0.42** | **61.4** | **85** | **1412** | **671** |
| **Max** | **26** | **7.60** | **1429** | **826** | **1615** | **0.93** | **71.2** | **139** | **1768** | **995** |

Source: compiled by consultant based on (MoEnv, 2019)

These figures are used as a basis for estimating wastewater quality for DWWTPs.

### 6.7 Increased Water Demand for Irrigated Agriculture

Irrigated agriculture in the Jordan Valley relies predominantly on surface water, which includes water from the tributaries to the Jordan River; water flows from the side Wadis, and treated WW from the urban areas in the highlands.

Irrigated agriculture in the highlands east and south of the Jordan Valley relies predominantly on groundwater and is thus a direct competitor for the current major water source of municipal and industrial water supply.

Recorded water abstraction for agriculture amounted to 544 mcm in the year 2017 according to the MWI (MWI, 2018). which represents about 52% of the total annual total water use, although for the last two decades the allocation to agriculture was reduced to 700 mcm per year.

From groundwater resource, irrigated agriculture used 46% of the total water abstracted from groundwater for all purposes, with a sum of 251 mcm for that year.

Water allocated to agriculture is being reduced in response to increasing municipal demand, technological improvement of water saving irrigation technologies and more efficient use of water. Figure 16 shows the increasing trends of irrigated areas in the Jordan valley and Highland areas which shows that there is minor growth in the irrigated areas in the JV, but very high in highland areas. Figure 17 shows the main sources of irrigation water. The main resources of irrigation water in Jordan Valley is surface water followed by groundwater and treated WW, while in the uplands the main irrigation water source is groundwater followed by surface water, while treated WW reuse is increasing.

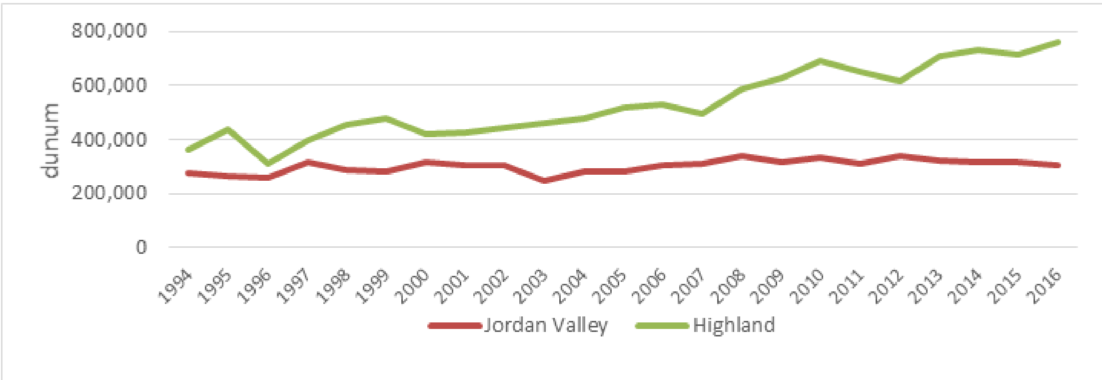


Figure 16: Development of irrigation areas in Jordan Valley and Highland, (DOS, 2019a) [15]

[15]A Dunum equals 0.1 hectares, a measure of land area used in the middle east except in Egypt

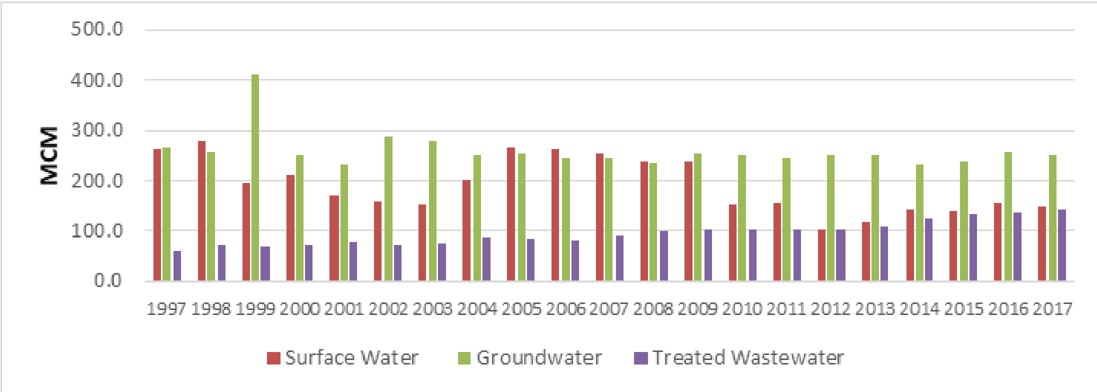


Figure 17: Development of irrigation water use and sources in MCM, (MWI, 2017)

Jordan's water strategy estimates the irrigation water demand to be 1,000 mcm for 2010 and beyond, based on the irrigated areas and on the water crop requirement[16]. Consequently, the agricultural sector receives far less than it demands.

## 6.8 Wastewater Reuse in Irrigated Agriculture

Farmers have limited options to cope with water scarcity and generally resort to reducing the cultivated areas, or to accept using treated WW for irrigation. In 2017 treated water used in agricultural irrigation was estimated to be 144 mcm, of which about 117 mcm are used in Jordan Valley and about 27mcm in the highlands near WWTPs. Direct use of treated WW for restricted agricultural crops such as fodder crops (e.g. alfalfa, maize) is becoming one of the technical options to cope with increasing water scarcity. However, the potential adverse effects on soils, land use and crops are major concerns both for farmers and for public institutions (MWI, WAJ, MoH, MoA and MoEnv). Nearly about 2 mcm of treated WW are re-used by some industries for cooling purposes (MWI, 2018).

Most of the WWTPs' effluent qualities conform to WHO guidelines and the Jordanian water quality standards for restricted irrigation, but they violate the unrestricted irrigation standards. Also, illegal irrigation practices on crops for raw consumption are still reportedly happening alongside the Wadis (valleys) downstream from the treatment plants before the effluent get mixed with surface water (Albakkar, 2014).

[16]Irrigation demand is simply the summation of the multiplication of cropped area by the crop water requirement planted in each area.

# 7. Institutional and Regulatory Framework for DWWM

## 7.1 Stakeholder Mapping and Institutional Mandates

The MWI is the official body responsible for the overall monitoring of the WW sector and the related projects, donor financing and aid coordination, WW resources planning and management, the formulation of national WW strategies and policies, research and development, information systems and procurement of financial resources[17]. Its role also includes the provision of centralised water-related data, standardization and consolidation of data. The MWI incorporates two entities dealing with WW in Jordan:

- The Water Authority of Jordan (WAJ) is responsible for water supply, WW connection, sewerage and WW treatment facilities[18].
- Jordan Valley Authority (JVA): responsible for the socio-economic development of The Jordan Rift Valley, including water development and distribution of irrigation that generated for WW treatment facilities. Units for public relations, internal monitoring and water security and protection are directly subordinate to the MWI with responsibilities overarching MWI, WAJ and JVA.

Article 3 of the Water Authority Law No. 18 of 1988, establishes WAJ as an autonomous corporate body that carries full responsibility for the public water supply, WW services and related projects as well as for the overall water resources planning and monitoring, construction, operations and maintenance (MWI, 2013). The responsibilities of WAJ are summarised as:

a. Study, design, construct, operate, maintain, and administer water and public sewerage projects including collecting, purifying, treating, disposing and the use of any other methods dealing with water.
b. Carry out theoretical and applied research and studies regarding water and public sewerage to achieve the authority’s objectives including the preparation of approved water quality standards for different uses and technical specifications concerning materials and construction to apply the findings to WAJ’s projects in coordination with other concerned departments; and publish the final findings and standards to generalize their application by all means available to the Authority.
c. Issue permits to engineers and licensed professionals to perform public water and sewerage works; and participates in organizing special training courses to qualify them to improve the standard of such works and to reduce water losses and pollution. All those involved in water and sewerage works are requested to adjust their practice in accordance with the provisions of this Article and to obtain the specified permit accordingly.

[17]http://www.mwi.gov.jo/sites/en-us/default.aspx

[18]http://www.waj.gov.jo/sites/en-us/default.aspx

- The Ministry of Agriculture (MoA) is responsible for a wide variety of tasks, ranging from managing public lands to regulating hunting to protecting soil resources. The ministry's stated goals with respect to water are to maximize production of food and agricultural outputs, achieve sustainable use of natural agricultural resources. The MoA is authorized by Law to control treated effluent to be used for irrigation purposes in cooperation with MoH. An inter-ministerial team with the help of the environmental police inspects the cultivated areas near WWTPs and water courses to prevent the cultivation of fresh and edible crops. They have the full authority to destroy any field irrigated with direct WW without prior permission from MWI, MoH and MoA. For the DWWM approach it is necessary to involve MoA, if the treated effluent will be used for irrigated agriculture to agree on the crop type and crop tolerance and suitability

- The Ministry of Health (MoH) strategy (2018-2022) addresses several common and significant elements of risk related to problem that arise from shortage in sanitation services. The health sector in Jordan consists of service providers (public, private, international and charity sectors) and councils and institutions working on the development of a health policy. The MoH is in charge of improving the health of the population through fighting diseases caused by vector born diseases and water borne diseases. In addition, the Ministry inspects the population's food consumption to ensure that it includes all the required micronutrients, iron, vitamins and other necessary ingredients. The MoH provides a similarly broad array of services. Its water-related responsibilities are to monitor the quality of WW effluent discharged from WWTP and inspect any potential source of pollutants. Regulations are issued in coordination between the MoH and the MWI to regulate the use of treated WW for irrigation. The monitoring of WW is the responsibility of the MoH in order to ensure compliance with public health standards. The expected role of MoH in the DWWM approach will be similar to that of the centralised system approach.

- Ministry of Finance (MoF), Jordan has embarked public-private partnership (PPP) program with the broad objective of creating a driving force for economic growth and employment through well-defined partnerships in the infrastructure, utilities, and service sectors. Fiscal constraints demand the leveraging of private sector resources to meet infrastructure development requirements using public-private partnerships (PPPs). PPPs are recognized as a catalyst for growth and employment and a key ingredient for achieving the national development goals. PPPs are intended to achieve the following goals[19]:

[19]https://pppu.gov.jo/en-us/The-PPPU/About-Us

1. Building, rehabilitating, operating, and maintaining public infrastructure.
2. Encouraging the private sector to enter investment partnership projects with the Government Body.
3. Finding the necessary funding to support feasible projects presented by the Government Body.
4. Benefiting from up-to-date technical and technological experience and knowledge in building and managing projects.

The 2014 Public-Private Partnership Law is the exclusive legal framework for public-private partnership projects in Jordan and takes into account all sectors, including water The PPPs regulation have been released[20]. The PPP Unit, under the supervision of the MoF and the Public-Private Partnership Council led by the Prime Minister, acts as a central body for the supervision, regulation, and support of all PPPs conducted by the Government of Jordan.

- The Ministry of the Environment (MoEnv) is mandated to maintain and improve the quality of the Jordanian environment by sustaining and conserving Jordan's environmental resources and contributing to sustainable development. The Ministry also monitors public and private WW facilities to assure its compliance with standards and regulations. The Ministry demands corrective actions when the treated effluents does not comply with the Jordanian Standards. For the DWWM approach it is necessary to involve the MoEnv to ensure compliance with the applicable standards. (in particular Jordanian Standard JS893/2006 on treated wastewater effluent quality).

- The Water Utilities, namely Yarmouk Water Company (YWC)[21] in the North, Miyahuna[22] in the metropolitan area of Amman, and Aqaba Water[23] are organisations registered as limited share partnership owned by WAJ and partners These companies are authorised by WAJ to provide water for much of the population through desalination and purification plants, and the government relies on them to treat WW. The private sector is also an important source of funding. To attract this funding, Jordan has used Build-Operate-Transfer (BOT) contracts in the development of water and WW infrastructure. Funds for building are contributed by the government through contractors who build and operate a facility for a time and then transfer control back to the government. In Jordan, the concessions period of private operation tends to be long, and the government sometimes decides to leave control in the hands of the private operator. For Example, As-Samra WWTP project is a public private partnership (PPP) for financing the construction and operation of a public infrastructure in Jordan based on a "Build Operate, Transfer" (BOT) approach over a period of 25 years. It is the

[20]https://pppu.gov.jo/Portals/0/PDF/FINAL-PPP%20Law%20(English).pdf

[21]http://www.ccd.gov.jo/bycompanynameframe21.aspx?CompanyID=168935

[22]http://www.ccd.gov.jo/bycompanynameframe21.aspx?CompanyID=115065

[23]http://www.ccd.gov.jo/bycompanynameframe21.aspx?CompanyID=92176

first BOT project in Jordan. The Swedish International Development Agency (SIDA) financed the technical assistance during the preparation phase, construction, commissioning and 18 months of the commercial operation period of the project.

- Ministry of Municipalities and Municipal Affairs is taking up the supervisory role over the activities of the municipalities and the Joint Services Councils (JSC) operating all over the Kingdom with a total of (93) municipalities and (22) JSCs. The main duties are: (1) preparing the regional, organizational and detailed construction plans for the municipalities including sewer system and WW treatment facilities; and (2) monitor and controlling the implementation of the regulations, policies and instructions of the municipalities and joint services councils including sewer system and WWTPs.

## 7.2 Engaging Stakeholders

Successful implementation of DWWM requires the engagement of many stakeholders, encompassing government and non-government actors. Implementation efforts should be guided by a careful analysis and an understanding of the roles of different stakeholders in the country's development process.

DWWM implementation will require the cooperation of many government actors, including the head of state's office, parliament, finance and planning bodies, sector ministries and sub-national bodies, the judicial system and the national statistics office. It is important to first determine which government agency will lead the coordination process. Non-governmental actors, including civil society organizations and the private sector, can play a key role in advancing the SDG agenda. Table 26 shows the main challenges and opportunities in working with key stakeholders related to DWWM.

For example, DWWTPs offer an opportunity to introduce WW treatment and generate irrigation water in places that are not connected to centralised WWTPs. The advantages of decentralised technologies include their capability to provide WW treatment infrastructure in remote and hilly rural communities[24].

[24] However, stakeholder engagement is a challenge. An international project with cooperation of MWI identified a DWWM project in Al-Salt Maghareb after consultation with stakeholders in the targeted areas. One of the parliament members succeeded to cancel the whole project. The selected project location was expected to reduce the land price in the surrounding areas due to the presence of WWTP and expected bad smell. A conflict of interest between surrounding landowners and public interest of providing sewer system and WW treatment appeared, a pressure from parliament members succeeded to cancel the project. Exactly the same happened to the GIZ ACC Project in the villages Bwaidah Gharbiyeh and Dajaniyeh in the Rehab area of Mafraq Governorate. Hence social acceptance and political commitment and enforcement towards DWWM is a challenge for scaling-up DWWM in Jordan.

Table 26:Challenges and opportunities in working with key stakeholders of DWWM

| Actor | Challenges | Opportunities | Impact |
|---|---|---|---|
| **Cabinet** | • Has numerous priorities to deal with<br>• May face conflicting and other priorities | • Has a leading role in coordinating the implementation of the target policy of DWWM | • High |
| **Parliament** | • Often not involved in all stages of national development planning<br>• May have limited awareness of the sanitation problems<br>• May face conflicting interests | • Leverage its legislative role<br>• Foster its advocacy role, especially for budgeting<br>• Foster awareness among parliament members about the non-action option of sanitation in small communities | • High |
| **Judicial system** | • May have limited awareness of sanitation problems<br>• Enforcement of laws may be lacking | • Develop synergies with laws related to good governance (e.g., corruption, tax evasion, illegal trade) | • Medium |
| **Finance and planning** | • Linkages with sector ministries and subnational bodies may be weak<br>• Addressing the lack of sanitation necessary in rural areas | • Turn these bodies into DWWM champions as solution of burden on public budget<br>• Have them play a key role in coordinating implementation of the DWWM policies<br>• Develop synergies with revenue collection measures (e.g., fees collection, tax evasion) | • Very High |
| **Sector ministries and sub-national bodies** | • May have weak capacities<br>• Lack of funding of subnational bodies can impede DWWM policy<br>• Some sector ministries are not well connected to other miniseries | • Support them in fulfilling their roles in development planning of DWWM<br>• Encourage them to integrate with DWWM and sanitation objectives into plans/budgets<br>• Involve them in monitoring and implementation of DWWM | High |
| **Department of statistics** | • Data collection and management often weak, especially rural and small communities<br>• Data not generally captured by regular surveys | • Increase investments in data and national statistical systems<br>• Build statistical capacity to monitor sanitation, including capacity to collect, manage and analyze data on a regular basis on WW and small communities | • Medium |
| **NGO, Civil society organizations (CSO)** | • Capacities may be weak, especially with respect to engagement in national planning | • Involve them in early stages of development planning, conducting a need assessment | • Low |
| | • Often not involved in stages of planning and implementation | • Encourage them in their watchdog role (i.e., in promoting transparency and accountability)<br>• Foster their role in information collection, information-sharing and awareness-raising (from policymakers to local communities) | |
| **Business and industry** | • legislation as a barrier to their activities | • Engage them in planning process to provide effective and innovative solutions to achieve target policy of DWWM<br>• Make use of this major source for financing the DWWM policy by incentives and tax exemption<br>• Offering a profitable and viable contact services from private sector interest | • Low |
| **Academic and research institutions** | • May be disconnected from the technology development<br>• Capacity to produce policy-relevant information may be weak | • Leverage their innovative ideas, including new scientific approaches, to deploy sustainable solutions and appropriate technologies of DWWM<br>• Work with them to enhance the science-policy link to find solutions to problems of sanitation | • Low |

Source: Consultant's compilation

### 7.3 Gaps in the Wastewater and Sanitation Legislation

There are many overlaps and gaps in responsibilities assigned for each ministry, which require careful coordination between both for adequate control of produce. In addition to existing overlaps and lack of coordination, it is expected that lack of capacities at ministries be behind reluctance to take decision on responsibilities to adopt the DWWM approach. The public institutions are already over-committed with their current responsibilities and are therefore reluctant to add new issues (such as DWWM) to their lists of priorities.

Due to the lack of a supportive and coherent framework for WW reuse, control and monitoring between MWI and MoA, the MWI regulates the direct use of treated WW in the neighborhood of WWTPs by issuing an agreement between farmers and MWI that restricts types of crops allowed to be irrigated with reclaimed WW to fodders and fruit trees.

The national building law (1993 as amended, 2017) specifies the sanitation system inside the building and its requirements. Article 75 requests from the owner to provide septic tanks[25] and drainage or absorptive holes in case there is no sewage, and the WW may not be drained to the rainwater drains for whatsoever reason. The specifications in the building code are oversized. It requires a septic tank capacity for 200 l/c/d with a retention time of 15 days. In practice, when the septic tanks are full, the owner can hire emptying services upon request. The oversized septic tank specification may encourage stakeholders and beneficiaries to adopt DWWM to avoid extra construction costs in their property.

The Municipality Law #41/2015 (as amended 2017) gives municipalities the legal capacity to own and operate WWTPs and to specify standards for construction. The law also specifically entrusts the municipal government's water agency with the responsibility to "prevent the pollution of water supply springs, canals and basins or wells". The law also provides the Governorate the powers to construct public sewers and to undertake the "management and supervision of the sewers". This enabling legislation applies only to the defined area of the municipality. The legislation gives the municipalities the authority, with the approval of the cabinet, to develop concessions for operation of public utilities by private-sector engineers and contractors so long as such concessions did not exceed 30 years. This may be contradictory or overlapping with the WAJ law regarding the establishment and control of sewers and WWTPs.

Due to the lack of a supportive and coherent framework for WW reuse, control and monitoring between MWI and MoA, the MWI takes the role to regulate the direct use of treated WW in the neighborhood of WWTPs by issuing an agreement

[25]In many Jordanian documents the terms "septic tanks" and "collection tanks" are used synonymously although the respective installations are serving fundamentally different purposes. A septic tank is supposed to treat wastewater by containing settleable solids and grease/oil and releasing the treated wastewater into a drain or directly into the environment, while collection tanks simply collect all wastewater and need to be emptied from time to time. Both systems are used in Jordan, and often it remains unclear which type has actually been built.

between farmers and MWI that restricts types of crops allowed to be irrigated with reclaimed WW to fodders and fruit trees

Coordination and synergies between different related institutions is a major WW governance issue. Rivalries between different water institutions are common, and the responsibilities of each are not always clearly established. Inefficient delivery of WW services is often the outcome. There is a need for institutional reform in almost all water related institutions and structures. Regardless of the institutional structure, it is recommended that inter-ministerial commissions be endorsed at the highest level, and engage ministries of planning, finance and economy, health, education and social development, agriculture, environment and national statistical offices.

concentration limits should be introduced (operator can choose between one of the 2 options).

### 7.4 Standards, Regulations of Treated Effluents

Treated WW and sludge samples are subject to monitoring through laboratory tests by WAJ labs and/or RSS water &WW labs to determine the physical, chemical and bacteriological characteristics, and then to evaluate the quality of the effluents in accordance with the Jordanian standard specifications to demonstrate the suitability of treated WW in different sources for reuse. The water quality of the monitored sources is assessed depending on the results of analysis and with reference to the followings:

- Jordanian Standard for Reclaimed Domestic WW Quality No. (893/ 2006) (JSMO, 2007b).
- Jordanian Standard for Reclaimed Industrial WW Quality No. (202/ 2007) (JSMO, 2007a).
- Food and Agriculture Organization (FAO) Guidelines for Irrigation Water Quality
- Jordan Standards for Irrigation Water Quality No. (JS 1766/2014). (JSMO, 2014)

Jordanian Standards JS893/2006, JS202/91, JS 1145/96, WAJ's regulations for the quality of industrial WW to be connected to the collection system and WAJ's specifications for sewerage works, have been, thus far, the benchmarks against which specifications of treatment plants and WW reuse are evaluated. These standards and regulations should be reviewed and modified periodically to reflect changing circumstances. Other aspects shall also be considered, e.g. economic, socio-cultural, environmental and regional aspects. Currently, the Jordanian Standards forbid the use of reclaimed water for irrigation of vegetable crops that may be eaten raw such as lettuce, peppermints, and other leaf vegetables.

### 7.5 Existing wastewater treatment specifications and standards

The Jordanian standard (JS 893/2006) (Annex 2) for wastewater discharge and reuse is the mandatory standard that covers the scopes related to: (i) the treated effluent discharge to wadis, streams and water bodies, (ii) the effluent reuse for groundwater recharge and (iii) the effluent direct reuse for agricultural irrigation.

Content and applicability of JS 893/2006 have been critically commented by numerous authors. e:

1. The JS 893/2006 is based on the outdated WHO guidelines from 1989 despite the updated version of those guidelines issued in 2015
2. For irrigation uses, the JS 893/2006 does not consider the unavoidable fluctuation in irrigation demand over the year. Surplus water not needed for irrigation during the winter has to be disposed of into the nearest receiving water body or wadi, but standards for irrigation still apply, resulting in unnecessary treatment costs.
3. The limit for Total Suspended Solids (TSS) varies between 15 and 300 mg/l, which is difficult to justify.
4. The nitrate limits for the discharge purposes, i.e. 80 mg/l, is higher than those required for all irrigation purposes, i.e. (30 – 70 mg/l), which does not make sense in that plants require nitrogen as an essential nutrient. The potential uptake of nitrate by plants has not been considered. Moreover, the permitted limit of nitrate in drinking water is only 50 mg/l (WHO Guidelines).
5. The maximum allowable count of the E. coli for irrigation of cut-flowers is considered too stringent
6. The standard does not consider pollution loads, but rather pollutant concentrations only which is difficult for small scale WWTPs to comply with.

The following is proposed for improving JS 893/2006, and to support the application of DWWT country-wide[26]:

1. Allow surplus water not needed for irrigation during the winter to be disposed of into the nearest receiving water body (wadi), while existing discharge standards into surface water bodies shall apply.
2. Allow higher concentrations for N and P in irrigation water, acknowledging their value as nutrients and reducing investment and O&M costs of DWWTPs.
3. For small-scale WWTPs a pollution load concept in combination with concentration limits should be introduced (operator can choose between one of the 2 options).

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[26] Also refer to other parts of the compendium where the JS is discussed in the REUSE CONCEPT and ORIENTATION GUIDE

[27] Regulators should not normally be involved in dispute resolution unless the dispute in question is likely to have a material regulatory impact and the precedent set by the dispute resolution will need to be embedded in the regulatory framework. General dispute resolution should normally be within the jurisdiction of an ombudsman or similar.

### 7.6 Legislations and Regulations

In recent years an apparent lack of political will to enforce the laws and by-laws has resulted in a loss of confidence in law enforcement. Furthermore, continuous changes in leadership positions within the MWI, JVA, WAJ and water related institutions have contributed to delays in legal amendments and differing opinions on WW and sanitation policy priorities.

These WW regulation and reuse standards in agriculture are appropriate as a fundamental step to protect the public health of both consumers and farmers. However, the major challenge continues to be the implementation and enforcement of these regulations and standards. In the Jordanian context, there are several socio-cultural and political factors hindering the successful implementation of established laws and standards that regulate the use of treated WW.

There has been a recent shift away from centrally planned provision of infrastructure towards demand-led approaches that create and serve people's motivation to improve their own sanitation. Although sound technological judgment about appropriate solutions remains essential, appropriate programming approaches are now more important and contribute most to the success of sanitation work.

Some of the most promising approaches that apply to both rural and urban sanitation are decentralised systems. Adopting the DWWM approach requires appropriate legislation to enhance private sector engagement. The local private sector can also be encouraged to become involved in collection, treatment, pit-emptying, sale of safely composted human excreta as fertilizer, generation of methane from biogas toilets, and the operation of public toilets. PPPs have become attractive to governments as an off-budget mechanism for infrastructure development as this arrangement may not require any immediate cash spending. The public sector's other main advantages include the relief from bearing the costs of design and construction, the transfer of certain risks to the private sector and the promise of better project design, construction and operation.

To eliminate or minimize these risks, a regulatory system needs to be in place, with usually more than one body involved in regulation. For example, environmental protection agencies should be responsible for overseeing wastewater discharge quality compliance, agricultural (if not environmental) agencies to oversee wastewater reuse standards and an economic regulator for regulating prices (or revenues) for services.

The MoEnv, MoH and WAJ in addition to JSMO constitute the regulatory framework. It comprises of a set of legal instruments and rules (laws, contract agreements, statutory rules framed by the government, etc.); procedures and processes (for obtaining required approvals, licenses and permits, etc.); and regulatory authorities (ministry, regulatory agency, judiciary, etc.) with the delegated power. The actual functions of individual regulatory authorities would depend on the overall structure of the regulatory regime, empowerment of authorities as provided in the relevant legal instruments and rules, administrative arrangements and autonomy, and technical capacity. However, some of the essential functions of regulators include:

- Protection of public interest (all regulators)
- Monitoring compliance with contractual obligations to the government and users, and other legal and regulatory requirements (environmental protection regulation in the main)
- Following the technical, safety and quality standards (should be defined in the contract agreements) and monitoring their compliance (if they are legal standards there is no need to include in agreements, i.e. the law supersedes any contract obligations)
- Imposing penalties for non-compliance
- Administering tariff adjustments and periodic reviews (economic regulator)
- Establishing accounting standards and undertaking operator's cost and performance analysis (economic regulator)
- Facilitating dispute resolution[27] but confined to matters of regulation. Providing advice and counsel to government on policy matters and other related matters to private sector involvement in the sector (on request by government).

## 7.7 Monitoring and Evaluation of DWWM Service Performance

Monitoring is a key part of any DWWM arrangement. Three key issues for decision makers and officials to consider are the frequently high cost of monitoring, alternative monitoring techniques, and responsibility for monitoring. The cost of monitoring can be insignificant or very high. Monitoring techniques include inspections, reports, complaints, and accountability and performance standards. Monitoring can be performed by officials or appointed third parties at different levels within the governmental agency (WAJ lab). Such arrangements should be considered on their respective merits, e.g. an arrangement working well in one organization (RSS lab) for one type of contract may not work well under different circumstances.

For adopting the DWWM approach, there is a need to regulate a service provider to ensure that services provided reflect the adequate level and meets the desired standard or quality. Regulatory control is also needed to ensure sustainable development in a sector. There are three main requirements that any sustainable development must satisfy. First, it must be economically and financially sustainable to ensure that a continuing capability exists to produce and deliver goods and services from contacted firms. Second, it must be environmentally and ecologically sustainable to ensure an overall improvement in the general quality of life, and not merely results in an increase in traded goods and services. Third, it must be socially sustainable so that the goods and services can be equitably shared by all sections of society.

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[27]Regulators should not normally be involved in dispute resolution unless the dispute in question is likely to have a material regulatory impact and the precedent set by the dispute resolution will need to be embedded in the regulatory framework. General dispute resolution should normally be within the jurisdiction of an ombudsman or similar.

Building on existing sector monitoring frameworks and indicators, a clear monitoring framework for the implementation of the plan needs to be developed. This should focus not only on outputs (e.g. access) but also outcomes, considering factors such as service provider performance, service levels received, and any overall aggregate for sustainability. Such tracking should update datasets from the baseline created during the Assessment Phase. Mechanisms for collecting the monitoring data need to be included (and costed) such as periodic surveys, implementation monitoring and supervision, service provider key-performance indicator reporting, periodic participatory stakeholder reviews, etc.

Monitoring can be viewed as the "interactive link" between policy formulation and on-the-ground implementation of the DWWM reform. Monitoring provides evidence for enforcement measures without which enforcement can easily be challenged. Effective monitoring will imply that policies can be fine-tuned, allowing for financial reallocation between reform priorities. Non-compliance with and inability to enforce WW reforms are generally due to lack of inspection and monitoring capabilities of water authorities, lack of procedures and rules for investigating violations and assessing penalties and lack of enforcement powers and the willingness to apply them. The appointed authorities should have adequate enforcement powers to ensure compliance without resort to court action, e.g. the imposition of fines and other sanctions. In fact, court action normally comes from the service provider appealing against a regulatory decision rather than the regulatory body enforcing compliance. Enforcement through court action should be a last resort.

## 8. Private or Public Ownership of DWWM systems

Ownership of WWTP can range from fully public to fully private. Currently all WWTP are owned by the public sector and operated in different ways, either by WAJ directly, water utilities, or through contractual arrangements.

The MWI, which is responsible for formulating water strategies and policies; performing water resources planning and developing national master plans; monitoring and evaluating water resources; and conducting water, wastewater, and irrigation studies. Under the Ministry a Performance Management Unit (PMU) is working to monitor the performance of and audit the corporatized utilities; and develop PPPs and promote private sector participation (PSP) in water services and management.

The management of the water sector is very much centralised, and undue political influence is common. The "autonomous" water companies are not actually independent (MWI 2010b). Regulatory functions remain limited to monitoring the performance of the companies through performance indicators. It has been generally accepted in the sector that the key principles of separating policy, regulation, implementation together with the introducing commercialisation of operations (including PPP) apply to Jordan.

Despite these principles, in Jordan, WAJ undertakes a multiplicity of roles; sometimes it is the operator, sometimes a contracts supervisor, and sometimes a regulator. The regulatory structure for most of the PPP projects is by contract, and WAJ is directly responsible for the administration of the contracts. In some cases, this extends to external technical and financial audits to review the performance of contractors to determine the respective performance incentives.

The choice of public or private systems is a subject of debate. The public sector is usually composed of non-profit entities managed by the Government, with rates set by regulations created by a governing board. Private water systems are driven by the need for profit-making and managed by investors and shareholders. Although rates are usually monitored by a state's commission or public institutions, private systems are not necessarily subject to this regulating board but rather through a form of regulatory oversight.

Ownership has always been considered an important dimension of industry structure. Ownership structure affects utility performance largely because the incentive systems that guide performance vary according to ownership. Publicly and privately-owned utilities have different tools at their disposal to finance water utility systems. Each ownership form offers certain advantages or disadvantages in a given situation. Nonetheless, public ownership should not be entirely ruled out as a structural option to improve the financial viability of some water / WW utilities.

DWWM is not yet fully established and integrated in the WW sector in Jordan. However, several WWTPs are privately owned and operated that could be classified as decentralised WWTPs, indicating that there is a need for establishing small-scale solutions for suburban and rural areas.

O&M for DWWM systems, i.e. systems that comprise one or more DWWTPs with a design flow servicing less than 5,000 PE, shall be established through an agreement between the MWI/WAJ, the responsible water utility, and private sector companies. The respective contract shall be stipulated between the DWWTP (public institutions such as WAJ, water utilities, community, municipality, commercial enterprises, or household) and one of the above-mentioned potential O&M providers. However, O&M for DWWTPs shall be controlled and monitored by a public regulator (WAJ, MoEnv, RSS) and should be based on an O&M certification scheme that covers education and training for O&M of DWWM systems.

In Jordan, the ownership models in DWWM can be shaped as follows:

- State enterprises are founded and provided with property by the Government or other public administration authorities.
- Associations (Cooperatives) of beneficiaries and customers working under legal framework of cooperatives laws.
- Municipal enterprises established and provided with property by local public administration authorities and are legal entities liable for their obligations with all their property.
- Departments within municipality do not act as separate municipal enterprises but rather operated directly by the municipality.

- Commercial companies (joint stock or limited liability companies).
- Private operators which may own or partly own the infrastructure.

In Jordan, the municipalities law gives the responsibility to local administration (municipalities, cities and villages) to ensure proper conditions for sanitation services; including establishment of sewer system, and WW treatment. While in urban areas (municipalities, cities) water and WW utilities exist as legal entities, it is a WAJ mandate to provide WW services and related projects as well as for the overall water resources planning and monitoring, construction, operations and maintenance (MWI, 2013).

The responsibilities of WAJ is the administration of public sewerage projects including collecting, purifying, treating, disposing. The specialized WW utilities are almost non-existing in rural areas; therefore, WW and sanitation is the responsibility of municipalities. In some rural localities, some public infrastructure for water supply and WW treatment exists and is operated by municipalities. WAJ was set up as an autonomous corporate body with financial and administrative independence. In reality, however, civil service constraints were imposed, government procurement by-laws were followed and all activities were scrutinized by the central Audit Bureau and the Bureau of Supervision and Inspection (Abu-Shams & Rabadi, 2003).

### 8.1 Public Ownership of Wastewater Facilities

The public budget will provide the capital investment cost of WW sanitation projects; re-investment costs also are required to be covered by public central budget. The public utilities (YWC, Miyahuna, Aqaba Water company) are required to cover operation and maintenance cost. A benefit of public ownership of water assets in Jordan is the ability of governments to fund capital improvements with 100 percent debt financing. Bureaucratic procedures for one-time procurement are one of the main obstacles in successful operation of WW facilities. Privatisation is structural in nature when it involves a transfer of ownership. However, many privatisation options do not involve ownership changes. Public owned utilities can be operated by private sector in different forms. The public utilities demonstrating higher production and operating costs, are less efficient in their procurement and scheduling practices, and adopt cost-saving devices and innovation more slowly, if at all.

Public ownership maintains public control over essential services and the infrastructure needed to provide those services. Arguably, no public utility services are as essential as water and WW services. WW services are essential for public health and sanitation.

Public ownership may be the only realistic solution for the viability problems of the many small water and WW systems which may be too small to be financially viable without tariffs exceeding affordability constraints.

### 8.2 Associations (co-operatives) for Sanitation Services

Associations work under legal framework of cooperative laws, similar to Water User Associations (WUA) in Jordan valley. The key feature is their not-for-profit character, but in reality, it is very difficult to establish such associations, especially, in Jordan which is characterized with weak cooperative skills and attitudes.

State-cooperative relations are very weak, cooperatives are not recognized as social enterprises, it is part of private business, the number of cooperative members is limited, with no "sense of ownership" among members, due to the virtual absence of cooperative education and training.

Government support services are inadequate to help cooperatives stand on their own feet and work independently. Cooperatives lack sufficient access to finance and credit and are donor dependent. Cooperative organizations are weak and subject to undue government influence , further undermining their independence and autonomy (Polat, 2010).

According to figures provided by the Jordan Cooperative Corporation (JCC), there are 1,591 cooperatives registered with the agency, two thirds of which are actually active, with the overall membership base comprising 142,000 citizens. The value of total assets is JD327 million, while the available cash at hand stands only at JD42 million in 2018. The figures, JCC officials acknowledge, are modest, and can be multiplied if the sector receives the attention and support it deserves from decision makers. The JCC's budget is JD2 million, 95 per cent of which is spent on salaries and operational expenses. The agency, which plays the dual role of monitoring and developing the sector, finds it financially challenging, and is short of qualified manpower to realize the envisioned change in the way it operates (Al Abed, 2018). The JCC seed its functions limited to cooperative registration and legal supervision.

### 8.3 Departments Unit within Municipalities responsible for Sanitation Services

As mentioned in Section 8.3 municipalities can establish a designated unit for WW and sanitation. Prior to the establishment of MWI and WAJ, the WW and sanitation was performed and operated by municipalities according to Health and Municipalities laws. This organizational unit is within municipality and do not act as separate municipal enterprises. The municipality can register a private company or enterprise with sole property or shareholders. In this model, the system is operated directly by the municipality.

Local municipalities are expected to share and participate in the capital investment cost of WW projects. Re-investment costs also are required to be covered by municipalities. The municipalities are required to cover operation and maintenance cost. The treated effluents could be sold to farmers or industry or gardening the municipality street.

From an institutional perspective, public ownership may offer certain advantages. It may be easier for the central government to provide acquisition and incentives to local municipalities, as compared to privately owned utilities. Public ownership also may promote more comprehensive water resource planning.

## 8.4 Municipal Enterprises for Sanitation Services

Public enterprises are founded and provided with property by the Government or other public administration authorities. Municipal enterprises are established and provided with property by local public administration authorities. State and municipal enterprises are legal entities liable for their obligations with all their property. The advantage conferred on municipal governments in the form of lower borrowing costs.

Local municipalities are expected to recruit private firms under the overall management of municipality board. The municipality firms are expected to cover the total capital investment, re-investment costs (including capital maintenance) and operation and maintenance.

## 8.5 Private Sector Operators

Sometimes WW service is provided by private operators, especially if one owns a part of the infrastructure. In Jordan, for example specialized private enterprises provide and operated their own DWWTPs, e.g. hotels, semi-public institutions and small industrial enterprises.

Privately owned utilities are expected to perform more efficiently and effectively than publicly owned utilities. The most frequently cited advantages of private involvement are construction and operational savings, improved regulatory compliance and risk management, reduced undue political influence, bureaucracy, improved procurement and scheduling practices, access to expert personnel, tax benefits and cash flow to the local government, debt capacity benefits, and access to private capital.

## 8.6 Private Sector Ownership

Advantages and disadvantages are associated with each ownership form are shown in (Table 27). The evidence on efficiency differences and other differences between utilities with alternative ownership forms is mixed (Beecher, Dreese, & Stanford, 1995). Some studies indicate that the private sector can provide services more efficiently; others are not so conclusive. Both sectors seem to suffer from a degree of inefficiency. Local officials prefer to retain ownership of utility assets and use partnerships for operational services.

Table 27: advantages and disadvantages of each organizational structure

| Organizational Structure | Advantage | Disadvantage | Applicability to Jordan |
|---|---|---|---|
| **Public Utility** | Secured capital investment costs, required operational costs are covered by public central budget. | Demonstrate higher production and operating costs, are less efficient in their procurement and scheduling practices, and adopt cost-saving devices and innovation more slowly. | Most of public WWTPs are government ownerships. |
| **Associations** | Voluntary association of services consumers; The report regarding the activity of association is delivered to the association's members and public authorities. Services to consumers are considered in decision making. Possibilities to attract financings from foreign donors. Important decisions are taken with the approval of the majority of association's members. | It does not provide comprehensive solution to WW services in rural areas. The association of water users approves connection of new users. The management of the association is usually not recruited from among WW professionals. Conflict of interest may appear between association members. | The model is applicable, especially in small remote rural settlements. |
| **Municipal enterprises** | Property is owned by local public authority. Impossible to go bankrupt. Possible to attract the funding from internal and international donors. Possible to receive funding from the central budget Municipality councils have the authority to monitor the quality of sewerage services. | Undue political influences on management especially regarding the tariff decisions. Operator's management is negatively influenced by central and local administration due to the lack of authorization contracts with administration. Legislative framework is not according to the reality of relation development between local public administration and service operators regarding the water supply and sanitation sector. | Little experience on concession and no experience on leasing in Jordan. The model would be applicable, but capacity building and new legislation are required. |
| **Departments within municipality** | Property is owned by local public authority which cannot go bankrupt. Flexibility in recruiting technical staff in WW management. | Lack of technical capacity Very little staff, who also have other duties Undue political influences on management and especially regarding the tariff decisions. Operator's management is negatively influenced by public administration. | Little experience on concession and no experience on leasing in Jordan; the model would be applicable, but capacity building and new legislation are required. Applicable, but little obvious benefit. |

| | | | |
|---|---|---|---|
| **Commercial companies** | Possibility to attract private investments; Welcome for private public partnership and concession; Possibility to accumulate financial assets for the rehabilitations of fixed assets and the extension of existing systems; Profit maximising. Possibility to ensure a performance management; Reduce the policy's influence on the activities of service operator; Increase the quality level of water supply and sewerage services. | Decreased possibilities to attract the funding resources (grants and preference loans) regarding the private properties on production means; Reduced involvement of stakeholders in the operator's activity regarding WW services. Severe consequences of the mistakes and gaps made in the delivery process to operate the service by local authority to Operator; High risks regarding the tariff policy applied by operator in the conditions of small user charge revenues | Limited experience on management contracts in Jordan; the sector is not attractive for private providers due to affordability constraints and tariff setting rules |
| **Small private operators** | Private sector involved, bringing its management and technical expertise, and capital (even if just working capital); Improved efficiency. | Limited technical capacity; Relations to local administration authority-operator should be based on contractual basis; Profit making operator what may exacerbate affordability constraints. | Problem with technical capacity could be solved through outsourcing and applying national rules for all providers (licensing); Service contracts to be introduced. |
| **Private Sector ownership** | Private sector involved, bringing its management and technical expertise, and capital to meet the regulation of WW discharge. | High cost of land acquisitions. | Private WWTPs existed in Jordan for private enterprise, industry, hotels, Universities etc. |

The community ownership of DWWTP could be sustainable. It can be insulated against undue government influence and its bureaucratic procedures. It will rather depend on the local actors.

The municipality, or community ownership of DWWTP is an attractive solution to Jordan, largely because land acquisition is a major barrier The municipality can choose the appropriate location of the DWWTP and allocate the land ownership to municipality, even if the land is privately owned on the grounds that it is the public interest as set out in the land Expropriation Law for Public Benefit[28].

The Community ownership in this sense will adopt direct and autonomous responsibility for their local wastewater solutions

[28]Land acquisition is undertaken in accordance with Decree (12) of 1987 referred to as the Land Acquisition Law (LAL) and in accordance to its amendments. The LAL applies in all cases of land acquisition in the Kingdom of Jordan. Article 3 and Article 9 of the LAL stated the two main conditions under which land can be expropriated: (1) No land can be taken away unless it is for public benefit and that there is fair and just compensation, -Article 3 of the LAL.(2) The law requires direct negotiation between the purchasers for public benefit project and land owners until agreement is reached - Article 9 of LAL.

# 9. Regulation and Control

## 9.1 Setting standards for DWWM

The existing standards (especially JS893/2006) in Jordan are applicable for centralised WWTP. Other standards exist for industrial WW and for Energy generation plants (oil shale industry). An individual standard for WW generated from DWWTPs may be necessary as discussed above.

## 9.2 Establishment of a Monitoring system for DWWM

Until recently, the lack of reliable monitoring technology has impeded the adoption of DWWM systems. Reliable remote monitoring technology that is now commonly available significantly reduces such requirements, allowing remote-control of DWWTPs of distant facilities and demand-actuated on-site maintenance when needed. One of the recommendations of this study is to establish a single monitoring body or Unit for WW in Jordan within MWI.

The proposed monitoring Body shall report frequently to decision makers. Some parameters could be continuously monitored and others at periodic and regular intervals. The body should be authorised to follow up the performance of the DWWTP on a regular basis, e.g. at a rate of once every six months. Effluent sampling analysis should be collected and analysed, e.g. once every three months. For successful program monitoring of DWWTPs, it is required to have:

a. Effective Monitoring system to be in place
b. Authorized private entity to follow up the DWWM performance
c. Accredited laboratory for Monitoring

## 9.3 Update and Amendment of Legislations

An enforcement system for non-compliance with the required effluent standards could be introduced. This could be based on polluter-pay principles for the influents and compensation or a reduction of treatment fees for the treated effluents. Existing legislation may need to be enhanced to provide for appropriate enforcement mechanisms including financial measures.

## 9.4 Certifications and Certification Body for Technology and Operations

Proper and effective certification can improve operational efficiency. Once a technology certification system is established in Jordan, monitoring frequency could be reduced (German authorities request 1 to 2 effluent samplings per year, depending on the technology and grade of remote monitoring).

Certification protocols are currently developed together with Jordanian representatives within the NICE working group "Certification". The aim is to present coordinated protocols to the MWI and to further accompany their implementation[29].

### 9.5 Contract Based Service Performance

For Jordan, a competitive market for O&M services for DWWTPs smaller than 5,000 PE may develop that allows outsourcing of these services to the private sector and to alleviate the pressure of the public sector. This market needs to be regulated to ensure compliance with statutory and regulatory obligations.

### 9.6 Revising the Trading laws and by-laws

Effective and enforced legislation and standards for construction, O&M diligence, and reuse are required. Company registration at the Ministry of Trade and Industry is a barrier. The subcategory "maintenance" only exists under the category "contracting" whereas any company that wants to bid for O&M tenders must be registered under constructor/contracting while there are companies in Jordan, that are registered otherwise but could be competitive providers of O&M services. The subcategory "operation and maintenance for WW treatment" for both main categories are needed.

## 10. The Business Model Concept

### 10.1 Understanding the Term BM in DWWM

The conventional approach to the development of a business model (or plan) is to address it through a series of questions, i.e.

1. What do we have to do? (policy objectives etc. reflected in statutory obligations)
2. How are we going to do it? (investment and operational activities designed to meet obligations)
3. How much is it going to cost? (determining the costs of the activities set out in the plan and informing decision making as to the selection of options)
4. Where does the money come from? (tariffs, grants, subsidies, loans etc.)
5. How do we know if the plan is successful? (Monitoring and performance indicators)

This approach serves public sector and private sector utilities alike, although the outcomes and the final decision making may differ depending upon the organisational structure and ownership.

WW reuse is not confined to the delivery of wastewater services and its economic benefits but it has the ability to generate other returns including resource recovery from these facilities in the form of energy (biogas generation, nutrients in treated

[29] The European certification system (EN 12566-3, https://www.beuth.de/de/norm/din-en-12566-3/188431713) serves as the basis for the preparation of a National Jordanian certification protocol and provides an overview of the parameters that should be considered.

effluents, reusable water, and bio-solids).It represents an economic and financial benefit that contributes to the sustainability of the system and of the water utilities operating them.

The size of the revenue streams depends on the types of resources that can be recovered from WW. There is a range of options to move from a 'revenue model' to a 'business model', with costs and value recovery offering a significant advantage from a financial perspective, not only for private sector engagement, but also to the public sector.

A major pre-condition for successful private sector participation in the delivery of public utility services (including water supply and wastewater) is investor confidence supported by regulatory certainty. The investor /operator needs to be confident that any agreements reached, be they through contracts, licences or other legal instruments are robust and resilient undue political influence. Tariffs, in particular, will need to be set at levels that will maintain viability of the business and that investor must have the confidence that future regulatory tariff determinations will not be undermined to suit political or other motives. Without that confidence there will be no investor interest. This does not mean that regulators should reward inefficiency but rather the decision making should ensure that the utilities operate as efficiently as could be reasonably be expected including challenging but achievable expectations of performance but NOT to a level that is unrealistically so demanding that viability is no longer achievable. The concept of independent economic regulation has been developed to ensure this delicate balance of demanding efficiency yet protecting against undue influence from any individual or organisation, including the political establishment.

### 10.2 Analysis of challenges and proposed solutions for BM in DWWM

A workshop on Business Models for Decentralised Wastewater Management (DWWM) in Jordan was carried out on November 1st, 2018, in Amman, organised by GIZ. Participants analysed the challenges they are facing from their respective position as private operators, public officials, academia and non-governmental expert organisation related to the legislation, financing, construction, capacity development, operation and maintenance (O&M) and other factors that play a role in setting up sustainable BM for DWWM. For each challenge a solution was proposed. The analysis took place in working groups. In plenary the findings from the different working groups were discussed and condensed in a single result matrix (refer to Figure 5).

The main **challenges** identified are:

- The **feasibility** of DWWM, especially its financial viability has not yet been comprehensively investigated. Open questions include DWWM legal, financial, technical and social sustainability; those need to be clarified. Social acceptance of treatment plants, recycled wastewater and the willingness of customers to pay for DWWT remain challenges; required technical and operational capacities in Jordan are not yet as required.

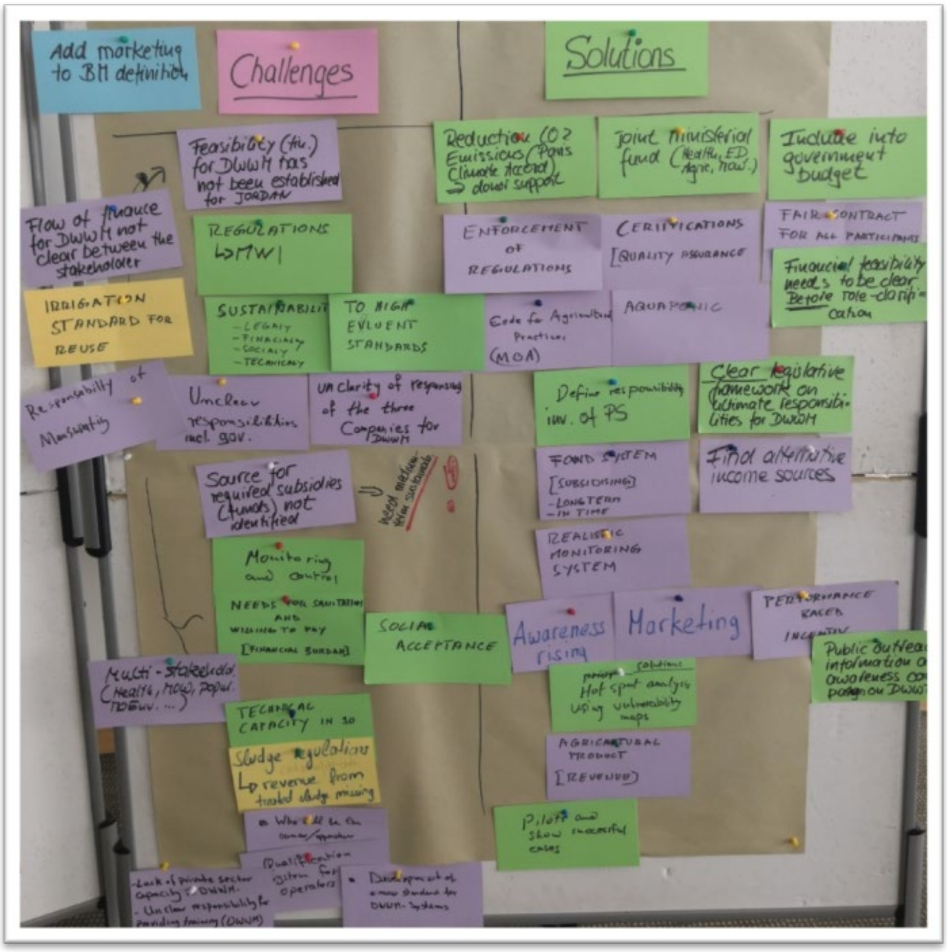



Figure 18: Workshop results

- **Roles and responsibilities** of relevant stakeholders (including operation, training, legislation, monitoring and supervision) remain unclear; those include the government itself (MWI and other concerned ministries as well as WAJ), the municipalities, private sector companies (ownership versus operator) and stakeholders on the community level.
- **Regulations and standards** tailor-cut for DWWM (small treatment volumes) are not yet established, those include effluents and standards for irrigation and regulations for sludge.

Several clusters of solutions were proposed. The most intensely discussed challenge for which solutions were proposed, was the economic feasibility. Questions raised were how to solicit the required funds? How to ensure that required subsidies are only needed in the initial phase? How the government could provide incentives for DWWM and how to create alternative sources of income from DWWM?

A second cluster focused on the needed support from the local population and private households for DWWM (in terms of location, use of treated WW and cost coverage).

For the questions of financial/economic feasibility participants proposed to use the reduction of CO2 emissions as contribution to the Paris Climate Accord and hence a good fund-raising argument for donors. A joint ministerial fund (with MoH, MoA, MWI and others) and/or the inclusions into the government budget were proposed. Alternative income sources could be agricultural products grown with the recycled WW.

Regarding public support for DWWM participants proposed awareness raising, marketing and the introduction of performance-based incentives. Successful pilots could illustrate for the public the benefit and feasibility of DWWM.

# 11. Considerations on Potential and Applicable Business Models

## 11.1 Selection of potential BM options

The Consultant analysed numerous potential business model options which are summarised and explained below. In all cases the operation and maintenance of the sewer system (see remarks above) is included in the scope of services to be provided by the operator.

### 11.1.1 Option 1: Wastewater conveyance and treatment only

Conveyance and treatment of sewage is the core task of a (public or private) operator of wastewater infrastructure. Related activities can be considered “a business” if a comprehensive management contract is in place which allows for a reasonable profit for the operator. Cost covering tariffs are usually a precondition, but often only cross-subsidizing from state budgets ensures sufficient funding for operations.

Services to be provided under Option 1 are:

1. Operation and maintenance of the entire sewer system including house connection boxes and pumping stations. This includes repair works and minor replacements of worn or faulty parts of the sewer system.
2. Operation and maintenance of the WWTP(s) including all auxiliaries. This includes repair works and minor replacements of worn or faulty parts of the WWTP.

### 11.1.2 Option 2: Sale of treated effluent to farmers and other potential users

Treated wastewater free of harmful contaminants and fit for agricultural use is a valuable commodity that may create additional income for the operator of a DWWTP. Jordanian regulations and legislations allow and encourage the use of treated wastewater, although some details of the current legislations are still debatable and may require adaptations.

Services to be provided under Option 2 are:

1. Operation and maintenance of the entire sewer system including house connection boxes and pumping stations. This includes repair works and minor replacements of worn or faulty parts of the sewer system.
2. Operation and maintenance of the WWTP(s) including all auxiliaries. This includes repair works and minor replacements of worn or faulty parts of the WWTP.
3. Provision of treated wastewater fit for irrigation or other uses, including the O&M of required installations such as tanks, pipelines or bottling plants. These services include sales and marketing activities[30].

### 11.1.3 Option 3: CO2-compensation

This relatively new approach is based on funds generated from international CO2-compensation payments which are collected and distributed by a respective entity (not necessarily Jordanian)[31].

This business model features a $CO_2$ compensation program that invests in plant-based wastewater treatment with subsequent biomass production.

It uses the mechanisms of mitigation by using $CO_2$-neutral wastewater treatment, and active $CO_2$ removal from the atmosphere. At the same time, municipal

[30]If the operator has a side-line agricultural business, he can undertake one of two approaches:

1. Take the wastewater for free (i.e. the wastewater customers pay for the wastewater in full) and use the water to undercut competing farmers. This is effectively wastewater customers subsidising his farming side-line and could be perceived as unfair competition. And why would he sell his produce at less than the market rate anyway? He would sell at the market rate and take a profit (subsidised by the consumers)

2. Sell his products at the market rate and take a profit that is comparable to the profit of other farmers and use the balance to reduce charges for consumers. This is 'fairer' but in essence is no different than selling the water to a farmer at the same price that he is effectively charging himself by reducing charges to consumers.

Bottom line. It makes no difference if the operator used the wastewater effluent to help his agriculture if the price to consumers was dropped to reflect the value than it would be if the operator was to sell the water (equivalent to the value determined).

The value of the wastewater is no different if it is sold to a farmer or it is used by the operator.

[31]For examples refer to https://www.atmosfair.de/en/climate-protection-projects/

wastewater in rural areas is treated at favourable costs for the connected communities, a major contribution to the Sustainable Development Goals and an important side effect to $CO_2$ compensation. It is also important to mention that the wastewater treatment stage of this concept will meet all legal requirements on effluent quality. As a result of this approach, wastewater treatment in developing countries will experience a considerable upswing.

Plant-based wastewater treatment with downstream biomass production are characterised by positive $CO_2$ effects on many levels:

- The plants absorb $CO_2$ from the air, especially if the plant is coupled with the production of renewable raw materials such as bamboo. The wastewater treatment plant thus acts as a carbon sink. This mechanism is designed in such a way that it can also be calculated and certified using a CDM method.
- The technology usually does not need any energy compared to other technologies, hence no $CO_2$ will be generated! If, in exceptional cases, there is a low electricity requirement, this can be covered $CO_2$-neutrally by a photovoltaic system including a simple electricity storage device.
- Plant-based purification systems decompose aerobically, not anaerobically, which largely avoids the formation of methane
- The harvested biomass (e.g. bamboo) is landfilled (open pit mining, etc.) and covered to avoid biological degradation or alternatively used as building material and thus serves as a carbon sink in the long run. Processing into vegetable coal (Terra Preta) – a high-value soil conditioner- is another option.

This approach is also an emission avoidance strategy, since CH4/ $CO_2$-emitting processes (= conventional sewage treatment plant) are replaced by $CO_2$-absorbing processes ($CO_2$ mitigation).

The approach will increase the total amount of avoidable greenhouse gases compared to conventional wastewater treatment.

The **technical concept** comes with the following characteristics:

**Technology:**

- vertical-flow plant-based wastewater treatment system (“French System”)
- Biomass plantation as 2nd treatment step
- Advantages: no sludge generation and accumulation, no or very low energy requirement

**Areas of application:**

- Rural and peri-urban regions with sufficient available area
- Villages / settlements up to 1,000 inhabitants
- Domestic wastewater
- Cleaning capacity up to 100 $m^3$/day (approx. 1,000 to 2,000 inhabitants under conditions in developing countries)

**$CO_2$-minimized construction of wastewater treatment plants:**

- As far as possible no use of machines
- Local procurement and building materials
- Local implementation planning and site management

**$CO_2$-minimized operation of wastewater treatment plants**

- If possible, without pumps
- If necessary, with solar energy

**Use of methane**

The generation of methane within the plant must be avoided, as it cannot be ruled out that this highly climate-relevant gas will be released due to faulty operational management and/or accidents. In contrast to many other $CO_2$ compensation models, this concept therefore does NOT aim at the use of methane.

**Production of biomass and removal from the biosphere**

- Biomass production (e.g. bamboo, Guadua Angustifolia) for binding CO2 (carbon sink). The biomass can be used as building material or (for the removing it from the biosphere) to refill pit mines etc.

**Production of vegetable carbon**

As an alternative to removing the produced biomass from the atmosphere, the biomass can be charred to produce Terra Preta (TP). The use of TP is a recognised method for long-term carbon sequestration and improvement of agricultural soils.

Within the framework of this approach, emission reduction measures can be implemented in developing countries and these savings certified. The resulting certificates (Certified Emission Reductions or CERs) can be offset against the reduction targets in industrialised countries. Certification according to the “CDM Gold Standard” should be sought for this project.

**Revenue from CO2 compensation payments**

Presently, the market prices for $CO_2$-compensations are ranging between 20 and 50 Euro/t $CO_2$. The prices are usually based on project-related, internal costs and are hence not fixed

As of 17.9.2019, the European Emission Allowance was 26,75 EUR per ton $CO_2$, traded at the European Energy Exchange (EEX) in Leipzig.

**CO2 removal from the atmosphere through biomass production**

The production of one ton of bamboo biomass removes about 1.8 tons of CO2 from the atmosphere.

The growth time of a single bamboo trunk to harvest maturity is - depending on location and species - on average 2 years. From the third year onwards, it will be possible to harvest approximately ~ 14,4 t of biomass carbon per ha per year (equalling the annual removal of ~ 52 t of $CO_2$ from the atmosphere).

For the irrigation of one hectare of bamboo plantation, 30 - 80 $m^3$ of water per day are required, depending on the bamboo species. In arid areas (e.g. Jordan) 100 $m^3$ of pre-treated wastewater can irrigate 1.2 - 3.8 ha of bamboo plantation per day. In areas with higher precipitation the bamboo plantations can be dimensioned accordingly larger, since the water is then no longer the limiting factor.

In the case of Jordan, a wastewater treatment plant with a capacity of 100 $m^3$/day and downstream biomass production could bind around 200 t $CO_2$ per year under optimal conditions.

In other words: 1 cubic metre of wastewater per day binds 2 tonnes of $CO_2$ per year via the biomass produced. If a population equivalent of 100 litres of wastewater per day is assumed for developing countries, 1 inhabitant removes up to 200 kg $CO_2$ per year via biomass production within the wastewater treatment system.

**Potential usage conflicts**

The required areas are potentially in competition with other uses. Food production is a potential source of conflict here. This potential for conflict can, however, be assessed as low:

- The concept can be applied to saline agriculture areas with little or no food productivity
- The concept can upgrade unused land without current food productivity (e.g. arid areas in Jordan).

The purified water is used in principle for irrigating biomass production. In arid regions, there is potential competition for the irrigation of agricultural products with treated wastewater. However, the corresponding conflict potential is low, as irrigation of plants for direct consumption with treated wastewater is generally prohibited or undesirable. There is hence no commercial competition, especially against the background of income from CO2 sequestration in the biomass plantation.

**Services to be provided under Option 3 are:**

1. Operation and maintenance of the entire sewer system including house connection boxes and pumping stations. This includes repair works and minor replacements of worn or faulty parts of the sewer system.
2. Operation and maintenance of the WWTP(s) including all auxiliaries. This includes repair works and minor replacements of worn or faulty parts of the

WWTP.

3. Operation and maintenance of a biomass production unit (field), including harvesting, processing or deposition of the biomass.

The following options were **not considered** as potential business cases:

**Production and Sale of added-value products (e.g. alfalfa or others) by operator**

For a justification of not having considered this option refer to Section the footnote in Section 12.1.2.

**Co-composting of sludge from WWTPs with organic waste for energy production, resource recovery and/or compost production**

Co-composting refers to the simultaneous composting of at least two organic sources: Nitrogen-rich sludge from on-site sanitation or DWWTPs with the carbon-rich organic portion of municipal organic waste, sawdust or agro-waste to create the right carbon to nitrogen ratio for optimal composting, i.e., heat development and pathogen destruction.

The technology selected for the study's typical example is a constructed wetland ("French System") which features the lowest CAPEX and OPEX compared with all other potentially suitable technologies. However, this technology does not generate any sludge, and septic tank sludge will not occur due to the assumed connection rate to sewers. Dealing with sludge is hence not a requirement. Within the scope of this study options like digestion or (co-)composting of sludge in order to produce a marketable product do not require further considerations due to the lack of the raw material.

Furthermore, there is little evidence that the sale of compost generated from DWWTPs has proved economically successful in other countries if the final product is not certified and meets a noteworthy market demand (Danso et al., 2017). Both preconditions do not apply in Jordan.

For mentioned reasons, this business model option has hence not been further considered.

**Use of sludge in cement industry**

Among various disposal methods, co-processing of sludge from WWTPs in cement kilns has been one of the most promising disposal methods in recent years in numerous countries.

The cement sector in Jordan has grown to meet development requirements, and during the past five years, the country has seen construction of several new cement companies, namely Al Rajhi Cement Holding Qatrana Cement Company, Northern Cement Company (grinding only), and Modern Cement and Mining Company (Al Manaseer Group) (GIZ 2019). A number of companies have expressed interest in using biosolids in their cement production process.

At this time, however, they do not appear ready to reimburse MWI/WAJ for costs associated with drying and transporting the biosolids. Communications in this regard should continue between the MWI and the cement companies, as recommended by the GIZ study mentioned above.

From a regulatory standpoint, only JS 1145:2016 regulates the reuse of sludge/ biosolids produced from municipal WWTPs and addresses production, handling, transporting, and possible reuse with a focus on land application. Should reuse in cement kilns be seriously considered, regulatory aspects as well as emission regulations would need to be revised.

Given the lack of practical experience and potential regulatory problems associated with this potential sludge disposal solution, the Consultant does not consider this option viable for further considerations within the scope of this study.

# 12. Development of Potential and Applicable BMs

The design of technologically sound and cost-efficient WW solutions is a challenge for any WW infrastructure planner. Finding the most adequate size and configuration of WW infrastructure will determine the cost-efficiency of the investment as well as the expenditures for operation and maintenance throughout the system's entire operational life-time. Hence, the development of WW infrastructure projects should be based on comprehensible data and realistic assumptions. The selection of appropriate technical configuration depends on the:

a. volume of WW
b. quality of WW
c. local temperature
d. underground conditions
e. land availability
f. legal effluent requirements
g. cultural acceptance and social conditions
h. final handling of the effluent (discharge or reuse)
i. rural and suburban areas, where costs for long-distance sewerage to centralised treatment are prohibitively expensive
j. challenging topographical conditions that require pumping stations for central solutions
k. investment costs and operation and maintenance requirements due to economies of scale

The involvement of the private sector in DWWM infrastructure investments and O&M services shall be enhanced and expanded with the objective to strengthen performance-based, consumer-oriented, and cost-efficient operations and to alleviate the burden of the general public and the public water sector through accounting for economic feasibility (e.g. adapted business models) and financial viability (e.g. sustainability).

One extreme is full private ownership and operation by investor-owned water companies, whose charges and rates are typically set by state public service commissions, or who have their charges determined through a formula set out in a in a long-term licence agreement or contract. In some cases, legislation sets the formula but still without the need for a regulatory body established for that purpose. More common are publicly owned systems that fund and manage their assets without economic regulation (except for accountability to government) and that perform most of their operations with public utilities (companies) or municipal employees. Nearly all large-sized cities in Jordan follow this approach.

### 12.1 Public-Private Partnership of WW Management Service

Water and wastewater services were used to be provided by public bodies. This was associated with a series of problems like poor performance and low productivity (Idelovitch & Ringskog, 1995). Public awareness was raised in the 1980s about the necessity of introducing the concept of privatisation as solution and enhancement tools for service provision. Privatisation or different private sector participation (PSP) forms involve the concept of operating and monitoring the water utility by the private sector (Dua'A B. Telfah, Halasheh, Ribbe, & Roth, 2017). Commercialisation, as alternative to privatisation in its conventional notion, was adopted as a strategy to extend partnership with the private sector and to establish new corporatized water service companies wholly owned by the Government and operated under commercial principles.

MWI started different initiatives using different tools and methodologies to overcome the weak financial position, weak management, geographical and hydrogeological constrains, and social constrains. Several technical approaches were considered including water sector reforms of which the main pillar is commercialization as alternative to privatisation in its conventional notion (Bank, 2001).

On 9th January 2007, WAJ signed an Assignment and Development Agreement with Jordan Water Company (Miyahuna), as a limited liability company fully owned by WAJ and formed under laws of Jordan. Miyahuna is a limited liability national company, it operates under a mandate agreement with WAJ. It started its operations from the beginning of 2007. It is responsible for the management of water and wastewater services in Amman and its outskirts (Miyahuna, 2007). Miyahuna performance monitoring is assigned to the Performance (Program) Management Unit (PMU). PMU is a unit established within the MWI to monitor the water and WW services provisions and to enhance the application of commercial principles in the Jordanian water sector. According to the Articles of Association, Miyahuna (with Limited Liability) has the responsibility of service provision, management and operation, and expanding investment of water and WW services in Amman. It owns the mobile assets and revenues generated from the service area; it is responsible for investment from its own resources; the company enjoys full independence in terms of managing its budget and revenues (Dua'A B. Telfah et al., 2017).

The private sector can be involved in WW management services in many different options as discussed below. Financial incentives, such as subsidies, tax reliefs, can be effective drivers for the private sector and communities to engage in planning, establishing, and operation and maintenance of WW infrastructure (MWI, 2016b). The full privatisation, in which a facility is privately owned and operated, are often not accepted by policy decision makers. Furthermore, most users of public WW services have not paid the true cost of these services. The common types of partnerships business model are summarized in (Table 28):

Table 28: Common Public-Private Partnership Business Model

| Partnership Option | Description |
|---|---|
| **Acquisition, Divestiture** | Public partner sells the facility to private partner resulting in private ownership and operation. |
| **Joint venture** | Private partner own facility in conjunction with public partner |
| **Concession or build, own, and transfer (BOT)** | Private partner builds, owns, and operates the facility. At the end of the specified period, such as 30 years, the facility may be transferred to the public partner for a nominal fee. |
| **Turnkey facility** | Private partner designs, constructs, and operates the facility. The public partner retains ownership and generally assumes the financing risk, while the private partner assumes the performance risk for minimum levels of service and/or compliance. |
| **Full-service contract (often referred to as enhanced lease contracts)** | Public partner contracts with private partner for a fee to operate and maintain the facility. The public partner owns the facility (although it may have been built by the private partner). |
| **Contract operations (often referred to as lease contracts)** | Private partner operates and maintains public partner's facilities over the long or short term. |
| **Contract management** | Private partner manages and supervises the public partner's personnel. |
| **Operations assistance** | Private partner provides transition management or program management to improve effectiveness of public partner's operations. |

Source: (Beecher et al., 1995) page 48

A more detailed description of these private sector business model options is presented in Annex 3.

### 12.1.1 Jordanian Experience on Private Public Partnerships

The Public-Private Partnership Unit (PPPU) was established in the Ministry of Finance under Public-Private Partnership Law Number 31 of 2014. The PPP Law provides the legal basis for implementation of the PPP program and outlines the institutional framework and implementation procedures as well as the duties and responsibilities of all parties related to partnership projects(MoF, 2014).

The aim of PPPs is to provide the necessary funding for government projects without resorting to external borrowing or increasing government capital spending. The PPP program allows the Government to bypass fiscal and budgetary constraints and supports political and economic stability by providing required services to citizens without imposing new taxes. PPP projects allocate risks so that the Government does not bear risks associated with design, financing, construction, operation, and maintenance. PPPs leverage the experience and expertise of the private sector and reduce maintenance and operational expenses.

The Public Private Partnership Unit (PPPU) established in the MoF operates according to the PPP Law and Regulations. Technical requirements are determined by the unit to be submitted by the contracting authorities, which includes feasibility studies and sustainability reports. PPP project proposals must be completed using the approved forms and registered after the project is approved by the PPP Council. Terms of reference must be drafted for all consultants hired by contracting authorities. The PPPU reviews feasibility studies and assists relevant parties with to negotiate contracts and participate in committees formed for each project (MoF, 2015).

The PPPU also prepares the guidelines for Terms of Reference and PPP contracts and tracks reports from the project implementers. It maintains a database for all PPP projects. The PPPU will not play the same role as contracting parties in the implementation of the projects, but will be limited to determining technical requirements, reviewing documentation, administering PPP contracts, and monitoring progress, as well as providing support, assistance, and capacity building to the contracting parties. An example of PPPs projects in Jordan related to WW and Waste are shown in (Table 29). As for a private investment in infrastructure, two large-scale projects have been implemented in the water sector of Jordan on BOT basis. The first is the As-Samra WWTP which started in 2002 (discussed above) and the second is the Disi Water Conveyance Project which started in 2009 (MoF, 2016).

Table 29: Example of PPPs projects in Jordan related to WW and Waste

| Project | Description | Contracting Authority | Project estimated cost (million) |
|---|---|---|---|
| **Zarqa IWWTP** | Design, finance, build, operate and transfer (DFBOT) an industrial WWTP in Al Hallabat | MoEnv | 35 |
| **Medical and Hazardous Waste** | Process and dispose of all hazardous and medical waste generated in the Kingdom. | MoEnv | 35 |
| **Amman new slaughterhouse** | DFBOT a new modern slaughterhouse in AL-Madonah. | Greater Amman Municipality (GAM) | 53 |

Source: MoF, 2019; https://pppu.gov.jo/en-us/Projects

# 13. Economic, Financial and Socio-economic Analysis of the Selected BMs

## 13.1 Assumptions and Preconditions for the Exemplary Business Models Considered in this Study

### 13.1.1 Technical Assumptions and Preconditions

**Project Location**

The village of Rasoon in Ajloun Governorate has been selected as an exemplary location, following earlier investigations made by ACC in the S4M study and in agreement with the Client. Valuable data for detailed investigations is available for this area. The size (4327 capita in 2013), the rural setting and the acknowledgement as a so-called hot-spot area featuring vulnerable groundwater resources makes it an exemplary showcase for a decentralised solution under typical rural Jordanian conditions. Rasoon was also located in the study area of the NICE-financed project "Feasibility Study on Decentralised Wastewater Treatment and Reuse Clusters on Regional Scale in Jordan" (DORSCH 2014).

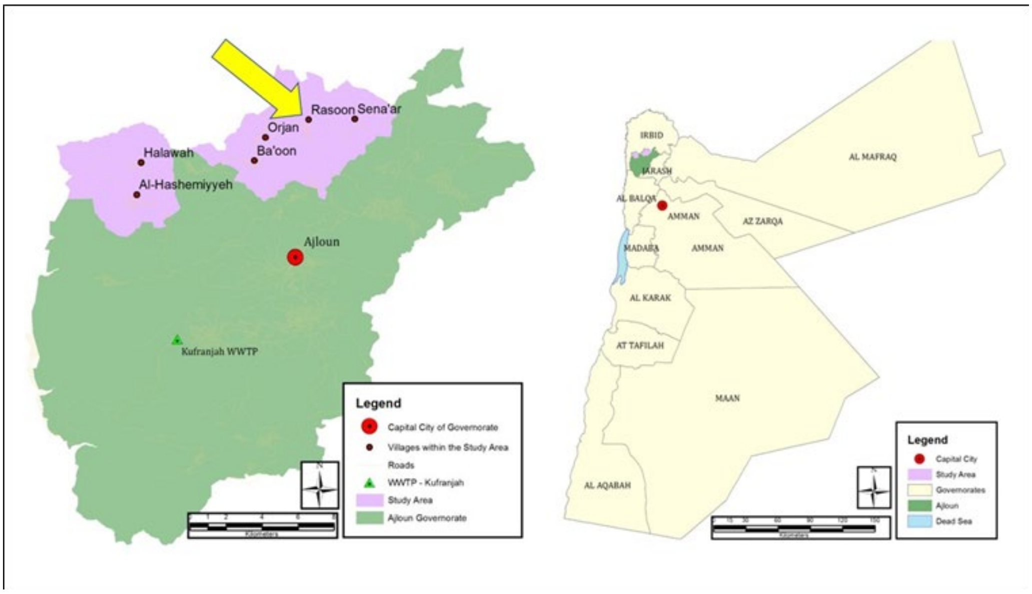



Figure 19: Location of the selected village (source: DORSCH 2014)

## Sewer System

It was assumed that the majority (some 75%) of all households will be connected to a traditional gravity sewer system. The remaining ones will be served by regular emptying of their collection tanks, since earlier surveys (DORSCH 2014) showed that appr. 25% of all houses cannot be connected to street sewers due to elevation problems. A total sewer length of 12 km was assumed, a figure based on earlier calculations (DORSCH 2014).

Furthermore, it was assumed that the sewer system includes a proportion of sewage that is pumped.

## Wastewater Treatment Technology

For this exemplary case a 2-stage vertical flow constructed wetland ("French System") was chosen for mainly two reasons:

1. This technology features very low investment and O&M costs compared with all other potentially applicable wastewater treatment technologies; hence it represents the best-case scenario in terms of economic considerations.
2. It is a robust and proven technology that has been used in Jordan already, is relatively easy to operate and does not require imported spare parts.

The plant consists of two planted soil filters. The first one is supposed to remove settleable solids and pre-treat the wastewater, replacing a conventional screen or primary settler. The actual and final clarification takes place in a second filter. A recirculation pump (if possible powered by a PV system) for treated effluent into the first filter should be provided for in case additional denitrification is required.

By intermittently dosing the wetland (4 to 10 times a day), the filter goes through stages of being saturated and unsaturated, and, accordingly, different phases of aerobic and anaerobic conditions. During a flush phase, the wastewater percolates down through the unsaturated bed. As the bed drains, air is drawn into it and the oxygen has time to diffuse through the porous media. The filter media acts as a filter for removing solids, a fixed surface upon which bacteria can attach and a base for the vegetation. The top layer is planted, and the vegetation is allowed to develop deep, wide roots, which permeate the filter media. The vegetation transfers a small amount of oxygen to the root zone so that aerobic bacteria can colonize the area and degrade organics. However, the primary role of vegetation is to maintain permeability in the filter and provide habitat for microorganisms. Nutrients and organic material are absorbed and degraded by the dense microbial populations. By forcing the organisms into a starvation phase between dosing phases, excessive biomass growth can be decreased, and porosity increased (IWA/EAWAG).

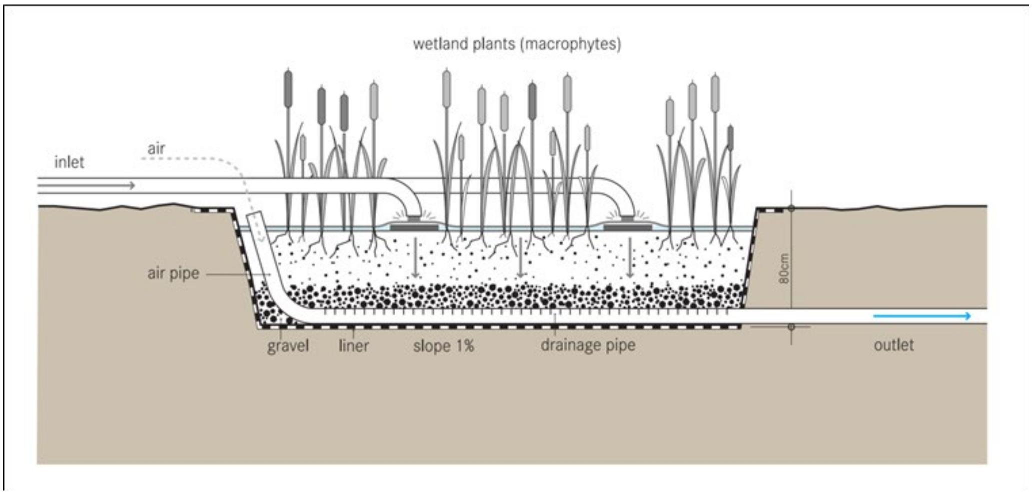



Figure 20: First step of a vertical flow CW (Source: IWA/EAWAG)

While this well-proven technology is able to achieve all relevant effluent parameters, it also avoids the generation of sludge, indisputable a huge advantage compared to other treatment systems. Settleable solids and all kinds of waste will be retained on the surface of the first filter, where organic compounds will be biologically degraded over time. No sludge piles up or has to be stored or treated further, and hence no additional costs for sludge treatment will occur.

For this study and based on the conditions prevailing in Rasoon the Consultant has calculated a footprint of approximately 5,000 $m^2$ for the treatment plant.

Wastewater from collection tanks will be delivered by trucks to the DWWTP. Septic tank sludge (faecal sludge) will not occur due to the absence of septic tanks in the chosen concept.

### 13.2 Model analysis rationale

#### 13.2.1 Purpose

This report is to be read in conjunction with the MS Excel model developed for this analysis together with the model's guidance notes annexed to this report (see Annex 5).

The financial analysis was originally intended to be a hypothetical exercise using data that reflects a typical small town qualifying as meeting the criteria for small-scale wastewater treatment systems. This original intention was modified to comprise an analysis of an actual small community of about 5,000 people for which the town of Rasoon was selected for this purpose. Although the analysis focussed on this specific community the model was to be prepared in a generic fashion that could be rolled out and used for other communities. Consequently, the model has had to include a wide array of input parameters and variables which may appear to add to the model complexity. On the other hand, the model is considered reasonably simple to use with a single input data worksheet and simple to use macros to test various scenarios.

It is not possible to develop a single model to cover every possible scenario and although this model can be used elsewhere it may be necessary to modify it in places to accommodate specific and unique characteristics for each community.

The model is not to be regarded as a regulatory tool for tariff setting purposes but rather a means of illustrating the financial and tariff impacts of various options.

The model is designed to emulate the behaviour and decision making of a potential small-scale operator and as a result it steers away from the more conventional financial analyses incorporating intangible financial rules but rather concentrates on the basics of cash flow.

The model analysis is based on the provision of wastewater services only. It does not consider the impact of wastewater services being provided in parallel with water supply services. We do not consider this to be a major omission as the costs and revenues of water supply and wastewater services should be separated and any financial benefits of a combined service are relatively small, e.g. unified billing and revenue collection services.

#### 13.2.2 Principal features

Where possible the model employs existing documented data, notably the report by National Implementation Committee for Effective Decentralised Wastewater Management in Jordan (NICE), Feasibility Study on Decentralised Wastewater Treatment and Reuse Clusters on Regional Scale in Jordan, Dorsch International Consultants GmbH, (2014). Other data sources include: IMF projections, current published electricity prices, and more. However, much input data is based on informed professional judgement.

The model analysis has the following principal features:

- Population growth assumes all new housing to be connected to the system (no new septic or collection tanks). This assumes improved building control processes that effectively prohibit new developments in areas where the provision of sewerage services is not possible.
- All of the initial investment is anticipated to be financed by grant in aid, either from international development agencies or central government. The analysis provides for a scenario for all investment to be paid for by users

through tariffs to illustrate the impact of the grant support. We recognise that current practice in Jordan is that new consumers make capital contributions to the wastewater system based on house area. For the purposes of this model we have assumed that these contributions will not apply as the investment is funded by others. If such contributions were, in fact, payable to the operator then the operator would effectively be paid twice for the investment, once by the donor and again by the customer. Alternatively, the model could allow for the donor funding to be reduced by the total value of customer contributions but the net effect on tariffs will be the same as customer contributions to investment and grant funded investments are treated similarly in tariff models.

- Although[32] the initial investment is to be funded from grant in aid all subsequent capital maintenance is to be funded by the operator and passed through to tariffs.
- The conventional accounting approach of applying depreciation as a means for determining capital maintenance provisions is flawed when applied to grant funded investment, especially networks . This model applies reasonable estimates of cash expenditure on capital maintenance on an as and when needed basis and passed through to tariffs. For networks this results in low financial demands (and hence lower tariffs) in the years shortly after construction but increasing expenditure (and hence increasing tariffs) over time as the system ages. This approach is often referred to as the infrastructure renewals accounting convention. For non-network assets (pumping stations, treatment facilities etc.) the investment takes place at periodic intervals which is financed by the operator but passed through to tariffs through current cost depreciation from the point that such capital maintenance expenditure is made.
- The model provides for expansion of the tertiary network at periodic intervals to accommodate consumer growth. The model assumes that such network enhancement is to be funded from the new consumers that are, in effect, responsible for triggering the need for the enhancement and that it would be non-cost-reflective for existing consumers to meet the costs of network expansion. Why should existing consumers finance the network needed solely for new consumers? The model therefore assumes that the

[32]Capital maintenance is defined as the investment in the major repair or replacement of assets at the end of their useful lives. It is not routine operational maintenance or investment in system expansion or enhancement.

[33]Strictly speaking the accounting treatment of depreciation on grant funded investments is to either balance depreciation against deferred income of the grant amortised over the life of the asset or to not apply depreciation (the net effect being the same for both options although the latter is easier to accommodate in financial models). Furthermore, new assets such as networks do not correspond to major replacement as a whole but rather small-scale annual expenditure on repairs and replacement that will be low when the network is new and higher as the network ages.

costs of the enhancement are passed on to the new network users after the current tertiary network design horizon as a consumer contribution to network expansion, effectively either as a surcharge to a connection fee or included in the cost of the new property[34].

- The model assumes that the operator is fully responsible for operating costs which are passed through to consumers in tariffs. Included in these operating costs is a sum of JOD 12,000 per year as a management charge based on an assumed salary for a professional engineer and any associated social and other costs.
- The model allows for cost-reflective charges to be applied where possible, in particular wastewater treatment, i.e. charges based not only on the volume of wastewater generated but also the quality of the wastewater. This is, in effect, an application of the 'polluter pays' principle. This largely affects users of collection tanks where the collected wastewater is more concentrated and such users will be expected to pay a higher treatment component of charges. This is balanced to significant degree by such users not being charged for the network component that they do not use. For the analysis we have assumed that the quality of wastewater generated by the non-household consumer base is marginally more concentrated in COD and TSS than the household sector. As a result, the treatment component of the tariff for non-household is marginally higher than for the household sector. This assumption may or may not be correct and would require verification on a case by case basis.
- For a system where the bulk of the capital investment is financed through grant in aid a conventional discounted cash flow model does not work as the returns will be disproportionately low relative to the degree of effort and risk associated with the business. Consequently, the model has assumed a minimum margin (JOD 5,000 per year) to cover the risk borne by the operator[35]. This value is reduced to zero if the model considers zero grant in aid and investment is passed through to tariffs including a return on capital which, by definition, is a reflection of the risk category of the business.
- Where the operator undertakes capital investment from its own resources that are not immediately fully recoverable in tariffs, e.g. periodic investment in the capital maintenance of non-network assets, the value of this investment is regarded as a regulatory asset value upon which a return can be earned and passed on to tariffs.

[34]The model suggests that such a contribution amounts to circa JOD 170 per new house connected to the system. Assuming a typical house in a rural area of 150 m2 the contribution fee would normally be in the order of JOD 1.50/m2 x 150 m2 = JOD 225.00. The difference can therefore be interpreted as the cost of the non-tertiary network contribution which has been financed by grant in aid and therefore should not be imposed on consumers.

[35]The value of the margin is a model input variable. The figure of JOD 5,000 p.a. is a subjective assessment of the degree of compensation an operator would expect to compensate for the responsibilities and risks associated with the delivery of wastewater services.

### 13.2.3 Options analysis

The analysis considers only one option for the sewerage network, i.e. the sewerage network system is the same for all options.

For wastewater treatment the options considered include:

1. Conventional option – wastewater treatment in constructed wetlands only
2. Conventional option + irrigation (or other use) water sales
3. Biomass option with $CO_2$ credits

For Option 2 above we have considered irrigation for agriculture as the principal market for treated wastewater effluent, but the same principle would apply to any other business such as aquaculture. From an economic perspective what the effluent is used for does not affect the viability of the wastewater system but rather the revenue stream it can generate. If there was a market to use the wastewater effluent for something other than agriculture and that market was prepared to pay a higher price, then that price would be taken by the operator thereby allowing even lower tariffs.

An option to allow the operator to use the wastewater effluent for its own agricultural or other business purposes is disregarded as this is considered, economically, no different from option 2 above[36].

The analysis

- considers two principal funding options, i.e. with and without grant in aid for capital investment, although it does have the flexibility to vary the source of funding for various elements if required,
- considers the degree of operational subsidies necessary to plug any financing gaps as a result of any limits (caps) imposed on tariffs,
- examines the impact of adjusting specific variables, notably: the price paid by farmers for the use of effluent, the carbon fixing credit, and the tariff caps if applied, and
- provides a breakdown of operating costs between its various component of labour, energy and other costs.

[36]The rationale is based on why an operator would place a higher value on wastewater effluent than a farmer or any other user of the effluent would. Why would an operator choose to effectively sell the water to him/herself at a rate lower than he/she could get by selling to a farmer? To do so would be financially and economically irrational. Furthermore, if the operator-imposed tariffs on consumers to allow his agricultural activities to enjoy the effluent at a price below the market value this would effectively be consumers subsidising the operator's agricultural activities to be able to undercut other farmers and therefore be justifiably regarded as unfair competition. In some respects, any agricultural activities of the operator should be regarded as a side-line business activity and treated as a separate entity to the utility side of the business.

## 13.3 Current tariffs and household affordability

### 13.3.1 Current tariffs

The current water supply and wastewater tariffs applied in Jordan have been examined[37]. The current tariff structure is a combination of rising block and fixed charges. The analysis for this particular scheme suggests annual wastewater generated to be in the order of 200 $m^3$ per year per household. This equates to water input of about 250 $m^3$ per year[38]. for a typical household using an 80% return factor. The household wastewater charge for this level of outside the scope of this analysis to discuss the merits or otherwise of the existing tariff structures and the examination of existing tariffs is simply to compare the results of this analysis with what is currently applied.

### 13.3.2 Affordability and willingness to pay

We have been unable to source detailed data on affordability and willingness to pay for wastewater services. However, a crude estimate of 1-2% of household income to be used to pay for wastewater services can be used as a proxy for this criterion. We are also unable to source data related to income distribution but using GDP per capita as a proxy for income (JOD 2,908 in 2018[39]), multiplying by average household size in the project area (7.2), and adjusting for geographical distribution of income effects in Jordan (62%) (UNDP 2015) we estimate typical household income levels in the project area to be in the order of JOD 13,000 per year. This suggests that the affordability ceiling for wastewater services could be in the order of JOD 130 – 260 per year. This, assumption requires substantial further analysis that is outside the scope of this project to confirm its validity.

The analysis assumes that the household income, and hence the affordability ceiling, will increase in real terms as GDP per capita increases. This is balanced against expectations of increased demand.

We have been unable to source detailed data on willingness to pay but we are advised that although tariffs may be well below affordability constraints the willingness to pay threshold may be lower. A more detailed assessment of willingness to pay may require further investigations including contingent valuation analyses where appropriate.

### 13.3.3 Government willingness to increase tariffs

The Government of Jordan has the sole authority to adjust water and wastewater tariffs. The decision making of the Government is largely driven by political considerations and there is a perception that the Government is unlikely to approve material real increases to tariffs in the foreseeable future, certainly not to the levels as suggested in this analysis.

[37]http://miyahuna.com.jo/en/services/form/2

[38]The current tariff schedule applied elsewhere in Jordan for 250 m3 of water input generates an average wastewater tariff of about JOD 0.18/m3 of water input (assuming all the fixed charge component is for water supply services) although the marginal tariff rate at that level of consumption is JOD 0.57 /m3.

[39]https://www.ceicdata.com/en/indicator/jordan/gdp-per-capita

## 13.4 Analysis results

### 13.4.1 Comparison of options

The three basic options at baseline values for factors such as irrigation tariffs, carbon credits, grant in aid support and no operational subsidies are compared in Figure 21 and Figure 22 below[40] . All values are real at 2019 price levels.

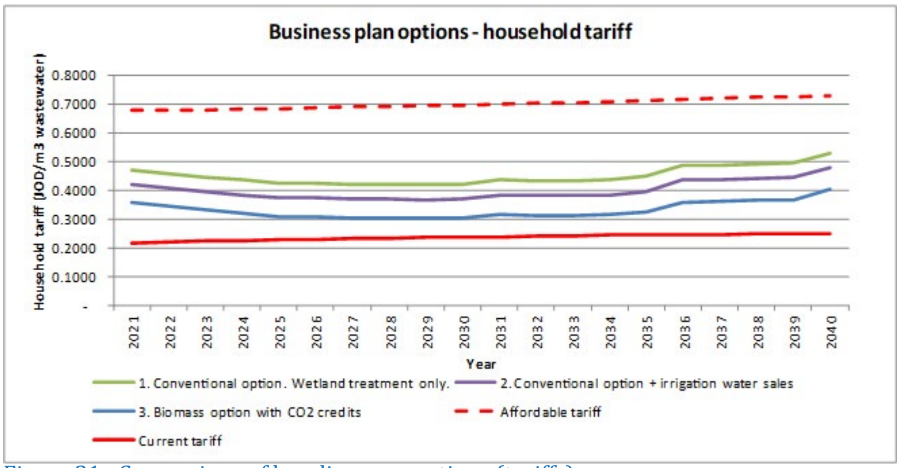



Figure 21: Comparison of baseline case options (tariffs)

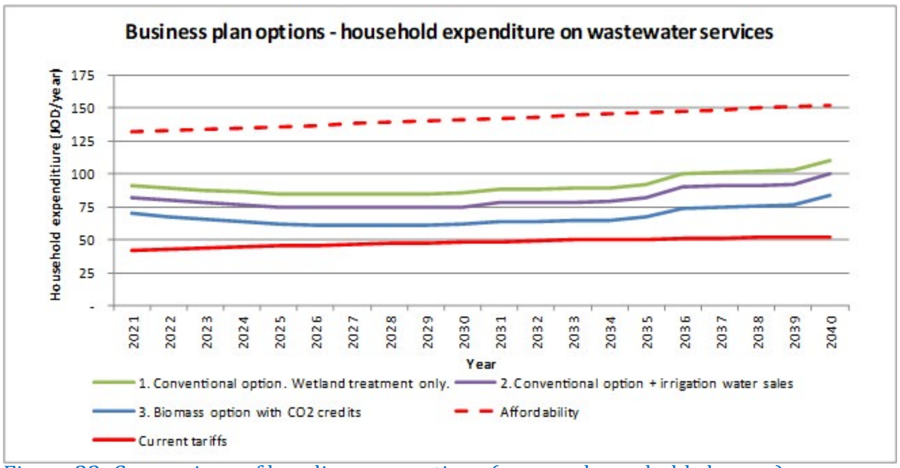



Figure 22: Comparison of baseline case options (average household charges)

The analysis reveals that the best option for consumers is the biomass option together with carbon credits provided the credit of JOD 24 per tonne of $CO_2$ removed can be secured for the long term. Despite this outcome the resulting lowest tariffs and household charges for wastewater services exceeds the current tariff levels although such charges are still comfortably below the lower end of the estimated affordability ceiling. In the longer run the gap between the current tariff levels and the tariffs necessary to satisfy the revenue requirements widen. This is due to the effect of capital maintenance demands kicking is as assets or their components start to require major repairs and/or replacement as the end of their useful lives.

[40]For this comparison the analysis assumes baseline inputs of a selling price of effluent of JOD 0.10 /m3 and the carbon compensation price of JOD 24.00 per tonne of carbon capture.

### 13.4.2 Operating costs

As the majority of the initial investment is expected to be financed by grant in aid from development agencies or government it is the direct operating costs that will largely drive the charges to households and other users. Figure 23 illustrates the build-up of operating costs for the collection and treatment system (for the biomass and $CO_2$ credits option) which shows that labour and management charges are by far the largest components amounting to over JOD 40,000 per year. This equates to a manager (engineer) and about four semi-skilled personnel. If the operator believes that the services can be provided with less staff, then obviously the costs (and user charges) could be lower.

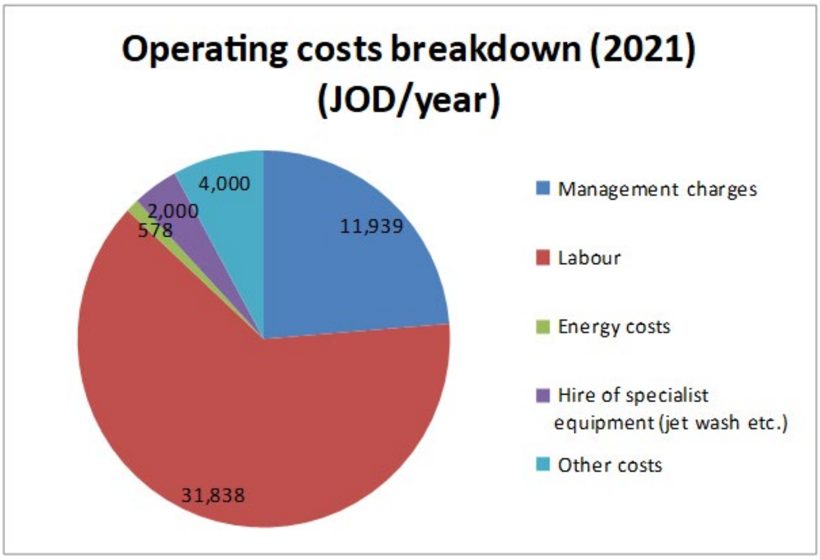



Figure 23 :Operating cost analysis for collection and treatment (Biomass and CO2 credits)

Figure 24 illustrates the allocation of costs between management activities, wastewater network costs and the sewage treatment.

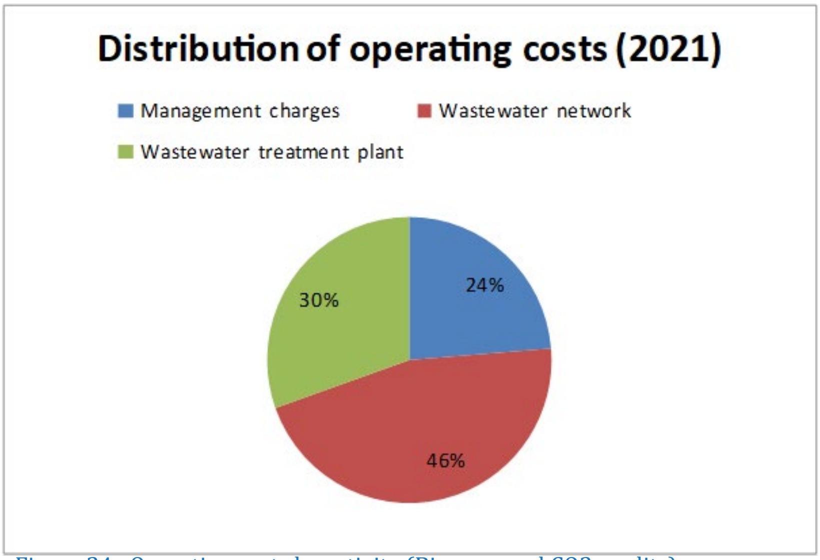



Figure 24 : Operating costs by activity (Biomass and CO2 credits)

### 13.4.3 Compare with and without grants

The analysis assumes that the investment is provided through grant in aid support. Figure 25 and Figure 26 below illustrate the impact that the support has on tariffs and household expenditure on wastewater services for the lowest tariff $CO_2$ compensation option. Figure 26 illustrates the effect on overall household charges.

As the inherent over-capacity of the system gets absorbed and the wastewater capital maintenance obligations increasingly fall on the operator (and are passed through to user tariffs) the difference in charges between with and without grant in aid support lessens over time. The tariffs and user charges without grant in aid are substantially greater than the assumed affordability ceiling but over a period of nearly 20 years they do eventually fall to affordable levels. Technically, this suggests that in the long-term full cost recovery[41] tariffs may be possible. This best-case outcome is dependent upon long term commitments to the CO2 compensation scheme and if alternative schemes were adopted full cost recovery charges are likely to be even further away.

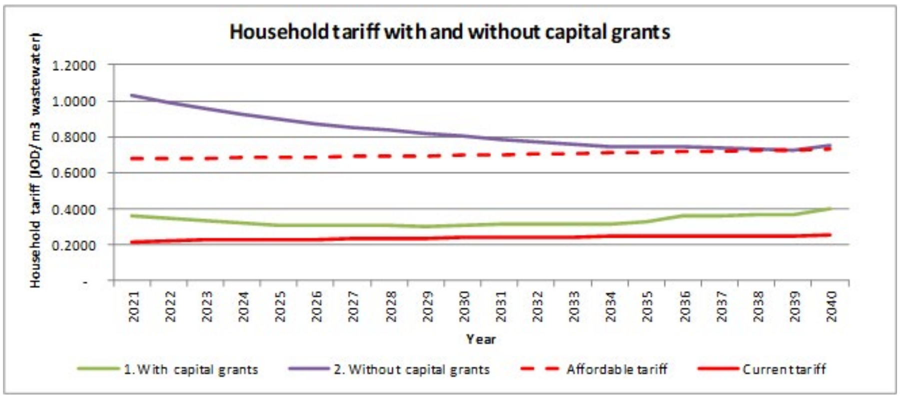



Figure 25: With and without grant in aid support (tariffs) (Biomass and $CO_2$ credits)

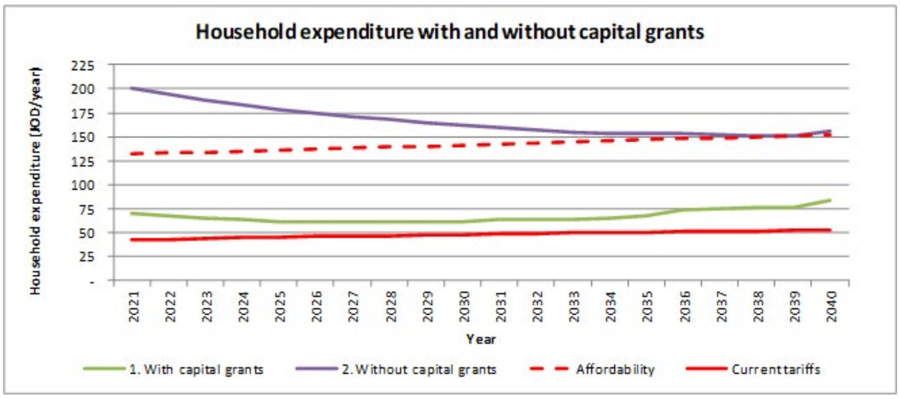



Figure 26 :With and without grant in aid support (average household charges) (Biomass and CO2 credits)

[41]Full cost recovery' is a difficult term to define and can have many different meanings to different people. For the purposes of this report we define full cost recovery as a revenue stream sufficient to finance (now and in the future) the operator's activities in accordance to prescribed standards of service and quality.

### 13.4.4 Impact of irrigation revenues

The baseline analysis assumes an irrigation tariff of JOD 0.10 per $m^3$ of wastewater effluent sold[42], the current statutory tariff for irrigation water. We have examined the impact that higher and lower revenues will have on the tariffs and household charges. Figure 27 and خطأ! لم يتم العثور على مصدر المرجع. suggest that although charges to households will undoubtedly fall as the irrigation revenue increases it requires at least a fourfold increase (from JOD 0.10 to JOD 0.40 per $m^3$ of effluent) before household tariffs fall to below the existing tariffs and even then the effect is short lived. Irrigation charges of JOD 0.50 per $m^3$ of wastewater effluent are necessary for sustained viability at current tariff levels.

Emad Kamel Al-Karablieh et al (2012) have examined the value of water for irrigation in Jordan and concluded that, *"The average value of irrigation water is JD 0.51/$m^3$ at the country level."* The specific value of water in each case will vary depending on location, crop and other factors.

In all cases tariffs and household charges fall comfortably below estimated affordability constraints.

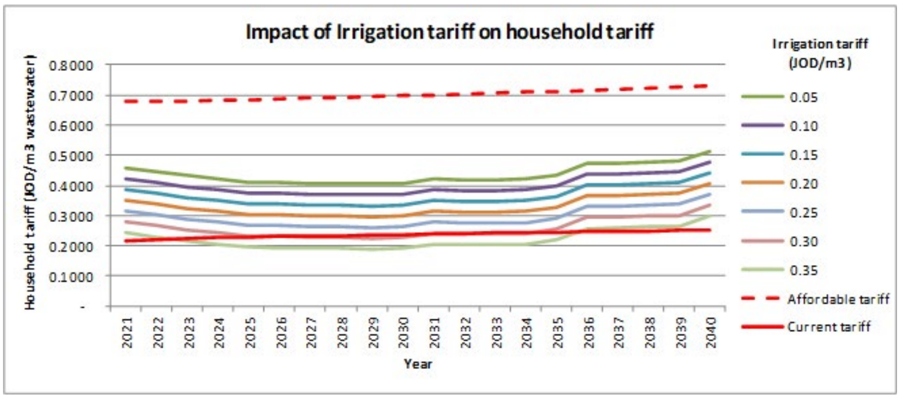
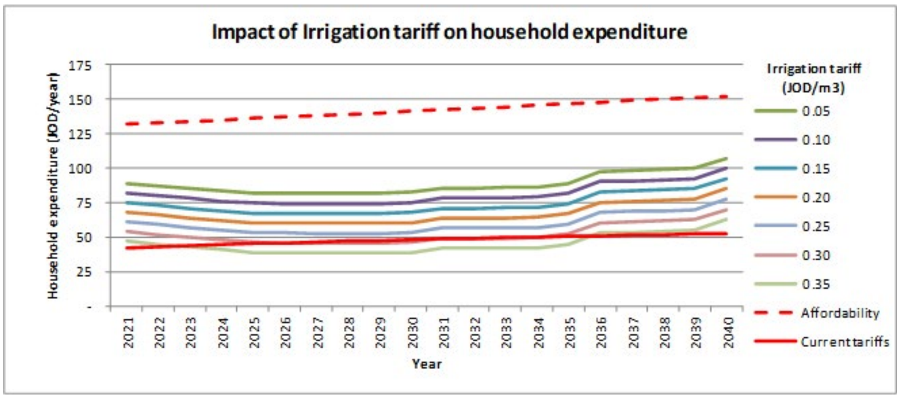



Figure 27: Impact of irrigation tariffs (tariffs)




[42]The base case model assumes the statutory maximum tariff of JOD 0.10 per m3 of wastewater effluent sold but in practice the rate is approximately JOD 0.05 per m3 of wastewater effluent sold

Although the best-case analyses suggest that the $CO^2$ compensation scheme appears to be the most viable it is probable that with a higher irrigation tariff than that currently permissible the irrigation option may be preferred by delivering the lowest tariffs to consumers. An irrigation tariff of JOD 0.20 per $m^3$ of treated wastewater effluent effectively results in near identical tariffs to those resulting from the $CO^2$ compensation option. Irrigation tariffs in excess of JOD 0.30 make it unquestionably the preferred option, but no information was gained about the likeliness of a respective tariff increase.

On the basis that a higher market driven irrigation tariff may be easier to secure and more certain in the longer term than a higher $CO^2$ compensation rate the irrigation option is probably the best overall. Further investigations may be necessary to properly evaluate the opportunities (and risks) for higher irrigation and $CO^2$ compensation tariffs prior to any investment decision making.

### 13.4.5 Impact of carbon credits

The baseline analysis assumes a carbon compensation price of JOD 24.00 per tonne of carbon capture by the scheme. We have examined the impact that higher and lower compensation rates will have on the tariffs and household charges.

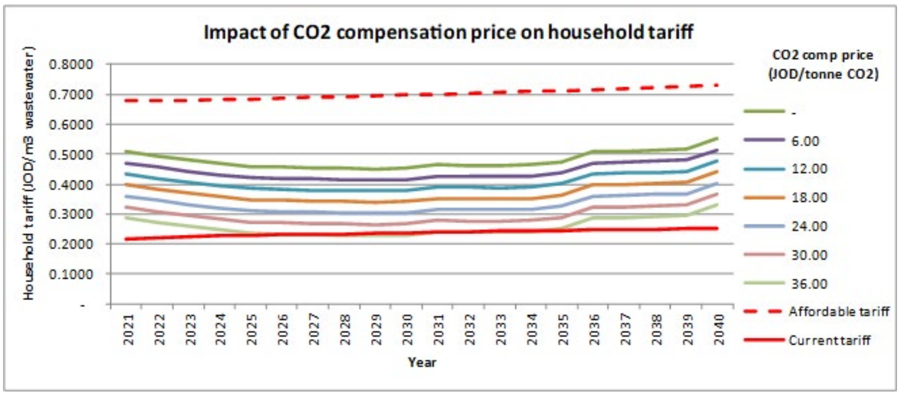



Figure 28 and Figure 29 suggest even a 50% increase in the carbon compensation tariff from JOD 24.00 to JOD 36.00 per tonne is insufficient get tariffs below existing levels.

In all cases tariffs and household charges fall comfortably below estimated affordability constraints.

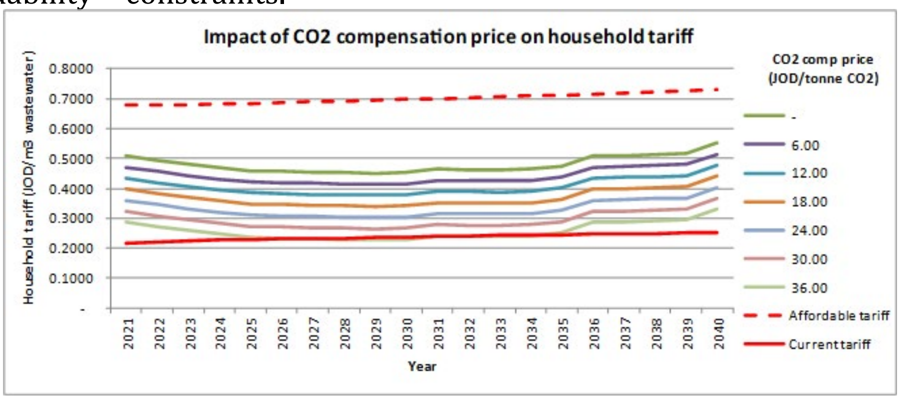



Figure 29: Impact of carbon compensation price (tariffs)

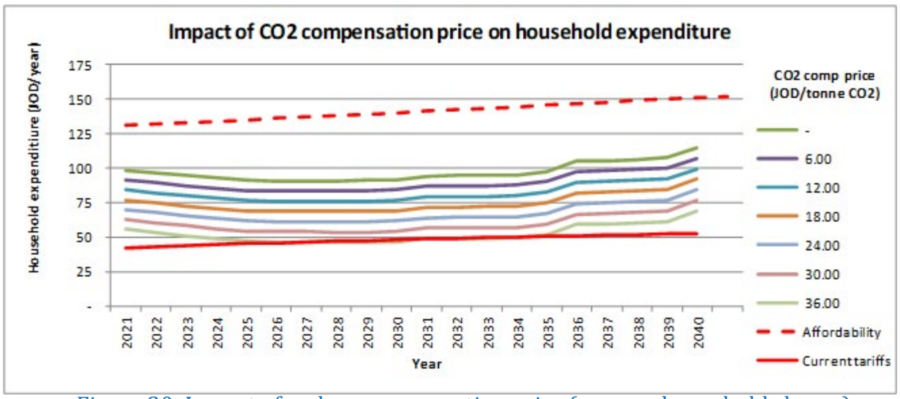



Figure 30 :Impact of carbon compensation price (average household charge)

### 13.4.6 Impact of tariff caps

The above analyses have assumed that the tariffs necessary to meet the revenue requirements can be applied unrestrained. It is possible government and regulatory policy demand limits to tariffs that are below the calculated tariff levels as already evidenced by current unwillingness of the Government of Jordan to increase tariffs in water and other sectors by any material amount. This policy is only viable if the resulting revenue gap between the suppressed tariffs and the calculated tariffs is filled by means of direct subsidies. Without sufficient subsidies the level of service will deteriorate or even collapse altogether. In some circumstances the falling service levels could have subsequent consequential effects that further damage viability. For example, if the quality of the wastewater effluent falls there may be no market for it depriving the operator of a revenue stream that will exacerbate an already bad situation. Similarly, a failing system may fail to qualify for carbon compensation, again resulting in a significant loss in revenue.

Using the carbon compensation scheme as the base case the impact that the imposition of tariff caps will have on subsidy requirements is illustrated in Figure 30.

From an economic perspective the use of tariff caps can be considered illusory. By reducing the direct costs of service to consumers by depressing tariffs the cost to the taxpayer (also consumers) increases to compensate for the loss of revenue. Consequently, users still pay, either through increased taxation or through reduced government services in other sectors. Subsidies are best applied if they are funded from one sector of the population and targeted towards a sector of the population that need them, e.g. the vulnerable, where it is a wealth and social distribution process from those that can afford to pay more to those that need assistance. All subsidies, however, contain inherent economic inefficiencies which need to be balanced against the wider social benefits that subsidies can provide.

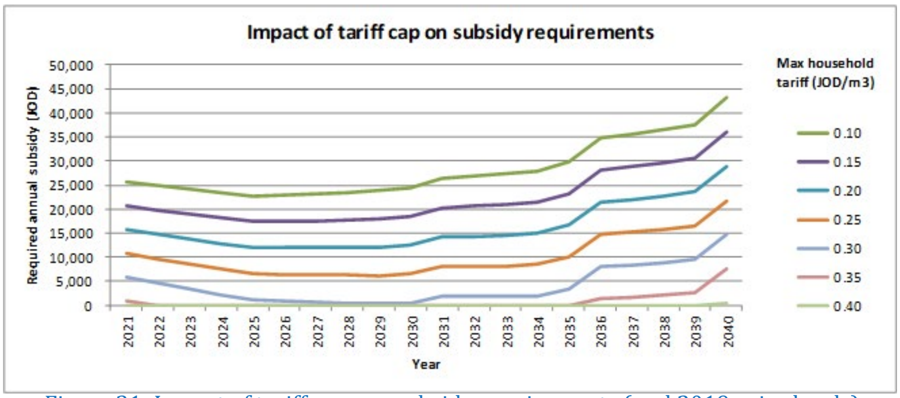


Figure 31: Impact of tariff caps on subsidy requirements (real 2019 price levels)

### 13.4.7 Non-sewered consumers

The analysis has attempted to derive tariffs that are as cost reflective as reasonably practicable. In this regard some consumers will pay more or less than other consumers depending on the quality of the wastewater generated and the services they employ.

We have identified several user groups who would be expected to pay different charges although the charges derived from the analysis are based on assumptions of wastewater quality and would require verification. These are:

Table 30 User groups and their rational for different charges

| User group | Rationale for different charges | Net effect |
|---|---|---|
| **Non-household consumers (schools, clinics, small enterprises etc.)** | An assumption that the quality of wastewater generated is more highly concentrated (BOD, COD and TSS) than domestic sewage and therefore imposes higher costs on the wastewater treatment plant. | Initial estimates suggest that such consumers should pay a surcharge of JOD 0.0261 /$m^3$ of wastewater discharged into the system. At an estimated wastewater return rate of 80% of water input this equates to a surcharge of about JOD 0.0209 /$m^3$ of water supplied. |
| **Collection tank users** | The wastewater drawn from the tanks will be considerably more concentrated (BOD, COD and TSS) than domestic sewage and therefore imposes higher costs on the wastewater treatment plant.<br>On the other hand, such users do not employ the network and therefore should not be charged for this element. | Charges will be imposed on the tankers as they deliver the collected wastewater to the wastewater treatment plant, i.e. a gate fee. Initial estimates suggest tankers should be charged a rate of JOD 0.169 per $m^3$ of collected wastewater that is discharged from tankers into the treatment works. Administrative charges could be imposed in addition to this.<br>These charges will form the build-up of charges imposed on the household which will include the cost of the tanker, driver and other associated costs. |
| **Septic tank users** | This is similar to collection tank but the septage (septic tank sludge) is considerably much more concentrated than collection tank wastewater.<br>Similarly, septic tank users should not be charged for the use of the network. | In this case tankers delivering septic tank sludge should be subject to a gate fee of JOD 2.000per m3 of sludge.<br>In practice for this scheme there are no septic tanks. Furthermore, it is unclear if the treatment works would be able to handle such concentrated faecal matter and it may need to be transported to another facility. |

### 13.5 Institutional issues

The analysis and the model are based on an assumption that an operator will be a small private enterprise. This may not necessarily be the case and a local government institution or even WAJ could adopt the responsibility for the service. We do not see any material differences in a financial analysis for a private sector or state-owned operator aside from access to borrowing which we have not considered in our analysis[43].

However, although a larger provider such as WAJ, or a multi-service provider (water and wastewater combined) may provide some economies of scale and scope (e.g. billing and revenue collection services) the cost of service is unlikely to be materially different from that determined in this analysis.

It may be possible for wastewater services to be cross-subsidised by water charges by a multi-service provider. It is outside the scope of this project to undertake detailed analysis of water and wastewater charges to evaluate the effects of such cross subsidies suffice to say that it is economically inefficient as it steers away from cost-reflectivity.

Jordan employs relatively strict standards of performance with stringent enforcement measures for non-compliance including fines and, in extremis, custodial punishment. Compliance with these standards are monitored and enforced by a variety of regulatory agencies (health, environment and others). For these small schemes the degree of regulatory oversight needs to be balanced against the perception of risk borne by the operator. If regulatory oversight is heavy, it will act as a deterrent and could scare away potential interest but at the same time a degree of oversight is necessary to ensure an acceptable level of service.

### 13.6 Alternative evidence

There have been many studies around the world to consider the challenges faced by small scale water and wastewater systems and their inherent financial disadvantages when compared to their larger scale counterparts in cities and regions. There are three fundamental parameters driving these disadvantages:

1. **Economy of scale:** Where smaller utilities incur higher operating costs per unit of production or per consumer due to minimum requirements, e.g. one manager for each individual small scheme compared to one manager for many small schemes. Furthermore, small schemes tend to incur higher capital costs for networks and treatment facilities due to higher peaking factors[44].

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[43]Small private operators or local government institutions may not necessarily have access to borrowing and as such it would need to generate annual revenues sufficient to meet its annual cash needs, including investment in capital maintenance. This may result in occasional spikes in charges, e.g. to pay for a replacement pump. A larger entity may be able to spread such costs through borrowing and thereby provide greater price stability and predictability.

[44]In this instance peak factors relate to daily or seasonal peaks in water demand that have to be accommodated in the networks and treatment facilities. For small schemes these peaks can be very pronounced whereas for larger schemes the peaks are balanced over a larger number of consumers and are therefore smaller.

2. **Economy of scope:** Where multi-service operators can combine activities at less cost than if carried out separately, e.g. combined billing and revenue collection services for both water and wastewater services.
3. **Economy of density:** Smaller (and more rural) schemes with low population densities require more network infrastructure per household than larger and more densely populated areas. As a result, both operating and capital costs per household, for networks in particular, are generally higher in rural and less densely populated areas.

Economy of density is probably the most influencing factor behind financial disadvantages facing small schemes in Jordan. In the UK Strategic Management Consultants (Strategic Management Consultants 2002) state:

*"The sizes of existing companies (made larger by amalgamations) mean that what is measured is averaged over large areas. The balance of benign and adverse resource and supply circumstances (and thus the extent of averaging) is influenced by the topographical and/or geographical features of the areas of supply. Averaging of costs of service is inevitable in all sizes of companies but larger companies average across sometimes quite different supply systems. The averaging is beneficial to rural users as a cross-subsidy and detrimental to businesses taking large volumes at single locations. Even a cooperative might elect to apply price discrimination (such as deliberate subsidy of business or marginal costs of supply to rural areas)."*

If population is nucleated i.e. the same urban density as larger urban areas, then the length of mains/sewers will be the same as for larger supply/collection systems and unit distribution/collection costs could be restricted to no more than double large system costs. However, if the small systems are more dispersed then costs can be very much higher, e.g. in water systems, more than 70% of the asset value is water mains. If a system has twice the length of main per capita then it has twice the cost of construction and operation/maintenance. If a small system has to transfer its collected volumes to distant treatment or discharge, then the costs go up again in contrast to dense urban systems (usually close to suitable sites for treatment and discharge). In Scotland, from discussions with the Water Industry Commission Scotland (WICS) they can have unit water supply costs for small Highlands and Islands systems which are between 5 and 10 times the cost of urban systems to operate. In another UK area, South Staffs, their most remote areas served by the smallest sources cost about 7 times more to serve than the urban areas. However, for many of the large operating companies it is only a small proportion of the population (less than 5%) that falls into the category of non-urban rural and therefore has little impact on overall costs of operation.

Economies of scale, scope and density have their limitations and Strategic Management Consultants determined that beyond 400,000 connected properties there is very little additional economy by becoming larger. They state in their conclusions:

*"It is also clear that the water supply companies do not need to be constituted as single operators of an optimum scale plant. There are continuing returns to scale on many of the service and labour-based activities of the companies, and common management of multiple plants close to demand will be a first-best solution.*

*Modelling carried out in the course of this review shows a rapid reduction in the costs to customer with size which diminishes to a stable and slightly declining relationship once a size of around 400,000 billed properties is reached."*

For Rasoon and similar communities, populations of circa 5,000 with less than 1,000 served properties would more than likely be at the extreme level of inefficiency that could benefit from being part of a larger institutional structure (see Figure 31). Note, although this analysis relates to water supply it is rational to assume that an analysis of wastewater systems will come to a generally similar conclusion.

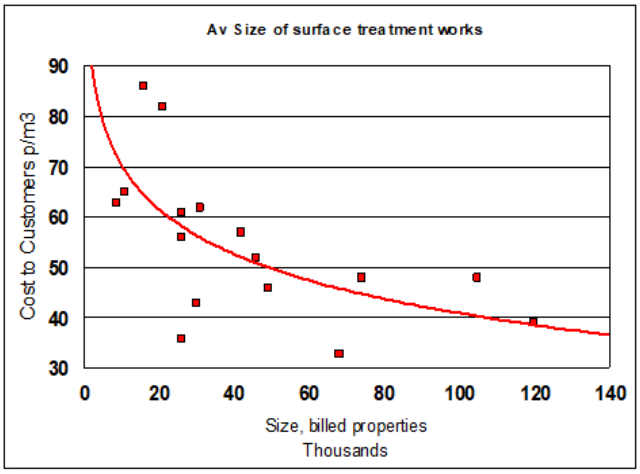


Figure 32: „Economy of Scale "example (source: Strategic Management Consultants, Ofwat, 2002)[45]

In the case of Jordan there are various options to address the diseconomies of scale, scope and density.

Amalgamating several smaller schemes into a single ownership and management structure will improve the economy of scale effect, e.g. certain minimal fixed costs resources, including management costs, could be spread over a wider consumer base. This option, however, does not remove all of the economy of scale disadvantages in that localised peaking factor issues remain resulting in infrastructure sizing that is less than it would be if it was part of a large scheme. This is inescapable for small schemes and has to be balanced against alternative options. Furthermore, amalgamating many small schemes in this manner does not address the economies of scope disadvantages and if they are all low-density communities the economy of density issue is not addressed. The option of combining wastewater services with water supply services as practised in Jordan provides some improvement in the economy of scope, e.g. shared billing and revenue collection services, shared management and other resources. However, on a micro scale this will still fall short of addressing the economies of scale, and, more importantly the economies of density issues.

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[45]Note: p/m$^3$ refers to 'pence' per m3 where GBP 1.00 = 100 pence.

To address the economy of density issue, and at the same time improve the economy of scope and scale, the option of expanding the remit of the larger urban utilities that serve the cities and towns to these smaller communities should be considered. Although this does not solve the economy of density issue at a micro level the tariff impact is very much diluted if the higher local unit costs for the small schemes are effectively spread out across a wider consumer base. In Jordan the population served by these small schemes is estimated to be less than 10% of the total population. If the unit cost of service in the small towns was double that of larger towns the increase in tariff over all if the costs were shared would only be 10% above that of the smaller towns. Furthermore, it would be impossible for the larger utilities to immediately implement the necessary investment across its extended remit and the adoption of new schemes would therefore be gradual, say over ten years of more. Consequently, the process of annual tariff adjustments to absorb these higher unit costs would be gradual and the annual increases small, say 1% per year in real terms.

# 14. Conclusions

### 14.1 Conclusions of the financial analysis of the 3 selected Business Models

The financial analysis of options has reached the following conclusions:

1. The small size of the operations, narrow scope and the dispersed population density relative are such that the minimal costs of service for consumers are considerably higher than for consumers in larger and more densely populated urban areas in Jordan. The result is that tariffs to cover the minimal operational costs (never mind capital costs) will be higher than tariffs elsewhere. Without significant operational subsidies it is not possible to provide the wastewater services at current tariff levels.
2. Despite the calculated tariffs being substantially higher than existing tariff levels elsewhere they are still within the range of estimated affordability constraints.
3. There are limited opportunities to secure additional revenues to ease the burden on consumers, notably the sale of wastewater effluent to the agricultural sector or securing carbon credits from international agencies providing financial vehicles for industry to offset their carbon emissions. These have been examined and although they provide a benefit to consumers, they are insufficient to reduce tariffs to levels comparable to those used elsewhere in Jordan. However, the current statutory price for the sale of water for agricultural irrigation appears to be below the assessed market value and there may be scope to improve viability if this price could be increased.
4. Although carbon credits at current international market values only marginally reduce the burden on consumers, these prices are expected to

increase dramatically in the medium term (10 years), which, if realised, could have a major positive impact on the viability of the biomass option with $CO^2$ credits[46.] However, this is not assured and until such time that the market price increases to these levels and longer term carbon compensation payment agreements are in place these schemes will be subject to a high degree of uncertainty and risk which will deter interest from potential operators in either the private or public sector. Consequently, such schemes are only likely to be viable at low consumer tariff rates in the future rather than the present and only if the prices for carbon compensation increases to the levels anticipated.

5. To address the economy of density issue, and at the same time improve the economy of scope and scale, the option of expanding the remit of the larger urban utilities that serve the cities and towns to these smaller communities should be considered

### 14.2 Additional conclusions

1. Privatisation of WW Management Service by PPP in a form of BOT, BOOT, DBO, DBFO, DCMF are applicable for large scale WW projects, but can be also applicable to DWWM if sufficient revenues are guaranteed and certain, and a specific amount of WW to be treated is guaranteed as a minimum.
2. WW collection and treatment are not usually financially justified in the most cases, but economically and socially justified (when considering the non-direct monetary benefits, which would be the majority of villages in Jordan). A full cost recovery of decentralised system will not be feasible due to affordability constraints by beneficiaries. Thus, a decentralised model needs to be established based not only on the demand of services, but also on the vulnerability of surface groundwater contamination (rivers, spring, shallow aquifer), health issues (diarrheal and vector borne diseases), and environmental pollution.
3. In general, DWWM is financially viable in terms of operational costs recovery, if the capital investment cost is covered by public budget or donors and not included in the financial analysis. In that case DWWM appears to be attractive for private investors.

## 15. Recommendations to Policy Makers

The Consultant recommends the following clarifications, legal actions and improvement of framework conditions to make small-scale sanitation in Jordan a viable business, based on full cost recovery, clear responsibilities and transparent share of tasks:

[46]The German government will increase the price per ton CO2 to 60 Euro by 2026 (source: https://www.spiegel.de/wirtschaft/soziales/co2-preis-emmisionszertifikate-schmerzen-den-verbraucher-a-1292599.html). The German Federal Environmental Agency recommends a price of 180 Euro / ton CO2 (source: https://www.dw.com/de/welcher-co2-preis-ist-fair-co2-steuer-co2-abgabe-deutschland/a-48593494)

### 15.1 Institutional, regulatory and organisational issues

The existing governance structure of DWWM in Jordan is still underdeveloped and lacks clear institutional and legal arrangements. As per the MWI's DWWM Policy, WAJ is mandated to handle DWWM issues in the country, but WAJ repeatedly indicated that DWWM is not within their responsibility. DWWM is a multi-disciplinary approach and should engage a wide spectrum of stakeholders. To improve the Institutional and regulatory framework for DWWM the following issues require MWI consideration:

- Enhance the capacities of the public and the private water sector to effectively plan, implement and operate DWWM infrastructures.
- Effectively enforce building standards that avoid exfiltration of WW through leaking sewers, cesspits and septic tanks.
- Promoting DWWM in rural communities regardless of the population size of <5000 PE. The selection shall be based on community characteristics, topography, groundwater and health vulnerability, volume of WW, quality of WW, land availability, investment costs and operation and maintenance requirements due to economies of scale.
- Establish inter-ministerial commissions be endorsed at the highest level, and engage ministries of planning, finance and economy, health, education and social development, agriculture, environment and national statistical offices under the leadership of MWI to take the responsibility of DWWM related issues.
- Support PPP schemes that have become attractive to governments as an off-budget mechanism for infrastructure development as this arrangement may not require any immediate cash spending. In addition to the existing role of private sector in the construction of sanitation systems and treatment, contract-based management can be promoted in a wider range.
- Agglomeration of rural communities into one DWWM scheme, if possible. Viable business models for small towns and rural sanitation depend on the scale: rural communities, which may form an agglomeration where WW collection and treatment is economically justified, or remote communes where local solutions have to be provided
- Awareness and behavioural change is a pre-requisite for successfully applying DWWM models. Related Information-Education- Communication (IEC) activities are recommended, including land issues, the questioning of traditional engineering practices environmental requirements, etc.)
- Improve and amend legislation. In particular, this applies to the establishment of service providers, municipal associations, WW user associations and wider implementation of fiscal incentives to promote selected business models.
- It is recommended to improve stakeholder involvement and participation especially during the planning and project preparation phase in order to avoid resistance from potential beneficiaries and local authorities.

### 15.2 Technical issues

- DWWM systems based on the "most appropriate technology" should be selected, case-by-case, as the one that is economically affordable, environmentally sustainable and socially acceptable. Management strategies should also be site specific. Decentralised or cluster WWTPs designed to operate at small scale, not only can reduce the effects of WW disposal on the environment and public health, but may also increase the ultimate reuse of WW, depending on community type, technical options and local settings. Selecting the most appropriate technology might be difficult for decision makers in administrations, government and donor agencies, and engineering companies etc., as the extensive range of commercially available technologies challenges the personnel responsible for implementation that may not have comprehensive knowledge on comparing technology types and their individual features. This is particularly the case for technologies applied in DWWM solutions. Therefore, a technology selection methodology can be applied.
- Enhancing Technology Transfer for DWWM is needed. Currently, there is a good level of knowledge regarding implementation and performance of DWWTPs at the experts' and scientific levels, however, technological transfer into practice is still insufficient, and low awareness and recognition of DWWMs benefits and a "business as usual" mentality still persist at the institutional and administrative levels.
- Develop and adopt technology certification procedures and O&M operation certifications.
- Adopting a reliable remote monitoring system, since in the past the lack of reliable remote monitoring technologies constituted a serious obstacle to decentralization, often resulting in unsustainable personnel requirements and/or unreliable treatment results. Recent common availability of robust remote sensor technology dramatically reduced onsite monitoring requirements, allowing telemetric control of distant facilities (for example for controlling pumps, solar panels and security requirements) and demand–actuated on-site maintenance.

### 15.3 Managerial / O&M issues

- Prepare a template for a sound and continuous operation and maintenance scheme of DWWM infrastructure based on their robustness and on effective O&M schemes.
- Support community ownership in the sense of taking direct and autonomous responsibility for their local WW solutions. Municipality ownership of DWWM system can facilities a wider adoption of DWWTPs.

### 15.4 Financial and business model issues

- Allocate sufficient funds for DWWM and seeking out-sourcing for capital investment.

- Ensuring uninterrupted, high-quality and reliable services, is necessary to ensure sufficient financing and available funds for DWWM system operations. This relates both to investment needs and to coverage of all necessary costs for maintaining and operating the system (energy, labour, infrastructure maintenance etc.). There are different financing models of DWWM operations, starting from full privatisation to operation by public institutions and in between. Full privatisation is not attractive to investors. Public operation suffers from weakness and in capabilities of public entities to operate.

- Government interventions in a form of subsidy, lease of services, tax exemption, revenue collection is needed to be financial attractive for the private sector to be involved in DWWM. The Financial feasibility and sustainability for the investor relies on the appropriate combination of taxes (transferred from central budgets), tariffs (revenues from user charges), and transfers for capital investment from international assistance.

- Re-examine the regulatory framework supporting DWWM to allow greater flexibility in determining tariffs at a micro level limiting intervention to providing guiding principles with respect to affordability and cost recovery. This has to be balanced against a need to provide regulatory certainty and investor confidence.

This financial analysis of the 3 selected BMs proposes the following recommendations:

1. The Government of Jordan and/or the responsible regulatory agencies to re-examine the current charging structure for irrigation and to determine if there is any market appetite to increase the rate (substantially).

2. The Government of Jordan and/or the responsible regulatory agencies to consider allowing higher tariffs in smaller towns provided they do not breach affordability constraints, although there is a need to develop a mechanism to determine such constraints. Alternatively, cross-subsidizing between larger and smaller towns and settlements could be considered.

3. The Government of Jordan and/or the responsible regulatory agencies to consider wastewater treatment in conjunction with biomass production and respective financing through $CO_2$ emission offsetting mechanisms.

4. The Government of Jordan and/or the responsible regulatory agencies to consider the option of compelling WAJ to take on the responsibility of providing wastewater services to these smaller towns and thereby enjoy the benefits of cross subsidies from larger communities (cities) to smaller ones.

Discussions at a workshop held on 19 November suggested that the options of increasing either the irrigation tariff or the consumer tariffs are unlikely to be approved or will face significant levels of resistance and resentment. Consequently, the remaining option of expanding the scope of the already existing larger utilities serving towns and cities to include the smaller communities remains the only longer-term viable option.

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# Annex 1: Data and Statistics

Table 31: Forecasted Population by Governorate

| Governorate | 2018 | 2020 | 2025 | 2030 | 2035 |
|---|---|---|---|---|---|
| **Amman** | 4,327,801 | 4,554,107 | 5,139,996 | 5,748,367 | 6,370,025 |
| **Balqa** | 531,000 | 558,766 | 630,652 | 705,296 | 781,570 |
| **Zarqa** | 1,474,000 | 1,551,077 | 1,750,624 | 1,957,829 | 2,169,558 |
| **Madaba** | 204,300 | 214,983 | 242,641 | 271,360 | 300,706 |
| **Irbid** | 1,911,600 | 2,011,560 | 2,270,349 | 2,539,068 | 2,813,656 |
| **Mafraq** | 593,900 | 624,956 | 705,357 | 788,843 | 874,152 |
| **Jarash** | 256,000 | 269,386 | 304,043 | 340,029 | 376,802 |
| **Ajlun** | 190,200 | 200,146 | 225,895 | 252,632 | 279,953 |
| **Karak** | 341,900 | 359,778 | 406,064 | 454,126 | 503,237 |
| **Tafiela** | 104,000 | 109,438 | 123,517 | 138,137 | 153,076 |
| **Ma'an** | 171,100 | 180,047 | 203,210 | 227,262 | 251,839 |
| **Aqaba** | 203,200 | 213,826 | 241,335 | 269,899 | 299,088 |
| Jordan | 10,309,000 | 10,848,071 | 12,243,682 | 13,692,848 | 15,173,663 |

Source: consultant estimate based on DOS population statistics (DOS, 2019b), (DOS, 2016)

Table 32: Historical Municipal per-capita water supply (l/c/d)

| Year | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
|---|---|---|---|---|---|---|---|---|
| **Amman** | 131 | 123 | 119 | 122 | 133 | 124 | 126 | 127 |
| **Zarqa** | 138 | 137 | 122 | 128 | 145 | 129 | 122 | 121 |
| **Irbid** | 84 | 87 | 80 | 77 | 76 | 72 | 72 | 74 |
| **Mafraq** | 145 | 138 | 137 | 117 | 133 | 125 | 132 | 130 |
| **Balqa** | 203 | 198 | 209 | 197 | 216 | 220 | 230 | 225 |
| **Karak** | 189 | 180 | 175 | 192 | 192 | 201 | 190 | 173 |
| **Tafiela** | 201 | 135 | 158 | 140 | 169 | 162 | 170 | 164 |
| **Ma'an** | 281 | 273 | 291 | 256 | 293 | 262 | 261 | 260 |
| **Jarash** | 77 | 82 | 89 | 84 | 84 | 83 | 88 | 88 |
| **Ajloun** | 86 | 77 | 88 | 86 | 82 | 76 | 71 | 77 |
| **Madaba** | 154 | 133 | 135 | 153 | 139 | 127 | 123 | 134 |
| **Aqaba** | 301 | 304 | 293 | 279 | 252 | 239 | 225 | 195 |
| **Jordan** | **134** | **129** | **125** | **125** | **133** | **126** | **126** | **125** |

Source: Compiled from MWI-NWIS, (MWI, 2019)

Table 33: Coverage of Public Sewer System by Governorate in 2018

| Governorate | Number of Households 2018 | Household with Public Sewer Network 2018 | Households Need to be connected to sewer system | % of HH connected to sewer system | Percentage of Household Need Sewer |
|---|---|---|---|---|---|
| **Amman** | 934,495 | 732,392 | 202,104 | 77.3% | 22.7% |
| **Balqa** | 108,127 | 61,605 | 46,522 | 55.5% | 44.5% |
| **Zarqa** | 302,371 | 244,261 | 58,110 | 80.4% | 19.6% |
| **Madaba** | 41,327 | 21,948 | 19,379 | 53.2% | 46.8% |
| **Irbid** | 384,011 | 182,169 | 201,842 | 47.2% | 52.8% |
| **Mafraq** | 115,034 | 29,451 | 85,583 | 25.3% | 74.7% |
| **Jarash** | 50,537 | 30,122 | 20,414 | 60.1% | 39.9% |
| **Ajlun** | 37,753 | 17,232 | 20,521 | 45.1% | 54.9% |
| **Karak** | 68,557 | 16,061 | 52,495 | 22.2% | 77.8% |
| **Tafiela** | 20,841 | 9,248 | 11,593 | 43.0% | 57.0% |
| **Ma'an** | 34,012 | 14,857 | 19,440 | 35.9% | 64.1% |
| **Aqaba** | 41,598 | 32,617 | 8,981 | 76.5% | 23.5% |
| **Jordan** | 2,138,797 | 1,391,963 | 746,986 | 63.7% | 36.3% |

Source: Compiled from DOS, (DOS, 2019b)

Table 34: Collected and non-collected generated WW by governorate

| Governorate | WW Generation from Whole Population | WW Generation from Served Population | Non Collected WW from Served Population | WW Generation from Non Served Localities | WW Generation from Non served Localities > 5,000 | WW Generation from Non served Localities < 5,000 |
|---|---|---|---|---|---|---|
| Amman | 140.2 | 109.9 | 30.3 | 2.7 | 0.9 | 1.8 |
| Balqa | 13.0 | 8.2 | 4.9 | 3.5 | 1.8 | 1.4 |
| Zarqa | 36.5 | 30.3 | 6.3 | 2.5 | 1.7 | 0.9 |
| Madaba | 4.6 | 2.8 | 1.9 | 1.5 | 0.8 | 0.7 |
| Irbid | 43.9 | 23.0 | 20.8 | 14.4 | 11.7 | 2.3 |
| Mafraq | 12.8 | 3.8 | 9.0 | 6.6 | 3.4 | 3.1 |
| Jarash | 6.1 | 3.9 | 2.2 | 1.3 | 0.8 | 0.5 |
| Ajlun | 4.2 | 2.2 | 2.0 | 1.8 | 1.4 | 0.4 |
| Karak | 7.2 | 1.9 | 5.3 | 4.4 | 2.2 | 2.2 |
| Tafiela | 2.3 | 1.1 | 1.2 | 0.9 | 0.7 | 0.2 |
| Ma'an | 3.4 | 1.4 | 2.0 | 1.7 | 0.6 | 1.1 |
| Aqaba | 4.9 | 4.0 | 0.9 | 0.8 | 0.2 | 0.6 |
| **Jordan** | **279.2** | **192.5** | **86.7** | **42.3** | **26.2** | **15.4** |

Source: Compiled from DOS, (DOS, 2019b)

Table 35: WWTP Compliant or Non-Complaint with Jordan Standard of Treated Effluents

| Th | WWTP Name | Compliant with JS standard | Violation Parameters | Technology |
|---|---|---|---|---|
| 1 | Kufranja | Non-Compliant | FOG | Activated Sludge |
| 2 | Wadi Hassan | Compliant | | Activated Sludge |
| 3 | Me'yrad | Non-Compliant | PO4, HCO3, Na, SAR, E-coli | Activated Sludge |
| 4 | Aqaba-Natural | Non-Compliant | FOG | Waste Stab Ponds |
| 5 | Tafila | Non-Compliant | COD, BOD5, TSS | Trickling Filter+ Activated Sludge |
| 6 | Karak | Non-Compliant | COD, HCO3,TSS | Activated Sludge |
| 7 | Madaba | Compliant | | Activated Sludge |
| 8 | Jiza | Compliant | | Activated Sludge |
| 9 | Wadi Esseir | Non-Compliant | COD, HCO3,TSS, T-N | Oxidation Sludge |
| 10 | Fuheis-Mahes | Non-Compliant | E-Coli | Activated Sludge |
| 11 | Ramtha | Non-Compliant | T-N | Activated Sludge |
| 12 | Samra | Non-Compliant | NO3, Na | Activated Sludge |
| 13 | Wadi Mousa | Compliant | | Activated Sludge |
| 14 | Aqaba-Mechanical New | Compliant | | Under construction |
| 15 | Ekedar | Non-Compliant | COD, FOG,TSS,No3,T-N | Waste Stab Ponds |
| 16 | Abu Nuseir | Compliant | | Activated Sludge |
| 17 | Baqa'a | Non-Compliant | Phenol ,E-Coli, Na | Trickling Filter |
| 18 | Salt | Non-Compliant | E-Coli | Activated Sludge |
| 19 | Irbid Center | Non-Compliant | PO4, HCO3, Na, SAR, E-coli | Activated Sludge |
| 20 | Wadi Arab | Non-Compliant | Hco3, Na, E-Coli | Activated Sludge |
| 21 | Mafraq | Compliant | | Oxidation Sludge |
| 22 | Ma'an | Non-Compliant | Phenol | Activated Sludge |
| 23 | Lajoon | Non-Compliant | TDS, No3, Cl, HCo3, Na, SAR | Waste Stab Ponds |
| 24 | Tal Mantah | Non-Compliant | T-N | Trickling Filter+ Activated Sludge |
| 25 | | compliant | | |
| 26 | Mansorah | compliant | | Waste Stab Ponds |
| 27 | Shobak | compliant | | Waste Stab Ponds |
| 28 | Mutah-Mazar-Adnaniyyah | Non-Compliant | E-Coli | Activated Sludge |
| 29 | Azraq Camp | Non-Compliant | COD, FOG,TSS,No3,T-N | MBR+TF |
| 30 | Za'atari Camp | Compliant | | MBR+TF |
| 31 | North Shouna | Non-Compliant | | Waste Stab Ponds |
| 32 | South Amman | Compliant | | Activated Sludge |

Source: (MoEnv, 2019)

Table 36: Distribution of communities connected with sewer system and non-connected to sewer

| Governorate | Connected Communities with sewer | Non-connected Communities for centralised system (>5000 PE) | Non-connected Communities for decentralised system (<5000 PE) |
|---|---|---|---|
| **Amman** | 38 | 7 | 66 |
| **Balqa** | 15 | 12 | 43 |
| **Zarqa** | 6 | 8 | 42 |
| **Madaba** | 3 | 6 | 64 |
| **Irbid** | 20 | 52 | 63 |
| **Mafraq** | 3 | 20 | 138 |
| **Jarash** | 15 | 7 | 31 |
| **Ajlun** | 10 | 7 | 35 |
| **Karak** | 10 | 13 | 89 |
| **Tafiela** | 7 | 4 | 26 |
| **Ma'an** | 7 | 4 | 55 |
| **Aqaba** | 1 | 1 | 26 |
| **Jordan** | **135** | **141** | **678** |

Table 37: Distribution of population connected with sewer system and non-connected to sewer system by governorate in 2018

| Governorate | Population within Public Sewer Network 2018 but not connected | Population in Non-sewered Communities for centralised system (>5000 PE) | Population in Non-sewered Communities for decentralised system (<5000 PE)) |
|---|---|---|---|
| **Amman** | 835,256 | 48,449 | 100,079 |
| **Balqa** | 44,855 | 113,364 | 78,251 |
| **Zarqa** | 148,606 | 92,716 | 47,675 |
| **Madaba** | 11,338 | 45,750 | 38,444 |
| **Irbid** | 215,102 | 664,617 | 129,573 |
| **Mafraq** | 80,436 | 189,655 | 173,787 |
| **Jarash** | 29,033 | 43,922 | 29,197 |
| **Ajlun** | 2,269 | 77,586 | 24,594 |
| **Karak** | 19,494 | 121,766 | 124,694 |
| **Tafiela** | 8,565 | 38,891 | 11,812 |
| **Ma'an** | 4,850 | 32,828 | 62,085 |
| **Aqaba** | 2,563 | 13,459 | 31,732 |
| **Jordan** | **1,402,368** | **1,483,004** | **851,921** |

Source: compiled from DOS, (DOS, 2019b)

# Annex 2: Jordanian Standards

Sources:

JSMO,2007. Jordanian Standards 893/2007 (Water – Reclaimed Domestic Wastewater): Technical Regulation. Jordan Standards and Metrology Organization, Amman, Jordan

JSMO,2007. Jordanian Standard 202/2007; Water - Industrial reclaimed wastewater. Third Edition: Technical Regulation. Jordan Standards and Metrology Organization, Amman, Jordan

JSMO,2006 Jordanian Standards 1145/2006: (Sludge – Reuse of treated sludge in agriculture).: Technical Regulation. Jordan Standards and Metrology Organization, Amman, Jordan

JSMO,2014 Jordanian Standards 1766/2014: (Irrigation Water): Technical Regulation Non-Obligatory. Jordan Standards and Metrology Organization, Amman, Jordan

Table 38 Jordanian Standard for Reclaimed Domestic Wastewater, Technical Regulation JS 893/2006

| | | Water - Reclaimed Domestic Wastewater Technical Regulation JS 893/2006 | | | | | |
|---|---|---|---|---|---|---|---|
| Parameter | Standard Unit | Cooked vegetables, parks, play grounds and side roads inside cities Category (A) | Fruit trees, side roads inside cities outside of cities, green areas Category (B) | Field crops, industrial crops, and Forest trees Category (C) | Cut Flowers | Flow into streams and valleys, water bodies | Groundwater Artificial Recharge |
| $BOD_5$ | mg/l | 30 | 200 | 300 | 15 | 60 | 15 |
| COD | mg/l | 100 | 500 | 500 | 50 | 150 | 50 |
| DO | mg/l | >2 | - | - | >2 | >1 | >2 |
| TOC | mg/l | | | | | | |
| TSS | mg/l | 50 | 200 | 300 | 15 | 60 | 50 |
| pH | mg/l | 6-9 | 6-9 | 6-9 | 6-9 | 6-9 | 6-9 |
| Turbidity | NTU | 10.0 | - | - | 5.0 | | 2 |
| $NO_3$ | mg/l | 30 | 45 | 70 | 45 | 80 | 30 |
| $NO_2$ | mg/l | | | | | | |
| $NH_4$ | mg/l | | | | | | 5 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| T-N Total Nitrogen | mg/l | 45 | 70 | 100 | 70 | 70 | 45 |
| E.-coli | MPN/100 ml | 100 | 1,000 | - | < 1.1 | 1,000 | < 2.2 |
| Fecal Colif. | MPN/100 ml | | | | | | |
| Intestinal helminth eggs | egg/litre | <= 1.0 | <= 1.0 | <= 1.0 | <= 1.0 | < 0.1 | <1.0 |
| FOG | mg/l | 8 | 8 | 8 | 2 | 8 | 8 |
| Phenol | mg/l | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | < 0.002 |
| MBAS | mg/l | 100 | 100 | 100 | 100 | 25 | 25 |
| TDS | mg/l | 1500 | 1500 | 1500 | 1500 | 1500 | 1500 |
| TH, $CaCO_3$ | mg/l | | | | | | |
| P (as $PO_4$) | mg/l | 30 | 30 | 30 | 30 | 15 | 15 |
| Cl | mg/l | 400 | 400 | 400 | 400 | 350 | 350 |
| $SO_4$ | mg/l | 500 | 500 | 500 | 500 | 300 | 300 |
| $HCO_3$ | mg/l | 400 | 400 | 400 | 400 | 400 | 400 |
| Na | mg/l | 230 | 230 | 230 | 230 | 200 | 200 |
| Mg | mg/l | 100 | 100 | 100 | 100 | 60 | 60 |
| Ca | mg/l | 230 | 230 | 230 | 230 | 200 | 200 |
| SAR | mg/l | 9 | 9 | 9 | 9 | 6 | 6 |
| Al | mg/l | 5 | 5 | 5 | 5 | 2 | 2 |
| As | mg/l | 0.1 | 0.1 | 0.1 | 0.1 | 0.05 | 0.05 |
| Be | mg/l | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| Cu | mg/l | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 1.5 |
| F | mg/l | 2 | 2 | 2 | 2 | 1.5 | 2 |
| Fe | mg/l | 5 | 5 | 5 | 5 | 5 | 5 |
| Li | mg/l | 2.5 | 2.5 * | 2.5 | 0.075 | 2.5 | 2.5 |
| Mn | mg/l | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |
| Mo | mg/l | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| Ni | mg/l | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |
| Pb | mg/l | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |
| Se | mg/l | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |
| Cd | mg/l | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| Zn | mg/l | 5 | 5 | 5 | 5 | 5 | 5 |
| Cr | mg/l | 0.1 | 0.1 | 0.1 | 0.1 | 0.02 | 0.05 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Hg | mg/l | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.001 |
| V | mg/l | 0.1 | 0.1 | 0.1 | 0.1 | 1 | 0.1 |
| Co | mg/l | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |
| B | mg/l | 1 | 1 | 1 | 1 | 1 | 1 |
| CN | mg/l | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| Ba | mg/l | - | - | - | - | - | - |
| Ag | mg/l | | | | | | |
| Sb | mg/l | | | | | | |

Jordanian Standard for Reclaimed Industrial Wastewater Technical Regulation JS202/2007

| Parameter | Unit | Cooked vegetables, parks, playgrounds and side roads inside cities Category (A) | Fruit trees, side roads inside cities outside of cities, green areas Category (B) | Field crops, industrial crops, and Forest trees Category (C) | Cut Flowers | Flow into streams and valleys, water bodies |
|---|---|---|---|---|---|---|
| **$BOD_5$** | mg/l | 30 | 200 | 300 | 15 | 60 |
| **COD** | mg/l | 100 | 500 | 500 | 50 | 150 |
| **DO** | mg/l | >2 | - | - | >2 | >2 |
| **TOC** | mg/l | | | | | 55 |
| **TSS** | mg/l | 50 | 200 | 300 | 15 | 60 |
| **pH** | mg/l | 6-9 | 6-9 | 6-9 | 6-9 | 6-9 |
| **Turbidity** | NTU | 10.0 | - | - | 5.0 | 15 |
| **$NO_3$** | mg/l | 30 | 45 | 70 | 45 | 80 |
| **$NO_2$** | mg/l | | | | | |
| **$NH_4$** | mg/l | | | | | 5 |
| **T-N Total Nitrogen** | mg/l | 45 | 70 | 100 | 70 | 70 |
| **E.-coli** | MPN/100 ml | 100 | 1,000 | - | < 1.1 | 1,000 |
| **Fecal Colif.** | MPN/100 ml | | | | | |
| **Intestinal helminth eggs** | egg/litre | <= 1.0 | <= 1.0 | <= 1.0 | <= 1.0 | < 0.1 |
| **FOG** | mg/l | 8 | 8 | 8 | 2 | 8 |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Phenol** | mg/l | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 |
| **MBAS** | mg/l | 100 | 100 | 100 | 100 | 25 |
| **TDS** | mg/l | 2000 | 2000 | 2000 | 2000 | 2000 |
| **TH, $CaCO_3$** | mg/l | | | | | |
| **P (as $PO_4$)** | mg/l | 30 | 30 | 30 | 30 | 15 |
| **Cl** | mg/l | 400 | 400 | 400 | 400 | 350 |
| **$SO_4$** | mg/l | 500 | 500 | 500 | 500 | 300 |
| **$HCO_3$** | mg/l | 400 | 400 | 400 | 400 | 400 |
| **Na** | mg/l | 230 | 230 | 230 | 230 | 200 |
| **Mg** | mg/l | 100 | 100 | 100 | 100 | 60 |
| **Ca** | mg/l | 230 | 230 | 230 | 230 | 200 |
| **SAR** | mg/l | 9 | 9 | 9 | 9 | 9 |
| **Al** | mg/l | 5 | 5 | 5 | 5 | 2 |
| **As** | mg/l | 0.1 | 0.1 | 0.1 | 0.1 | 0.05 |
| **Be** | mg/l | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| **Cu** | mg/l | 0.2 | 0.2 | 0.2 | 0.2 | 1.5 |
| **F** | mg/l | 2 | 2 | 2 | 2 | 2 |
| **Fe** | mg/l | 5 | 5 | 5 | 5 | 5 |
| **Li** | mg/l | 2.5 | 2.5 * | 2.5 | 0.075 | 2.5 |
| **Mn** | mg/l | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |
| **Mo** | mg/l | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| **Ni** | mg/l | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |
| **Pb** | mg/l | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |
| **Se** | mg/l | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |
| **Cd** | mg/l | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| **Zn** | mg/l | 5 | 5 | 5 | 5 | 5 |
| **Cr** | mg/l | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| **Hg** | mg/l | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 |
| **V** | mg/l | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Co** | mg/l | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |
| **B** | mg/l | 1 | 1 | 1 | 1 | 1 |
| **CN** | mg/l | 0.1 | 0.1 | 0.1 | 0.1 | 0.05 |
| **Ba** | mg/l | - | - | - | - | 1 |
| **Ag** | mg/l | | | | | 0.1 |
| **Sb** | mg/l | | | | | |

Jordanian Standard for Reclaimed Grey Water and Drinking Water, Technical Regulation JS286/2015

| | | JS 1776/2008 | JS 286/2008 | JS 286/2008 | JS 286/2015 |
|---|---|---|---|---|---|
| **Parameter** | Unit | Reclaimed Grey Water | Drinking Water | Drinking Water no alternative source | Drinking Water |
| $BOD_5$ | mg/l | 300 | | | |
| COD | mg/l | 500 | | | |
| DO | mg/l | >2 | | | |
| TOC | mg/l | | | | |
| TSS | mg/l | 150 | | | |
| pH | mg/l | 6-9 | 6.5-8.5 | 6.5-8.5 | 6.5-8.5 |
| Turbidity | NTU | 25 | 5 | 5 | 5 |
| $NO_3$ | mg/l | 50 | 50 | 70 | 50 |
| $NO_2$ | mg/l | | 2 | 2 | 3 |
| $NH_4$ | mg/l | - | 0.2 | 0.2 | 0.2 |
| T-N Total Nitrogen | mg/l | 70 | | | |
| E.-coli | MPN/100 ml | - | < 1.1 | < 1.1 | < 1.1 |
| Fecal Colif. | MPN/100 ml | | < 1.1 | < 1.1 | < 1.1 |
| Intestinal helminth eggs | egg/litre | <= 1.0 | | | |
| FOG | mg/l | - | | | |
| Phenol | mg/l | 0.05 | | | |
| MBAS | mg/l | 25 | 0.2 | 0.2 | 0.2 |
| TDS | mg/l | 1500 | 1000 | 1300 | 1000 |
| TH, $CaCO_3$ | mg/l | | 500 | 500 | 500 |

| | | | | | |
|---|---|---|---|---|---|
| P (as $PO_4$) | mg/l | 15 | | | |
| Cl | mg/l | 350 | 500 | 500 | 500 |
| $SO_4$ | mg/l | 500 | 500 | 500 | 500 |
| $HCO_3$ | mg/l | 400 | | | |
| Na | mg/l | 230 | 200 | 300 | 200 |
| Mg | mg/l | 100 | | | |
| Ca | mg/l | 230 | | | |
| SAR | mg/l | 9 | | | |
| Al | mg/l | 1 | 0.1 | 0.1 | 0.1 |
| As | mg/l | < 0.005 | 0.01 | 0.01 | 0.01 |
| Be | mg/l | 0.1 | | | |
| Cu | mg/l | 1 | 1 | 1 | 2 |
| F | mg/l | 1.5 | 1.5 | 1.5 | 1.5 |
| Fe | mg/l | 2 | 1 | 1 | 1 |
| Li | mg/l | 2.5 | | | |
| Mn | mg/l | 0.1 | 0.1 | 0.1 | 0.4 |
| Mo | mg/l | 0.01 | 0.07 | 0.07 | 0.09 |
| Ni | mg/l | 1 | 0.07 | 0.07 | 0.07 |
| Pb | mg/l | 0.1 | 0.01 | 0.01 | 0.01 |
| Se | mg/l | <0.005 | 0.01 | 0.01 | 0.04 |
| Cd | mg/l | 0.01 | 0.003 | 0.003 | 0.003 |
| Zn | mg/l | 2 | 4 | 4 | 4 |
| Cr | mg/l | 0.1 | 0.05 | 0.05 | 0.05 |
| Hg | mg/l | <0.004 | 0.001 | 0.001 | 0.006 |
| V | mg/l | <0.03 | | | |
| Co | mg/l | 0.05 | | | |
| B | mg/l | 1 | 1 | 1 | 2.4 |
| CN | mg/l | 0.05 | 0.07 | 0.07 | 0.07 |
| Ba | mg/l | 0.1 | 1 | 1 | 1 |
| Ag | mg/l | | 0.1 | 0.1 | 0.1 |
| Sb | mg/l | | 0.005 | 0.005 | 0.002 |

# Annex 3: Private Sector Business Model Options

**Privatisation through Divestiture**

An extreme form of privatisation is the absolute divestiture of government-owned utility assets including land ownership. A complete transfer of ownership occurs when a private entity purchases public or municipal utility's assets, assumes the city's franchise and operating certificates, and takes control over all future planning, construction, and operations. The local government is released from responsibility for managing utility operations and complying with regulatory standards. As a privately-owned utility monopoly providing retail service, the operations of the private firm are probably subject to economic regulation by the state.

The barriers to completely divestiture generally are more substantial than the barriers to other forms of privatisation. Governments are not necessarily interested in selling their assets; private firms are not necessarily interested in buying the assets owned by many local municipalities or public utilities. Government officials seem to be more interested in exploring opportunities "to partner" with private firms for the purpose of building and/or operating utility facilities. Under some circumstances, the concept of partnerships may be more palatable and more practical than the concept of divestiture. The concept of divestiture is not accepted by decision makers in Jordan. They believe that pubic services should not be in the hands of the private sector.

**Build–Operate and Transfer (BOT)**

BOT finds extensive application in infrastructure projects and in PPP. In the BOT framework the public administration delegates to a private sector entity to design and build infrastructure and to operate and maintain these facilities for a certain period. During this period the private party has the responsibility to raise the finance from the third party in cooperation with public institutions for the project and is entitled to retain all revenues generated by the project for repayment of fund and it is considered as the owner of the regarded facilities for the purpose of operation. The facility will be then transferred to the public administration at the end of the concession agreement, without any remuneration of the private entity involved. Some or even all of the following different parties could be involved in any BOT project. In a BOT project, the company or operator generally obtains its revenues through a fee charged to the utility/ government rather than tariffs charged to consumers directly. It is the responsibility of the government to collect using fees from the customer and beneficiaries. In the BOT, the private organization does not own the project as an asset; they merely receive a concession to operate it for a period of time. The revenues for enterprises that adopt a BOT approach come largely from the initial setup fees and these revenues are not recurring. Most BOT-cases prefer to take up projects initiated by the Government or funded by multilateral agencies.

An Example of BOT in WW services in Jordan is As-Samra WWTP. As Samra WWTP is the first WWTP in the Middle East to use a combination of private, local government and donor financing. Closing the financing of the expansion proved the feasibility and demonstrated the significant benefits of combining private sector financing with grand funding in a scheme referred to as viability gap funding by bringing down the capital costs, the grant funding enabled the project to be financially viable, thus benefiting the government and local rate-payers, without subsidizing the private sector.

**Build-Own-Operate and Transfer (BOOT)**

A build, own, operate and transfer (BOOT) contract is a project business model that can be used for DWWM projects developed through PPPs. The term PPP refers to a very broad range of partnerships in which the public and private sectors collaborate for some mutual benefit.

Under a BOOT contract, a private organization undertakes to complete a project, which they are granted a concession to finance, build and operate by a private sector partners under the supervision of public partner, typically a government department. The public partner may provide limited funding or other benefits (such as tax exemptions) but the private organization accepts most of the risks. The private organization is then granted the right to own, maintain and operate the project for a set period of time, during which they can draw fees from users of the asset. Once the time-period has elapsed, the control of the project transfers to the public sector partner, either freely or for a fee that is stipulated in the original contract. It is common for the time-period to be several decades in the case of big infrastructure projects that carry a lot of construction and operational risk.

Using the BOOT model, the public sector is able to take advantage of the efficiencies found in the private sector for a minimal investment. Much PPP relationship using this model will offer an incentive, such as tax breaks, to the private organization to develop the infrastructure. Because the private sector assumes the risk for planning and use, they are given an opportunity to profit from the structure by recruiting tenants for it. Then, after the contracted time, the public sector takes over ownership. In the case of DWWM the private partner needs to purchase the land for the project. Land acquisition may arise as one of the obstacles, since the project is becoming of private benefits not as a public benefits project.

**Design-Build and Operate (DBO)**

A design build operates (DBO) contract is a project delivery business model in which a single contractor is appointed to design and build a project and then to operate it for a period of time. The common form of such a contract is a PPP, in which a public client (e.g. government or public agency) enters into a contract with a private contractor to design, build and then operate the project, while the client finances the project and retains ownership. It also differs from the traditional design and build contract in that it includes operation and maintenance of the completed works, which means that the contractor's duties and responsibilities to the client do not end at final acceptance but continue through a defined operational term.

**Design-Build-Finance and Operate (DBFO)**

The design build finance and operate (DBFO) contract in which the contractor also finances the project and leases it to the client, or third part sub-contractor, for an agreed period (perhaps 30 years) after which the development reverts to the client. In theory, this encourages the contractor to develop a project with its long-term performance in mind from the outset, rather than just considering the efficiency of its construction, as the contractor will be responsible for any high operating, maintenance or repairs bills. However, it ties both the client and the contractor into a very long-term relationship that can be difficult to price. As a result, contractors may price considerable risk into their tenders, and so the client may not always achieve a best value outcome

**Design–Construct–Manage–Finance (DCMF)**

A private entity is entrusted to design, construct, manage, and finance a WWTP, based on the specifications of the government. The private firm can contract other firms for operation and maintenance. Project cash flows result from the government's payment for the rent of the facility. In the case, the government has the ownership over the facility and has the price and quality control. Therefore, this model could be interpreted as a means to avoid new indebtedness of public finance.

**Build–Lease and Transfer (BLT)**

A lease is a written agreement under which a property owner allows a tenant to use the property for a specified period of time and a specified rent. The private-sector operator is responsible for providing the service at its own risk, including operating and maintaining the infrastructure for a given period of time. The operator is not responsible, however, for financing investment such as the replacement of major assets or expansion of the network. If payments from users cover more than the operator's remuneration, the operator is generally supposed to return the difference to the public authorities in order to cover the cost of the investments under the latter's responsibility

Under BLT a private entity builds a complete project and leases it to the government. On this way the control over the project is transferred from the project owner to a lessee. In other words, the ownership remains by the private sector (shareholders), but operation purposes are leased. After the expiry of the leasing the ownership of the asset and the operational responsibility are transferred to the government at a previously agreed price. For foreign investors taking into account the country risk BLT provides good conditions because the project company maintains the property rights while avoiding operational risk. This category of privatizers is comprised of third-party service providers (or private vendors) who enter into contractual arrangements with publicly and privately-owned WW utilities. In some cases, these privatizers also offer special financing arrangements to the contracting utility or municipality.

For investor-owned utilities, leasing is a means of reducing equipment costs and eliminating construction expenditures. For municipally owned WWTPs, leasing is a form of privatisation, as well as a means of compensating for the reduced availability of state government construction grants. Leasing provides several advantages for the various parties involved. The primary advantage for the lessee to WAJ or to water utility is the capability to have equipment or facilities in place more quickly due to fewer obstacles than with conventional financing.

The discussion above on PPP is in a summary, BOT contracts involve take or pay provisions, i.e. revenue guarantees, that subject governments to contingent liabilities. On expiration of a BOT, the assets are returned to the public sector. BOOs are similar to BOTs except that they do not involve transfer of the assets to the public sector after a pre-determined period of time. The private operator thus remains responsible for carrying out all the investment required to meet its service obligations. Under BOOT schemes, the private sector obtains the capital needed for construction, builds and operates the infrastructure for an agreed period of time (anywhere between 15 and 30 years) and then transfers ownership back to the relevant government. BOTT (build-operate-train-transfer) is another variation of BOT whereby the private operator commits to train the public sector to allow a smoother transfer. Other permutations of the activities for which the private sector takes responsibilities exist and typically involve design, build, operate, maintain and finance.

Inability to cover the capital and operating expenditures within the currently applied tariffs which are non-dynamic and are not linked to service delivery costs,

The main disadvantage of the above all types of business models are:

- The private sector will not get started on the infrastructure project until there are funds in place to begin the planning phase of the project. If no funds can be raised to complete the project, then it won't get done. For that reason, the public sector often looks for private entities which already have a funding mechanism in place to complete the proposed project.
- To be successful from a private standpoint, there must be large revenues generated during the operational phase of the contract, so that the private organization has the best possible chance of making their investment back, plus some profits.
- The BM requires the full commitment of policy makers to correctly balance financial and political objectives;
- The public sector must stay involved with the supervision of the project during the operational phase to ensure it remains successful. One of the most common reasons for the failures in these projects are the weak of communications between the private and public entities involved as reported by , (Dua'a B Telfah, Minciardi, & Roth, 2018) (Dua'A B. Telfah et al., 2017)
- Baseline knowledge and information available at the beginning of a PSP process is quite often insufficient and unreliable leading to problems in target definitions during contract development or later in implementation of PSP and the assessment of performance. It is essential to improve data availability and reliability thus strengthening grounds for PSP and the cooperation base of the two partners. (ACWUA, 2016)

In privatisation of WW management services, the investor will cover the full cost, either from own resource or by outsourcing from third party (local, international or even public sources), like any other private sector investment. The investor is expected to cover project cost from A-Z including the feasibility study costs. Full privatisation is very different, since in the bankrupt case of the investor, one cannot stop providing sanitation service. Privatisation could involve management only, or whole WW services, but operating on publicly owned assets. In some countries, non-movable fixed WW assets, including pipelines and WWTPs, have been privatized.

# Annex 4: Types of Management / O&M Contracts

MWI is committed to securing water services at affordable prices and acceptable standards. It is also committed to extending these services to remote and less developed areas (MWI 2010b). With all the technical and financial challenges, it is facing, it is more and more turning to engaging the private sector in developing the water sector (capital investments as well as management contracts). It intends, through private sector participation, to transfer infrastructure and services from the public to the private sector, in order to improve performance and ensure the delivery of services to the population

There are a multitude of privatisation options ranging from the most extreme (full divestiture as per the England and Wales model through to outsourcing of specific services and a whole raft of options in between (management contracts, leases, enhanced leases, concessions, BOT, BOOT, and many more)

Much of the interest and activity in the privatisation of the WW services is in the area of contracts for operational services. One reason is that the institutional constraints are greater for sales of assets and capital improvement projects than for operational agreements. The Service providers-contactor also are quick to point out the potential benefits of contracting.

Management contracts provide 100% coverage of labor, consumables, parts and materials as well as emergency service, which means, comprehensive management services. Such contracts usually include comprehensive preventive maintenance for equipment and systems. Respective management capabilities and experiences need to be verified prior to assigning a company, as the contractor is completely responsible for operating and maintaining WWTPs and related installations. Potential contractors should be pre-qualified, and the tender should be very specific about the requested O&M standards and routines. When repair and replacement coverage is part of the agreement, it is to the contractor's advantage to perform rigorous preventive maintenance on schedule, since they must replace the equipment, if it fails prematurely. In the short term (< 5 years), full-coverage contracts are usually the most comprehensive and expensive type of agreement. For longer contract periods, however, such a contract may be most cost-effective. Major advantages are ease of budgeting and risk bearing by the contractor.

Management contracts are a greatly expanded and more comprehensive form of service contracts in which the private sector assumes responsibility for most or all of the public utility activities including operation, maintenance, billing and collection fees from customers as well as day-to-day management with only limited and temporary delegation of authority to the public sector.

This approach was considered a good first step towards greater PPP. Management contracts for specific operations and management of facilities in Jordan's water sector requires no significant change in the existing regulatory or legal structure and therefore could be implemented quickly with relatively low costs and level of effort. Tariff setting has remained within the responsibility and decision making of the public sector, albeit more improvement in service delivery, which can justify any tariff increases.

There are many different types of management contracts. The simplest involves paying to a private firm a fixed fee for performing managerial tasks based on performance indicators, while the more complex ones introduce greater incentives for efficiency by defining performance targets and basing the reward at least on their fulfilment. A comparison of main benefits and drawbacks management and service contract in water and WW Jordan is shown in (Table 40).

WAJ proposed to enter into a contract with a private entity as a management contract for six years' duration with potential for an extension beyond that time to provide all services related to the management, operation and maintenance of the water and waste water serving communities in the Petra area district, which constitutes 14 villages with 49 hotels in the service area beside 6,000 subscribers. The basis of compensation are based on a lump sum fixed fee plus an incentive fee related to performance of the operator; the contractor are not be responsible for any other costs related to capital improvement (Abu-Shams & Rabadi, 2003).

The operation and management of water and sewage services has been opened to private sector participation since 1999. However, asset ownership has been fully retained by the public sector. WAJ has implemented a management contract in Amman Governorate by which a private sector consortium managed water and sewage services during the period from 1999 to 2006.

In Jordan, the management contract achieved most of its objectives and targets and created the right conditions for WAJ to establish the water company "Miyahuna" which has been vested with water and sewerage services delivery in Amman since the beginning of 2007. A public water company has also been established in Aqaba, owned jointly between WAJ and Aqaba Special Economic Zone, which owns water and sewage assets and functions, according to commercial principles. Several small-scale management contacts options have been implemented in Madaba (2006-2011) Governorate, Balqa Governorate (2010-Ongoing) and Karak Governorate (2010-Ongoing) with the objective of improving billing and revenue collection procedures and amounts, reduction of outstanding amounts (arrears) and subsequently Non-Revenue Water (NRW). A management contract was started in 2011 and a new water company was established (Yarmouk Water Company) for the Northern Governorates

However, most PSP has been in the form of management and service contracts for the provision of water services. Private water operators have been present in Jordan since 1999, starting with a management contract in Amman that was awarded to LEMA, a French-Jordanian consortium, for the management of water supply in Greater Amman. A performance-based management / lease contract was signed for the Yarmouk Water Company, a utility serving the Northern Governorates of Ajloun, Irbid, Jerash and Mafraq, in 2012 but it has since been terminated. The Yarmouk contract stipulated that the private partner would be paid by a combination of a fixed payment and a variable performance-based payment

**Service Contract**

A service contract covers 100% of the labor for repair, replacement, and maintenance of the core WW facilities and related installations. The facility owner is required to purchase all equipment and parts. Preventive maintenance and operation are usually part of the contract, while the actual installation of major treatment plant equipment such as pumps and control panels are typically covered by the owner. Risk and warranty issues usually preclude anyone but the manufacturer installing such equipment for the period specified in the contract. The cost of emergency repairs may be factored into the original contract in contrast to an agreement to responding to an incident within a defined period with the owner paying for the emergency labor separately. Some preventive maintenance services are often included in the agreement along with minor materials such as lubricants and other consumables. A full-labor service contract is the second most expensive arrangement in terms of short-term impact on the maintenance budget. Because they are responsible only for providing labor, the contractor's risk is significantly low when compared to a full-coverage contract.

Service contracts have also been an important modality for involving the private sector. These contracts were introduced in the early 2000s, in the context of Operation and Management Support, a German technical cooperation project, as a way to fast track the implementation of contracts with the private sector. The contracts entailed outsourcing specific business processes to local private companies in order to support commercialization and efficiency of service delivery in the operation and maintenance of water supply and wastewater disposal (Rothenberger, 2009). Under this approach, service contracts were signed for Madaba (2006-2011), Balqa (2010–2013) and Karak (2010-2013). The service contact of Madaba are: "The Management of water & wastewater billing and revenue collection including the implementation of Geographical Information System based tools, implementation of Customer Information System and implementation of Sewerage Database within Madaba Governorate (Rothenberger, 2009).

Orient Company[47] was assigned to deliver services composed of the management of water, wastewater, customer service, as well as the full management of Karak Water Administration Units. The contract was designed to deliver services over three years, and the objectives were as follows: (a) Improve new water and waste water customer application procedure, (b) Improve meter installation, meters readings, billing and management procedures., (c) Improve water and waste water collections and revenues, (d) reduce customer outstanding amounts, (e) Improve customer management efficiency.

The contract was implemented in two phases; the first phase (Phase 1) which is the preparatory period that focused on implementing the billing system including link with GIS and data clean up, subscribers redesign, and introducing the updated version of the billing system. Phase 2 of the implementation was the Performance Management Period. Orient took over the operation of the customer service component to improve the performance in different customer service-related operation areas including increasing revenues, reduce illegal connections, reduction of account receivable.

**Preventive Maintenance Service Contract**

The preventive maintenance contract is generally purchased for a fixed fee and includes a number of scheduled and rigorous activities such as comprehensive inspections, equipment overhauls, and calibration of measurement devices and servicing of buildings. Generally, the contractor provides the materials required for preventive maintenance as part of the contract. The contract may or may not include arrangements regarding emergency repairs. The contractor shall provide scheduled preventative maintenance, inspections as described in the contact document. The goal of these inspections is to maintain optimum equipment performance and reduce the likelihood of unexpected failures. Each inspection shall be performed in accordance with the agreed checklist and inspection task details.

The main advantage of this contract type is that it is initially less expensive than both, the full-service and the full-labor contract, and it provides the owner with an agreement that focuses on quality preventive maintenance. However, budgeting and cost control regarding emergency repairs and replacements is more difficult because these activities are often done on a time-and-materials basis.

With this type of contract, the owner takes on most of the risk. Without a clear understanding of requirements, a facility owner could end up with a contract that provides either too much or too little service. In order to set up a preventive maintenance contract properly, a detailed understanding and experience of the preventive maintenance efforts is required.

[47]https://orientengllc.com/project/karak-governorate/

**Inspection Service Contract**

An inspection contract, also referred to as a "fly-by" contract, is purchased by the facility owner for a fixed annual fee and includes a fixed number of periodic inspections of the WWTPs and related installations. However, inspection activities are much less rigorous than preventive maintenance. Simple tasks such as checking treatment plant outfalls on blockages, visual checks on fences, doors and buildings etc. are performed routinely, and for the most part inspection means looking to see if anything is broken or is about to break and reporting it to the facility owner.

The contract may or may not require that a limited number of materials, e.g. vehicles, tools, etc., to be provided by the contractor and it may or may not include an agreement regarding other services such as emergency repairs. In the short-term perspective, this is the least expensive type of contract. It may, however, also be the least effective. Low cost is the main advantage to this contract.

Operating risks may be contractually assumed by private companies. But failures in services that affect health, safety, and other public goods will be attributed to political leaders. Outsourcing of operations and maintenance alone is often driven by a desire for cost savings through economies of scale and service efficiencies that may be possible through private enterprises.

The inspection service contact is currently practiced in Jordan for WW effluents monitoring, where the JVA and MoEnv contracts the RSS to inspect and conduct chemical/physical and biological analysis for central WWTPs and DWWTPs belong to private sector, such as DWWTPs existed and operated by many hotels, universities, slaughterhouses, commercial and small-scale industrial enterprises. (MoEnv, 2019)

**Private Sector O&M Performance Based Management Contracts** The private based management contract is not required to participate in the capital investment cost. The capital investment cost can be financed through public budget or outsourcing from different sources (local bank, loans, funds and international aid). A contract-based management firm is expected to cover the re-investment required in the future for depreciated machinery and repair.

The other category of private participation is contract operations, maintenance and management (OM&M). With contract OM&M, a publicly owned facility is operated by a private firm. The municipality retains ownership of the facility, and the firm assumes responsibility for operating the facility and guaranteeing performance, including compliance with regulatory requirements. The contract may also include the design, construction and financing of a WWTP in addition to its operation.

**Advantages and Disadvantage of Contracting WW Services**

Arguments favouring and opposing privatisation through contracting are provided in (Table 37) below. The advantage and disadvantage related to WW sector in Jordan are displayed in Table 38.

Table 39: Advantages and Disadvantage of Contracting WW service

| Advantages | Disadvantages |
|---|---|
| • Contracting out is more efficient because it permits better management, free of most of the distracting influences that are characteristics of overtly political organizations.<br>• The costs and benefits of managerial decisions are felt more directly by the decision makers; whose own rewards often are directly at stake.<br>• Contracting out makes it possible for government to take advantage of specialized skills that are lacking in its own workforce; it overcomes obsolete salary.<br>• Contracting allows flexibility in adjusting the size of a program up or down in response to changing demand and changing availability of funds.<br>• Contracting permits a quicker response to new needs.<br>• Contracting is a way of avoiding large capital outlays; it spreads costs over time at a relatively constant and predictable level.<br>• Contracting permits economies of scale regardless of the scale of the government entity involved.<br>• Contracting a portion of the work offers a benchmark for comparing costs.<br>• Contracting fosters good management because the cost of service is highly visible in the price of the contract.<br>• Contracting can reduce dependence on a single supplier.<br>• Contracting limits, the size of government, at least in terms of the number of employees. | • Public employees fear the loss of employment and pensions in public utility or municipal utility works.<br>• Privatisation may mean loss of grant money or tax-exempt financing for capital improvements.<br>• The rates charged by privately owned water utilities are generally higher than the rates charged by publicly owned utilities because private firms charge full costs and must pay taxes and earn a profit.<br>• Communities are concerned that privatisation means giving up control over day-to-day operations and service standards, as well as planning for long-term growth and economic development.<br>• Community leaders and the public may not appreciate the potential value of privatisation or the range of privatisation options and may lack the expertise needed to evaluate these options.<br>• Contracting is ultimately more expensive; high profits seeking, the cost of managing the contract and monitoring contractor performance; cost-plus-fixed-fee provisions in some contracts, which provide no incentive for efficiency; and the absence of effective competition in "follow-on" contracts.<br>• Contracting limits, the flexibility of the government in responding to emergencies.<br>• Contracting fosters an undesirable dependence on contractors and leaves the public vulnerable to strikes and slowdowns by the contractor's personnel and to bankruptcy of the firm.<br>• Contracting depends on adequately written contracts, which are difficult to draw up, and as a result there is a loss of government accountability and control.<br>• Contacting limits, the opportunity to realize economies of scale. Entrusting services to private organizations increases the political power of the latter and creates a lobby for more government spending.<br>• Contracting causes a loss of autonomy of the contractor and thereby decrease the latter's effectiveness in the long run by muting its role as critic and social conscience. |

Table 40: Comparison of main benefits and drawbacks of management and service contracts in WW management in Jordan

| Option | Main benefits | Drawbacks |
|---|---|---|
| **Management contracts** | • Improve services with reduced risks to the WAJ (government).<br>• Result in significant improvements in system operation efficiencies and services.<br>• Improve organizational reform of operations.<br>• Good first step towards significant private sector involvement in WW management. | • Government is responsible for the financing of all capital and parts of operational investments. |
| **Service Contracts** | • Public sector gains access to private sector expertise for technical tasks for which it may lack expertise.<br>• Lead to improvements in efficiency.<br>• They are relatively simple and widely used.<br>• Require no specific conditions; however, must be carefully managed and monitored. | • Will not improve utility's overall management.<br>• Cannot eliminate or solve problems such as improperly designed tariff rates or poor cost recovery. |

Source: adopted from (Abu-Shams & Rabadi, 2003)

# Annex 5: Business Model Guidance Notes

**Excel model guidance notes**

**V.01**

**September 2019**

Disclaimer: These guidance notes are to assist users of the excel model only. The opinions expressed in these notes are those of the model developer and do not necessarily reflect the opinions of GIZ or any other organisation mentioned.

## Introduction

1. This document describes the MS Excel model used for the determination of proposed tariffs for the business model options and resulting outcomes, importantly cash flow.
2. The model is to inform decision makers with respect to any future institutional and financial arrangements for the provision of wastewater services in small towns.
3. The model does not specify mandatory requirements but is to illustrate realistic projections of outcomes based upon the best available data and probable future expectations.
4. These guidance notes set out the rationale for the model and the options for using it to test various scenarios based upon a private sector operator

responsible for the delivery of wastewater services at a micro level. It does not, however, provide for the wider options of wastewater services to be included in water supply services (currently a Water Authority of Jordan (WAJ) responsibility) nor does it allow for a regional service provider serving several small towns / communities in the area and thereby capturing economies of scale effects.

5. These notes are to read in conjunction with the MS Excel model.

## Model platform, key, structure and base principles

Model platform, key and structure

6. The model is developed using an MS Excel workbook (macro enabled). The input and calculation cells are colour coded as below:

| | |
|---|---|
| (grey-blue) | Input cells |
| (green) | Reference to other cells in the workbook (input or other calculations) |
| (yellow) | Calculations |

7. The model is broken down into multiple worksheets as below:

| Ref | Sheet name | Description |
|---|---|---|
| 0 | Options dashboard | |
| 1 | Input data | All model input data appears on this sheet. No input appears on any other sheets. |
| 2 | Population & demand | Determines population projections, levels of service, volumes of wastewater generated, and volumes of wastewater delivered to irrigation. |
| 3 | Cost refl treatment charges | Determines cost reflective differentials between consumer groups depending upon the quality of wastewater generated. |
| 4 | Capital investment | Determines initial and future capital investment based upon nature of investment, replacement rate, capital maintenance of network infrastructure, and how the investment is financed. |
| 5 | Depreciation | Determines depreciation for non-network assets based on a current cost basis (i.e. it assumes depreciation provisions passed through to tariffs are adjusted with inflation). Depreciation is only charged to tariffs on those assets financed by the service provider, i.e. depreciation on grant financed assets are not passed through to tariffs. No depreciation is charged to network assets and infrastructure renewals accounting is applied, i.e. expenditure on the capital maintenance of network assets is passed through to tariffs as if it is an operational expenditure. |
| 6 | Operating expenditure | Determines the operating expenditure including variable costs (energy), allows for wage inflation above general inflation and the potential of labour efficiency expectations over time. Operating expenditure is separated between grant funded and tariffs funded. |
| 7 | Tariffs asset base | Determines the asset base of the service provider but only for those assets financed by the provider. In most cases this does not include the initial investments as this is expected to be grant financed but does include periodic expansion of the tertiary network and capital maintenance on pumping stations and treatment facilities. |
| 8 | Tariffs revenue requirement | Determines the total annual cash expenditure by activity (network, treatment, irrigation pumping) which determines the revenue requirement. This includes operational costs, capital maintenance, return on capital (where the service provider has financed investment) and a minimum annual margin. Unit revenue requirements are determined. |
| 9 | Tariffs | Determines tariffs for different consumer groups and the expected revenues from each group that meets the revenue requirement. |
| 10 | Cash flow | Determines net cash flows for the service provider capturing all revenues, operational expenditure, capital maintenance and service provider funded capital investment. |
| 21 | Impact of irrigation price | Determined the tariffs necessary to satisfy cash flow requirements for varying tariffs for irrigation sales. This sheet relies on a macro to be activated to generate the required graphs. |
| 22 | Impact of tariff cap | Determines the level of subsidy required to satisfy cash flow requirements on an annual basis where tariffs are subject to caps. This sheet relies on a macro to be activated to generate the required graphs. |
| 23 | Impact of capital grants | Compares tariffs against what they would be if the operator was responsible for all capital investment, i.e. no capital grants. |
| 24 | Comparison of options | Compares the tariff outputs for the three principal options. |
| 25 | Impact of CO2 comp price | Determines the resulting tariffs across a range of CO2 compensation credits. |
| 26 | Operating costs analysis | Provides a breakdown of operating costs for the selected option |

### Base principles

8. The model is long-run (20 years). This is an ambitious assumption as the probability of forecasting error is significant beyond five years. On the basis of informing long-run decisions with respect to institutional and financing arrangements a longer run model is necessary but this is limited to informing the longer run general outcomes and effects rather detailed numerical expectations.
9. Unless specified otherwise the model is based on 2019 base year price levels, i.e. all costs and revenues have not been adjusted for future inflation. Similarly, all margins and returns on capital are real as opposed to nominal. Consequently, all outcomes (tariffs, profits etc.) are assumed to increase with inflation.
10. Taxation has not been considered and all margins and returns on capital are regarded as pre-tax.
11. No provision has been made for commercial efficiency and it is assumed that revenue collection is at or near 100%.

## Model rationale and theory

### Cash flow and cost recovery

12. The financial model is largely cash flow driven with tariffs set on an annual basis to meet operational costs, capital maintenance, return on capital and a pre-determined margin.
13. The only exception to the cash flow principle is capital investment (non-network) undertaken by the service provider where current cost depreciation is applied to smooth the investment costs over the useful asset life. Where the service provider undertakes such investment, the net written down value of the assets is added to an asset base upon which a return on capital is provided for to cover the service provider's financing costs and/or the opportunity cost of capital.

### Cost reflective charges

14. The model sets charges to be as cost reflective as reasonably possible. In this regard groups of consumers are charged according to the costs they as a group impose on the service provider. This applies to consumers whose wastewater quality is different from average, e.g. collection and septic tank users, who will be charged an extra over/under premium to reflect the cost of treatment. This is applied using the Mogden formula.
15. Similarly, collection and septic tank users do not impose any network related costs and as such are not charged the network component of the tariff.
16. Tanker services are assumed to be provided by a third party. Charges related to treatment of wastewater from collection and septic tanks are imposed on the tanker company who pass the charges on to consumers through their charges. The determination of charges to consumers for privately owned

and operated tanker services is outside the scope of this model.

### Infrastructure renewals accounting approach

17. The model applies the infrastructure renewals accounting approach to network assets. This approach assumes that the value of the network assets are maintained in perpetuity with zero depreciation but any expenditure on capital maintenance is passed through in full to tariffs (unless the expenditure is grant financed). For a new system the expenditure on capital maintenance will be expected to be very low in the early years but will increase as the system ages. The model is designed to reflect this assumption.

### Capital investment and capital maintenance

18. Capital investment is expected to be grant financed at the outset (although the model provides for this to be financed by tariffs if required). However, any capital maintenance[48] of non-network assets will start to manifest as components reach the end of their useful lives with electrical components needing to be replaced in a short period of time, mechanical components some time later and civil engineering works to be replaced even later. The model assumes that the service provider will be responsible for financing the capital maintenance and that the costs shall be passed through to tariffs. The net effect of this is that the revenue requirement, and hence tariffs, will be lower in the early years but as the capital maintenance demands start to materialise the revenue requirement and tariffs will increase.
19. Furthermore, as the population grows certain aspects of the system will need to be enhanced to accommodate growth. We have assumed that for the purposes of this model this is confined to periodic expansion of the tertiary network and that all other investments are designed to beyond the model's design horizon. An option in the model is for such enhancement to be financed by the new consumers that trigger the need for it through customer contributions beyond a connection fee. This is a charge to be imposed on each new property as a contribution to this enhancement. This charge is assumed to be imposed on the housing developer or owner and included in the sale price of the property and/or the home-owner. The model can provide for this to be tariffs financed, i.e. paid for by both existing and new consumers but in some respects such an approach cannot be considered to be cost-reflective in that existing consumers will be financing activities that they had no part in generating.

[48] Capital maintenance is defined as the investment in the major repair or replacement of assets at the end of their useful lives. It is not routine operational maintenance or investment in system expansion or enhancement.

**Asset values, return on capital and margin**

20. The model determines the service provider's asset base which includes the value of only those assets financed by the service provider net of depreciation.
21. This asset base is subject to a return on capital to cover the service provider's financing costs and/or the opportunity cost of capital.
22. As the level of investment by the service provider is small, especially in the early years, a return on capital where the asset base is small is likely to be too small to be attractive for a prospective service provider. In this instance the model provides for a minimum value of a service provider's margin to be included in the revenue requirement.

**Revenue requirement**

23. The tariff build-up comprises a revenue requirement for each activity made up of: operational costs, capital maintenance (network capital maintenance and current cost depreciation), return on capital and a pre-determined margin.
24. This value is adjusted by removing revenue from cost reflective treatment charges and income from other sources to determine the base revenue requirement for each activity.
25. Unit charges for each activity are derived.

**Tariffs**

26. The tariffs necessary to meet the requirement are determined and include:
    - Tanker fees (JOD/m3) for wastewater from collection and septic tanks (but excludes the network component of tariffs)
    - Unit wastewater charges (JOD/m3) for wastewater consumers served by the sewerage network (household and non-household)
    - Unit wastewater effluent reuse charges (JOD/m3) for wastewater delivered to irrigation.

### Detailed model description

27. The following table describes the model in more detail. The number notation below corresponds to the numbering system applied in the model.

Table 41 Detailed business model description

| Sheet | Section | Description |
|---|---|---|
| **0 Options dashboard** | | The model provides for three options to be considered:<br>- A baseline conventional option based on wetland treatment only.<br>- As above but with the added revenue stream (and associated additional costs) for water sold to agricultural irrigation.<br>- An alternative treatment option comprising a biomass plantation and a revenue stream from carbon credits<br>The model options under consideration considered the option of the operator using the wastewater effluent for its own agricultural purposes. After due consideration this option was disregarded as it was found in principal to be no different to the second option above, i.e. the operator would effectively have an agricultural interest who would still sell produce at a market rate and therefore the value attributable to wastewater effluent would be no different than the value it would have to another agricultural producer. Furthermore, the operator could not be seen to inflate charges to consumers to subsidise his agricultural activities as this would be economically unjustifiable and would pose serious questions over anti-competitive practices that could face justifiable resistance from other agricultural producers. |
| **1. Model input data** | General | Principal data input sheet. No inputs elsewhere in the workbook. |
| | 1.1 Population and level of service | Baseline population data from NICE/ Dorsch - Feasibility Study, DRAFT FINAL REPORT - Table 4. Estimated population from 2013 to 2043 at 10-year intervals.<br>Includes population density (existing and projected).<br>Levels of service (% of population served by sewerage septic tanks, collection tanks at year 1 (2020) of model period). The model rationale assumes additional housing generated by population growth will be served by sewerage system. Rational as new housing will be better planned and regulated, and infrastructure will be designed to suit. |
| | 1.2 Wastewater volumes and characteristics | Volumes of wastewater generated by households drawn from the NICE/ Dorsch - Feasibility Study… , DRAFT FINAL REPORT - Table 11. Non household wastewater, e.g. from schools, clinics, small shops etc., is assumed to be 10,000 m3/year in 2020 rising to 15,000 m3/year in 2040.<br>Household wastewater quality characteristics drawn from NICE/ Dorsch - Feasibility Study… , DRAFT FINAL REPORT - Table 13. Non-domestic wastewater quality assumed to be marginally higher than household but as yet no firm data available. For household collection tanks no data is available but due to seepage it is assumed to be higher than for household wastewater but less than septic tanks. Assume 100% greater than household. Septic tank sludge characteristics drawn from existing literature, **Metcalf and Eddy**, *Wastewater engineering, Treatment, Disposal, Reuse* (3rd edition), T3-17. |
| | 1.3 Wastewater network performance | Infiltration estimates drawn from NICE/ Dorsch - Feasibility Study … , DRAFT FINAL REPORT - Table 31 |
| | 1.4 Wastewater treatment performance | Effluent output relative to input assumed to be 95% (no data sources).<br>Sludge generation (not required) |
| | 1.5 Irrigation | Months per year when water demanded, i.e. not required in wet or non-growing seasons. Advised to be 10 months per year (no firm data in this regard). |
| | 1.6 Capital investment and sources of finance | Estimates of capital investment costs by system components (broken down by asset type). Data from engineering estimates and professional judgement.<br>Tertiary network investment undertaken after 10 years and periodically every 5 years thereafter (assumption based on |

| | | |
|---|---|---|
| | | professional experience). Cost of this investment is assumed to be borne by new houses generating the investment through consumer contributions over and above connection fees.<br>Treatment costs apportioned between volume, BOD and TSS according to experiences elsewhere in the world (necessary for the determination of cost-reflective treatment charges).<br>Sources of finance; grants for initial capital expenditure but capital maintenance to be funded through tariffs. |
| | 1.7 Capital maintenance and sources of finance | Capital maintenance of existing networks to be set at 2% of modern equivalent asset values (MEAV).<br>For new networks capital maintenance will be low in early years (0.25% of MEAV) but will steadily increase over time to 25 of MEAV by 2040.<br>Components of other assets will require regular replacement with electrical components being replaced after a short period of time, mechanical in a medium period and civil works in the long term. |
| | 1.8 Operating costs | Electricity tariffs used to determine energy costs based on assumed pumping head and volumes. No data on pumping details – assumed data only.<br>Operating (labour and other) costs for system components based on professional judgement. For networks specialist equipment (jet wash etc.) assumed to be hired as unlikely to be cost efficient to purchase such equipment for a small community.<br>Operating costs financed from tariffs. |
| | 1.9 Economic parameters | General inflation from IMF projections.<br>Real GPD growth per capita from IMF projections assumed as a surrogate for real wage inflation.<br>Labour efficiency factored in as 10% reduction in labour input over first 5 years and 0% thereafter (although this can be increased in the model).<br>Grant financing renders conventional distorts the use of return on capital as a means of determining a suitable profit margin. The model provides for a margin of JOD 20,000 per year (variable input) as a minimum profit before depreciation, interest and tax.<br>Where operator undertakes investment, the operator will earn a 5% real return on capital. No return is earned on investment financed by grants.<br>Where a tariff cap is applied the capped tariff value can be included. This only applies to tariffs cap options.<br>Technical data related carbon fixing assumed to be: 3.8 ha/100 m3/day of effluent and 52 tonnes of carbon removed per year per hectare |
| | 1.10 Additional revenues | Effluent sale price set at JOD 0.10 per m3 (model variable)<br>Carbon credit set at JOD 24.00 per tonne (model variable) |
| **2 Population and demand** | 2.1 Population growth | Determines population growth projections by total, households and level of service. Assumes no growth in household served by septic and collection tanks as planning regulations in future should ensure new housing is appropriate for sewer connections. |
| | 2.2 Wastewater volumes and characteristics | Determined the volumes of wastewater generated by consumer groups including wastewater collected from collection and septic tanks and delivered to treatment works.<br>Determines wastewater sent to sewers and from sewers to treatment plant allowing for infiltration. |
| | 2.3 Irrigation wastewater provided | Determines volume to irrigation based on months where irrigation water is demanded. |
| | 2.4 Carbon capture where applicable | Biomass area and carbon capture values determined. |

| | | |
|---|---|---|
| **3 Cost reflective treatment charges** | | This calculation sheet determines the treatment component of charges that is cost-reflective of the costs that users or groups of users impose on the treatment process. The concept is to ensure that specific groups of consumers do not subsidise (or be subsidised by) other groups of and to send economically efficient price signals to encourage optimum consumer behaviour. In this regard we do not consider the source of financing as grants would distort these price signals. The outcome of the analysis is a cost difference over or under household charges for specific groups of consumers. The effect of grants on tariffs is effectively built into the wastewater network and volume component of the treatment processes. |
| | 3.1 Plant characteristics (dry weather) | Plant size by annual volume loading at design horizon. |
| | 3.2 Wastewater characteristics | Household and non-household BOD, COD and TSS values. |
| | 3.3 Wastewater treatment capital costs | Allocation of capital expenditure by treatment activity. |
| | 3.4 Wastewater treatment operating costs | Allocation of operational expenditure by treatment activity. |
| | 3.5 Wastewater treatment unit costs | Unit costs per m3, per kg COD, and per kg TSS. |
| | 3.6 Wastewater treatment unit costs by customer group | Unit charges by consumer group and determination of surcharges over household charges. |
| **4 Capital investment** | 4.1 Sewerage network | Capital investment of networks providing for periodic expansion of tertiary network.<br>Capital maintenance of networks based on % of MEAV.<br>Investment in network pumping stations if necessary and associated capital maintenance expenditure. |
| | 4.2 WWTP | Investment in WWTP and associated capital maintenance expenditure. Provides for two options depending upon options dashboard selection.<br>Sludge drying investment – not applicable. |
| | 4.3 Irrigation pumping | Investment in pumping station for irrigation pumping (if necessary), and associated capital maintenance expenditure. |
| | 4.4 Summary totals | Total investment by year. |
| | 4.5 Expenditure by source of funds | Allocation of investment by funding source (grants or tariffs). |
| | 4.6 Unit charges per household - customer contributions | Determination of customer contributions for tertiary network expansion. |
| **5 Depreciation** | 5.1 Sewer network | Rationale based on the Infrastructure renewals accounting convention, i.e. the asset value is maintained in perpetuity with zero depreciation and capital maintenance treated as operational expenditure. |
| | 5.2 Network pumping stations (original) | Conventional (current cost) depreciation applied to pumping stations based on asset component lives. |
| | 5.3 Network pumping stations (capital maintenance) | Replaced assets subject to current cost depreciation. Net effect is that depreciation for each component is uniform over the analysis period. |
| | 5.4 WWTP (original) | As for pumping stations above |
| | 5.5 WWTP (capital maintenance) | |
| | 5.6 Sludge drying (original) | As for pumping stations above |

| | | |
|---|---|---|
| | 5.7 Sludge drying (capital maintenance) | |
| | 5.8 Irrigation pumping (original) | As for pumping stations above |
| | 5.9 Irrigation pumping (capital maintenance) | |
| | 5.10 Summary totals | Total current cost depreciation regardless of funding sources. |
| | 5.11 Written down asset values | Total net written down asset values regardless of funding sources (investment less depreciation) |
| | 5.12 Network capital maintenance by source of funds | Capital maintenance of network by funding source (grant or tariff). |
| | 5.13 Depreciation by source of funds | Depreciation by funding source (grant or tariff). |
| | 5.14 Written down value by source of funds (end year) | Written down values by funding source (grant or tariff). |
| **6 Operating expenditure** | 6.1 Inflation and efficiency factors | Determination of inflation and labour efficiency expectation multipliers. |
| | 6.2 Energy charges (2019) price levels | Calculation of energy charges based on pumping heads, volumes and current electricity charges. |
| | 6.3 Operating costs - 2019 price levels | Total operating costs by system component. |
| | 6.4 Summary totals | Total operating costs by system components. |
| | 6.5 Summary totals by funding source 2019 price levels | Totals by funding source. |
| | 6.6 Summary totals by cost category and funding source 2019 price levels | Totals by funding source and cost category. |
| **7 Tariffs asset base** | 7.1 Tariff asset base | Written down asset values for only those assets funded by tariffs. These are the asset values upon which the operator should be entitled to a return on capital. |
| | 7.2 Return on capital to tariffs | Calculated return on capital for the operator. |
| **8 Tariffs revenue requirement** | 8.1 Revenue requirement | Total revenue requirement including margins for operator.<br>Revenue requirement separated by activity (network, treatment and irrigation pumping). |
| | 8.2 Revenue from alternative sources | Determination of revenues from irrigation and /or carbon credits where applicable. |
| | 8.3 Unit revenue requirement | Unit charges for network and treatment services (by consumer group) to meet revenue requirement. |
| **9 Tariffs** | 9.1 Tanker charges | Charges and resulting revenues from tankers that discharge waste to WWTP. These are treatment charges only and adjusted to be cost-reflective depending upon wastewater quality characteristics. Does not include network component of charges. |
| | 9.2 Sewered consumer charges | Charges and resulting revenues from consumers served by sewerage system (treatment component adjusted to reflect wastewater quality characteristics differences between consumer groups). |
| | 9.3 Government operational subsidies | Charges and resulting revenues from government subsidies necessary to meet revenue requirements where caps on tariffs are imposed. |
| | 9.4 Irrigation pumping | Charges and resulting revenues from irrigation pumping activities where applicable. |
| | 9.5 Other revenue | Revenue from carbon credits. |
| | 9.6 Total revenue | Total revenue. This includes a revenue check which should be zero. |

| | | |
|---|---|---|
| **10 Cash flow** | 10.1 Revenue | Total revenues by source of revenues including consumer contributions. |
| | 10.2 Expenditure | Total expenditure including capital expenditure. |
| | 10.3 Net cash flow | Net annual and cumulative cash flows. |
| **21 Impact of irrigation price** | Determines the resulting household tariffs (JOD/m3) and annual household charge based upon a range of values for the irrigation tariff revenue source. The higher the irrigation tariff the lower the household tariff and vice versa.<br>The tariffs fall in early years largely due to efficiency gains but start to rise as efficiency gains level off and the capital maintenance demands kick in.<br>The worksheet requires the running of a macro to populate the tables and graph (use control button in top left corner of sheet). The range of values for the irrigation tariff can be adjusted by the model user. | |
| **22 Impact of tariff cap** | Determines the level of government subsidy to cover the difference between required revenues and actual revenues based upon a range of tariff caps that may be imposed by regulatory bodies. Failure to meet the revenue requirements will result in falling levels of service and/or the operator abandoning his/her responsibilities. The lower the cap the greater the need for subsidies and vice versa.<br>The worksheet requires the running of a macro to populate the tables and graph (use control button in top left corner of sheet). The range of values for the tariff cap can be adjusted by the model user. | |
| **23 Impact of capital grants** | Determines the household tariffs assuming that there are no grants for capital investment, i.e. full cost recovery and compares these tariffs to the resulting tariffs with grants.<br>The results suggest that tariffs may be about 2 times higher (from about JOD 0.40 /m3 with grants to about JOD 0.80 without grants). Although this appears to be a large increase the absolute value of the wastewater tariff is in the right order of magnitude of full cost recovery wastewater tariffs applied elsewhere in the world.<br>The worksheet requires the running of a macro to populate the tables and graph (use control button in top left corner of sheet). | |
| **24 Comparison of options** | Determines the household tariffs for the three principal options.<br>The results suggest that tariffs may be lowest with the use of carbon credits. Although this is largely driven by the additional revenue stream the lower capital costs (and resulting lower capital maintenance) of this option is a smaller contributing factor. The benefits, however, are minimal and depend upon the willingness of external agencies to offer carbon credits to a project of this nature.<br>The worksheet requires the running of a macro to populate the tables and graph (use control button in top left corner of sheet).<br>The annual cost to a typical household ranges from JOD 83 to 105 in the short term, falling to JOD 75 to 99 in the medium term but rising to JOD 94 to 120 in the longer term (at 2019 price levels). | |
| **25 Impact of CO2 comp price** | Determines the resulting household tariffs (JOD/m3) and annual household charge based upon a range of values for the carbon credits. The higher the carbon credit tariff the lower the household tariff and vice versa.<br>At a base irrigation tariff of JOD 0.10 per m3 the carbon credit has to fall to about JOD 10.00 per tonne of carbon removed before benefits of the carbon credit option are effectively eliminated. Similarly, an irrigation tariff of about JOD 0.20 per m3 is competitive with the carbon credit option.<br>The worksheet requires the running of a macro to populate the tables and graph (use control button in top left corner of sheet). The range of values for the carbon credit can be adjusted by the model user. | |
| **26 Operating costs analysis** | This sheet illustrates the operating costs of the three principal options. As expected, the principal cost is labour amounting to about JOD 30,000 per year. This equates to a labour force of about 3-4 people which appears reasonable for a project of this scale. | |

# Part D

# Social acceptance as a priority for sustainable decentralized wastewater systems

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With inputs from: Ismail Al Baz, Jens Götzenberger,

## 1. Introduction

Decentralized wastewater management systems offer an opportunity to introduce wastewater treatment and generate irrigation water in places that are not connected to centralized treatment plants. The wastewater is treated and discharged (or reused) directly at or near the point of generation. Decentralized Wastewater Treatment Plants (DWWTPs) include a large range of sizes and technologies whose advantages include their capability to provide wastewater treatment infrastructure in remote and rural communities and their flexible adaptation to fast-growing semi-urban settlements. Appropriate applications of this alternative in developing countries, including Jordan, are still far from being satisfactory. This perhaps can be attributed to relative high investment costs per cubic meter wastewater compared to large-scale systems (economies of scale), absence of awareness of the damage existing practices are imposing on the scarce water resources and lack of regulations. However, most of previous projects and initiatives overlooked socio-economic, environmental and cultural aspects; moreover, they lacked management models that guarantee sustainability. Although well-designed technologies, satisfactory operation and maintenance (O&M) processes (i.e. business models) are important to empower decentralized wastewater management projects, getting an overview of the knowledge and perceptions of people in the community and involving them in such projects are also crucial for achieving sustainability and success.

DWWTPs are becoming of special interest because of its possibility of reducing treatment costs (i.e. O&M cost) in long term, minimizing environmental impacts and facilitating wastewater reuse. It is strongly believed that DWWM could fill the gap between onsite systems like septic tanks and centralized treatment options, both in term of treatment performance, costs and reliability. Success of a decentralized system depends on many factors related to social acceptance of the population served and the surrounding population where the system in located. Furthermore, successful DWWM needs a degree of involvement to work. In other terms, the community participation and social acceptability as well as the management capacity and change of routines are issues that are to be addressed, when thinking about implementing such systems.

The purpose of this paper is to identify the different encountered public concerns when planning and implementing DWWM projects. The different causes of a refusal/non-acceptance from the Jordanian rural population will be examined, which may help us to identify solutions oriented towards the preferences and interests of the people concerned.

## 2. Background and reticence about decentralize wastewater systems

In some places, the demand for alternative sanitation systems exists while it may be that in other places, the current situation satisfies the populations. In all cases, the implementation of DWWTPs is a challenge in Jordan. This first part aims to examine the different issues related to the acceptance of communities, whether it is a matter of perception of such systems or with regard to a future sustainable O&M of them.

### 2.1 Frist challenge: location of the treatment plant

Although experience shows that most of the people and stakeholders concerned demonstrate an interest in taking part of the implementation of such systems during the early stage of the project, concerns related to the location of this treatment plant are among the most difficult to address when assessing the feasibility of the project.

During the conceptualization and planning of DWWM projects, one of the most decisive criteria for populations refusing to see their sanitation system being changed is the location of the DWWTP[49]. The choice of site location highlighted the following issues.

#### 2.1.1 Price and value of the land

The choice of site is the first challenge, since the wastewater treatment plant must be installed in an area whose topography is strategic to facilitate the flow of water without resorting to costly electricity systems (i.e. pumping). In preferable cases, the adapted area is on public land, facilitating decision-making by local communities. If only private land is available due to the topographic or technical requirements for the installation of the treatment plant, the purchase of the land should be negotiated. On the other hand, even in this case, the choice of a site even far from the dwellings could pose a problem. Indeed, landowners around this area are particularly concerned about the decline in the price and value of their land. This limitation in the installation of decentralized systems is the most important to take into account in the case of Jordan. In order to take this problem into account in an appropriate way, it is important to consult the different political, religious and tribal representatives and to include them in the choice of decisions in the early stages of conceptualization of the project (when assessing feasibility, interests of each party, acceptance of the concept etc). Greater public acceptability of having facilities nearby would have a positive impact on the perception of the value of

[49]Wastewater Treatment Plant

these lands. This cognitive perception being negative so far, can only change in the case where these treatment plants satisfy the expectations of the populations in terms of risks and appearance (see next paragraph *Health and wellness related concerns*).

#### 2.1.2 Health and wellness related concerns

Most of the problems encountered due to lack of sanitation are health-related because of contamination of groundwater, and frequent emptying of the onsite cesspools inevitably results in additional financial burdens for the dwellers and infestation of flies and mosquitos. In some places, the inhabitants are directly affected by the surrounding odors. To this matter, the challenge of decentralized wastewater treatment plants the construction of DWWTPs would be to offer solutions to these health and wellness related concerns. However, these have been barely accepted so far, especially because of non-existing successful applications in Jordan. Indeed, in order to convince the population of the advantages and sustainability of such plants, it is necessary for them to have a role model to look at. When it comes to the necessity of getting rid of cesspool systems, people are not informed enough to see what they have to gain from a decentralized system that is probably as disturbing in terms of odour and appearance as existing systems. Moreover, the benefits in terms of reusing water for irrigation that these systems bring, and the quality reliability of this water is not something totally rooted in mentalities and of which the populations concerned have no certainties.

#### 2.1.3 Cultural and religious factors

Although the religious factor does not play a direct role in Jordan regarding sanitation management, it remains a culturally entrenched criterion, which may explain the reluctance of populations to become involved in a decentralized wastewater system at the household and community levels. There is a general concern for cleanliness or purity from the religious viewpoint. Therefore, it might be useful to highlight religious considerations of wastewater treatment and reuse in any future awareness plans. Last but certainly not least, other cultural aspects might be taken in account such as the fear for some people of being associated with the proximity to the WWTP; what could also be solved by improving how people perceive the facilities and by removing any apprehension about their cleanliness and odour emission.

### 2.2 Second challenge: Economic and financial aspects

For many people who would install this decentralized system, the benefits seem least. Indeed, by adopting DWWM, users would have to swap their existing system, which does not cost much in emptying fees (especially for people whose septic tanks leaks and get therefore never full), for another system including first time fee (connecting fee) and monthly payment (wastewater tariff). In such projects the connection fee is often taken over or subsidized by the government or donors in case of donor-funded projects. Moreover, direct users do not see any advantage in this new system, since the wastewater reuse provided for by it only benefits farmers who reuse this water for irrigation. The advantages of connections to a DWWTP in Jordan would only be for farmers, who could benefit from this treated water cheaper than fresh water and in larger quantities. However, from an economic perspective, households that are not in the agricultural sector see only disadvantages to this type of system and to their installation near their area of residence (the main negative consequence is the decrease in the value of their land[50]). Furthermore, the desludging cost of septic tanks is a factor to be taken in consideration; the issue will be to make connections to DWWTP more attractive for the population by subsidizing the connection fee and by reducing the tariff as much as possible.

### 2.3 Third challenge: Type of sewer system and treatment technologies

The "most appropriate technology'' is the technology that is economically affordable, environmentally sustainable and socially acceptable. Many factors fall under the economic aspect and are used to decide on the affordability of a system. The community should be able to finance the O&M costs including the necessary long-term repairs and replacements. With regard to social acceptance, the choice of the technology seems an important issue, on the one hand because systems with low maintenance costs (as it is the case for DWWTP in particular close-to-nature systems, e.g. wetlands ), which enable communities and the operator to cope, are preferable and on the other hand because it appears that people often prefer high-tech technologies. Therefore, it is a real challenge to emphasize the fact that decentralized systems are more adapted for rural areas and do not require as much maintenance, workforce and energy as conventional systems and are, therefore, more sustainable from a long-term perspective.

As influential people or groups weigh in decision-making and could at any time veto the idea of installing new decentralized systems, it is important to include them in the choice of technologies (i.e. collection, treatment and reuse) and to inform them well enough while promoting the advantages of such systems for their communities (e.g. with field trips, communication materials, regular meetings etc.).

There are different reasons why the social cultural acceptance and appropriateness of DWWM perceptions are low in Jordan. Differences between target groups also exist, some households use a private service provider for sanitation and cleaning service, others only use these services when they encounter an occasional problem with their septic tank. Moreover, the weight of landowners and influential people or groups should not be overlooked.

In order to identify the interests of these communities and possible solutions to make sanitation more attractive, it is important to identify what has or has not worked in other projects.

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[50]See above paragraph Price and value of the land

# 3. Experiences in DWWM projects

### 3.1 SANIMAS in Indonesia: Pro-active participations of all relevant stakeholders

The Government of Indonesia through the Ministry of Public Works (MoPW) has committed to increase resources to support the replication and scaling-up approach of community-based decentralized sanitation nationwide through a program entitled SANIMAS since 2006. The SANIMAS program is based on community driven development principles. SANIMAS is a program to provide wastewater infrastructure for the people in the crowded urban slums. After 2007 this approach is considered a success and the central government was adopting SANIMAS as national program to accelerate sanitation development by replicating it to other cities, in order to achieve the MDG targets. The program goal is to encourage community initiatives in an open, participatory and self-reliance approach. Community involvement is also required in financing the facilities, both in construction and operational phase[51].

*Lessons learned:* A community-based wastewater management project must involve all relevant stakeholder groups, including both governmental and non-governmental stakeholders such as local actors or private sectors at the early stage of the decision-making process in order to ensure transparency in management and sustainability of the project.

### 3.2 GIZ in Vietnam

Households flushed toilets into septic tanks with fresh water, which is also the case for many households with septic tanks in Jordan. Whenever the tanks are full or blocked, they called for sanitary services. It was assumed, that they were obviously affected by wastewater and thus, by experience, see the necessity of its treatment. The cause of a lack of awareness or the fear of additional costs or both were assumed.

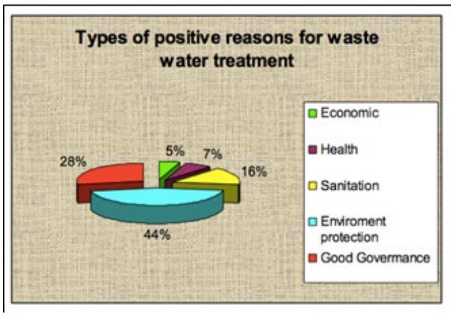


Figure 33 Types of positive reasons for wastewater treatment

GIZ staff has conducted surveys in which the reasons for wastewater treatment were classified into 5 main types: economics, health, community sanitation, environment protection and good governance. It was noted that environment protection was frequently mentioned, and good governance also scored better the other matters. One difference of this project with the cases observed in Jordan is mainly the environmental awareness of the population. Also, the 'good governance' criterion seems important, as trust in government institutions for water and wastewater management is relatively low in Jordan.

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[51]WEPA, Decentralised Domestic Wastewater Management In Asia – Challenges And Opportunities, 2013.

As mentioned in the part I (*cf. 1st challenge: location of the treatment plant*), in the project in Vietnam, most of the households opposed the suggestion to put the grid chamber on their own property. Moreover, there were no sufficient guidelines forcing them to take care of clogging problems in if the household connection lies on public ground (lack of regulations on punishments for violations and unsatisfactory quality of human resources). The lack of regulation as well as the unwillingness of the population to see the facilities installed near their property are recurrent problems.

*Lessons learned:*

- Awareness and capacities on how to operate wastewater companies as well as management and planning capabilities were enhanced. Wastewater companies managed their business more transparently, have more open relation and better qualification with the public and target group.
- The consulting team and local partners should work together from the early stages of the project (to build original ideas about the project) and theirs goals should be synchronized. The characteristics of each wastewater management company should be reflected in training and coaching plans.

*Several measures have been put in place to raise public awareness:*

- Open-days in wastewater treatment plants and water facilities, IEC[52] campaigns to raise awareness and change behaviour of community on environment and wastewater, communication campaigns on wastewater tariff. Measures in schools to capacitate teachers in education and communication on environmental sanitation through positive teaching methods or practical activities (development of a school toilet management plan, teaching materials competition on environmental sanitation, hand-washing campaign etc.) have been put in place. Other objectives were to mobilize the community to participate in works related to O&M of the drainage system.

It is, however, hard to compare with the situation in Jordan because of differences in economic systems and as the government in Vietnam still provides the population with many facilities free of charge in the context of a vertical democratic centralism whose policies are usually accepted by the population.

### 3.3 Malaysia: policy and fine as an answer to non-compliance[53]

In Malaysia, an increasing number of septic tank owners showed unwillingness to pay the desludging fee and contacted a sludge extractor only when their tanks had trouble. To tackle this issue, the government of Malaysia has adopted a new policy for desludging which requested that sludge must be collected once every 3 years

[52]Information, Education and Communication

[53]Wepa - Decentralised Domestic Wastewater Management In Asia – Challenges And Opportunities, 2013

either by IWK[54] or a private contractor. If septic tanks are not desludged within 3 years, owners can be fined up to 50,000 Ringgit (about 8,900 JOD). Under Water Service Industrial Act (WSIA), the fines for non-compliance have significantly been increased to require owners to comply with their desludging duty and pay for sewerage services in covered areas.

*Lessons learned*: Setting policies and law enforcement; due to political reasons, this would be, however, difficult to implement in Jordan

### 3.4 SWIM Sustain Water in Tunis: An awareness program (focus on agriculture sector/water reuse for irrigation)

In the context of a pilot project to improve the reuse of treated wastewater in Medenine[55], GIZ and ONAS conducted an awareness program mainly aimed at people working in the agricultural sector. The program consisted of

i. The preparation of a manual to be distributed to the population (popularization of the advantages of a decentralized system and water reuse),
ii. Training sessions and capacity buildings,
iii. A door-to-door survey to investigate the various grown crops (irrigation equipment, fertilization program and yield achieved), followed by the preparation of a synthesis report and
iv. The elaboration of complete manuals determining the methods of fertilization, maintenance of irrigation equipment, choice of crops, etc.).

*Lessons learned:* Target-oriented material is essential (with trainings and manual adapted to the needs and the equipment of the target group.

## 4. Recommendations and action plan for the implementation of the “DWWM Policy”

In wastewater management, public awareness and participation programs leads to more acceptable decisions to all parties involved. It is very crucial to account for the needs, constraints and practices of local people in order to define problems, set priorities, select technologies and evaluate impacts. Environmental issues do not always command a high priority in light of the severe social, political, and economic problems that might encounter the country. However, it is of paramount importance to point out the issue of groundwater pollution as a matter of national security and to consider implementing environmental control policies as an answer to that.

[54]Indah Water Konsortium

[55]GIZ, ONAS, Programme de Gestion Durable et Intégrée de l’Eau (SWIM), Mission pour l’Etude d’Evaluation de la Situation de Reference du Système de Traitement et de Réutilisation des E.U.T de la STEP de Medenine et la Proposition d’un Projet Pilote d’Amélioration de ce Système (SWIM TN BA), report December 2013.

***Identify population needs / priorities and integrate people from the early stages of the project***

As it has been demonstrated by the RSS[56] in the GIZ projects "Decentralized Wastewater Management for Adaptation to Climate Change" in Jordan[57] , it is crucial, in order to evaluate the feasibility of the project, to define influential groups and people in each targeted village or community, who have consensus for their influence in formulating the general attitudes and behaviors of each community. It is also important to define priorities of the community by looking at already existing public services in order to be able to formulate the DWWM appropriately, and in shape that fits each community priorities. It is also important to know whether the areas are underserved and to what extent the connection to the sanitation network is urgent.

***The necessity of the community participation[58]***

Participation should be context-sensitive and meet the expectations of different interests. Moreover, the project initiator needs to decide consciously on how much control to confer to others and the participation in terms of power has to be well-balanced in order to create synergy and benefits for all participants.

If possible, gender participation should be allowed in order to arrive at sustainable project outcomes.

In order to promote the participation of the communities concerned, trust between the various partners should be built and a common commitment should be developed. It is of paramount importance to correlate participant commitment to their problem consciousness and their sense of being able to achieve something. Initiators of the project should give people a chance to feel that the idea could have been their own, enabling people to take complex decisions entails promoting confidence and may require additional capacity building. In order to motivate people to take part of the capacity building and to be involved in the environmental and health campaign, certification can also be an important incentive.

Finally, even if participation is particularly essential in the O&M phase and during site selection, the involvement and opinion of the populations concerned must be questioned in cases where excessive participation blocks the progress of a project, thus preventing necessary and urgent environmental measures from being put in place.

[56]Royal Scientific Society

[57]Project in Rehab villages of Bwaidhah Gharbiyyeh and Al Dajaniyyeh – in the context of the ACC Project 2014/2020

[58]The EMWater Guidelines, 2007.

### Strengthen awareness and acceptability of sanitation systems

Before even thinking about the planning and the designing of equipment and infrastructure, the environmental awareness campaign has to be developed among people, including children and young adults. The aim is to provide local people with access to resources, education and information necessary to influence environmental issues that affect them is a crucial step toward sustainable management of wastewater and to strengthen the knowledge base of environmental problems and solutions by presenting country empirical experience (emphasizing existence of sites where groundwater is affected with the discharge of effluent into the environment). In order to conduct an awareness campaign, there are several tools available[59]:

Table 42 Objectives for possible awareness activities with potential target groups

| Targeted groups | Possible activities | Objectives |
|---|---|---|
| • **Public institutions (schools, hospitals)**<br>• **Elected officials**<br>• **Youth**<br>• **Parents**<br>• **Peer group**<br>• **Responsible for O&M** | • School competitions (e.g. impact of septic tank leaks, hand washing and improved toilets, the link between water and health).<br>• Art performance<br>• Video presentations, broadcasts<br>• Brochures, hand-outs, press releases<br>• Public meetings (e.g. town hall meeting)<br>• Field visit (e.g. to the sewerage treatment works or to improved *demonstration* toilets)<br>• Billboards and banners<br>• Training material | • Promote and create demand for improved basic sanitation and best hygiene practices<br>• Make residents and local opinion leaders aware of the treatment process, the appearance and possible odorous disturbances<br>• Bridge the knowledge gap and raise public awareness about the value of DEWATS (dispersion of treated effluent, groundwater recharge and maintenance of base flow in streams)<br>• Promote advantages and necessity of water reuse for irrigation purposes<br>• Wastewater effluent and sludge as potential resource<br>• Pollution of groundwater as national security issue |

A well-organized public information campaign must be planned. Its first objective will be to trigger collective awareness and present DWWTP used as a reliable substitute technique. It should also inform the potential users of the benefits associated with wastewater reuse. Farmers and the general public should be aware not only of the benefits, which will result from reuse, but also of the health and environmental risks associated with use of wastewater. The information campaign should aim to minimize the cultural and psychological bias associated with wastewater. Thus, the awareness program must include technical, environmental, health, socio-economic and cultural aspects. The educational contribution must provide farmers with comprehensive technical details and associated risks and precautions to be taken so that operations take place with an acceptable level of safety and at a reasonable cost. Moreover, to be able to observe an improvement of the awareness, respective objectives with clear indicators should be set (e.g. implementation of water awareness program in schools, number of positive feedbacks from a field trip etc.).

[59]Most of following elements are drawn from experience in existing projects.

As low environmental consciousness in Jordan could be a barrier to the implementation, one should emphasize the long-term costs reduction[60] of such decentralized system as well as the necessity of it in order to preserve scarce water resources and natural resources from pollution for the future generation.

*Information material*

Effective information materials can awaken curiosity and interest in the subject matter. The timing and duration of the outreach program is critical. In addition, the different awareness-raising methods must be used in a relevant way, in order to attract the attention and interest of the targets.

***Timing***

If not provided to the targeted audience at the right time, external information can short-circuit the learning process of the group and hinder the expected program results. Benefits of such information materials can be limited if the delivery is too soon, or too late or if it has not been well prepared, it may not be understood or be counterproductive.

***Target-oriented material***

As different people understand things differently, it is important to have access to orderly information. Whereas some information materials (e.g. poster and flyer) might be designed for general consumption of a wide community audience, other materials with more detailed technical information might be directed to a specific group (e.g. farmers or parent-teachers association) or even individuals with specific responsibilities (e.g. people responsible for installation and maintenance). In this way, the people who receive the information might apply it directly or, in turn, disseminate and transmit it to others, outlining steps to teach and train others.

***Community***

When creating information material, the community (the users of the information) must be indirectly at the centre of the process.

[60]Especially the costs of O&M, as these technologies are usually low-tech and require little electricity for pumping, aeration, etc.

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# Part E

# Orientation Guidelines developed based on the Experiences of the ‘Decentralized Wastewater Management for Adaptation to Climate Change in Jordan’ (ACC) Project from 2014-2019

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With inputs from Jens Götzenberger and Hesham Asalamat

## 1. Background and Use of the DWWM in Jordan

### 1.1. Introduction

The availability of enough safe water is a basic requirement for survival of human beings. Water can be contaminated by several means. Discharge of domestic wastewater can cause bacteriological contamination of groundwater and surface water. Due to (a) the wide practice of septic tanks / cesspits in habitations without collection systems, (b) the absence of appropriate necessary further downstream treatment, (c) the non-availability of supportive wastewater management, and (d) the absence of fecal sludge management, especially in relatively dense populations in rural and peri-urban areas. Due to this shortcoming, shallow groundwater as well as surface water sources are often contaminated with pathogens.

Jordan has one of the lowest levels of water availability per capita in the world. The country has been overexploiting its groundwater resources for decades and continues to do so unabated. As a result, groundwater tables decline up to 5 meters per year and become increasingly saline particularly in Northern Jordan.

Approximately three million people reside in around 1,350 communities with less than 50,000 inhabitants per community. One million of them live in around 1,200 communities with less than 5,000 people each. Some of these communities, particularly the larger ones near major towns and cities, are served by sewers connected to a WWTP. Most small communities, with over two million people in total, however, depend on cesspits for collection and disposal of their wastewater, estimated at around 40 million cubic meters (MCM) per year. Around 37 MCM of this wastewater seeps and leaks directly from, commonly unsealed, cesspits into the ground, or is disposed into the open environment or at unregulated dump sites. In most communities, emptying of cesspits is very infrequent due to unsealed cesspits that allow the wastewater to seep into the ground. In other cases, the geology of the area (e.g. impermeable soils) or small size of the pit relative to the wastewater deposited into it necessitates more frequent pumping. (USAID, 2012).

Reuse of treated wastewater in landscape irrigation, agricultural reuse for selected food and/or forage crops, reuse for aquaculture production, or other acceptable reuse applications, is a crucial climate change adaptation measure in a water-stressed country like Jordan.

## 2. ACC activities and lessons learned

The ACC project seeks to support partner organizations such as MWI, WAJ and YWC to disseminate DWWM as a measure for adaptation to climate change through protection of groundwater resources from pollution by raw wastewater, improvement of sanitation conditions and reuse of treated wastewater productively. In this context, the project conducted several activities to achieve the goal of the partnership as per the following sections:

### 2.1 Rehab District

A conceptual study was done in 2014 to identify potential areas for implementing DWWM in Jordan. The study built on selection criteria verified under the National Implementation Committee for Effective Decentralized Wastewater Management (NICE). Within the scope of the study, information on appropriate options for implementing DWWM in three selected hot spot areas in Irbid, Mafraq and Al-Karak were collected and conceptual designs were prepared.

Based on the outcomes of the study and discussions with the MWI and WAJ, the villages Bwaidhah Gharbiyyeh and Al Dajaniyyeh in the Rehab district at Mafraq governorate were selected as a pilot area to demonstrate the viability of DWWT and reuse in rural areas of Jordan.

The villages Al Dajaniyyeh and Bwaidhah Gharbiyyeh are located at respectively 18 km and 15 km west of Mafraq city, in the north of Jordan, close to the border with Syria. The main land use categories in the region are residential, commercial, governmental, farms and open areas.

Al Dajaniyyeh has approx. 5,000 inhabitants, approx. 20% being Syrian refugees. The village area is about 14 hectares. The village has clusters of homes located far from other populated areas of the village. Groups of homes are located in hilly terrain. Bwaidhah Gharbiyyeh consists of scattered houses deployed around a main route of approximately 2 km. The population of Bwaidhah Gharbiyyeh is approx. 1,000 inhabitants, including approx. 15% Syrian refugees. The village area is about 2.5 hectares.

In 2016 a detailed feasibility study for a wastewater collection, treatment and reuse system within the area of these two villages was conducted by ACC. Several community-on-site sanitation options were evaluated. These included collection, transport, treatment and reuse systems for domestic wastewater. Three different sewer systems, viz. a simplified sewer, solids free sewer and conventional sewer were compared based on technical and financial performance. With respect to the DWWTP, the knowledge on the different sewer and treatment systems was combined with the available information on the local situation, leading to a shortlist of in total four concepts:

1. Conventional and simplified sewer in combination with waste stabilization ponds;
2. Conventional and simplified sewer in combination with French-type constructed wetlands;
3. Conventional sewer in combination with anaerobic main treatment and post treatment in constructed wetlands; and
4. Solids-free sewer in combination with constructed wetlands.

For anaerobic treatment two reactor types were considered: The Up flow Anaerobic Sludge Blanket reactor (UASB) and the Anaerobic Baffled Reactor (ABR). Both systems are proven technologies for the treatment of domestic wastewater, although the experience in Jordan is limited. With a view on compactness and limited sludge generation, anaerobic treatment was thought to be very interesting for this application.

The four concepts were evaluated using a multi criteria analysis (MCA). For the MCA, technical, economic, environmental, institutional and social aspects were considered, subdivided into 22 indicators. Eight national and international technical experts assigned values to the performance of each indicator for the four concepts, which were then used to calculate a Sustainability Index (SI). Concept 3 obtained not only the highest SI but also the highest score for the technical, environmental and social criteria. Concept 4 comprised an alternative sewer system, viz. solids-free (new for Jordan) and scored the highest for the economic aspects. However, concept 4 scored the lowest with respect to the institutional aspects, since its application would demand an adaptation of the national standards.

A variety of activities were implemented by ACC to assure successful planning and implementation of the Rehab project. The different methodologies which were applied can be summarized as follows:

1. Technical studies to evaluate the applicability of DWWM (collection, treatment and reuse) in the two villages from technical, economic, environmental and social aspects were conducted. This included (i) the conceptual study on Decentralized Wastewater Solutions (DWWS) in Jordan, (ii) a rapid rural appraisal which evaluated the acceptability of DWWM within the two communities and discussed suggestions for potential sites for the WWTP, (iii) the feasibility study for the implementation of the DWWTP, households connections, sewer and reuse systems, and (iv) environmental impact assessment (EIA) at both villages.
2. Regular site visits and field checks at the project area to collect any required information and follow-up the outcomes of the technical studies.
3. Implementation of public awareness and capacity development needs assessment. Results and recommendations were incorporated in the technical studies regarding the development of an enabling environment for successful DWWM implementation, considering cultural, social, political, regulatory, economical aspects.
4. Public awareness activities like meetings with decision-makers and field trip to comparable wastewater treatment plants (e.g. constructed wetland) to reduce apprehensions related to potential odor nuisances.

5. Involvement of the project partners (MWI, WAJ) in technical discussions and decision-making processes through regular meetings of the Technical and Steering Committees.

The main challenge however was the selection of the site for constructing the DWWTP, especially that the most feasible option from technical and administrative point of view was a private land parcel. The owner was willing to sell the land to the government; however, several individuals were not in favor about the construction of a DWWTP on this parcel, despite of massive efforts to reduce or abolish resistance through meetings, awareness sessions, field visits with the local community and owners of neighboring lands to comparable WWTPs. Hence, the ACC team arranged a stakeholder meeting under the patronage of the Governor of Al-Mafraq Governorate to take a final and binding decision on the project implementation and site of the DWWTP. This meeting was arranged in coordination with the Secretary General of WAJ. During this meeting, the DWWTP location was approved by the Governor based on the consensus of most participants who attended the meeting. However, few weeks later a huge pressure by few influential representatives in combination with personal connections to influential decision-makers on a higher level negatively affected the decision that had been made. Consequently, ACC received an official letter issued by the MWI, on request by the Ministry of Interior, stating that the project had to move from both villages. The process for selection of a new project location had started.

It is well known that the site selection is a difficult challenge worldwide, but in Jordan there are specific reasons for the community to reject having a WWTP close to their properties, whether households, buildings, farms or empty lands. ACC clarified some of these underlying reasons that can be summarized as follows:

- Despite that the population is aware of the necessity to be connected to sanitation services (of whatever kin), people are worried about potential operational problem related to WWTPs in Jordan. People have already witnessed related environmental problems such as smell, bad effluent quality and discharge of improperly treated water into wadis.
- The depreciation of prices of lands that are located nearby a WWTP.
- The lack of financial resources to ensure the sustainability of sanitation services.
- Conflicts of interest when it comes to purchasing private lands for construction.
- The absence of trust to use the treated effluent for agricultural purposes.
- Unclear responsibilities among the water entities including MWI, WAJ and YWC related to operation and maintenance of DWWTPs, including the sludge management component.
- The tendency of people to be connected to a centralized system rather than having a small-scale system close(r) to the village boundaries.

More than two years of studies and work were invested in the project area, but many challenges hindered the continuation of the project in Bwaidhah Gharbiyyeh and Al Dajaniyyeh. As result of these challenges, the MWI decided to change the project location due to political reasons.

Figure 34 Rapid Rural Appraisal with decision makers of both villages

Figure 35 Site visit of local community to different WWTPs in Jordan

Figure 36  Local community participation in the site selection

Figure 37 Stakeholder Meeting under the patronage of the Governor of Al-Mafraq Governorate for site selection

## 2.2 DWWM at Feynan Ecolodge, Dana

In 2017 Feynan Ecolodge, located in the Dana Biosphere Reserve in the South of Jordan, was selected to pilot a DWWTP and reuse system as alternative to Rehab due to the ecological and environmentally sustainable concept of the lodge that fits perfectly with the concept of local wastewater treatment and reuse with close-to-nature DWWTPs. The project was implemented in collaboration with the Royal Society for Conservation of Nature (RSCN), the private operator of the lodge (EcoHotels), as well as Bremen Overseas Research and Development Association (BORDA) as a German civil society expert organization in the field of sustainable sanitation. Feynan Ecolodge is owned by RSCN, an independent national organization, and is operated by a private enterprise.

Feynan Ecolodge is located at the edge of Dana Biosphere Reserve. The lodge is totally off the grid, generating its electricity from the sun and its water from a nearby spring. Adequate wastewater disposal had been a challenge prior to the construction of the low-maintenance, nature-based wastewater treatment plant with the integrated reuse system.

The treated effluent is used for the irrigation of native trees that surround the lodge, which aims to improve the microclimate through shading and increasing air moisture. The system also treats the food waste that is generated by the lodge. As the treatment system runs solely on solar energy and generates biogas and water for reuse, it is a perfect measure for climate change mitigation and adaptation.

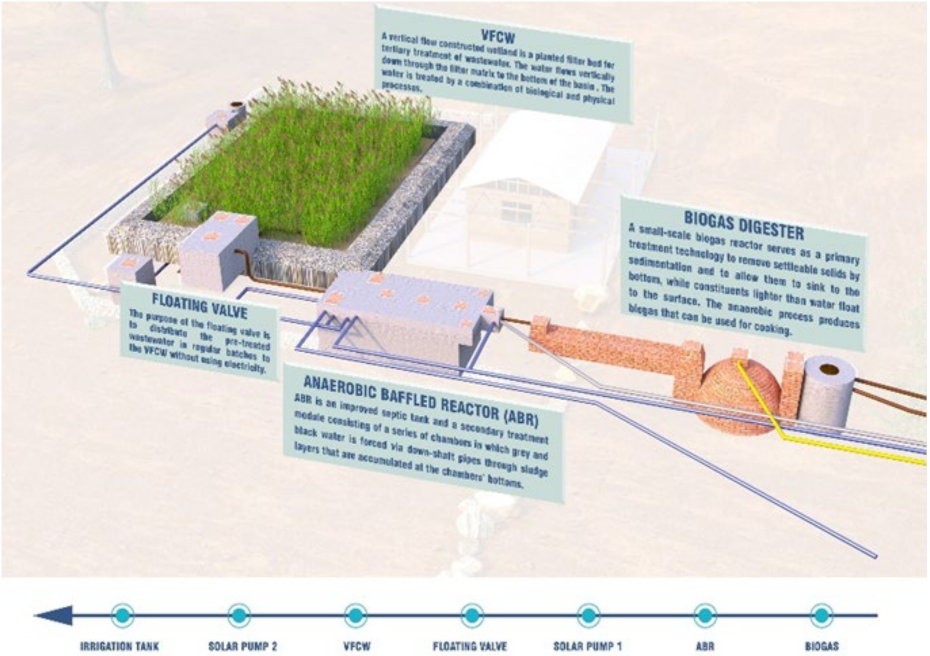


Figure 38 The DWWTP at Feynan Ecolodge – 3D-Model

For the technology, a low-maintenance and nature-based technology was chosen. The system consists of the following elements:

- Biogas digester: This primary treatment module is connected to the lodge's toilets and kitchen sinks. In addition, food waste is fed into the digester. Inside the reactor, anaerobic bacteria convert organic matter into biogas.
- Anaerobic Baffled Reactor: In this secondary treatment step the effluent of the biogas digester is treated together with greywater that is generated in the lodge. The module consists of a series of five up-flow chambers, in which microorganisms decompose the contained pollutants.
- Pump Chamber 1: The effluent of the reactor accumulates in a chamber, from where it is pumped into the subsequent float valve chamber. The pump is powered by a solar system.
- Float valve chamber: Once the water level inside the chamber reaches a certain level, the valve automatically discharges a defined quantity of water into the subsequent filter beds. With this intermittent loading the following treatment module reaches its full efficiency.
- Vertical Flow Constructed Wetland: This tertiary treatment further removes organic contamination as well as nutrients and pathogens through natural microbial processes. It creates aerobic conditions and ensures that the effluent is odorless.
- Pump Chamber 2: A solar-driven pump conveys the effluent of the wetland to a storage tank that is located on a hill close to the lodge.
- Irrigation storage tank: Treated wastewater flows from the tank by gravity back into the anaerobic baffled reactor for further nitrogen removal. The remaining water flows into the reuse system.

- Irrigation system: The treated water is distributed by gravity through a distribution network to 70 native trees that were planted as part of the project.

The pilot project demonstrates successfully that integrated decentralized management of wastewater is a feasible and sustainable approach that can be replicated in other areas of Jordan, particularly at locations that cannot be connected cost-efficiently to large-scale wastewater treatment plants.

Figure 39 DWWTP at Feynan Ecolodge, Dana Biosphere Reserve

However, design and construction of this successful pilot project was not an easy task due to the reasons mentioned in the following:

- The main challenge of the design was to fulfil the Jordanian standard (JS893/2006) for reuse of effluents from WWTP in terms of nitrate concentration. However, the purpose of reusing the treated wastewater for irrigation of trees conflicts with the necessity of removing nitrate as valuable nutrient for the plants. In many European countries, the standards for DWWTP, or small-scale treatment systems, do not require the removal of nutrients like nitrate and phosphorus. So, the discharge and reuse standards in Jordan deserve an update to adapt them to DWWTPs that emit smaller pollutant loads compared to large-scale centralized systems. This accounts particularly if the effluent is reused for nutrient-consuming irrigation. Naturally, the impact on soil, ground water and public health shall be taken into consideration while creating a standard for DWWM.
- During the construction, the lack of local capacities was a challenge. This refers for example to the installation of some system components such as the dome of the biogas digester. Also the process of selecting the filter materials that complies with the technical specifications was challenging,

especially as the double-washed sand required for the VFCW is not available on the local market and the Consultant had to apply specific test procedures in order to test the compliance of the sand washed on-site with the required specifications before filling the sand into the VFCW beds.

- Optimization of operations to produce the required effluent quality, needs intensive training and effort as well as understanding from the operator until the final operation schedule is determined to guarantee good performance of the DWWTP.
- Clear responsibilities among the project partners (Consultants, Contractor and Sub-Contractors, Owner, Operator, Financier) are important to avoid any conflictive discussions and any unforeseen challenges in the implementation and afterwards.

### 2.3 Sludge Drying Reed Beds (SDRB) at Wadi Hassan WWTP, Irbid

The existing sludge drying beds (SDB) located at Wadi Hassan WWTP perform well during the dry and hot summer months; however, during winter their performance is not sufficient, which resulted in the costly disposal of liquid sludge to the landfill Al-Akaider operated by the Ministry of Municipalities. Based on a decision taken by the ministry in 2018, the landfill does not accept the disposal of liquid sludge anymore. Therefore, the operator of the Wadi Hassan WWTP, Yarmouk Water Company (YWC), disposes liquid sludge at a land owned by YWC located nearby Al-Akaider landfill. However, as the land is not designed as a sanitary landfill, this solution is only considered temporary.

In order to solve this problem, ACC agreed with the MWI and WAJ that GIZ will provide sludge treatment infrastructure to treat the liquid sludge generated from the treatment of 900m3/d of wastewater. Improving the sludge management refers therefore particularly to the 6 winter months during which the existing SDB do reportedly not perform well. It was therefore decided to construct sludge drying reed beds (SDRB) to treat the sludge generated during the winter months (based on 900m3 wastewater per day) on-site.

This project aims to promote an efficient, robust, easy-to-operate and sustainable sludge treatment technology to complement the existing SDB, particularly during winter operations. To this end, SDRB's will be piloted at the WWTP Wadi Hassan to treat the excess sludge of the primary and secondary treatment stages. The sludge mineralization with reed beds is a well-known and proven technology from Germany and several pilot systems have demonstrated the high potential of these technologies especially in arid or semiarid climates. This natural sludge treatment system has a high potential to replace or supplement cost and energy intensive methods of drying and disposal of sewage sludge. The dewatered and mineralized sludge in SDRB's can be stored for up to 10 – 12 years in the basins, planted with reed (Phragmites australis or P. karka) and the accumulated sludge convert over the years into a soil-like substrate, not only storing nutrients but also CO2, giving the opportunity to various reuse options. In the worst case these basins can act at least as a mono-storage of mineralized sludge, making a future reuse much more probable than with the method of dumping the dried sludge into landfills.

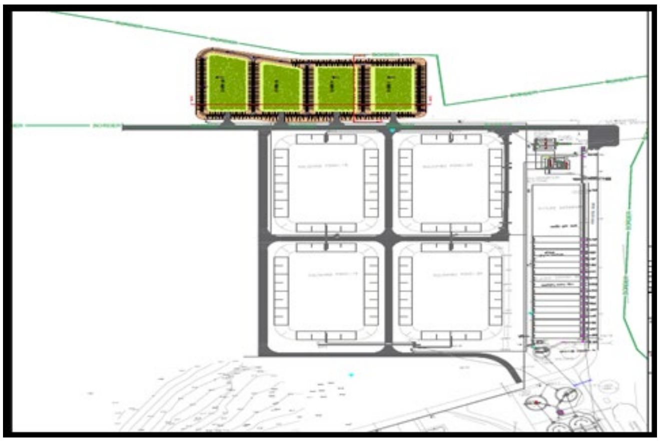

Figure 40 SDRB site plan (in green) next to the polishing ponds at Wadi Hassan WWTP

## 2.4 Capacity Development

The unique strength point of the capacity development plan implemented by ACC lies in the integration between theoretical and practical knowledge. On the one hand, the training instruments targeted building theoretical knowledge of trainees; on the other hand, their engagement in implementation processes of DWWM consolidated their practical expertise on the ground. Therefore, the selection of the trainees was based on certain criteria for specific target groups. The full engagement, in theoretical trainings and implementation process, added consistency and comprehensiveness to capacity development dimensions.

The main capacity building instruments used by the ACC project:

- Training Course in Jordan covering three modules: (i) Introduction of DWWM, (ii) Tendering of DWWM
- infrastructures and (iii) Legal framework and enabling environment for DWWM.
- Summer School in Germany about (i) DWWM and reuse as well as (ii) Financing of DWWM.
- E-Learning in two modules with several modules, incl. (i) Sanitation & Wastewater – Introduction and Background, (ii) Wastewater Management Approaches, (iii) User Interface, Wastewater Collection and Conveyance Systems, (iv) Wastewater Treatment Technologies, (v) Sludge Treatment, (vi) Operation & Maintenance, (vii) Re-use of Wastewater and Sludge, and (viii) Mitigation of and Adaptation to Climate Change.
- On-the-job trainings for operating staff of YWC (operation of the SDRB and SDB at Wadi Hassan WWTP) and EcoHotels (operation of the DWWTP in Feynan)
- Symposium about the enabling environment for DWWM in cooperation with the Jordanian Engineers association.
- Film about DWWM.
- Local and international study about business models for DWWM.
- Concept papers on (i) Industrial wastewater treatment, (ii) DWWM as a measure for climate change adaptation, and (iii) Reuse of effluents from

DWWTP.

- Construction manual for DWWTP (Do’s and Don’t’s).
- Operation & maintenance manual for the DWWTP at Feynan.
- Orientation guide for the ACC experience project in Jordan.

Most of the training materials are available on the ACC project website: http://www.dwm-acc-jordan.net.

## 3. Challenges of DWWM in Jordan

Without first acknowledging and addressing the challenges faced by DWWM in Jordan, it is not feasible to expand its implementation at suitable location. This chapter summarizes the main obstacles that hinder the scaling-up of DWWM in Jordan:

### 3.1 Enabling environment

- Stakeholders lack commitment to enact the DWWM Policy (MWI, 2016), which is an important step to pave the way for the roll-out of DWWM. The lack of full government commitment to address the problems related to the absence of sanitation services in rural and peri-urban areas creates a political and institutional environment that offers little incentive to manage wastewater effectively. This shortcoming is reinforced by a lack of financial resources to develop and implement effective policies and programs for managing wastewater in these areas.

- The decision not to proceed with the finalization of a dedicated Action Plan developed by the MWI and WAJ to implement the DWWM Policy - which is considered a suitable vehicle to create the required enabling environment for DWWM – slows down the implementation of the DWWM Policy on the ground.
- Harmonization and close collaboration between relevant partners are still missing to implement the DWWM Policy (or consolidated follow-up policies that are under preparation) in order to disseminate DWWM in a large-scale (scaling-up). DWWM requires greater coordination between government entities, the private sector and civil society. There is a need to look at the most appropriate institutional arrangements for managing DWWTPs and for monitoring and regulating those organizations that are responsible for them.

### 3.2 Clearly defined institutional responsibilities

Without a formal institutional framework within which decentralized systems can be implemented, efforts to introduce DWWM are likely to continue to be fragmented and unreliable. Although Jordan recognizes the need to implement improved systems for wastewater management in rural and peri-urban areas, the current DWWM Policy shall be combined with supporting legislation governing water-resource protection. These policies are generally not well defined and may be inappropriate for scaling-up the DWWM approach. Required improvements to the institutional framework prove to be difficult to implement due to an overall lack of resources and management capabilities

Many actors are involved in the implementation of a DWWM project. This refers to granting permissions (e.g. by governorates or municipalities), investing in infrastructure (e.g. through donors), operating DWWTPs (e.g. through the private sector), paying for operations (e.g. through the beneficiaries), monitoring (e.g. through WAJ or the Ministry of Environment). In the following, the involvement of certain institutions in DWWM is shown exemplarily:

- Generally, MWI through WAJ and WAJ-owned water companies are in charge for sanitation service provision in Jordan; however, a clear commitment of WAJ for DWWM does not yet exist.
- Equally, related roles and responsibilities of governorates and municipalities are not clearly defined.
- For permission to implement a DWWTP, an approval of an EIA is required by the Ministry of Environment.
- Reusing the effluent of DWWTPs for agricultural purpose requires a permission by the Ministry of Agriculture; same applies for landfilling the sludge that is generated during the treatment process.
- If a DWWTP shall be constructed on public land, the owner of the public land (e.g. Ministry of Municipalities, Ministry of Agriculture, the Governorate or Municipality) must allocate the land approve the location of a DWWTP.
- Finally, mechanisms for private sector engagement in service provision are not yet defined and implemented.

Hence the large number of involved parties in combination with unclear roles and responsibilities impede the large-scale dissemination of DWWM.

### 3.3 Funding of CAPEX

DWWM may reduce the capital investment cost (CAPEX) required for wastewater management in certain areas due to reduced length of sewers (considering the economies of scale for the WWTP itself), but the government of Jordan lacks the resources to invest in new infrastructure and relies on (soft) loans and grants from international agencies to finance improvements in service provision. Lack of access to credits and lack of the incentive to invest in infrastructure may also be critical factors.

The acquisition of land for more extensive forms of treatment (e.g. nature-based systems that require little O&M) may prove difficult for those with limited financial resources. In the absence of adequate cost-recovery mechanisms, investments in DWWM may become a financial liability and this may constitute a major hindrance to the sustainable operation of DWWM systems. Cost recovery in wastewater management is generally very poor and, even where enough financial resources exist, there is little willingness to pay for decentralized sanitation services in rural and peri-urban areas due to the following reasons:

- The economic status of rural communities, hence the target area for DWWM, is low; therefore, they are not top priority for infrastructure investments by the government.

- Decision makers rather prefer to connect densely inhabited areas to large-scale WWTP to increase sanitation coverage to the extent possible. The main reason for that is "economies of scale": CAPEX per connected person for large-scale WWTP is usually lower than for small-scale DWWTPs.
- Funding for "some" large-scale (centralized) WWTP is easier to obtain as for the implementation of "many" small-scale systems because the implementation of DWWTPs requires more effort, time and total CAPEX to cover the same number of people. Main reason for that is that for every DWWTP basically the same work steps are required as for a large-scale WWTP, incl. identification of location, conceptual and feasibility studies, EIA, design, tendering, construction, development of sustainable business models, etc.).

### 3.4 Sustainable business models for OPEX

The sustainable operation of DWWM systems must be compatible with the knowledge and skills available at the local level. Although even simple technologies often fail in practice due to a lack of capacities for O&M, DWWM may provide opportunities for these tasks to be carried out correctly by local stakeholders, who have a greater incentive to ensure that facilities continue to perform as intended. However, even if capacities for O&M of DWWTPs are available on local level or could be developed, coverage of operational expenditures (OPEX) is a challenge for the following reasons:

- Meanwhile CAPEX for sewers and WWTPs are currently largely covered by international partners, OPEX must be generally covered by the local government and beneficiaries of sanitation services.
- In order to ensure effective O&M of DWWTPs, feasible and sustainable business models must be identified. It seems unavoidable that the involvement of the private sector is a pre-requisite to come up with feasible business models. However, due to lacking certification schemes (e.g. certification of service companies to operate WWTPs) and cost-covering revenues (e.g. through wastewater tariffs) private sector involvement remains a challenge.
- The slogan "decentralized treatment – centralized management" is a well-known pre-requisite for sustainable operation in the context of DWWM, which also applies in Jordan, especially if the private sector is to be involved. A critical mass of DWWTPs is required to set up feasible business models as it is not cost-efficient to equip small-scale WWTPs with operating staff and equipment on a permanent basis meanwhile O&M requirements are low. In order to ensure cost-efficient operations, a certain minimum quantity of DWWTPs is required so that staff and equipment can rotate between the systems without the need to be transported over large distances.
- Currently, revenues of selling the treated effluent as replacement for fresh water are not cost-covering, especially as the water tariff is low and subsidized. Farmers or other recipients of the treated wastewater

are most likely not willing to pay more for the treated wastewater as for supplied freshwater, even though the effluent contains some remaining amount of valuable nutrients. Especially due to the subsidizes water tariff, revenues through sales of WWTP effluents are low.

- To achieve cost coverage for O&M the tariff system should be revised; nevertheless, subsidies for OPEX might remain necessary
- Innovative business models like selling ‘products’ (e.g. fodder crops grown with the effluent of DWWTP) instead of the effluent should be considered
- For more information about business models for DWWM, incl. potential scenarios, please refer to **Part D Business Models for Decentralized Wastewater Management in Jordan** of this compendium.

### 3.5 Regulatory framework for DWWM

For scaling-up it is required to incorporate DWWM within an integrated framework of water resources management and other services of water supply, sanitation and solid waste management. Official design standards may not be framed in a way that supports the development of DWWTPs. Therefore, there is a need to develop appropriate standards to be utilized for the design and construction of DWWTPs, and to promote realistic and acceptable reuse standards. Policies need to be based upon practical experiences and realistic objectives and should be developed in close collaboration with all organizations involved with those communities that DWWTPs are designed to serve. Challenges related to the existing regulatory framework for DWWM are summarized in the following:

- The valid discharge/ reuse standard (JS893/2006) requires that DWWTPs are highly efficient, incl. in terms of removing nutrients (N and P), irrespective whether the effluent is reused for irrigation or not. If effluents are used for irrigation, e.g. in agriculture or for the irrigation of fruit trees, it is disadvantageous to remove nutrients as nutrients contained in the wastewater can reduce the use of artificial fertilizers. Removing the nutrients as demanded in JS893/2006 increases the CAPEX for WWTP. Especially in case of DWWTPs, where the pollution load is smaller compared to large-scale systems due to the smaller influent quantities, overambitious discharge limits endanger the financial feasibility of such facilities.
- The standard proposed in the DWWM Policy (MWI, 2016) for irrigation relaxed all limits and removed phosphorus for DWWTPs; however, a limit for nitrogen is still included. The limits proposed in the policy were not yet included by the Jordanian Standards and Metrology Organization (JSMO). In 2019, JSMO suggested an overworked standard with limits for WWTPs, again not separating between large and small-scale systems. The standard, which was not yet approved at the time of writing the guide, was nevertheless even stricter compared to JS893/2006. At the time of preparation of this guide, WAJ intended to propose a separate, less stringent discharge / reuse standard for DWWTPs.

### 3.6 Local technical expertise for DWWM

Even where policy makers accept the validity of the decentralized approach, a lack of capacity to plan, design, implement and operate DWWTPs is likely to be a severe challenge on efforts to ensure its wide adoption. The sustainable operation of DWWM systems must be compatible with the knowledge and skills available at the local level considering that:

- Most WWTPs in Jordan are activated sludge systems (extended aeration). Practical experience with other technologies is limited. The design of WWTPs is usually done by donor-funded external consultants.
- DWWM can be generally high-tech (e.g. SBR) or nature-based (e.g. constructed wetlands), depending on the specific location (groundwater level and pollution, applicable reuse schemes, land availability, etc.). The most suitable technology shall be selected based on a holistic approach, e.g. a multi-criteria analysis.
- DWWM in Jordan is mostly applicable in remote rural, where the demand for effluent reuse in irrigation exists and space is available (especially in case that nature-based systems shall be applied). DWWM is also applicable in peri-urban areas if the connection to a large-scale WWTPs is less feasible. Suitable technologies for DWWTPs are e.g. biogas digester, ABR, UASB, constructed wetlands (vertical, horizontal, French-type). Local expertise in design, construction and O&M of these technologies is still limited.

### 3.7 Awareness and social acceptance

As ACC had experienced in Rehab, social acceptance is a major challenge related to the dissemination of DWWM. Resistance is mainly related to the location of the WWTP, which in the decentralized concept is naturally closer to the point of wastewater generation compared to the use of large-scale centralized WWTP. Negative opinions about WWTPs are based on bad experiences in Jordan with WWTPs in general. In order to increase social acceptance, raising awareness for the demand of DWWTPs is equally important than minimizing concerns related to smell emitting from WWTPs. In the following, the main facts related to social acceptance for DWWM in Jordan are summarized:

- On beneficiary level, the centralized approach of wastewater management is considered the most suitable and preferable solution. People strive for systems that are known from urban areas and developed countries, hence a sewer system that conveys the wastewater away from their house (flush and forget mentality).
- People do not want to be involved with their sanitation system. For example, regular emptying of pre-treatment modules as required in case of simplified sewer systems is not acceptable for house owners.
- Residents do not accept WWTPs, of any kind, close to their premises due to concerns about potential nuisances (odor, sight of infrastructure, etc.).
- Many Jordanians lack trust with governmental institutions that provide wastewater services due to negative past experiences with WWTP projects in Jordan. People have the perception that every WWTP will cause severe problems. This negative image of WWTPs specifically hinders the

implementation of DWWTPs as they are constructed closer to villages to reduce transport distances and to allow for local reuse of the treated effluent.

- Lack of successful examples and campaigns to increase acceptance are crucial to improve social acceptance in the long term.

# 4. Orientation Guidelines for implementing and scaling-up DWWM in Jordan

## 4.1 The definition of DWWM

DWWM may be defined as "the collection, treatment, and disposal/reuse of wastewater from individual homes, clusters of homes, isolated communities, industries, or institutional facilities, as well as from portions of existing communities at or near the point of waste generation" (Tchobanoglous, 1995). In case of decentralized systems, both solid and liquid fractions of the wastewater are utilized near their point of origin. It is obvious that most common definitions refer to the distance between generation and treatment / reuse.

MWI's definition considers the distance between generation and treatment as well as the capacity of the WWTP as mentioned in the feasibility study conducted by the National Implementation Committee for Effective Decentralized Wastewater Management (NICE). As per MWI and NICE, decentralized wastewater treatment and reuse systems are defined by their technical components consisting of a WWTP coupled with the reuse of the treated wastewater at or near to its point of generation that creates added benefits and contributes to sustainable water management in the region. The size of DWWTPs ranges from solutions for individual buildings to solutions for several houses or small villages up to a maximum size of 5,000 Population Equivalents (PE). While in the DWWM Policy (MWI, 2016) it is defined as most appropriate approach for suburban and rural communities, particularly toward the upper edge of catchments, where the costs of wastewater pumping over long distances to large centralized treatments plants outweigh the plant's potential economies of scale.

According to experiences collected by the ACC-Project in the past four years, the underlying principle of decentralized management of wastewater is to implement adequate and tailor-cut collection and treatment systems in areas that cannot be connected cost-efficiently to centralized wastewater treatment systems via a (long) sewer network. Which means that DWWM is not an alternative or competition but a complementation to centralized management and a comprehensive comparison is needed to identify the most feasible and sustainable approach for each case. Needless to say, that DWWM is not necessarily a non-sewer approach but it depends on the local conditions: the conventional sewer system and other sewer technologies such as the simplified and solid free systems as well as emptying of household tanks (septic tanks / cesspits) by trucks and transport to DWWTP could be integrated in DWWM scenario. This definition explains that connecting people to a WWTP under the DWWM approach is not limited by distance neither by the number of population but rather it is the most feasible option for sanitation provision under a given situation.

Hence, introducing DWWM as an alternative or new approach can create unnecessary tensions and confusion, especially when it is managed, regulated and monitored by a pre-defined operator, whether WAJ, water utility, private sector or NGO. DWWM summarizes the approach to build a WWTP, considering the most feasible treatment and reuse technology, size and location, considering aspects such as distance between the location of wastewater generation, treatment and reuse (which is a significant cost factor). As a result of technical, social, financial, and environmental considerations, DWWTPs are usually small- to medium-scale systems with relatively short transport distances. Due to the remoteness of potential target areas, nature-based solutions that require a larger footprint, are often suitable for DWWTPs, but not necessarily. Lack of understanding about the DWWM approach can increase fears and objections if potential beneficiaries think that the proposed sanitation solution is a new system different from what is known as "normal" WWTPs when it comes to the network, pumping station and technology. Likewise, centralized treatment plants, DWWTPs could vary from simple to high-tech technologies.

### 4.2 Situations Suitable for DWWM & Planning for DWWM

The following situations are suitable for the implementation of DWWM:

- Locations where clusters of on-site systems (e.g. cesspits / septic tanks) exist and provoke environmental pollution, e.g. due to leakages, especially in combination with shallow groundwater tables (so called hot sport areas).
- Improper maintenance of on-site treatment systems and exorbitant cost of conventional remediation by implementation of centralized systems with long sewer networks.
- Communities or institutional facilities that are far away from existing centralized WWTPs.
- Locations with scarcity of freshwater and the possibility for localized reuse of treated wastewater.
- Locations where the extension of the existing centralized system is impossible.
- Newly developed or existing clusters of residences, industrial parks, public facilities, commercial establishments and institutional facilities.

In order to support a proper implementation of the national DWWM strategy in Jordan, it is highly demanded to perform a national level evaluation with cooperation of all concerned stakeholders to identify and prioritize locations for DWWTPs based on what is mentioned above. Such evaluation shall be conducted in phases and in dependence on quantities and qualities of the generated wastewater as well as the available financial resources. A master plan should be developed for possible locations for DWWM. These possible locations should be aligned with an overall sanitation master plan that shall be developed for the country and should not overlap with those areas where a centralized system already exists or where it is planned because it was found to be more feasible.

Once the areas that shall be served with DWWM are identified in the master plan (that should be developed by the MWI), the first step in the planning process should be the site selection for the DWWTP. The potential sites should be identified based on the following factors:

- Land availability and ownership
- Social acceptance
- Topography and need for pumping
- Wastewater quantity and quality and related reuse potential
- Details of existing on-site treatment systems
- Presence of any drainage channel for discharge of treated wastewater if required to manage the surplus that will not be utilized by farmers and continues its destination into a natural wadi
- Soil and groundwater conditions and water resources protection zones

It is worth mentioning that the most dominant factor among the listed above is the social acceptance. In Rehab, most of the factors were applied in the technical design of the project, including social awareness campaigns. However, based on the local community experience with inefficient operation of the existing WWTPs in Jordan they lack trust because they don't know a good example for a WWTP that performs well. Another consideration related to social acceptance is the reduction in the land price that will affect the surrounding areas of the WWTP. Consequently, some concerned residents, e.g. land owners close to the selected site, refused the site. It is essential to understand the local context for site selection and deal rationally with peoples' concerns based on their experience with WWTPs in Jordan.

### 4.3 Institutional and Regulatory Framework for DWWM

In Jordan, many different national and local entities are involved in improving rural sanitation. However, there is no single agency or ministry that has an overall mandate for rural sanitation and wastewater management. The absence of a well-established institutional framework hampers coordination and implementation. This leads to an overlap of responsibilities and limited supervision of activities in the sector.

Policies, regulations and guidelines need to be clear. Importance needs to be given to clearly outline the responsibilities of different parties to minimize potential for conflict and improve the sanitation service in rural areas and wherever DWWM is to be applied.

National policies that address rural and peri-urban sanitation and wastewater management shall be implemented in Jordan. The DWWM policy shall set targets to increase coverage of basic services to assist reaching the 20% sanitation service coverage by 2030 mentioned in the MWI strategy in combination with the centralized system that will cover the remaining 80% of unserved people. At the local level, more specific policies are required to clarify decision making, to prioritize activities, and to ensure that key members of the community are represented and included in the decision-making process.

Policies must be based on a thorough understanding of the existing situation, utilizing accurate and relevant information. Policies are likely to be more effective in responding to needs if they draw upon the insights and experience of all those who are working to develop improved sanitation services (Tayler et al., 2003).

The policies should also promote the use of the most cost effective and appropriate approaches and options that protect human health and the environment. More complicated and more expensive is not necessarily better, especially where it is not sustainable.

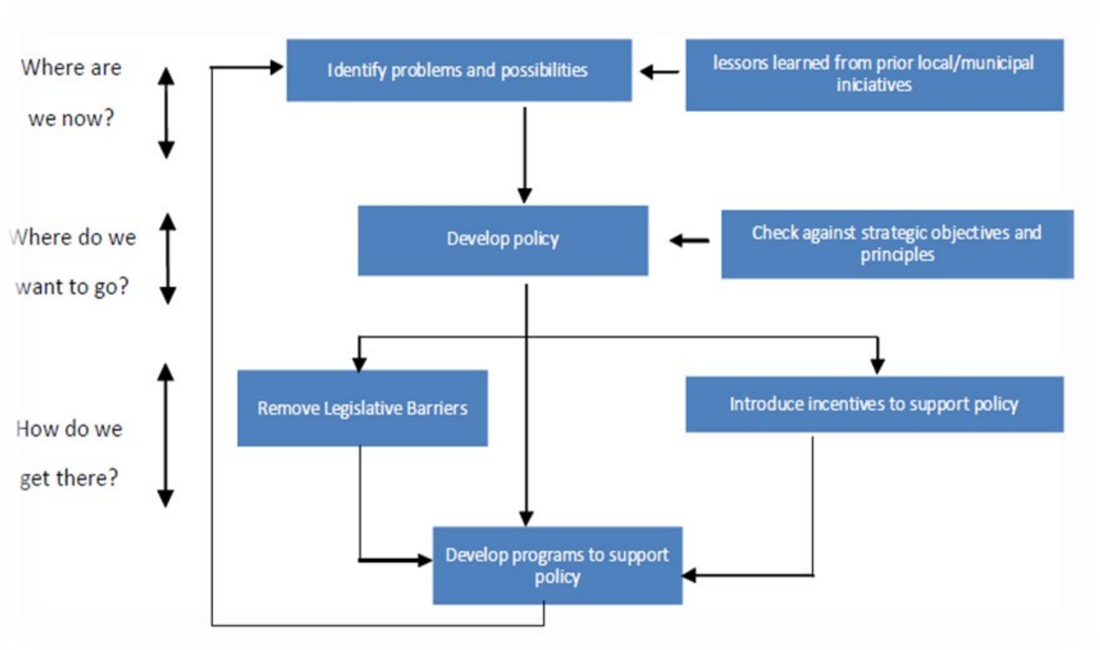


Figure 41 Stages in Developing and Implementing Policy (Tayler et at., 2003)

## 4.4 Community Participation and capacity building

Starting community participation activities shall be conducted based on a clear role for each involved party in DWWM. WAJ and water utilities (or a successor regulator) shall be officially responsible to monitor the quality produced by the DWWTPs to assure efficient operation and maintenance. However, community participation is necessary to ensure that the benefiting community has a vested and long-term interest and stake in the outcome. But community participation alone is not enough for the successful design and implementation of a sanitation program. Institutional support by the government is also needed to supply technical expertise and support services not available in the community.

It is essential to understand the attitudes and behaviors of rural communities in Jordan towards water and sanitation. It is the government’s responsibility through WAJ and local water utilities to provide basic infrastructure such as improved water and sanitation to all rural communities. But this is not a total solution. It is necessary to guarantee the sustainability of the operation and maintenance through the private sector/municipalities in the rural area. In case the municipalities or community are selected to be responsible for the operation, the financial resources for the operation and maintenance shall be covered to ensure sustainability.

Many aspects of the community participation/education process will depend on support from the government through municipalities and relevant ministries (Water, Environment, and Agriculture) as well as from private consultants/ contractors to facilitate and provide community training and education. Institutional support will focus on community organization, outreach, education, monitoring and evaluation of each phase of the project. The target from this support could facilitate the site selection process which is considered the most challenging issue in the project planning.

### 4.5 Technical Analysis and Design

Developing the technical capacity to implement sustainable DWWM at the local level is a key objective to implement affordable, practical, and effective sanitation project planning, design, implementation, and operations.

The required steps to plan and design an appropriate sanitation system for a rural community has two parts. The first part consists of the pre-design studies, incl.

- Community assessment involving compilation and analysis of geographic, population, economic, and other data,
- Consideration and comparison of all potential alternatives of achieving the project goals to determine which is the most feasible option, and
- Identify any potential environmental impacts, assess their importance, and specify mitigation measures.

The second part is the preparation of engineering detailed designs for the final project.

Regarding the treatment technology selection, appropriate wastewater treatment technology should be selected based on many factors such as treated effluent quality standards, land requirements, power requirements, capital cost of plant, operation & maintenance costs, maintenance requirements for the operator attention, reliability, resource recovery and load fluctuations.

The effluent quality that shall be produced by the selected treatment technology must be determined based on the reuse options, soil conditions and most importantly the ground water resources (location, depth, quality and quantity). In other words, first the reuse options shall be identified, second the quality needed to be reused for these options and then the treatment technology that is capable to produce the required quality shall be selected.

It is essential to mention that the engineers should respect the local culture and knowledge of the community and select the most appropriate approach to communicate with the local community considering the cultural background. All experts should concentrate on listening to the community members and gaining insight about the local experience. A fundamental goal at the outset is to gain the respect and confidence of the community, which will be a key to the successful execution of the project.

## 4.6 Financing, Subsidies, and Cost Recovery

Economic considerations of DWWM including sustainable and feasible business models, one of the most important aspects, require a detailed analysis of Cost-Benefit or Cost-Effectiveness. In general, there are three suggested funding sources to pay for DWWM:

- The government, especially MWI, WAJ, municipalities, water utilities (Miyahuna, YWC, Aqaba Water company),
- User or private funds,
- External funding sources from such as international bilateral or multilateral donors or non-governmental organizations.

Given that sanitation is a public good (poor sanitation conditions impact public health, the environmental and economic development), subsidies are sometimes appropriate and common practice when needed to expand coverage. The common reason that sanitation needs to be subsidized is to make it affordable to the poorest people in a community.

## 4.7 DWWM Administration, Operation, Maintenance and Monitoring

DWWM like any infrastructure projects consists of three phases of development. These include the planning and design phase, the construction phase, and most importantly, the operation and maintenance (O&M) phase. Commonly, development programs executed by national governments and non-government organizations (NGOs) will focus on the first two phases of development and leave the last phase of the project to beneficiaries of the project. This approach has commonly resulted in a high failure rate of projects for several reasons, including a lack of proper training of the private sector or local community on the O&M requirements of the system, inadequate on-going monitoring and evaluation by the regulatory community, the introduction of inappropriate technology that cannot be financially or technically supported by the community and other possible reasons. Therefore, all three phases: planning and design, construction, and O&M need to be considered as integral to sustainably develop projects.

An O&M program for DWWTP is to provide for and improve the efficient and effective sanitation service. O&M activities encompass technical, managerial, financial, and institutional issues that must be attended to, to achieve reliable and uninterrupted service.

It is highly important to identify clearly the official body responsible for the O&M of the DWWTP in order to assure the sustainability of these systems once they are implemented. Otherwise, scaling up the DWWM in Jordan without assigning the public or private entity responsible for running these systems will have massive environmental problems due to fragmentation and a failure to address overall problems adequately.

### 4.8 sStandards and Regulations

Strict monitoring and quality assurance of operation and maintenance of DWWTPs is very essential to protect the environment and water sources. The performance of the systems should be monitored with respect to different parameters such as BOD5, COD, suspended solids, total P, and fecal coliforms. The effluent should meet specific regulations that shall be developed separately from JS893/2006, which is too stringent for small scale WWTPs. In addition, meeting the JS893/2006 for DWWTPs will impact the capital investment needed for the implementation. For example, in the ACC Feynan demonstration project, a 100% recirculation of the wastewater was required, increasing the system capacity, in order to meet class C of JS893/2006 in terms of nitrogen.

Designers also are required to meet the standards that are tailored for DWWTP by assembling an appropriate treatment technology that may include a combination of treatment and soil-based processes that address the pollutant limits specified which means the effluent quality shall cause no/minimum harm on the soil characteristics as well as the entire environment surrounding the DWWTP. The main concern related to the treated wastewater is the salinity that shall be evaluated carefully for long-term reuse of treated wastewater on the soil. Due to that, nomination an official regulatory body (WAJ or water utilities) that is responsible for water quality monitoring and the entity which is responsible for O&M (private sector/municipalities/community) are crucial pillars in the scaling-up of DWWM in Jordan. However, the regulatory approach that could be developed by WAJ /water utilities does not require specifying the treatment methods and placing the burden of compliance on the system designer and ultimately the village. The advantage of developing a regulatory approach is that it allows for a site-specific approach that matches the risk reduction strategies to the site conditions (soil characteristics, depth of groundwater, pollutant transport and fate, and other factors) and the reuse purposes. This can lead to simpler, lower cost solutions, if the potential risk of exposure or environmental impacts is low. The disadvantage of this approach is that it can require more in-depth study and analysis of site-specific conditions, requiring the designer to tailor the wastewater project to match those conditions. However, the final designs will likely lead to more appropriate and sustainable solutions.

## 5. Conclusion and Recommendations

Despite the obvious demand for DWWM, its large-scale dissemination as a complementation of centralized systems remains a challenge for various reasons. In order to scale-up DWWM on a country-wide level, the further development of an enabling environment is essential. The enacting of the DWWM Policy through the MWI in 2016 was an important step to pave the way for the roll-out of the decentralized approach. Nevertheless, certain obstacles remain a challenge and only harmonization and a close cooperation between relevant sector players can create the environment to scale-up DWWM in areas that are not suitable for conventional solutions. In that sense it is crucial to clearly define institutional responsibilities for DWWM, incl. for capital investments and operations of the systems. This goes together with the identification of feasible and sustainable business models, including exploring options for private sector involvement. Setting a regulatory framework, incl. feasible tariff and reasonable subsidy systems, remains a pre-condition for scaling-up. Furthermore, discharge and reuse standards deserve an update to adapt them to DWWTPs that emit smaller pollutant loads compared to large-scale centralized system, particularly if the effluent is reused in nutrient-consuming irrigation as the purpose of reusing the treated wastewater for irrigation contradicts with removing nitrate as a valuable nutrient for plants. Therefore, it is recommended to update the allowable nutrient concentrations in treated wastewater in the Jordanian Standards, taking public health (food quality protection) and environmental concerns including ground water, and soil salinization into consideration.

Technical skills related to design, construction and operation and maintenance of DWWTPs need to be developed to replicate systems on a country-wide level in high quality. Apart from the rather supply-side oriented challenges, a paradigm shift is also required in the heads of the target group, making them more accessible to the idea of safe treatment and reuse of wastewater closer to their homes.

Many obstacles must still be brought down to roll-out DWWM as complementation of the traditional centralized management approach; however universal sanitation coverage, environmental protection, new businesses and markets, increased public health, additional water resources, just to name some, are worth to take the collaborative effort to put the DWWM Policy into practice.

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