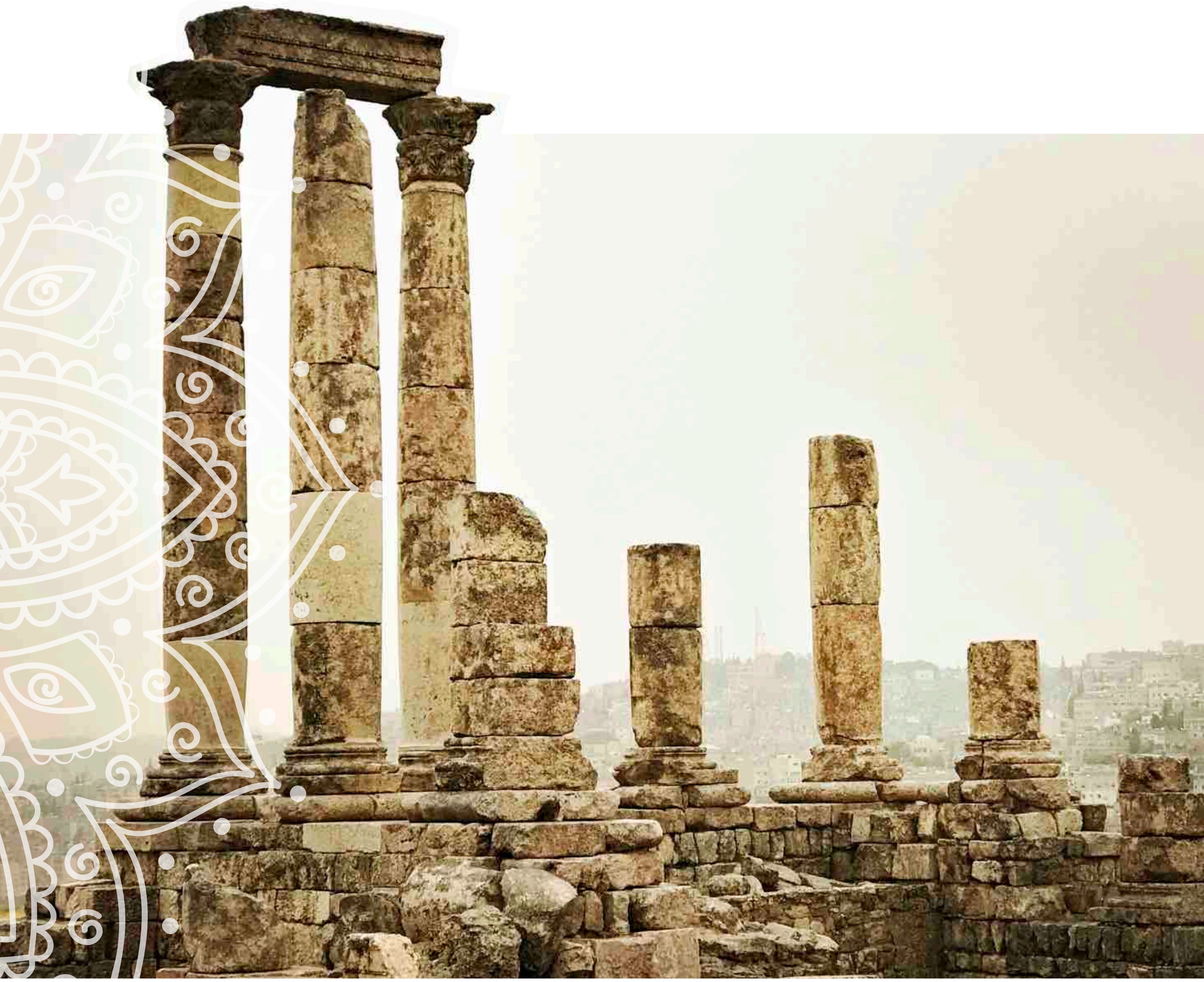

Reuse of Treated Wastewater and Biosolids in Jordan

Nationwide Evaluation

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NICE
National Implementation Committee for Effective Integrated Wastewater Management

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List of Acronyms

AECOM	Architecture, Engineering, Consulting, Operations, and Maintenance
AWC	Aqaba Water Company
BOD	Biochemical Oxygen Demand
BRDP	BADIA Research and Development Program
COD	Chemical Oxygen Demand
CWWTP	Centralized Wastewater Treatment Plant
du	dunum (one dunum = 1000 m^2)
DWWM	Decentralized Wastewater Management
DWWTP	Decentralized Wastewater Treatment Plant
FAO	Food and Agriculture Organization
FOG	Fat, Oil and Grease
GDP	Gross Domestic Production
GIS	Geographic Information System
GoJ	Government of Jordan
GIZ	German Agency for International Cooperation
GPS	Global Positioning System
ISSP	Institutional Support and Strengthening Program
IWA	International Water Association
IWRM	Integrated Water Resources Management
JFDA	Jordan Food and Drug Administration
JOD	Jordanian Dinar
JPMC	Jordan Phosphate Mines Company
JSMO	Jordan Standards and Metrological Organization
JUST	Jordan University of Science and Technology
JV	Jordan Valley
JVA	Jordan Valley Authority
JS	Jordanian Standard

MEAN	Middle East and North Africa
MCM	Million Cubic Meter
MoA	Ministry of Agriculture
MoEnv	Ministry of Environment
MoH	Ministry of Health
MPN	Most Probable Number
MWI	Ministry of Water and Irrigation
NARC	National Agriculture Research Center
NWRCC	National Water Reuse Coordination Committee
NGO	Non-Governmental Organization
NAWCO	Nabil Wakileh Contracting
NICE	National Implementation Committee for Effective Integrated Wastewater Management in Jordan
PE	Population Equivalent
PPP	Public Private Partnership
PSD	Public Security Department
RIAL	Reuse for Industry, Agriculture and Landscaping
RSS	Royal Scientific Society
SBR	Sequencing Batch Reactor
SDG	Sustainable Development Goal
SDRB	Sludge Drying Reed Beds
SSP	Sanitation Safety Planning
TDS	Total Dissolved Solids
TSS	Total Suspended Solids
TN	Total Nitrogen
TWW	Treated Wastewater
UN	United Nations
UNDP	United Nations Development Programme
UNHCR	United Nations High Commissioner for Refugees
USAID	United States Agency for International Development

WAJ	Water Authority of Jordan
WHO	World Health Organization
WSP	Water Safety Plan
WUA	Water Users Association
WWTP	Wastewater Treatment Plant

Summary

Many countries in the Middle East and North Africa (MENA) face challenges related to scarce water resources, population growth, and climate change. For this reason, treated wastewater (TWW) or reclaimed water should be used in place of conventional water resources across diverse sectors. Jordan has recently introduced policies which clearly state that freshwater used for irrigation should be gradually substituted with TWW whenever feasible. Many factors - including regulatory, institutional, social, technical, and financial aspects – will ultimately affect the success of this substitution process.

Although the agricultural sector in Jordan has been using treated water for decades, the potential for a direct reuse, in particular, is far from being exhausted. Direct use of TWW is still not popular in the country and faces several challenges, namely: (1) institutional fragmentation, which jeopardizes the design and implementation of effective reuse schemes; (2) the existing technical standards, which are particularly relevant when small-scale treatment and reuse schemes are considered; (3) the lack of well-established business models, which hinders the widespread use of decentralized wastewater treatment systems; and (4) the lack of social acceptance.

Public awareness programs have, up until now, ignored the issue of promoting TWW use. Hence, the government should invest in public awareness programs that focus on explaining wastewater treatment and reuse. Other areas for missing investment include: (i) reducing TWW losses through infiltration and evapotranspiration (e.g. King Abdullah Canal) and enhancing TWW transportation and storage; (ii) establishing an independent unit to monitor the decentralized and semi-centralized wastewater treatment plants and create an official database of these facilities; (iii) passing new official guidelines concerning registration, notification, supervision and performance evaluation, as well as developing a mechanism that can be used to monitor effluent quality and the end use of TWW; and (iv) enhancing the performance of certain centralized wastewater treatment plants (CWWTPs) to comply with the current Jordanian reuse standard (JS 893, 2006).

This study will give an overview on the actual amounts of TWW and existing reuse practices in Jordan. By using Geographical Information Systems 33 centralized wastewater treatment systems that serve communities bigger than 5000 PE have been mapped and the actual amount and quality of TWW (about 163 MCM in 2018) and its reuse is discussed, and the best practice examples for the reuse of TWW and biosolids in Jordan are presented.

Furthermore, 85 treatment systems serving communities, hotels, individual

houses smaller than 5000 PE have been identified.

These study results should serve as the basis for the establishment of a national inventory, in particular, for decentralized wastewater treatment and reuse systems, which facilitates the coordination of permit procedures and control measures in Jordan.

Furthermore, there are two main critical policy measures which are discussed that can improve the current situation and be used to overcome the previously described challenges. The first policy measure is related to the development and approval of an institutional framework for Sanitation Safety Planning (SSP) and the subsequent development and employment of SSPs for different catchment areas in accordance with the IWRM principles presented in the National Water Strategy 2016 – 2025 (MWI, 2016a). Sanitation Safety Plans would consider all agricultural inputs to prioritize hazards and define control measures that would minimize the identified risks. This approach would facilitate the implementation of new standards that would define the budget for wastewater treatment and TWW reuse technologies. This is important as investments in wastewater treatment have previously proven futile due to contamination later in the process. Moreover, SSPs would coordinate actions related to wastewater management which will reduce the existing burden on the Water Authority of Jordan (WAJ) and result in clearly defined responsibilities and interfaces among the specified controlling bodies and stakeholders. The second policy measure focuses on introducing a more integrated wastewater management approach that is based on the concept of a circular economy, i.e. the value creation process includes various waste streams. This approach would ideally result in cost recovery and improved societal acceptance of wastewater treatment plants (WWTP) facilities in local communities. Resource recovery facilities or green facilities – could then be established to encourage investments.

Such recommendations for more efficient water management would assist Jordan in achieving one of the goals for sustainable development listed by the United Nations, *‘Ensure access to water and sanitation for all’* (Goal 6).

الملخص

تواجه العديد من دول الشرق الأوسط وشمال أفريقيا تحديات تتعلق بندرة المصادر المائية، والنمو السكاني، والتغير المناخي. ولهذا السبب، يجب استخدام المياه العادمة المعالجة أو المياه المستصلحة في مختلف الصناعات كمصدر بديل عن مصادر المياه التقليدية. في الواقع، قامت الدولة مؤخرا بوضع سياسات تنص بوضوح على أن المياه العذبة المستخدمة في الري يجب أن يتم استبدالها تدريجيا بالمياه العادمة المعالجة كلما كان ذلك ممكنا.وقد تؤثر العديد من العوامل - بما في ذلك الجوانب التنظيمية والمؤسسية والاجتماعية والفنية والمالية – على نجاح نهج الاستبدال.

لقد استخدمت المياه المستصلحة في القطاع الزراعي في الأردن منذ عقود، وكان الدافع الرئيسي من ذلك هو شح مصادر المياه العذبة - وهذا التغيير أثر بشكل كبير على القطاع إلا أن احتمالية أعادة الاستخدام المباشركانت ضعيفة .ومع ذلك، لا يزال الاستخدام المباشر للمياه المستصلحة غير شائع ويواجه العديد من التحديات،مثل: (1) التجزئة المؤسسية (توزيع المسؤوليات)، والتي بدورها تهدد تصميم وتنفيذ خطط إعادة الاستخدام الفعالة؛ (2) المعايير/المواصفات الفنية الحالية المتبعة عند إعداد مخططات المعالجة وإعادة الاستخدام على نطاق صغير؛ (3) النقص في وجود سوق عمل بشكل جيد، مما يحد من استخدام الأنظمة اللامركزية على نطاق واسع؛ و (4) عدم التقبل الاجتماعي.

لقد تجاهلت برامج التوعية العامة، مسألة تشجيع استخدام المياه المستصلحة. وبالتالي، يجب على الحكومة الاستثمار في برامج التوعية العامة التي تركز على شرح معالجة مياه الصرف الصحي وإعادة استخدامها وهنا بعض أهم القضايا ذات الصلة: (1) تقليل الفاقد من المياه العادمة المعالجة عن طريق الارتشاح والتبخركما هو الحال في قناة الملك عبد الله وتعزيز نقل وتخزين المياه العادمة المعالجة؛ (2) إنشاء وحدة/ هيئة مستقلة لمراقبة محطات معالجة مياه الصرف الصحي اللامركزية وشبه المركزية وإنشاء قاعدة بيانات رسمية لهذه المحطات؛ (3) إقرار مواصفات جديدة بخصوص التسجيل والإشراف وتقييم الأداء، وكذلك وضع آلية يمكن استخدامها لمراقبة نوعية المياه الخارجة والاستخدام النهائي للمياه العادمة المعالجة؛ (4) تحسين أداء بعض محطات معالجة المياه العادمة المركزية لتحقق المعايير المطلوبة في مواصفة إعادة الاستخدام الأردنية الحالية (893/2006).

ستقدم هذه الدراسة لمحة عامة عن الكميات الفعلية لمياه الصرف المعالجة وممارسات إعادة الاستخدام الحالية في الأردن. وباستخدام نظم المعلومات الجغرافية الذي يوضح وجود 33 محطة معالجة مركزية لمعالجة مياه الصرف الصحي التي تخدم المجتمعات التي يزيد حجمها عن 5000 مكافيء سكاني، وتمت مناقشة الكمية الفعلية للمياه المعالجة ونوعيتها (حوالي 163 مليون متر مكعب في عام 2018 (MWI, 2018)) ؛ وتم إعادة استخدامها بالإضافة إلى تقديم أمثلة لإعادة استخدام المياه العادمة المعالجة و الحمأة في الأردن.

علاوة على ذلك، تم تحديد 86 نظام معالجة يخدم المجتمعات والفنادق والمنازل الفردية التي يقل حجمها عن 5000 مكافيء سكاني ويتم عرض البيانات المتاحة مثل كمية المياه العادمة المعالجة ونوعيتها وإعادة الاستخدام.

يجب أن تكون نتائج هذه الدراسة بمثابة الأساس لإنشاء قائمة جرد وطنية خاصة بأنظمة المعالجة اللامركزية وإعادة استخدام المياه العادمة، مما يسهل تنسيق إجراءات التصاريح وتدابير الرقابة في الأردن.

ستقدم هذه الدراسة اثنين من تدابير السياسة الهامة والتي يمكنهما من تحسين الوضع الحالي واستخدامهما للتغلب على التحديات الموصوفة سابقا.حيث يتعلق تدبير السياسة الأول بتطوير واعتماد إطار مؤسسي لتخطيط سلامة الصرف الصحي (خطط سلامة الصرف الصحي) وما تلاه من تطوير وتوظيف خطط سلامة الصرف الصحي في مناطق تجمعات المياه المختلفة وفقا لمبادئ IWRM المقدمة في الاستراتيجية الوطنية للمياه 2016-2025. ستنظر خطط سلامة الصرف الصحي في جميع المدخلات الزراعية لتحديد أولويات المخاطر وتحديد تدابير الرقابة التي تقلل من المخاطر التي من الممكن وقوعها. هذا النهج من شأنه أن يسهل تنفيذ معايير جديدة من شأنها تحديد ميزانية لمعالجة مياه الصرف الصحي وإعادة استخدام المياه العادمة المعالجة. ويعتبر هذا أمر مهم، حيث أثبتت الاستثمارات في معالجة مياه الصرف الصحي أنها غير مجدية من قبل بسبب التلوث الذي يحصل لاحقا. علاوة على ذلك، ستقوم

خطط سلامة الصرف الصحي بتحديد الإجراءات المتعلقة بإدارة المياه العادمة، والتي سوف تقلل من العبء الحالي على سلطة المياه وتؤدي إلى تقاسم المسؤوليات بين الهيئات المحددة وأصحاب المصلحة. أما التدبير الثاني للسياسة فإنه يركز على إدخال نهج أكثر تكاملا لإدارة مياه الصرف الصحي يعتمد على مفهوم الاقتصاد الدائري (circular economy)، نأمل أن يؤدي هذا النهج إلى استرداد التكاليف وتحسين قبول المجتمع لمرافق محطات معالجة مياه الصرف الصحي في المجتمعات المحلية. يمكن بعد ذلك إنشاء مرافق استرداد المصادر - أو المنشآت الخضراء - لتشجيع الاستثمارات. حيث يمكن دعم هذا التدبير من خلال توفير وظائف محلية إضافية، إلى جانب معايير أكثر كفاءة لإدارة المياه المعالجة.

ستساعد هذه التدابير في عملية إدارة المياه الفعالة في الأردن على تحقيق الهدف السادس من أهداف التنمية المستدامة التي أدرجتها الأمم المتحدة، "ضمان الحصول على المياه والصرف الصحي للجميع".

Data Collection and Validation

The data used in the presented study were collected by the WEE Pros GmbH with the support of the NICE-Office in Jordan by means of literature reviews, meetings with stakeholders and field visits. Relevant technical data from literature and reports developed by the Ministry of Water and Irrigation (MWI), Water Authority of Jordan (WAJ), Ministry of Health (MoH), Ministry of Environment (MoEnv), Water Users Association (WUA), donors such as the German Agency for International Cooperation (GIZ), United States Agency for International Development (USAID), the United Nations (UN), and other Non-Governmental Organizations (NGOs), along with water utility and various private companies were reviewed and summarized.

After the data collection process, the entire dataset was validated to ensure reliability and that it can be presented in the most accurate manner. Data validation was done by comparing received and gathered data with available data, the literature review, official publications and reports, which were published by other projects/organizations. Interviews with relevant persons at WAJ and the Miyahuna Water Company were also part of the data validation process. Geographical data were validated by using GPS coordinates as well as software and Google Earth. The data concerning centralized wastewater treatment plants (CWWTPs), decentralized wastewater treatment plants (DWWTPs) and biosolids management and reuse are summarized.

Various meetings with different stakeholders were conducted with the purpose of gathering missing data, updating old information and verifying the available data. The stakeholders included the Municipality of Greater Amman, Water and Agriculture Department, WAJ, Housing and Urban Development Corporation, GIZ, NAWCO, MoA, National Agriculture Research Center (NARC), Jordan University of Science and Technology (JUST), MoH, Royal Scientific Society (RSS), and the Inter-Islamic Network on Water Resources Development and Management. Moreover, 13 site visits to farms were conducted. The aim of these visits was to collect data which describe cropping patterns, cropping yields, as well as the irrigation systems applied by farmers.

GIS-based analysis

Geographic mapping using Geographic Information System (GIS) was performed at the national level to present available data for CWWTPs and DWWTPs, including reuse purposes and locations in Jordan. The development of the Geo-Database System comprised the following activities:

- GIS data received from NICE Office, literature review, and technical reports, GIS acquisition from field visits, GIS survey administration and an analysis of the results;
- Design and creation of a comprehensive geo-database using GIS; and development of national thematic layers and maps that illustrate different figures, statistics, descriptions and info-graphical designs.

1

Introduction

Jordan is a nation burdened by extreme water scarcity, a factor which has always been one of the biggest barriers to the country's economic growth and development. Jordan has one of the lowest levels of water availability per capita in the world and, as such, is constantly being challenged by water shortages. In addition, meeting water demands has become more difficult due to climate change.

The average annual per capita renewable water share does not exceed 100 m^3 (Halalsheh et al., 2018a), which is far below the global threshold for severe water scarcity (500 m^3 per capita per year). Challenges related to water scarcity have recently been aggravated by an influx of refugees, which is related to ongoing political unrest in the region. Furthermore, water scarcity challenges are exacerbated by the worsening drought conditions associated with climate change.

Jordan has very limited freshwater resources and is classified as a semi-arid to arid country, e.g., annual rainfall of less than 200 mm over 92% of the land. The country comprises 89.297 km^2, with 92% of the area considered to be desert/rangeland. Groundwater is the main source of freshwater in Jordan. However, more than 50% (301 MCM/year in 2016) of the total groundwater abstraction is considered unsustainable due to over-exploitation or abstraction from non-renewable fossil aquifers. Furthermore, the indirect disposal of untreated wastewater through cesspools or leaking sewer systems has further jeopardized the quality of country's scarce groundwater resources.

Moreover, competition among the domestic, agricultural and industrial sectors seriously burdens water sustainability. However, only 5% of the land receives enough rainfall to support cultivation. Even though farmers irrigate less than 10% of the total agricultural land, agricultural water requirements accounted for around 52% of national water needs - estimated at 571 MCM (MWI, 2018). This is controversial because the agricultural sector only contributed 3 – 4% to gross domestic production (GDP) in 2013 (MWI, 2016a).

Current efforts aiming to improve the performance of the Jordanian agricultural sector mainly focus on the sector's productivity, efficiency, and responsiveness to changing environmental conditions, such as decreases in soil quality and water supply (Sidahmed et al., 2012). It is important to note that 28.6% of the irrigation water used in Jordan is covered by TWW (**Table 1**).

Table 1 Irrigation water supply (in MCM) by water resource in 2017 (MWI, 2018).

Water resource	Irrigation use (MCM/year)	Percentage of water resource
Surface water	154.4	27.0%
Groundwater	253.2	44.3%
Treated wastewater	163.4	28.6%
Total	**571.0**	**100%**

1.1 Wastewater sector in Jordan

Despite facing severe challenges in water supply, Jordan has managed to provide approximately 67% of its population (5.8 million inhabitants) with a sewerage network (MWI, 2018). Furthermore, the reuse of TWW in agriculture is a well-established practice and has been identified as a priority by the government. A large amount of the TWW is used for agricultural production and, in most cases, is mixed with freshwater resources. However, this figure does not consider the losses through evapotranspiration and infiltration, among others, which have been shown to nearly halve the TWW supply (MWI, 2018). The rest of the population is served by onsite management systems, which mainly consist of cesspools, where unwanted infiltration of unpurified wastewater leads to serious contamination of the groundwater. The Government's strategy for wastewater collection and treatment is relatively comprehensive: there are 33 CWWTPs under the jurisdiction of the WAJ, which are expected to treat 240 MCM/year by 2025 to contribute approximately 16% to the total water budget. The treatment process includes "*as a minimum secondary biological treatment is applied and about 70% of the collected wastewater goes beyond and receives tertiary treatment*" (Halalsheh et al., 2018a).

The development of the wastewater sector also involves the adequate treatment, discharge or reuse of biosolids.

The reuse of biosolids may be possible in the future, but only if the quality of the biosolids is compatible with Jordanian Standards (JS 1145, 2016). Currently, sludge is not stabilized in most WWTPs. In general, biosolids are dried in so-called sludge drying beds and are either stored at the WWTP or transported to a landfill (AECOM, 2014).

According to the National Water Strategy 2016 – 2025, wastewater shall not be managed as waste but as a non-conventional water resource (MWI, 2016a). It shall be collected and treated to standards that allow it to be reused in agriculture (unrestricted irrigation) and other non-domestic purposes, including groundwater recharge (Barceló et al., 2011). The National Water Strategy, which recommends an overarching monitoring and evaluation policy for the performance of the water sector, further aims to revise the institutional and legal frameworks to streamline wastewater management.

1.2 Challenges in the water sector of Jordan

Treated wastewater has been reused in the Jordan Valley (JV) since the early 1980s. When considering how other countries in the MENA region use TWW for agricultural production, Jordan still faces challenges that can be categorized under two issues. The first issue is related to the increased demand in wastewater collection and treatment. This issue also covers the lack of available (economically viable) services in the scattered communities of rural areas and in the rapidly expanding peri-urban areas. The lack of such services severely impedes the full utilization of wastewater and, perhaps more importantly, the prevention of potential groundwater contamination. The high investment costs associated with conventional wastewater collection systems hindered the expansion of sanitation services to such communities. The only feasible solution would be the adoption of a new paradigm that proposes decentralized sustainable sanitation options as the core approach. A decentralized sanitation system integrates a variety of approaches for the collection, treatment, and disposal/reuse of wastewater from individual households, industrial sites, institutional facilities, clusters of homes or businesses, and entire communities. The main advantage of this type of system is that it can service areas that cannot be managed by centralized wastewater systems due to technical and financial constraints.

The second issue is related to the current policy, and comprises aspects such as the lack of socio-cultural acceptance, relatively limited government support, and the absence of a legal framework and related institutional arrangements. The science-policy interface is also indirectly linked to the limited valorization of wastewater in Jordan, as the inadequate collaboration between scientific experts and government entities means that technological advances are generally only adopted after a significant delay.

Demonstration projects, as well as improved communication and coordination, are required to accelerate the application of beneficial new concepts.

1.3 Wastewater reuse in Jordan

The scarce supply of water in Jordan has forced the MWI to pass a water management strategy that emphasizes the reuse of TWW as an additional water resource and method to improve the efficiency of water usage. Wastewater reuse has been included in the National Water Strategy since 1998 and the government has demanded that every new wastewater treatment project includes an investigation of reuse options. Guidelines for various reuse options were issued in 1995 (JS 893, 1995), while revised, and more stringent, standards were enacted in 2003 (JS 893, 2002); for example, it is prohibited to irrigate vegetables that will be eaten raw or recharge aquifers for potable use. The use of sprinklers for irrigation with TWW is only allowed at golf courses when irrigation is practiced during night. Further revisions in 2006 specified the quality standards for wastewater to be discharged into wadis/streams or used for irrigation (**Table 2**). include advice on irrigation practices and human exposure control (Kramer et al., 2007).

The standard JS 893 (2006) is currently under review by JSMO (Jordan Standards and Metrological Organization) and is expected to be published in 2020.

The past ten years have been defined by large investments for the construction of WWTP as key facilities for the implementation of water reuse strategies. The National Water Strategy 2016 – 2025 envisions that all TWW should be used for irrigation, as well as includes provisions for greywater reuse and rainwater harvesting at the domestic scale.

Table 2 Quality characteristics of treated wastewater to be used in irrigation and to be discharged to streams, wadis and water bodies according to JS 893 (2006).

Parameters		Maximum allowable limits				
		Irrigation				Discharged to streams, wadis & water bodies
	Unit	Vegetables cooked, parks, stadiums & side roads within cities	Fruit trees, road outside cities & green landscapes	Field crops, industrial crops & forest trees	Cut flowers	
Class		**A**	**B**	**C**		
BOD	mg/l	30	200	300	15	60
COD	mg/l	100	500	500	50	150
DO	mg/l	≥ 2	–	–	≥ 2	≥ 1
TSS	mg/l	50	200	300	15	60
pH	unit	6 – 9				6 – 9
Turbidity	NTU	10	–	–	5	–
NO_3^-	mg/l	30	45	70	45	80
TN	mg/l	45	70	100	70	70
E. coli	MPN/100ml[a]	100	1000	–	≤ 1.1	1000
Intestinal Helminthes Eggs	Egg/l	≤ 1				≤ 0.1
Fat, Oil and Grease	mg/l		8		2	8

BOD: Biochemical Oxygen Demand; *COD:* Chemical Oxygen Demand; *DO:* Dissolved Oxygen; *TSS:* Total Suspended Solids; *NO_3^-*: Nitrate; *TN:* Total Nitrogen; *E. coli: Escherichia coli;* [a]Most Probable Number per 100 ml.

Treated wastewater is used for restricted irrigation, while blended water (TWW mixed with rain water/freshwater) is mainly used in the Jordan Valley for the unrestricted irrigation of different fruits and vegetables. Drip irrigation systems show relatively high efficiency and can save significant amounts of water, which is relevant to the severe water shortages of Jordan. Moreover, Jordan is currently trying to improve water availability by influencing water demand behavior, optimizing water transfer and allocation, reusing TWW in irrigation, and providing additional freshwater sources by desalination. The Government of Jordan (GoJ) has recently developed and adopted several policies that specifically focus on wastewater reuse. For example, the Water Substitution and Reuse Policy was drafted to alleviate the pressure caused by water shortages. Additional policies – such as the Water Reallocation Policy and the decentralized wastewater management (DWWM) Policy – are all part of the National Water Strategy 2016 – 2025 (MWI, 2016a). The MWI is currently developing action plans for these policies that would optimize the management of Jordan's scarce water resources.

— *Farmers agreement*

Fields of crops and olive trees are irrigated with TWW in the surrounding areas of the CWWTPs. In regard for providing farmers with TWW for irrigation purposes, an agreement with MWI/WAJ has to be signed. The WAJ has entered into 263 agreements with farmers which specify that the water is to be directly used for either fodder crops or trees (mainly olive trees) (**Table 2**). The farmer-WAJ agreement defines the amount of water that each farmer will receive, as well as defines the roles and responsibilities of each party. The agreement includes the following main clauses:

- The "*Farmer*" will be responsible for abstracting the defined quantity of TWW from the location defined by MWI/WAJ, through pipes using natural flow or via pumping according to the specifications defined by the WAJ. The abstraction must be performed in a way that protects both the environment and public health. The cost of electricity used in pumping operations will be the responsibility of the farmer.
- The "*Farmer*" is committed to pay the amount of 40 Fils per m^3 as the cost of the consumed water in addition to 10 Fils/m^3 as a contribution for the electricity cost, paid to the Authority within one month of receiving the invoice.
- The "*Farmer*" is committed to use the TWW for irrigating fodder crops and in restricted irrigation, and not to use the TWW for irrigating vegetables that can be eaten raw. In the case of maize, the "*Farmer*" is committed to harvesting the crop before its maturity and using it as a food for livestock. Overall, all of the products irrigated by TWW should be consistent within JS 893 (2006). Any violation will give MWI/WAJ the right to terminate the agreement without compensation.
- The "*Farmer*" can be expected to know that the provided water is TWW that may contain microbiological pollutants; hence, its purity and chemical composition cannot be controlled. Accordingly, MWI/WAJ is not responsible for changes in the chemical, physical, biological and/or microbiological characteristics of the TWW. Thus, farmers should be aware of the results of the TWW analyses provided by the WAJ.

— Applied irrigation systems

There is currently a vast array of irrigation systems available. It is not a technical challenge, however, it is more an issue of hygiene and health precautions (DWA, 2019).

One of the challenges are that even if proper irrigation systems are in place often the systems are influenced by a lack of supplies, neglected maintenance, poor quality monitoring and management that could lead to "microbial re-contamination" of the irrigation water (DWA, 2019).

The choice of system is influenced by the type of crops, soil and irrigation water quality, and must ensure a uniform distribution of water.

Many irrigation methods are applied in Jordan, including border/surface-irrigation, drip-irrigation, and sprinkler irrigation systems. These systems are mainly used to irrigate fodder crops, olive trees, and urban landscapes in close proximity to CWWTPs with TWW.

Border/Surface irrigation

This system relies on furrows in the soil that allow water to pass and irrigate crops. Border irrigation systems use a flat basin (furrow) with a gentle slope and edges to ensure that all the plants receive water.

Advantage: washing down salts when using saline water such as TWW.

Disadvantage: direct human contact and low water efficiency by infiltration and evaporation.

Drip irrigation

Drip or trickle irrigation uses a pipeline network to distribute water among crops. In this system, water is conveyed drop by drop to the root zone of plant. This system can be the most efficient method of irrigation, as evaporation and runoff are minimized when the system is properly managed.

Advantage: Further reduction of pathogens (WHO, 2006c) and limited risk for direct contact.

Disadvantage: Salt accumulation in upper soil layer due to reduced infiltration.

Sprinkler irrigation[1]

In sprinkler irrigation systems, water is transported to one or more central locations within a field and distributed to crops by overhead sprinklers.

Advantage: Water use efficient.

Disadvantage: Formation of aerosols and higher risk of direct contact with TWW; high water quality required.

[1] According to JS 893 (2006), TWW is only allowed to be used for golf courses when irrigated during night.

2

Centralized Wastewater Treatment Plants

The data from MWI reports were complemented with field visits and meetings to gather relevant information.

The collected data demonstrated that the WAJ is currently responsible for 33 CWWTPs (**Table 3; Figure 1**). There are 11 CWWTPs in the Northern Governorates, 12 CWWPTs in the Middle Governorates, and 10 CWWTPs.

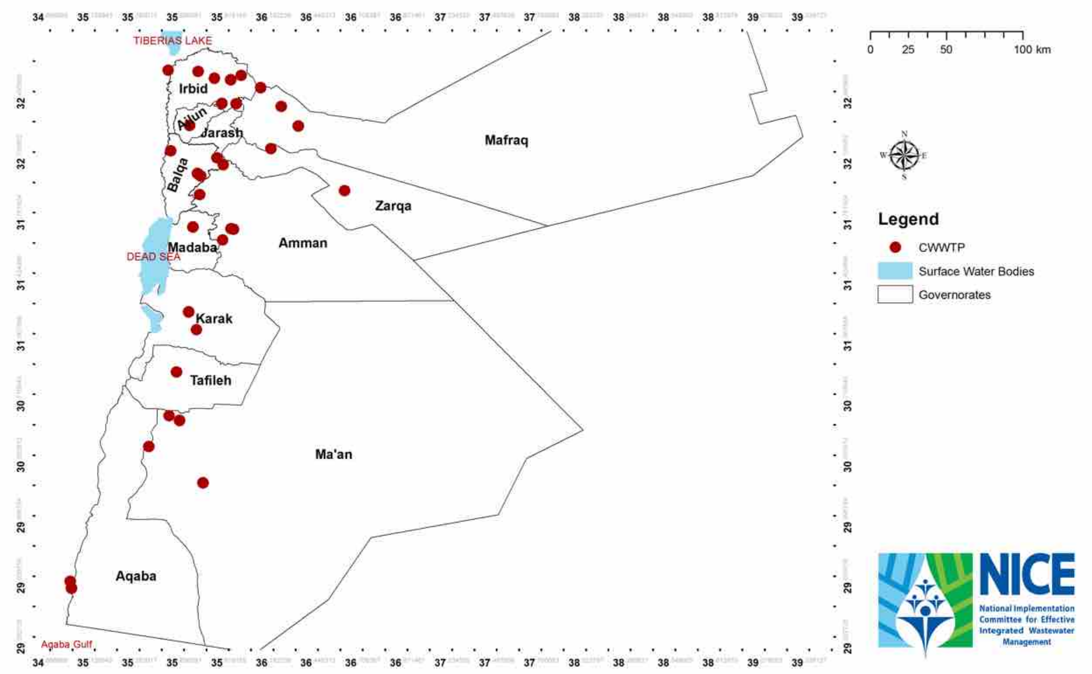


Figure 1 Locations of the 33 centralized wastewater treatment plants in Jordan.

Around 90% of the wastewater is produced in the middle governorate, as this is the region where most of Jordan's population is concentrated. When accounting for the minor quantity of TWW that is reused in the vicinity of WWTPs, about 80% of TWW is only reused after being discharged to wadis. The TWW used for irrigation is primarily meeting Class C of JS 893 (2006) (**Table 2**).

Of the 33 CWWTPs currently in operation in Jordan, the Al-Sharea'a facility, Mansorah and Shobak WWTPs are classified as CWWTPs according to the annual reports from MWI and WAJ. However, based on the design capacity of these WWTPs and according to the DWWM Policy (MWI, 2016b) – in which decentralized wastewater treatment systems are specified as having a design flow equivalent to ≤ 5.000 PE or a hydraulic capacity of ≤ 182.500 m^3/year (calculated with a specific wastewater production of 100 l per person per day) – these WWTPs should be classified as DWWTPs. Furthermore, Al-Sharea'a is rather a facility that is only used for cleaning/washing filters.

Nevertheless, the 33 CWWTPs classified according to WAJ will be used in this study.

Table 3 Available data for centralized wastewater treatment plants in Jordan (MWI, 2018; UNHCR, 2018).

No.	Region	Governorate	WWTP	Design capacity	Influent quantity	Effluent quantity	Reuse of Reclaimed Water: Irrigation	Forestry	Land-scaping	Discharge to wadis	Industry
				MCM/ year							
1	North	Irbid	North Shouna	0.4	0.2	0.2	0	0	0	0.2	0
2		Irbid	Wadi Arab	7.7	4.6	4.5	0	0	0	4.5	0
3		Irbid	Irbid Center	4.0	3.0	2.9	0	0	0	2.9	0
4		Irbid	Ramtha	2.7	1.6	1.4	1.4	0	0	0	0
5		Irbid	Wadi Shallaleh	5.0	3.1	2.9	0	0	0	2.9	0
6		Mafraq	Ekedar	1.5	0.8	0.7	0.7	0	0	0	0
7		Jarash	Me'yrad	3.3	1.6	1.6	0.5	0	0	1.1	0
8		Irbid	Wadi Hassan	0.6	0.5	0.4	0.4	0	0	0	0
9		Mafraq	Za'atari Camp	1.3	0.5	0.5	0.5	0	0	0	0
10		Mafraq	Mafraq	2.2	1.4	1.4	1.4	0	0	0	0
11		Ajlun	Kufranja	3.1	1.3	1.2	1.0	0.2	0	0	0
12	Middle	Balqa	Tal Mantah	1.8	0.1	0.1	0	0	0	0.1[$]	0
13		Balqa	Baqa'a	5.4	5.3	5.1	0.4	0	0	4.7	0
14		Balqa	As-Salt	2.8	3.0	2.8	1.0	0	0	2.8	0
15		***Balqa***	***Al-Sharea'a***	-	-	-	-	-	-	-	-
16		Balqa	Fuheis-Mahes	1.5	1.17	1.0	0.3	0	0	0.7	0
17		Zarqa	Azraq Camp	0.3	0.1[&]	0.1	0.1	0	0	0	0
18		Zarqa	Samra	130	125.8	115.7	10.0	0	0	105.3	0
19		Amman	Abu Nuseir	1.5	1.2	1.2	0	0	0.2	1.0	0
20		Amman	Jiza	1.5	0.3	0.3	0.3	0	0	0	0
21		Amman	South Amman	29.0	4.9	4.8	1.1	0	0	3.3	0.4
22		Amman	Wadi Esseir	17.5	1.8	1.8	0.8	0	0	1.0	0
23		Madaba	Madaba	2.8	2.7	2.3	2.3	0	0	0	0
24	South	Karak	Karak	0.7	0.5	0.5	0.5	0	0	0	0
25		Karak	Lajoon	0.4	0.7	0.3	0.1	0	0	0	0
26		Tafileh	Tafila	2.7	0.7	0.7	0	0	0	0.7	0
27		***Ma'an***	***Mansorah***	***0.02***				-			
28		***Ma'an***	***Shobak***	***0.1***	***0.1***	***0.1***	***0.1***	***0***	***0***	***0***	***0***
29		Ma'an	Wadi Mousa	1.2	1.0	1.0	1.0	0	0	0	0
30		Ma'an	Ma'an	2.1	0. 9	0.5	0.5	0	0	0	0
31		Karak	Mutah-Mazar	2.6	0.5	0.4	0.1	0	0	0.3	0
32		Aqaba	Aqaba-Mechanical	4.7	4.6	4.5	1.7	0	0	0	2.8
33		Aqaba	Aqaba-Natural	3.0	2.6	2.5	0	0	1.9	0	0.6
			Total:			**163.4**	26.1	0.2	1.9	131.4	3.8

[&] UNHCR (2018); [$] TWW is stored in evapotranspiration ponds. N/A: not available; MCM: Million cubic meter.

2.1 Northern Governorates

There are 11 CWWTPs in the Northern Governorates (**Figure 2**). These WWTPs produce a total TWW quantity of 17.7 MCM/year, with 6.9 MCM of this amount directly reused each year. The remaining TWW, which corresponds to 11.6 MCM and is mainly produced by Wadi Arab, Irbid Center, Wadi Shallaleh and North Shouna, is indirectly reused and discharged to wadis leading to the Jordan river (**Table 3**).

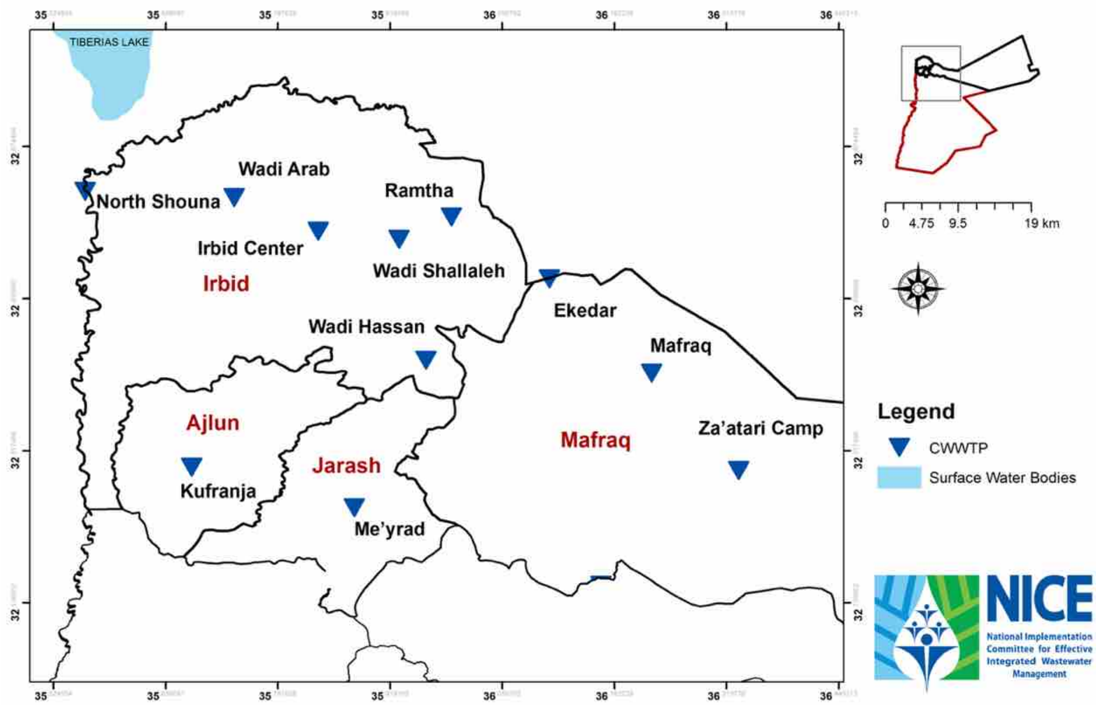


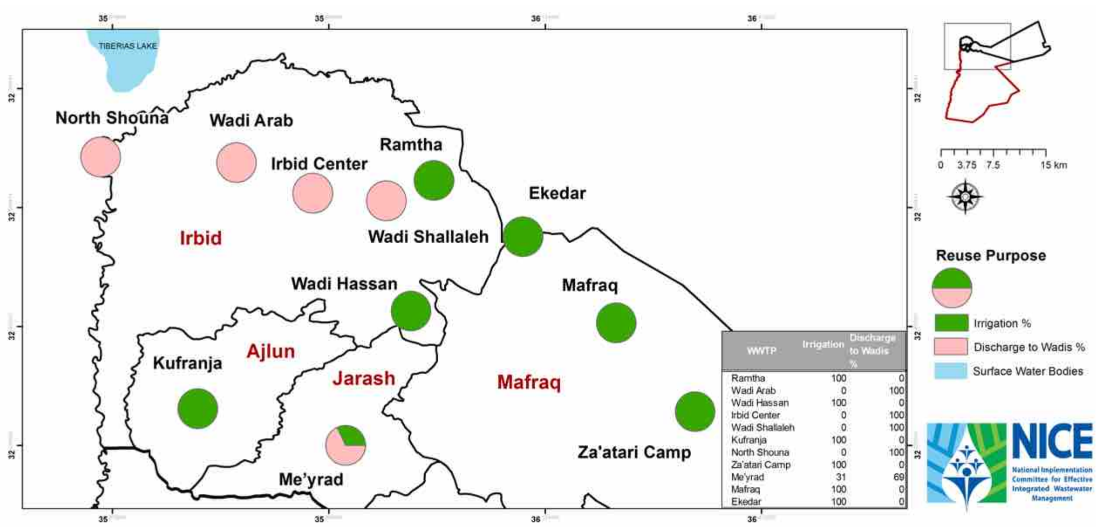
Figure 2 Locations of the centralized wastewater treatment plants in the Northern Governorates.

In the Ramtha, Wadi Hassan, Kufranja, Za'atari Camp, Mafraq and Ekeder facilities, 100% of the TWW is currently used for direct agricultural irrigation purposes. In contrast, only 31% of the TWW produced at the Me'yrad CWWTP is directly reused for irrigation while 69% is indirectly reused through discharge to wadis.

It is important to note that none of the TWW produced at the North Shouna, Wadi Arab, Irbid Center and Wadi Shallaleh facilities is used for direct irrigation purposes (**Figure 3**). Areas that are directly irrigated with TWW are mainly found around the Ramtha, Ekedar, Wadi Hassan, Kufranjah and Mafraq facilities, while the TWW from the North Shouna, Wadi Arab, Irbid Center and Wadi Shallaleh facilities is only used for indirect reuse.

In terms of TWW quality in the Northern Governorates, the BOD_5, COD and TN values of the effluents from CWWTPs are all below their respective maximum limits (Class C). An exception is the Ekedar WWTP, where BOD_5, COD and TN values all clearly exceed the maximum limits. The *E. coli* concentrations were generally higher than the permissible limits for discharge to streams, wadis and water bodies (JS 893, 2006) at locations where indirect use is present. This refers to the following facilities: Irbid Center: BOD_5, COD, *E. coli*; Wadi Shallaleh: COD, *E. coli*; North Shouna: COD, TN, *E. coli*; and Wadi Arab: *E. coli*.

Treated wastewater is distributed among farmers according to the signed agreements with the WAJ, with the allocated water quantity proportional to the irrigated area (**Annex Figure 1**).



WWTP	Irrigation	Discharge to Wadis %
Ramtha	100	0
Wadi Arab	0	100
Wadi Hassan	100	0
Irbid Center	0	100
Wadi Shallaleh	0	100
Kufranja	100	0
North Shouna	0	100
Za'atari Camp	100	0
Me'yrad	31	69
Mafraq	100	0
Ekedar	100	0

Figure 3 Treated wastewater reuse purposes in the Northern Governorates.

For instance, TWW from the Ramtha CWWTP is distributed among 20 farmers who manage a total irrigated area of 1182 du (**Annex Figure 4**).

The irrigated areas surrounding the Ekeder, Wadi Hassan, Kufranja,

Me'yrad, Ramtha, Mafraq and Za'atari camp facilities employ border irrigation systems (**Figure 4**).

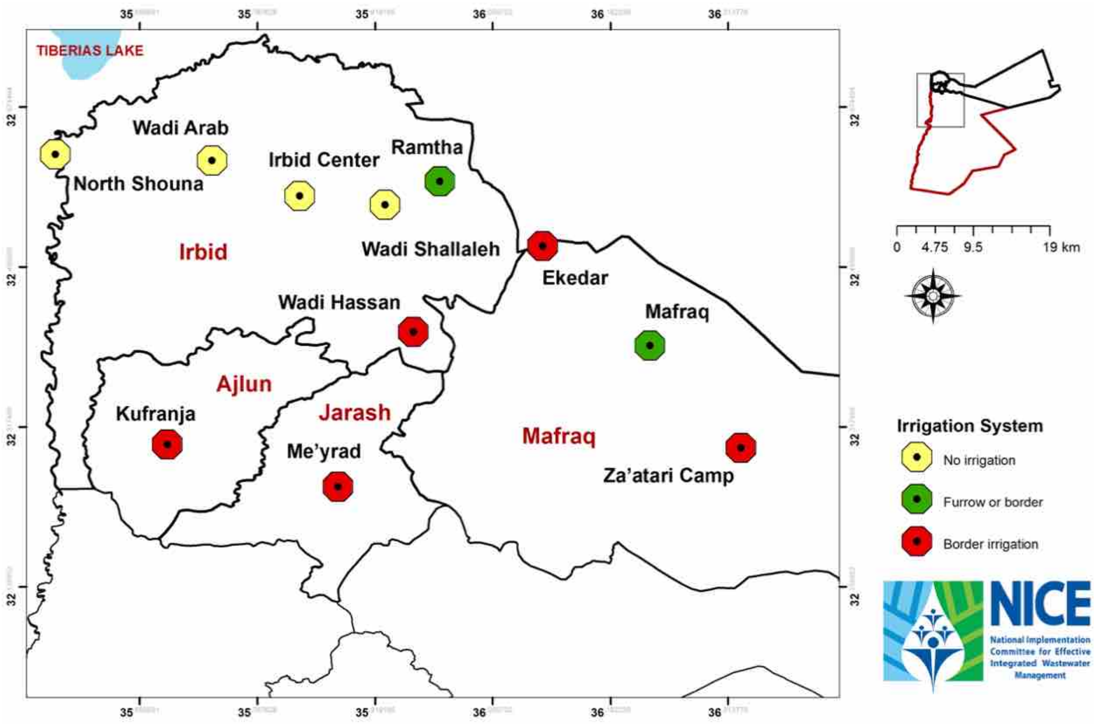


Figure 4 Irrigation systems in place for direct TWW reuse in the Northern Governorates.

2.2 Middle Governorates

The WAJ states that the Middle Governorates operate 12 CWWTPs. However, the Al-Sharea'a WWTP is only a station for cleaning filters; therefore, it should not be considered a CWWTP and is not displayed in **Figure 5**.

Facilities in the Middle Governorates produced a total of 135.2 MCM of TWW in 2017 (**Table 3**; **Annex Figure 2**).

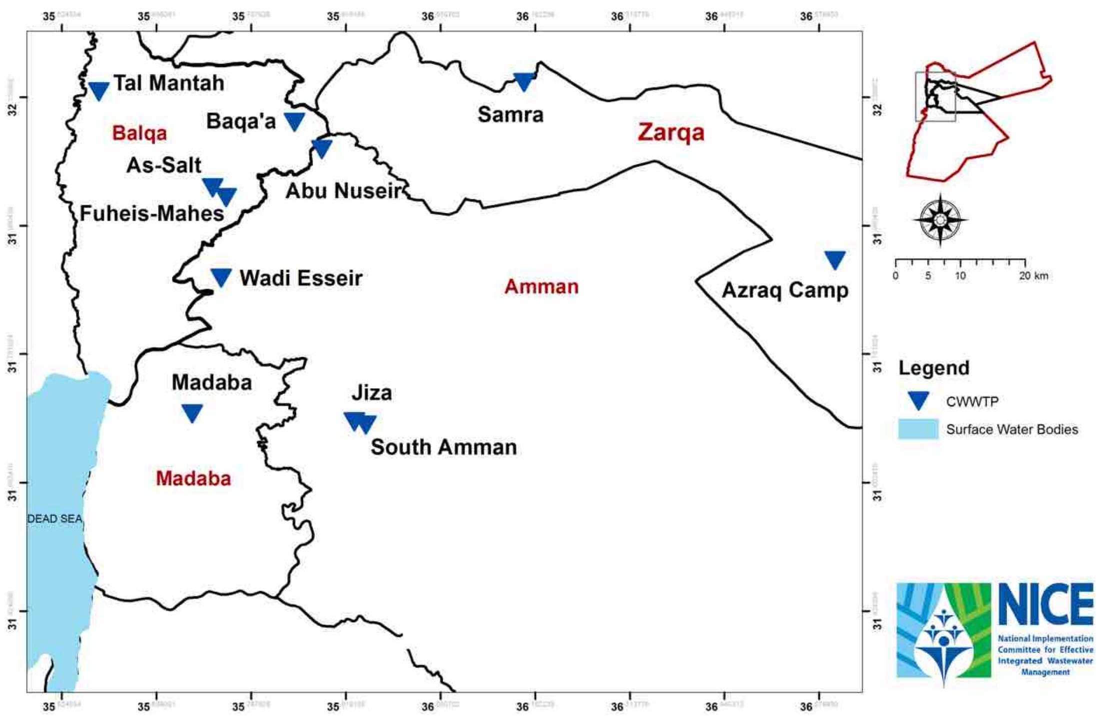


Figure 5 Locations of the centralized wastewater treatment plants in the Middle Governorates.

Of the 16.6 MCM that is reused directly, 16.2. MCM was used for irrigation/lanscaping and 0.4 MCM was used in industry, while the remaining TWW (118.8 MCM) was discharged to wadis leading towards King Talal Dam (**Table 3**; **Annex Figure 5**).

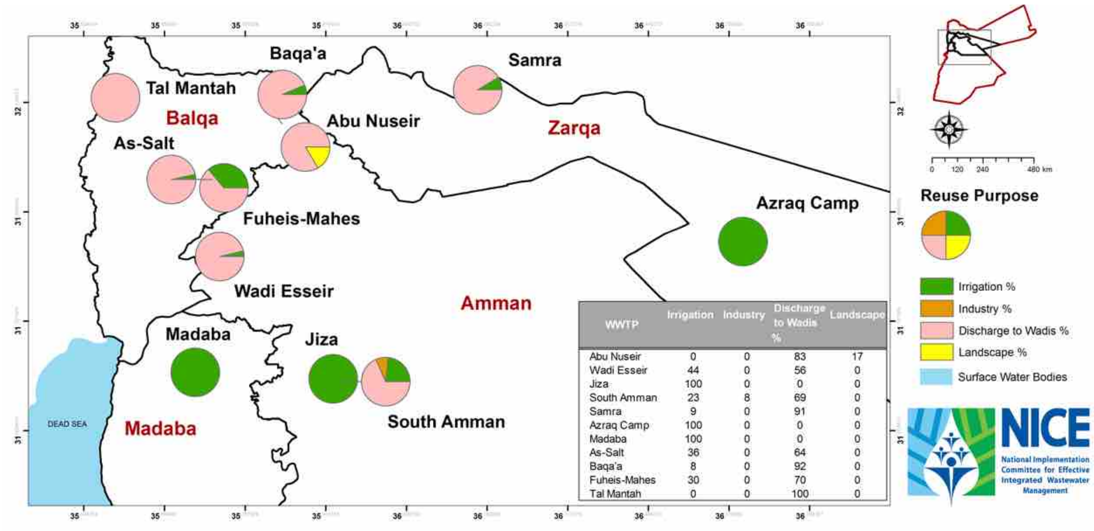
All of the effluent from the Madaba, Jiza and Azraq Camp CWWTPs is used for direct irrigation, while significantly smaller amounts of TWW produced at the South Amman, Wadi Esseir, Fuheis-Mahes, As-Salt, Samra and Baqa'a CWWTP are directly reused in irrigation. In terms of the quality of the TWW used for direct irrigation, the BOD_5, COD, TSS, TN, and Nitrate concentrations are all below the maximum limits of Class C of JS 893 (2006).

The majority of the TWW produced by CWWTPs in the Middle Governorates is not directly reused in the vicinity of the WWTPs, and several TWW quality parameters often exceed the permissible limits for discharge to streams, wadis and water bodies (JS 893, 2006).

Examples include Tal Mantah (BOD_5, COD, TSS, TN; *E. coli*), Wadi Esseir (COD; TSS, TN; *E. coli*), South Amman, As-Salt, Baqa'a and Fuheis-Mahes for *E. coli*.

The TWW produced at the Samra WWTP is mainly indirectly reused (91%) in the Jordan Valley after blending with rain water harvested at the King Talal Dam (**Figure 6**).

Currently, the TWW for direct irrigation (9%) at the Samra CWWTP is distributed among 55 farmers who manage a total irrigated area (direct irrigation) of 2281 du (MWI et al., 2017); (**Annex Figure 5**).



WWTP	Irrigation	Industry	Discharge to Wadis %	Landscape
Abu Nuseir	0	0	83	17
Wadi Esseir	44	0	56	0
Jiza	100	0	0	0
South Amman	23	8	69	0
Samra	9	0	91	0
Azraq Camp	100	0	0	0
Madaba	100	0	0	0
As-Salt	36	0	64	0
Baqa'a	8	0	92	0
Fuheis-Mahes	30	0	70	0
Tal Mantah	0	0	100	0

Figure 6 Treated wastewater reuse purposes in the Middle Governorates.

Drip and furrow irrigation systems are the most commonly used irrigation system in the Middle Governorates, accounting for about 90% of the irrigation of forage crops, while border irrigation systems are used for other types of crops (**Figure 7**). At the Samra and South Amman WWTP sprinkler irrigation systems are used, although not allowed according to JS 893 (2006).

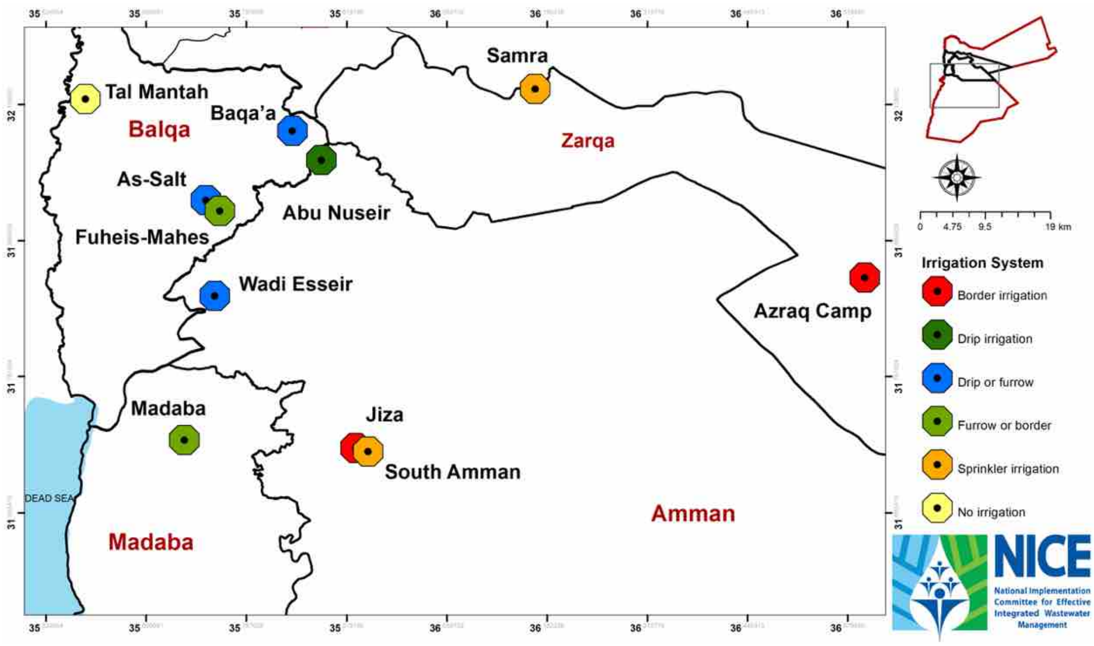


Figure 7 Irrigation systems in place for direct TWW reuse in the Middle Governorates.

2.3 Southern Governorates

The 10 CWWTPs in the Southern Governorates are shown in **Figure 8**. The Mansorah and Shobak WWTPs are classified as CWWTPs by the WAJ; however, according to the DWWM Policy (MWI, 2016b), they should be classified as DWWTPs based on their design capacity. These WWTPs produce an annual total of 10.5 MCM of TWW. The majority of this TWW quantity is produced by the Aqaba-Mechanical (4.5 MCM/year) and at Aqaba-Natural (2.5 MCM/year) facilities (**Table 3**; **Annex Figure 3**). Relative to the North and Middle Governorates, significantly more effluent is used for industrial purposes (32%) in the Southern Governorates. Of the remaining TWW, around 38% is used for irrigation, 18% is used for landscaping and 10% is discharged to wadis. The effluent that is used for industrial purposes mainly stems from the Aqaba Mechanical (62% of the effluent is used for industrial purposes), and Aqaba Natural (24%), WWTP (**Figure 9**; **Table 3**). The industrial applications are limited to the concrete, paper and iron industries.

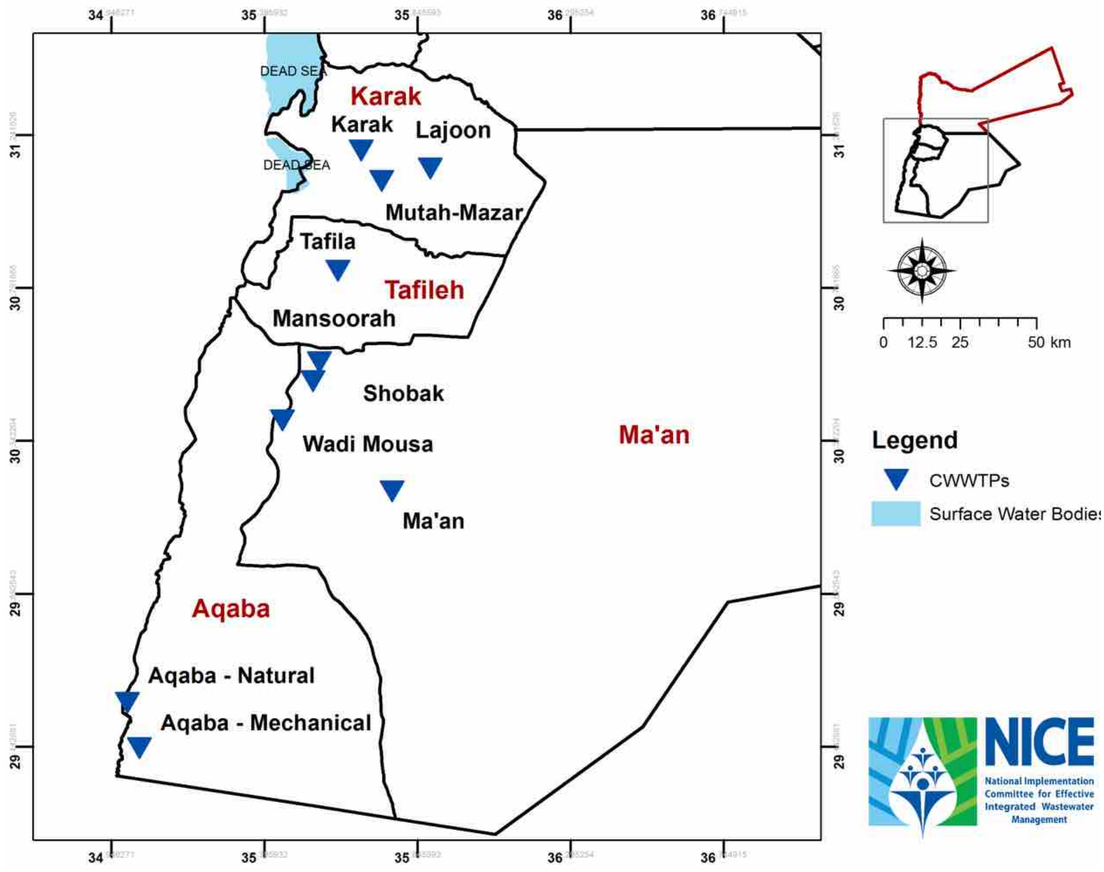
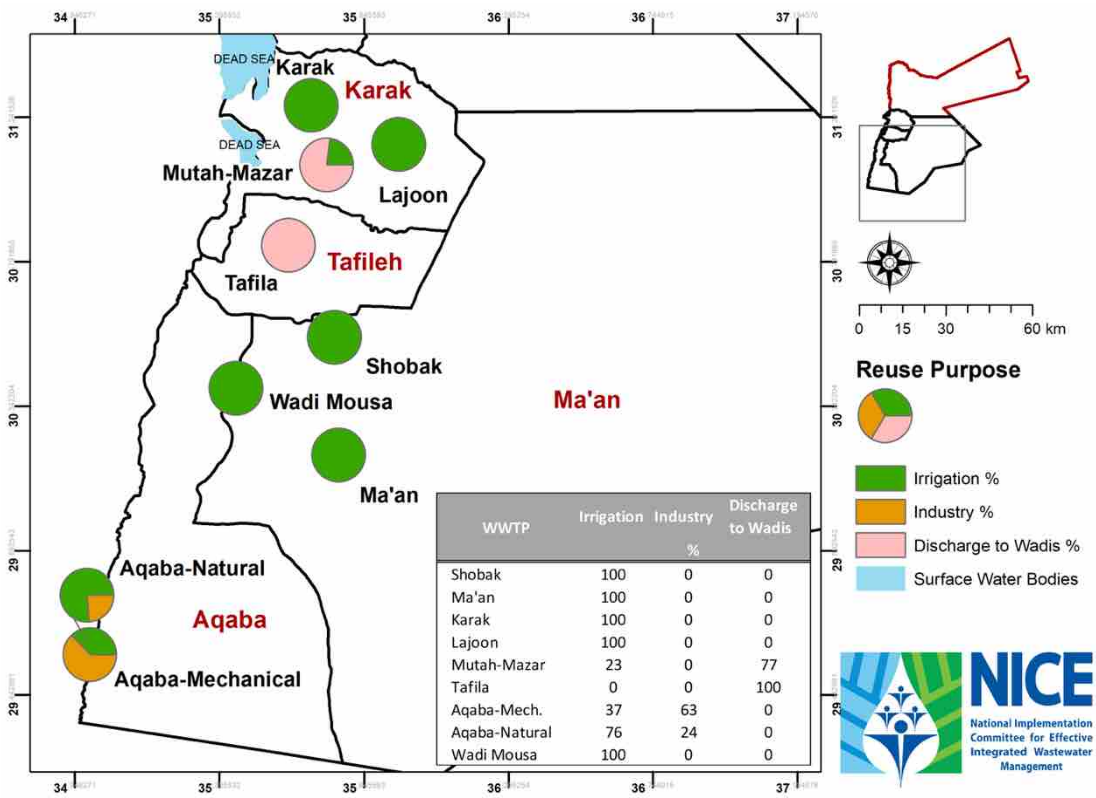


Figure 8 Locations of the centralized wastewater treatment plants in the Southern Governorates.

All of the TWW produced at the Ma’an, Karak, Wadi Mousa and Lajoon WWTPs is used for direct irrigation, while 100% of the TWW from the Tafila and Shobak WWTPs, and 75% from Mutah-Mazar WWTP, is discharged to wadis (indirect reuse; **Figure 9**).

Several CWWTPs produced TWW that did not meet certain quality parameters according to Class C of JS 893 (2006): Karak (BOD_5, COD, TN) and Lajoon (Nitrate).

Furthermore, several WWTPs produce TWW that does not meet the standards for discharge to streams, wadis and water bodies (JS 893, 2006); namely, the TWW produced at the Tafila CWWTP exceeds the maximum levels set for BOD_5, COD, TN, and *E. coli*, while the TWW produced at the Mutah-Mazar CWWTP exceeds the maximum level for TN and *E. coli.*



WWTP	Irrigation	Industry %	Discharge to Wadis
Shobak	100	0	0
Ma'an	100	0	0
Karak	100	0	0
Lajoon	100	0	0
Mutah-Mazar	23	0	77
Tafila	0	0	100
Aqaba-Mech.	37	63	0
Aqaba-Natural	76	24	0
Wadi Mousa	100	0	0

Figure 9 Treated wastewater reuse purposes in the Southern Governorates.

The TWW produced at the Ma'an CWWTP is distributed among nine farmers who manage a total area of 362.7 du (**Annex Figure 6**).

The WAJ has allocated 3 m^3 TWW per day for each dunum, and the main irrigation system currently in use in the Southern Governorates is border irrigation, which is used to irrigate forage crops. Drip irrigation is used in smaller fields of forage crops and in landscaping (**Figure 10**).

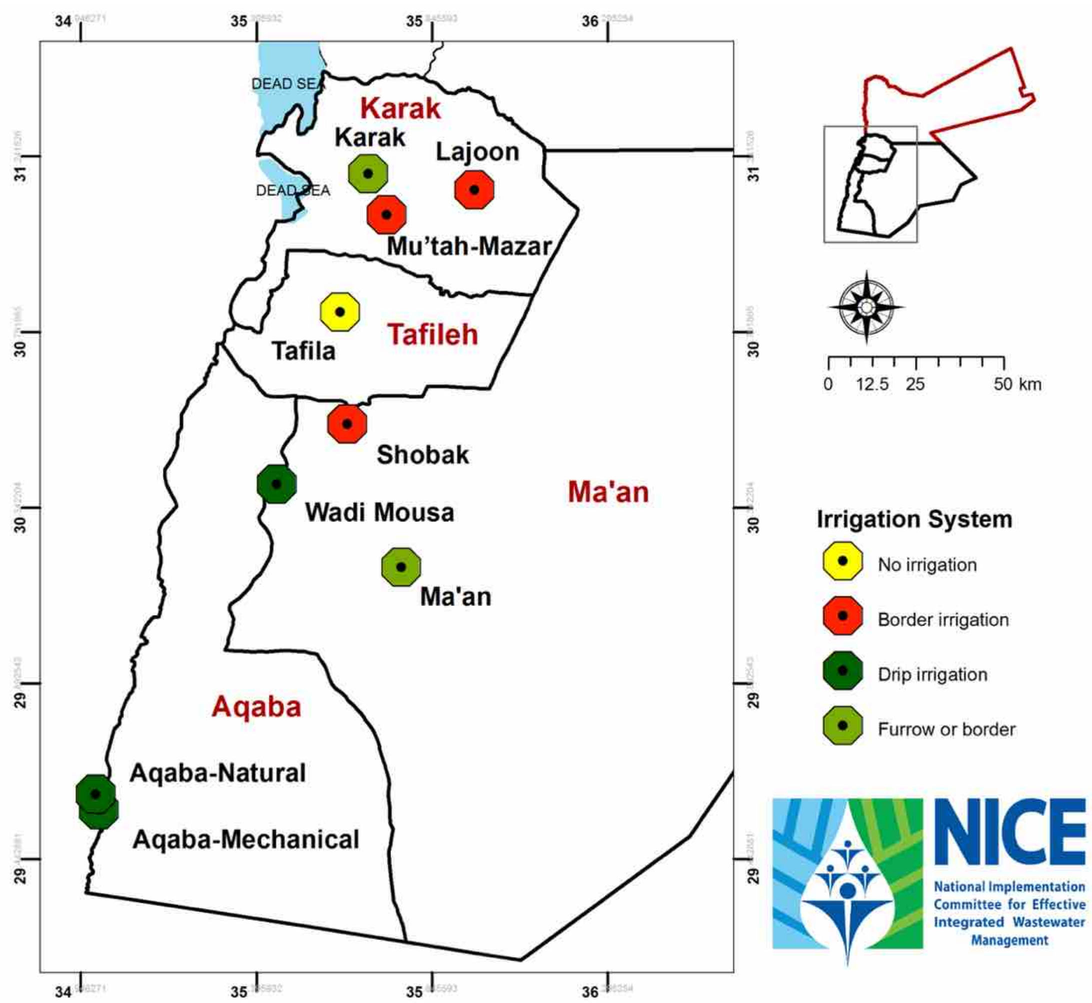


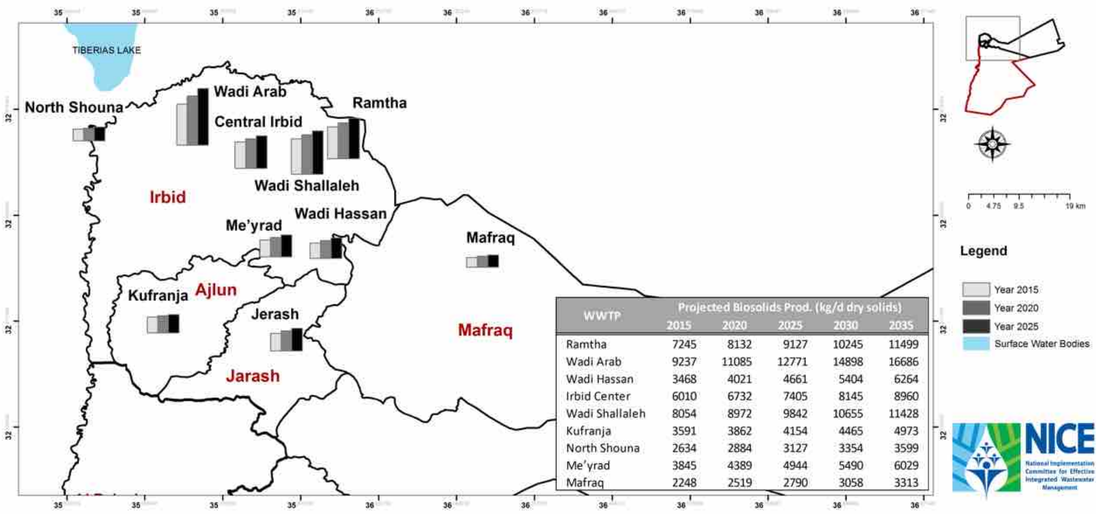
Figure 10 Irrigation systems in place for direct TWW reuse in the Sothern Governorates

2.4 Biosolids Management at CWWTPs

Issues related to the management and reuse of biosolids became prevalent after the stabilization ponds at the Samra WWTP were replaced with an activated sludge system in 2009. Other treatment plants, which originally used stabilization ponds, are undergoing similar changes. However, the most serious management issue is related to Samra WWTP, which produces around 127 t/d of stabilized sludge (biosolids) (AECOM, 2014). Currently, the biosolids produced at Samra WWTP are stored on-site until other management options can be considered. The company that operates and maintains the Samra WWTP claims that the plant will be able to store all of the produced biosolids for the entire contract period of 22 years. The current management practice for biosolids – following their removal from lagoons - is further compression and storage in an on-site "*mono fill*" landfill. Although this may be economically feasible, it obviously cannot be considered a sustainable option. Other treatment plants discharge biosolids to landfills. The Ekedar landfill receives both liquid and solid waste, but already suffers from overloading and many other environmental problems, such as leachate - which represents a serious threat to local aquifers. This demonstrates that sustainable biosolids management options should be developed for both centralized and DWWTPs in Jordan. This issue is highly relevant to both existing WWTPs and planned treatment facilities.

Figures 11–13 show the sludge projections for CWWTPs in Northern, Middle, and Southern Governorates in 2015, 2020 and 2025, respectively. These figures are based on data from the Kingdom Wide Biosolid Management Plan, which was coordinated by (AECOM, 2014). The figures clearly show that biosolids production is increasing rapidly in all of the cities across Jordan. However, there is no new available data regarding sludge production at Jordanian CWWTPs.

In Jordan, the standard JS 1145 (2016) regulates the production, transportation and reuse of biosolids. The standard only allows biosolids to be used for improving the soil quality of rangelands or to be disposed in landfills. The current standard classifies biosolids into three classes and delimits the final fates of each class. According to the Jordanian Standard, *Type III* sludge can only be transported to sanitary landfills, while *Type I* and *Type II* sludge can be used as a soil amendment in rangelands. The standard makes no clear distinction between *Type I* and *Type II* sludge in terms of selected crops, rates of applications, and conditions of application. The maximum rate of application for both *Type I* and *Type II* sludge is 6 tons/ha per year, and soil amendment with biosolids can only be performed in areas with less than 200 mm of average annual rainfall. An additional specification is the maximum moisture content, which has been set at 40% for *Type II* biosolids. A moisture content of 40% would require either solar drying or a combination of mechanical and solar drying. It is not clear on what basis the moisture content of *Type II* biosolids should be determined, and no methods for application and mixing of biosolids are recommended. Accordingly, it is recommended to check consistency of the JS 1145 (2016) for the use and disposal of biosolids. The standard also prohibits the use of untreated sludge; however, no management alternative is provided.

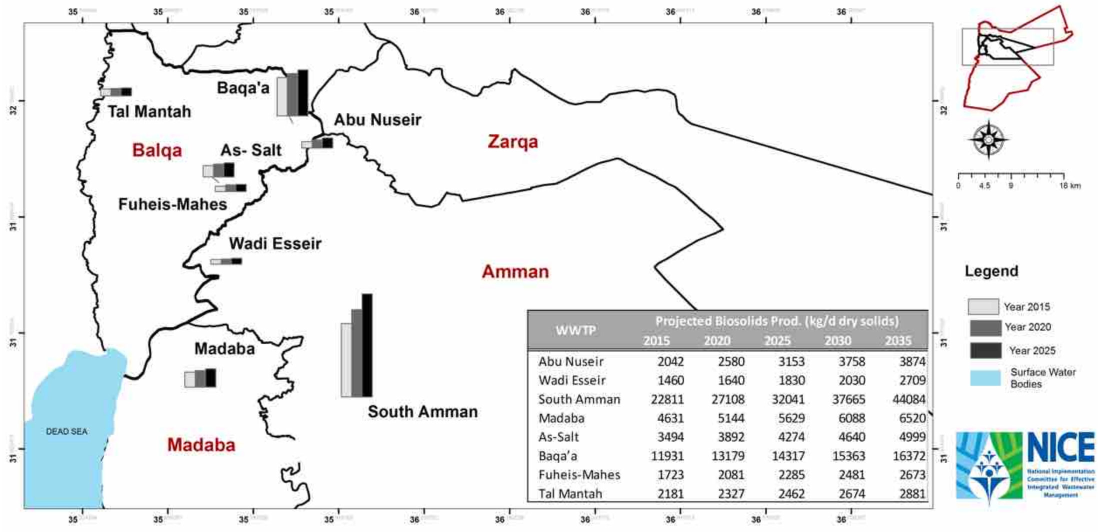


WWTP	Projected Biosolids Prod. (kg/d dry solids)				
	2015	2020	2025	2030	2035
Ramtha	7245	8132	9127	10245	11499
Wadi Arab	9237	11085	12771	14898	16686
Wadi Hassan	3468	4021	4661	5404	6264
Irbid Center	6010	6732	7405	8145	8960
Wadi Shallaleh	8054	8972	9842	10655	11428
Kufranja	3591	3862	4154	4465	4973
North Shouna	2634	2884	3127	3354	3599
Me'yrad	3845	4389	4944	5490	6029
Mafraq	2248	2519	2790	3058	3313

Figure 11 Projected production of biosolids (in kg/d dry solids) at CWWTPs in the Northern Governorates.

However, contrary to the legal framework of both, the MoEnv (‘*Instructions of Organizing the Storage, Transport and Treatment of Organic fertilizers and their Trading for 2009’*) and MoA (‘*Instructions for the Requirements of Licensing, Preparation, Storage, Handling and Trading of Fertilizers and Plant Growth Regulator for 2011’*) prohibit the production of organic fertilizers from biosolids, and refer to JS 962 (2011).

According to JS 1145 (2016), the quality of biosolids is monitored once every two years when biosolids production is less than 300 t/year. The quality of biosolids is monitored by the Ministry of Environment, with the latest available results from 2015 (MoEnv, 2018). However, no further analysis of the quality of biosolids is currently available.

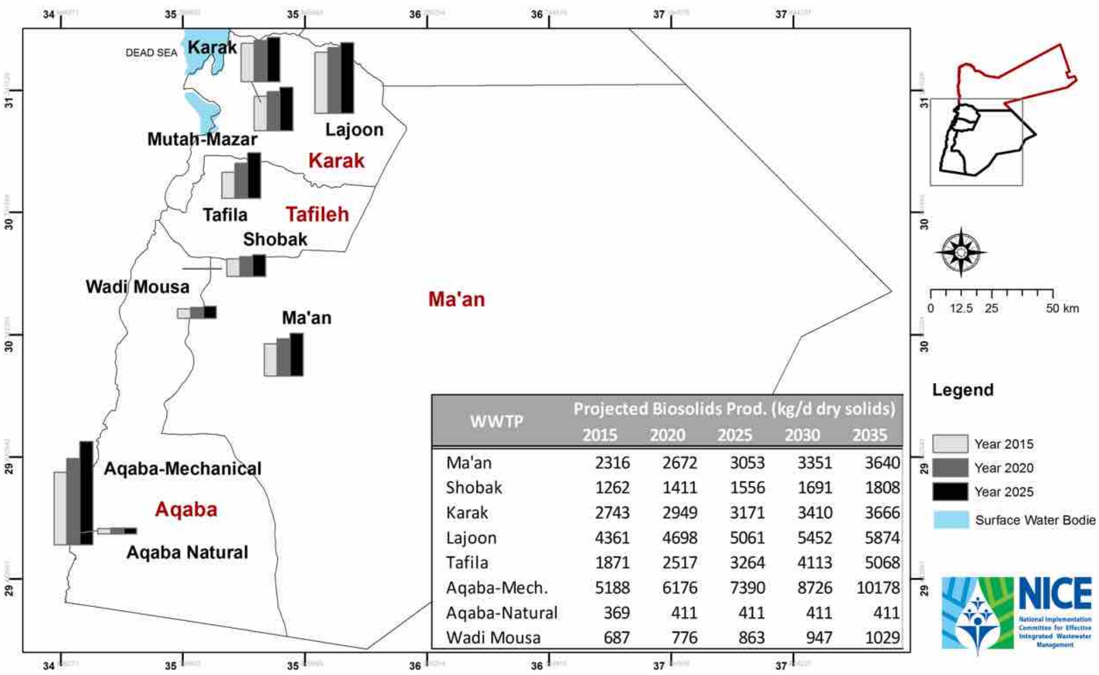


WWTP	Projected Biosolids Prod. (kg/d dry solids)				
	2015	2020	2025	2030	2035
Abu Nuseir	2042	2580	3153	3758	3874
Wadi Esseir	1460	1640	1830	2030	2709
South Amman	22811	27108	32041	37665	44084
Madaba	4631	5144	5629	6088	6520
As-Salt	3494	3892	4274	4640	4999
Baqa'a	11931	13179	14317	15363	16372
Fuheis-Mahes	1723	2081	2285	2481	2673
Tal Mantah	2181	2327	2462	2674	2881

Figure 12 Projected production of biosolids (in kg/d dry solids) at CWWTPs in the Middle Governorates.

On an international level, land application is still the most widely used biosolids management approach. For instance, over 50% of the 6 million metric tons (dry) of biosolids produced in the USA are land applied (Brooks et al., 2005).

Land application is not only relevant for agricultural production, but also for land restoration. A clear advantage of biosolids land application is the high nitrogen content, which was found to be around 4% for biosolids from the Wadi Mousa and Wadi Hassan WWTPs (Suleiman et al., 2010). The slow release of nitrogen has been shown to increase the productivity of crops (Lu et al., 2017). Top soil total nitrogen, extractable phosphorus concentrations, biomass nitrogen, and readily mineralized organic nitrogen have all been reported to increase following biosolids land application. Biosolids application was also reported to increase both plant available water supply and soil organic matter, as well as reduce top soil bulk density (Bhogal et al., 2009).



WWTP	Projected Biosolids Prod. (kg/d dry solids)				
	2015	2020	2025	2030	2035
Ma'an	2316	2672	3053	3351	3640
Shobak	1262	1411	1556	1691	1808
Karak	2743	2949	3171	3410	3666
Lajoon	4361	4698	5061	5452	5874
Tafila	1871	2517	3264	4113	5068
Aqaba-Mech.	5188	6176	7390	8726	10178
Aqaba-Natural	369	411	411	411	411
Wadi Mousa	687	776	863	947	1029

Figure 13 Projected production of biosolids (in kg/d dry solids) at CWWTPs in the Southern Governorates.

In terms of the health-related aspects of biosolids land application, the vast majority of literature reviews have identified certain barriers that prevent the transfer of enteric pathogenic organisms to human beings (Lang et al., 2003; Lajapathi Rai et al., 2008). In fact, long-term biosolids land application (over a time span of 20 years) enriched bacterial diversity (Brooks et al., 2005; Zerzghi et al., 2010). This is because the sustainable reuse of biosolids on land maintains soil health by promoting bacterial biodiversity, which plays a critical role in soil processes such as soil structure, decomposition of organic matter, toxin removal, and nutrient recycling (e.g., carbon, nitrogen, phosphorus and sulfur) (Zerzghi et al., 2010).

In the context of Jordan, a clear strategy that delimits the end uses of biosolids needs to be developed. Furthermore, the obstacles to efficient management that currently exist within Jordanian regulations need to be removed. It is important to note that there are additional opportunities for the reuse of biosolids than just land application and landfilling. For instance, biosolids could be used in cement kilns as an alternative energy source or in incineration plants for energy recovery (AECOM, 2014).

The need to find sustainable ways of treating and recycling large quantities of carbon- and nutrient-rich sewage sludge is not only a problem in Jordan, it is prevalent on a global scale (Breulmann et al., 2017). An innovative idea of converting biosolids into a carbonaceous material, called biochar, for use as a soil amendment is promising from both economic and ecological perspectives (Breulmann et al., 2015). The carbonization removes pathogens and can potentially degrade thermally labile pollutants, enabling the sustainable recovery of plant mineral nutrients that are present at high levels in sludge (Libra et al., 2014).

To summarize, the land application of biosolids is an option that is widely accepted worldwide. However, it is critical to consider biosolids characteristics and application rates to avoid potential negative effects of soil enrichment, e.g. salinity, metal toxicity and promotion of weedy and undesirable plant species Action plans must also be in place to control point sources of contamination. The characterization of biosolids in Jordan has shown that the biosolids are of exceptional quality with respect to heavy metals, as the concentrations of these compounds are far below the limits specified in JS 1145 (2016) (Suleiman et al., 2010).

However, there is only limited data on biosolids treatment and reuse, as the Ministry of Agriculture in Jordan does not allow biosolids to be used in agriculture; consequently, there is no reuse of biosolids in the agricultural sector. Furthermore, biosolids are not directly reused for any other purposes in Jordan. The only exception is the Samra WWTP, where biogas produced from the anaerobic digestion of sludge is used to produce electricity for running the facility. An additional anaerobic digester was recently introduced at the Al-Shallalah CWWTP.

This is part of a wider plan to introduce digesters at two other CWWTPs (Irbid Center and Wadi Arab) in order to reduce electricity consumption and simultaneously minimize biosolids volume.

Decentralized Wastewater Treatment Plants

3

Based on the available information, the 85 DWWTPs identified in Jordan produced about 4% of the total TWW flow (**Figure 14**; **Table 4**; **Table 5** and **Table 6**). Even though these plants represent a small fraction of the wastewater management program, they are nevertheless crucial to protecting groundwater resources from contamination. It is important to state that the calculated percentage could be significantly higher if all of the DWWTPs had been surveyed. Furthermore, these facilities also contribute to climate change adaptation measures as presented in the Climate Change Policy, published by the MWI in 2016, which identified solutions and implementation mechanisms that would assist the Jordanian Government build resilience towards the threat of climate change. The three main levels of resilience stated in this policy are *persistence*, *adaptability*, and *transformability*.

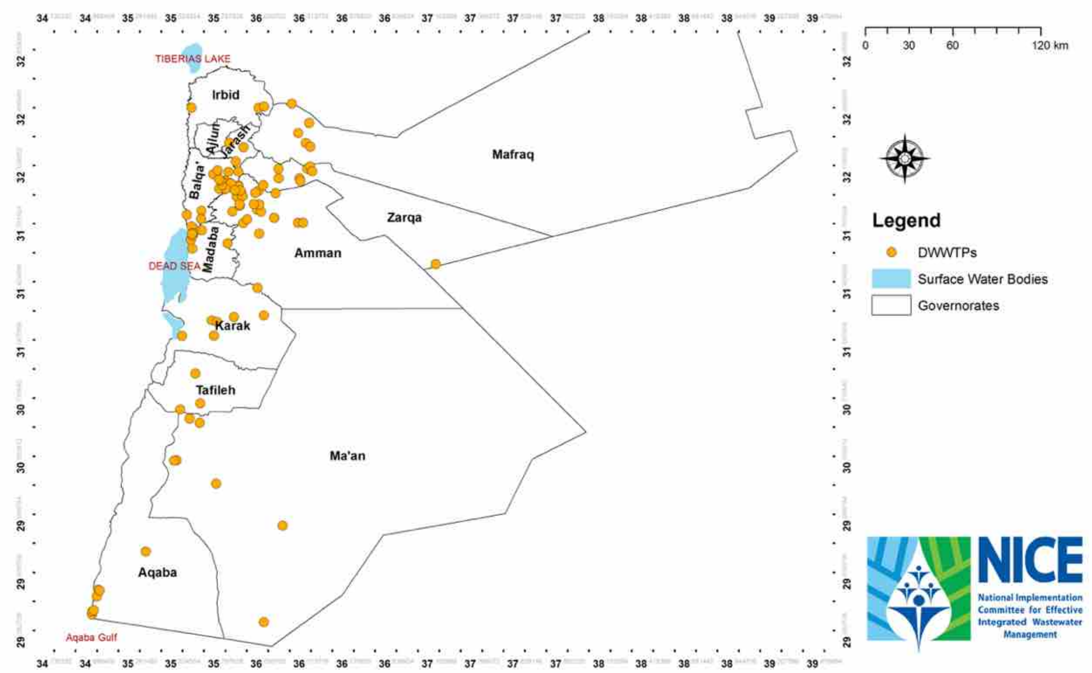


Figure 14 Locations of the 85 identified decentralized wastewater treatment plants identified in Jordan.

According to the Jordanian DWWM Policy (MWI, 2016b), decentralized wastewater treatment systems are defined as having a design flow equivalent to ≤ 5.000 PE or a hydraulic capacity of ≤ 182.500 m^3/year (calculated with a specific wastewater production of 100 l per person per day).

The Jordanian DWWM Policy is restricted to domestic wastewater only. However, this study also includes industrial WWTPs if they correspond to the definition of the design flow provided in the Jordanian DWWM Policy.

Within this study, the 85 DWWTPs were identified and grouped as follows: *Hotel,* *Resorts and Tourism sites*; *Industry*, *Institutions*, and *Public buildings*; *Houses* and *Additional DWWTPs* (see **Table 4**, **Table 5**, **Table 6**). The list of DWWTP included the Mansorah and Shobak WWTPs (see also **Chapter 2** Centralized Wastewater Treatment Plants and **Table 6).** Furthermore, the research identified an additional 22 WWTPs that could neither be considered CWWTPs according to WAJ nor DWWTPs according to the DWWM Policy (MWI, 2016b).

The DWWM Policy is an integral part of the National Water Strategy (2016 – 2025), along with related policies and action plans. It will be integral to shaping the Jordanian approach to planning, implementing and operating DWWM infrastructure over the next decade. The policy includes a broad scope, as it covers the wide spectrum of DWWM options and describes the many tasks necessary for successful implementation and sustainable operation. The policy mentions that DWWM can significantly alleviate water scarcity problems by an estimated 64 MCM/year. Furthermore, a DWWM system could help avoid annual health costs from inadequate wastewater disposal (overflowing household cesspits, return flow in sanitary pipes), providing savings of 3.757 JOD (suburb) and 2.652 JOD (rural) per 500 PE. In addition, the agricultural benefits (gross margins) were estimated at 679 JOD/du for greenhouses and 173 JOD/du for fruit trees. Additional benefits include savings from using less fertilizer (1.000 to 3.000 JOD/year) and avoiding the annual costs for cleaning cesspits (20.039 JOD per 500 PE; (MWI, 2016b). The policy estimated that an investment of 50 million JOD in the DWWM infrastructure could generate up to 1.250 sustainable jobs in the water sector.

The DWWM approach was envisaged in the Water for Life Jordan’s Water Strategy 2008 – 2022 and the National Water Strategy 2016 – 2025. The presented strategies reflect the current Jordanian Policy for the entire water sector and, with respect to wastewater, sets the goal of providing adequate wastewater collection and treatment facilities for all major cities and small towns (van Afferden et al., 2010; van Afferden et al., 2015). The objective of the DWWM Policy is to sustain development, public health and environmental protection, cope with water scarcity, improve local livelihoods, provide efficient wastewater services, improve water quality, and increase the involvement of the private sector in wastewater services. An additional objective was promoting the participation and ownership of local communities in improving water and sanitation management (Lee et al., 2013; MWI, 2016b).

Table 4 Available data for decentralized wastewater treatment plants in Jordan: Hotels, Resorts & Tourism Sites and Industry.

No.	Gov.	Location of WWTP	Design capacity (1000 m^3/y)	TWW (1000 m^3/y)	Year	Ownership	Operator	Reuse
			Hotels, Resorts & Tourism Sites					
1		Movenpick Dead Sea	127.8	73.0	2002	Movenpick Dead Sea	Own staff	Forrestry & ornamental trees
2		Baptism Site	29.2	26.3	2000	Ministry of Tourism	-	Landscaping & Forestry
3		Ma'in Spring Hotel	73.0	32.9	1989	Design Associated & Research Bureau (DARB)	Own staff	Irrigation
4		Marriott Dead Sea Resort	127.8	21.9	2001	-	-	Forrestry & ornamental trees
5		Dead Sea Panorama	8.4	7.6	2000	Ministry of Tourism	RSCN	Landscaping
6		Dead Sea Spa Hotel	36.5	32.9	-	Dead Sea Spa Hotel	Own staff	Landscaping & Forestry
7	Madaba	Al-Buhaira	-	-	-	-	-	-
8		O Beach Dead Sea	-	-	-	-	-	-
9		Holiday Inn Resort Dead Sea	91.3	62.1	2009	Holiday Inn Resort Dead Sea	Own staff	Landscaping
10		Crown Plaza Dead Sea	-	-	-	Crown Plaza Dead Sea	Own staff	
11		Ramada Resort	-	43.8	2014	Ramada Resort	Own staff	Irrigation & Flushing
12		Hilton Dead Sea Resort & Spa	-	-	2018	Hilton Dead Sea Resort &	Own staff	
13		Dead Sea Lagoon Hotel & Resort	-	-	-	Dead Sea Lagoon Hotel &	Own staff	
14		Kepinski	182.5	164.3	2005	United Saudi Jordanian	Own staff	Landscaping & Forestry
15	Ma'an	Bait Zaman Touristic Village	36.5	32.9	-	-	-	Landscaping
16	Tafila	Feynan Ecolodge	3.7	1.8	2019	RSCN	EcoHotels	Irrigation
17		Nawafleh Beit Zaman Hotel & Resort	-	-	-	Jordan Tourism Ivestment	Own staff	Landscaping & Forestry
18	Aqaba	Sunday Water Park	54.8	49.3	2005	Sundays International for	-	Landscaping & Forestry
			Industry					
19		Consolidated Sulpho-Chemical & Detergents	7.3	2.2	-	-	-	Irrigation
20	Mafraq	Arab Pioneers Carpets & Ayn Textile	109.5	73.0	-	-	-	Irrigation
21		Hammoudeh Food Industries Co.	43.8	29.2	-	-	-	-
22	Balqa	Fuheis Cement Factory	-	-	-	-	-	Forest trees
23		Jordan Petroleum Refinery	49.6	49.6	-	-	-	Forest trees; froage
24		International Poultry Company (Tamam)	73.0	73.0	-	-	-	Irrigation
25	Zarqa	Alaqlymyah Regional Supporting Industry	18.3	3.7	-	-	-	Plantations
26		Yeast Factory	-	73.0	-	-	-	-
27		Jabal AlMkabr Feed Factory	-	-	-	-	-	Landscaping & Forestry
28		Nuqul Group	54.8	49.3	1998	Nuqul Group	-	Landscaping & Forestry
29		Mid-Pharma	27.4	24.6	1996	Middle East Pharmac. Industr. & Medical Appliances		Landscaping & Forestry
30		Jordanian Pharmaceutical	25.6	5.5	-	-	-	Forrestry
31	Amman	Sahab Industrial City	-	-	-	Jordanian Industrial Estate Corporation	Own staff	-
32		Muwakar Industrial City	-	-	-	Jordanian Industrial Estate Corporation	Own staff	-
33		King Abdullah Industrial City	657.0	365.0	-	-	-	Farming and forage
34		Dar AlDawa Company	54.8	43.8	-	-	-	Forrestry
35		Philip Morris	18.3	5.4	-	-	-	Irrigation
36		Al-Keena Hygienic Paper Mill Co.	438.0	273.8	-	-	-	Forrestry
37	Madaba	Al Razy Pharmaceutical Company	14.6	13.1	1998	Al Razy Pharmaceutical Company	-	Forrestry
38	Tafila	Al-Raei Dairy Factory	11.0	9.9	1996	Al-Raei Dairy Factory	-	Landscaping & Forestry
39		Al-Janoub Cement	54.8	16.4	1984	-	-	Forrestry
40		Aqaba Oil Company	43.8	39.4	1999	Aqaba Oil Company	-	Landscaping & Forestry
41	Aqaba	Hijazi Ghosheh Livestock	146.0	73.0	-	-		Forrestry
42		Jordan India Fertilizer Co.	65.7	59.1	2009	Jordan India Fertilizer Co.	Priv. sector	Landescaping

Table 5 Available data for decentralized wastewater treatment plants in Jordan: Institutions and Public buildings.

No.	Gov.	Location of WWTP	Design capacity (1000 m³/y)	TWW (1000 m³/y)	Year	Ownership	Operator	Reuse
		Institutions						
43	Mafraq	Al Albait University	5.8	4.9	2005	Al Albait University	Own staff	Landscaping
44	Jerash	Jerash Private University	54.8	49.2	2005	Jerash Private University	Own staff	Landscaping
45	Balqa	Philadelphia University	36.5	32.9	2005	Philadelphia University	Own staff	Forrested landfill
46	Balqa	Philadelphia University	36.5	73.0	-	Philadelphia University	Own staff	Landscaping & Forestry
47	Balqa	Dept. of Motor & Drivers Licensing	54.8	49.3	-	-	-	Landscaping & Forestry
48	Balqa	SMART Project/ Fuheis-Mahes	9.1	8.1	2012	Al-Balqa Applied University	Own staff	Irrigation
49	Zarqa	Zarqa Private University	73.0	65.7	2003	Zarqa Private University	Own staff	Landscaping & Forestry
50	Amman	Al Essra University	54.8	49.3	2003	Al Essra University	Own staff	Landscaping & Forestry
51	Amman	Petra University	73.0	34.7	2012	Petra University	Priv. sector	Forestry
52	Amman	Middle East University	43.8	39.4	-	Middle East University	-	Landscaping & Forestry
53	Amman	German Archeological Institute	-	-	2018	German Archeological Institute	Priv. sector	Landscaping
54	Madaba	American University of Madaba	109.5	98.6	2011	American University of Madaba	Own staff	Landscaping
55	Madaba		54.8	18.3	2012			Landscaping & Forestry
56	Karak	Karak College	54.8	8.4	2013	Al-Balqa Applied University	Priv. sector	Forestry
57	Karak	Mu'ta University	182.5	164.3	-	Mu'ta University	Own staff	Forrestry; ornamental & olives
58	Ma'an	Al-Hussein University	146.0	131.4	-	Al-Hussein University	Own staff	Forestry
		Public buildings						
59	Irbid	Sheik Hussien Bridge border	29.2	26.3	-	Ministry of Public Works & Housing	Priv. sector	Landscaping & Forestry
60	Mafraq	Jaber border	73.0	65.7	1996	Ministry of Public Works & Housing	Priv. sector	Landscaping & Forestry
61	Zarqa	Al Omari Border	36.5	32.9	2005	Ministry of Public Works & Housing	Priv. sector	Landscaping & Forestry
62	Balqa	Balqa Rehab. Center (Public Security)	21.09	16.4	2005	-	-	Forrestry & ornamental trees
63	Balqa	Rmimien Rehab. Center	109,5	43,8	-			Forrestry & ornamental trees
64	Balqa	Dept Motor and Drivers Licensing	54.8	49.3	2000	-	-	Landscaping
65	Amman	Public Security Directorat	54.8	54.8	2015	Public Security Directorat	Priv. sector	Landscaping
66	Amman	Traffic Academy	36.5	32.9	2000	Public Security Directorat	Priv. sector	Forrestry, fruit trees and crops
67	Amman	Swaqa Rehab. Center	164.3	164.3	2007	Public Security Directorat	Priv. sector	Forrestry
68	Amman	Al- Muwaqar Correction & Rehab. Center	54.8	49.3	-	-	-	Forrestry
69	Ma'an	Al Mdawarah (Pumping Station)	182.5	91.3	2005	Ministry of Public Works & Housing	Priv. sector	Landscaping
70	Ma'an	Aqaba Southern Entrance (Border)	11.0	9.9	2000	Ministry of Public Works & Housing	Priv. sector	Forrestry & ornamental trees
71	Aqaba	Marine Forces	109.5	69.4	-	-	-	-
72	Aqaba	PSD Chalet	-	-	-	Public Security Directorat	Priv. sector	-

Table 6 Available data for decentralized wastewater treatment plants in Jordan: Houses and additional DWWTPs, along with wastewater treatment plants that could not be classified.

No.	Gov.	Location of WWTP	Design capacity (1000 m³/y)	TWW (1000 m³/y)	Year	Ownership	Operator	Reuse
			Houses					
73	Jerash	Sakeb Village	155.0	140.0	2006	-	-	
74	Balqa	Ismail Akeel (SMART)	0.3	-	-	Ismail Akeel	Priv. sect.	Landscaping
75		Maher Al Shehabi (SMART)	0.6	-	-	Maher Al Shehabi	Priv. sect.	
76		Fakri Hassan (SMART)	1.7	-	-	Fakri Hassan	Priv. sect.	
77		Nursing Home (SMART)	1.8	-	-	Nursing Home	Priv. sect.	
78		Abu Rumman (SMART)	1.3	-	-	Abu Rumman	Priv. sect.	
79		Hadidy (SMART)	0.5	-	-	Hadidy	Priv. sect.	
80		Al Awamleh (SMART)	0.6	-	-	Al Awamleh	-	
81		Ghalib Hiyari (SMART)	0.7	-	-	Ghalib Hiyari	Priv. sect.	
82		Princess Rahmeh College (SMART)	3.3	-	-	Princess Rahmeh College	Priv. sect.	
83	Amman	Al-Mustaneda Housing	182.5	164.3	2011	Housing and Urban Development Corporation	Priv. sect.	
			Additional DWWTPs					
84	Ma'an	Mansorah	0.02	-	2010	WAJ	WAJ	-
85		Shobak	0.1	0.1	2010	WAJ	WAJ	-

Classified as CWWTPs according to the annual reports from MWI and WAJ. However, concerning the size of these WWTPs and according to the Jordanian Decentralized Wastewater Management Policy (MWI, 2016) they can be classied as DWWTPs.

No.	Gov.	Location of WWTP	Design capacity (1000 m³/y)	TWW (1000 m³/y)	Year	Ownership	Operator	Reuse
			Further WWTPs					
a	Irbid	Al Hassan Industrial City	765.5	699.0	2007	Jordanian Industrial Estate Corporation	-	Forestry
b	Irbid	JUST University	765.5	273.8	1986	JUST University	Own staff	ornamental trees
c	Mafraq	Um Lolo	328.5	295.7	2014	Public Security Directorate	-	Landscaping & olive trees
d		Al-Thuraya Co. for Supply & Marketing Poultry	438.0	365.0	-	-	-	Forestry
e		Al-Reef Poultry	-	-	-	-	-	Forestry
f	Zarqa	Union for Agricultural Development & Slaughtering	200.8	54.8	-	-	-	Forestry
g		Jordan Poultry Processing & Marketing Company	292.0	146.0	-	-	-	Forestry
h		Third Dimensions Apparel LLC	219.0	91.2	-	-	-	Forestry
j		Teeba for Developed Food Processing	365.0	219.0	-	-	-	Forrestry, ornamental trees & landscaping
k		Royal Polo Club	350.4	226.3	-	-	-	Landscaping
l	Balqa	TalaBay Resort	365.0	328.5	2012	-	-	-
m	Amman	Abu Alanda Housing	529.3	476.3	2014	Housing and Urban Development Corporation	Priv. sect.	Forrestry & ornamental trees
n		Queen Alia'a International Airport	657.0	591.3	-	Civil Aviation Authority (AIG)	Priv. sect.	Landscaping
o		Jordan International Police Training Center	401.5	361.7	2006	Public Security Directorate	-	Forestry
p		Al-Watania Poultry	1095.0	365.0	-	-	-	-
q		Princess Eman Housing	328.5	-	2014	Housing and Urban Development Corporation	Priv. sect.	Forage
r		Al-Hussein Industrial City	244.5	182.5	-	Jordanian Industrial Estate Corporation	Own staff	Landscaping
s	Karak	Karak Hospital	438.0	255.5	-	Ministry of Health	Priv. sector	Discharge to wadi
t		Potash Housing	365.0	127.8	-	-	-	Forestry
u	Tafila	Phosphate Housing	365.0	-	1985	-	Priv. sect.	Forrestry, ornamental trees & landscaping
v	Ma'an	Jordan Phosphate Mines Co.	-	-	-	-	-	-
w	Aqaba	Tala Bay Resort	365.0	-	2012	Jordan Projects for Tourism Development	-	-

These WWTPs are not considered as CWWTPs according to MWI/WAJ and not as DWWTPs according to the DWWM Policy.

Decentralized wastewater treatment plants are currently obligated to follow the reuse standard (JS 893, 2006), however, are not specifically mentioned/classified in the standard itself with its own limits.

The Jordanian Standard JS 893 (2006), was designed for the reuse of TWW from CWWTPs and therefore cannot be applied to decentralized wastewater treatment systems.

The application of JS 893 (2006) is limited mainly to the direct reuse of TWW from CWWTPs for field crops, industrial crops and forest trees (Class C) and the discharge of large quantities of TWW to streams, wadis and water bodies (see Chapter 1.3).

The existing standard JS 893 (2006) does not fit to DWWTPs as decentralized systems handle smaller volumes of water, requiring different treatment, reuse and discharge systems.

For the first time, limit values for the reuse of TWW from decentralized treatment plants were proposed in the DWWM Policy (MWI, 2016b). In the policy effluent standard values are presented for decentralized wastewater treatment systems of up to 5.000 PE, where limits are based on the irrigation system in place (open discharge; infiltration trench, subsurface, drip and open irrigation).

It is therefore recommended to develop a new standard for the reuse of reclaimed domestic wastewater from treatment plants with a design capacity below 5.000 PE to improve sanitation and water reuse in Jordan by considering requirements such as: (i) public health (direct contact, groundwater), (ii) agricultural productivity (soil and plant), (iii) environmental health, (iv) technological feasibility and (v) economic development of the country.

Photo 1 Drip-irrigation system for olive trees. The irrigation system receives its water from a DWWTP (Sequenced Batch Reactor) at a nursing home in Fuheis, Jordan (© André Künzelmann).

A distinct characteristic of DWWTPs are the low operation and maintenance costs of the facilities, which means that DWWTPs are an ideal choice for systems with minimal sludge production and energy requirements (or, conversely, access to a continuous supply of energy). For instance, a treatment system that serves a small community in a rural area of Jordan might combine anaerobic and close-to-nature aerobic systems. The former (anaerobic system) would result in a very low amount of excess sludge production and not require much energy, while the post-treatment choice of a close-to-nature system would not produce excess sludge and depends only on natural aeration (no energy input). Excess sludge produced from anaerobic treatment can be dewatered and further treated (depending on its characteristics) using sludge drying reed beds (SDRBs), which might be the best option if adequate space is available. In this system, sludge can be further stabilized and stored in the reed beds for up to 10 years. The sludge can eventually be used in agricultural production. In fact, a pilot study was already conducted at the As-Salt WWTP to show that such systems are feasible for sludge dewatering and treatment in Jordan. A pilot reed bed system consisting of 4 beds was designed and built by BAUER Umwelt GmbH. The company operated the beds for two years and, after which the University of Jordan continued to operate Beds 3 and 4 for an additional year.

After the completion of the experiment, the sludge in these reed beds showed very interesting chemical and microbiological characteristics. All of the sludge had *E. coli* concentrations that were lower than 1.000 MPN/100mL. Concurrently, the sludge preserved nitrogen - with a total nitrogen content of about 7% - and showed high organic matter content (40%), both of which are line with the Environmental Protection Agency classification of good quality compost.

However, there is a large concern, as JS 1145 (2016) states that treated sludge can only be reused on rangelands, and is prohibited from being reused in agricultural production. It should be noted that the land application of sludge has already proven to be a promising alternative to chemical and manure fertilizers in Jordan during pilot studies performed by the University of Jordan and the Royal Scientific Society. Thus, future efforts should focus on making the MoA aware of the value of reusing sludge in agricultural production. This would lead to positive revisions in the current reuse standards.

Control mechanisms

Currently, no real control mechanisms for DWWTPs exist in Jordan. Furthermore, the lack of certified systems for DWWTPs, coupled with a shortage of skilled personnel for conducting O&M of such systems, will impede the development of successful business models. Regarding the management of DWWTPs, it is of utmost importance to establish an independent unit within a national body that will be responsible for monitoring and controlling the DWWTPs.

A clear definition of roles and responsibilities, as well as strong coordination among institutions/ authorities, will be indispensable in managing the DWWTPs in Jordan effectively. This type of information is currently unavailable or scattered among various institutions/ authorities. For example, both the Ministry of Health and the Ministry of Environment are legally obliged to check numerous effluent quality criteria (e.g. BOD_5, TSS, COD, *E. coli*) at various WWTPs on a regular basis and report the results to the WAJ.

As mentioned previously, DWWTPs in hotels, public buildings or in the industry, are obligated to follow JS 893 (2006) or JS 202 (2007). If, by chance, the MoH is informed about the existence of a DWWTP by the health directorate of the specific region, then the MoH will also be obliged to check the effluent quality at these DWWTPs (MoH, 2018). This is the reason why certain DWWTPs are already listed in the annual reports of the MoH. The reports, MoH (2018) and MoEnv (2018) indicate for instance that certain hotels and industries exceed the irrigation limits set in JS 893 (2006).

An official database (inventory) of all the existing DWWTPs should be created.

Furthermore, efforts should be made to establish new guidelines for the registration of DWWTPs and the monitoring of effluent quality and reuse of TWW.

Photo 2 Subsurface irrigation at a residential house in Amman, Jordan (© Nabil Wakileh).

Best Practices for the Reuse of Treated Wastewater and Biosolids

4

Sufficiently TWW is a reliable water source, and can partially substitute for freshwater when water demand increases. Wastewater management practices have recently shifted from disposal to reuse, as well as the recovery of valuable materials. Resource recovery has been actively promoted in recent years due to its environmental and economic benefits, with many technologies progressing towards commercially feasible solutions that attempt to integrate circular economy principles. The circular economy concept has emerged in response to criticism of the ubiquitous '*take-make-consume and dispose'* model of growth for its negative environmental effects (IWA, 2018). Velenturf et al. (2019) stated that one of the key tenets of a circular economy is that the value of products and materials is maintained for as long as possible. Hence, waste and resource exploitation are minimized. Moreover, when a product reaches the end of its life cycle, it is used again to create further value. In the context of the water sector, transitioning to a circular economy presents an opportunity to implement and scale-up recent technological advances that support greater efficiency in the sector. In this regard, transforming waste from domestic and agro-industrial sources into a valuable source holds promise for entrepreneurs, especially when mixed waste streams are used to create a successful business model. These types of changes are strongly supported by the Sustainable Development Goals (SDGs) from the UN, which target, among others, water reuse (SDG 6), renewable energy (SDG 7) and waste recycling and reuse (SDG 12). The last goal can help restore degraded soils (SDG 15), improve agricultural and food security (SDC 12) and create resilient cities (SDG 11) (Otoo et al., 2018). Moreover, the development of innovative business models could be encouraged by flexible regulatory and institutional frameworks, which would, in turn, reduce potential health and environmental risks through appropriate safety control measures, such as the multi-barrier approach presented by the World Health Organization (WHO) (WHO, 2006c). This would reduce the cost of treatment and lead to savings in operation and maintenance costs.

However, the creation of business models that apply circular economy principles and encourage private sector participation in waste management require regulatory and institutional frameworks that will facilitate the transition to a more circular economy. This is also a starting point for the provision of sustainable services and participation of private companies in the water sector. This has not yet been achieved in Jordan; accordingly, the best reuse practices discussed herein will consider the current Jordanian regulatory and institutional frameworks.

Within this context, the sale of TWW for irrigation shows limited cost recovery due to highly subsidized irrigation water. However, there is the possibility of sustainable cost recovery when TWW is used for industrial purposes since the water can be priced higher. In the industrial sector, TWW has been used in power stations, textile manufacturing, paper industry, oil refineries, heating and cooling networks, steelworks, and, recently, in large data centers, e.g., Google Data Center in Belgium (WWAP, 2017).

As shown in the following sections, Jordan has already made advances in how TWW is utilized in the agricultural and industrial sectors. However, it is first essential to define criteria that can be used to select the optimal reuse practices.

4.1 Criteria for selecting best reuse practices

This chapter – which covers the selection of best reuse practices - excludes the Jordan Valley for two main reasons. Firstly, the literature and relevant experts are in agreeance that the infrastructure in this area is of a good standard and, secondly, irrigation in the Jordan Valley can be classified as indirect reuse with TWW, which is not the ideal reuse option.

Most treatment plants in Jordan produce an effluent suitable for reuse, primarily used for irrigating fodder crops and fruit trees. Moreover, institutional fragmentation has resulted in the misconception that agricultural irrigation is a tool through which to dispose of TWW rather than a means of resource recovery. For instance, the Jordanian Standard 893/2006 demands nutrients removal even if TWW is mostly used for agricultural irrigation, in which case farmers have to apply organic or chemical fertilizers. Furthermore, border or basin irrigation – which is clearly not the most efficient system - remains widely used for the direct reuse of TWW. Hence, the best practices presented in the following chapters are specific to the Jordanian context, and consider the current direct reuse schemes at existing WWTPs.

The examples of best practices presented here consider social acceptance as one of the main pillars in the sustainability of a specific project. All of the alternatives were assessed using the following prerequisites:

1. Socio-economic reuse practice, defined as the level of end user involvement in the full project (treatment and reuse) and at all stages from planning to operation. This criterion assumes that the level of involvement is proportional to the level of social acceptance for the reuse scheme. If an industrial player is the end user, its willingness to pay is used as the criterion for acceptance.
2. The irrigation technique has already been implemented in Jordan (this holds for cases in which TWW is used for agricultural irrigation).

Criteria based on irrigation patterns related to crop-specific water requirements are also important in defining best practices. However, such criteria could not be included in the research due to a lack of documented meteorological and crop yield data.

Farmers in Jordan are only allowed to use biosolids (stabilized sludge) as fertilizer or soil conditioner in rangelands. Although existing regulations allow biosolids application at rangelands, it is currently only practiced on pilot and experimental levels. Moreover, biosolids application continues to be met with public opposition and low governmental support. In this way, no best practices for biosolids application have been established in Jordan.

4.2 Best practice of CWWTPs

The application of the aforementioned selection criteria identified two sites - the *Wadi Musa* WWTP and the Aqaba Natural and Mechanical WWTPs – as examples of best practices in TWW reuse.

Wadi Musa WWTP

In the case of Wadi Musa, the two most important examples of best practices are:

1. the use of a drip irrigation system instead of border- and basin-irrigation; and
2. the extensive involvement of the local community in the implementation of direct TWW reuse concepts.

The Wadi Musa CWWTP is located 270 km to the south of Amman and collects wastewater from four areas: Wadi Musa city (including hotels); Taybeh; Baydah; and Al Badoul housing areas. The treatment process includes primary treatment, secondary biological treatment, final clarification, effluent polishing lagoons, chlorination, biosolids holding tank and sludge dry beds. As of 2017, the Wadi Musa WWTP receives approximately 1.03 MCM of wastewater and generates about 1.02 MCM of TWW using extended aeration technology (**Photo 3**). The treatment plant is equipped with 16 drying beds for processing thickened sludge, and biosolids cake (>70% solid content) is produced mainly during peak flow operation (high tourist season). Dried biosolids are then collected and stored at the treatment plant.

The first community-based project was established in collaboration with USAID. The local community was provided with technical information on how irrigating their fodder crops with TWW could:

i. help improve the livelihoods of the local community;
ii. reduce the competition and demand for freshwater; and
iii. conserve natural resources and the surrounding environment.

Treated wastewater is the only water source for irrigation in the area and the project in Jordan is considered the first direct reuse project. The plant provides irrigated water for a total of 1069 du.

Photo 3 The Wadi Musa wastewater treatment plant (© Aqaba Water Company).

— *Social and economic impact* —

The Wadi Musa demonstration of direct TWW reuse has been implemented permanently and sustainably within the "*Reuse for Industry, Agriculture and Landscaping"* (RIAL) project, which was funded by USAID. In total, 45 farmers and their families benefited from the project, which allowed them to generate additional income by cultivating fodder crops. The RIAL project was implemented by the U.S engineering firm Camp Dresser and McKee, and had an overarching goal of successfully demonstrating how TWW reuse can sustainably utilize water resources, provide economic benefits and support community development. Furthermore, this RIAL project should show to the public that direct TWW reuse can be reliable, commercially viable, environmentally sustainable, and safe (AECOM, 2015). The project clearly demonstrated how the application of an environmental management system can improve both the financial and environmental performance of WWTPs. Following the completion of the project, the dissemination of easily comprehensible information and direct communication with the local community have both removed barriers to TWW

reuse. Members of the project were able to build trust with the local farmers, as well as help them realize the potential economic incentives. As a results the farmers' attitudes towards using TWW for irrigation changed from hesitant to accepting. It should be noted that social acceptance of the project was built over a decade of intensive communication with local communities. However, communication was complicated due to the fact that the reuse site was located in a natural reserve with very strict regulations.

— *Planted area* —

The WWTP produces approximately 1 MCM/year of TWW that is entirely used in irrigation to guarantee zero discharge to the Gulf of Aqaba.

Soil monitoring at the Wadi Musa reuse sites showed no salt accumulation over an eight-year observational period.

When the Wadi Musa treatment plant first began operating, the reuse site was managed through a subcontract between PA Government Services Inc. and the BADIA Research and Development Program (BRDP). The demonstration area was fully planted and irrigated with a functioning drip irrigation system. The area includes various crops, more specifically: field crops such as alfalfa, maize, sunflowers and Sudan Grass; tree crops including pistachio, almond, olives, date palms, lemons, poplars, spruce and junipers; and many varieties of ornamental flowers including irises, geraniums, petunias and daisies (**Photo 4**). The maize in this area showed approximately 25% higher growth than maize grown with freshwater, while sunflowers in the area demonstrated approximately 30% higher growth than sunflowers grown with freshwater (Khleifat et al., 2003). A total of 2.020 trees and 400 shrubs and flowers have been planted. Alfalfa has been the most profitable crop, followed by barley and olive (AECOM, 2012). Currently, the total area covers 1069 du, with a 350 du expansion planned in the future. The cropping pattern is: alfalfa and other fodder crops: 90%; olive trees: 7%; Grape trees: 2.5%; fruit trees such as Fig, Guava, and Lemon, along with cactus and ornamental flowers: < 1%.

The largest achievement of the project was introducing the direct reuse of TWW in irrigation to the area, which was considered a major development in the south of Jordan based on the amount of jobs that it created. It is important to note that farmers participated in the implementation of reuse projects in Wadi Musa; this most probably increased their awareness and acceptance of the practice. The direct reuse of TWW has increased economic returns by reducing the amount of fertilizer that farmers need to apply, which, in turn, has increased productivity. Instead of trying to convince farmers to irrigate their fields with TWW, the area around the Wadi Musa treatment plant is now struggling to supply enough TWW to meet the local demand. The plant, which reliably treats large quantities of wastewater to produce high-quality TWW, has enabled the government – with the support of donors – to demonstrate how TWW could improve agricultural productivity in the Wadi Musa area (SWIM, 2013). Better awareness and understanding at the community level have positively changed farmers' opinions of using TWW for irrigation. Moreover, the farmers have been highly satisfied with the results.

Some of the TWW has been utilized by local operators to create eco-tourism projects. According to the Wadi Musa WWTP manager, local farmers earn around 150 JOD/dunum when growing alfalfa and fodder crops. Furthermore, he has stated that farmers experience 60% and 20% savings in nitrogen and potassium fertilizers, respectively, due to the direct reuse of TWW in agricultural irrigation.

Photo 4 Reuse of treated wastewater in the area of the Wadi Musa wastewater treatment plant (© Amal Hijazi).

Photo 5 The Aqaba wastewater treatment plants (© Aqaba Water Company).

Aqaba WWTPs

The city of Aqaba enacted the Policy of Zero Discharge to the Gulf of Aqaba, which forced the wastewater sector to turn a challenge into an opportunity by effectively treating wastewater and identifying fit-for-purpose reuse schemes that would ensure sustainable cost recovery. The capital investment was paid by the tourism sector under a Public Private Partnership (PPP) contract (IWA, 2018).The water sector is managed by the Aqaba Water Company (AWC), which collects 90% of the wastewater, a total quantity of 7.0 MCM/year (IWA, 2018). The other 10% are collected in septic tanks followed by leaching fields. The collection system includes 250 km of gravity sewers and 7 km of rising mains (AECOM, 2015). Several pump stations direct the flow through a 1200 mm gravity interceptor to the WWTP, after which the influent is split into mechanical and natural treatment streams (AECOM, 2015). The influent is treated using two different treatment technologies, more specifically, 2.5 MCM/year is treated using a natural system featuring facultative and maturation ponds, while the remaining 4.5 MCM/year is treated at the secondary level using oxidation ditches, clarifiers, sand filtration and a UV-disinfection unit, as shown in **Photo 5**. It should be noted that the investment into the WWT provides the AWC with additional net income of 4 million US$ per year.

The ponds have an area of around 0.6 km^2 and lie at the tip of the Gulf of Aqaba, which is situated along a major bird migratory bottleneck between Eurasia and Africa. Thus, ensuring a sustainable and effective treatment process is an environmental priority (**Photo 6**). Effluent from the natural treatment plant is directed towards an agricultural water network, which serves a number of customers and was developed primarily for agricultural irrigation purposes. When the demand for irrigation water is low, effluent is sent to evaporation ponds. Effluent from the mechanical WWTP is diverted to industrial users (mainly for cooling water), used for landscaping, or sent to evaporation ponds when there is no demand for the effluent (AECOM, 2015). Treated wastewater already provides 15% of the city's water demand and enables Aqaba to maintain the green areas and urban landscape (Elimam et al., 2012). This water supply also meets the water demands of development projects and the industrial zone. The main industrial customer is the Jordan Phosphate Mines Company (JPMC), which may use up to 2.5 MCM, or 33% of the TWW flow, on an annual basis (World Bank, 2011). With respect to biosolids, all of the solids generated at the Aqaba Mechanical WWTP are diverted to conventional sand drying beds. Drying is performed in open air, which quickly results in dry cakes containing up to 90% solids that are landfilled on-site. This on-site disposal represents the least costly alternative for the Aqaba WWTP.

Photo 6 Aqaba birds' observatory (Aqaba Bird Observatory Gate © Feras Rahahleh).

Although details about cost recovery do not exist, personal communication with the treatment plant engineer revealed that reuse for industrial purposes provides the best return. Recent investments in golf courses and luxury residential complexes entail promising routes for cost recovery, as these types of properties have a high demand for water to upkeep lawns and ornamental plants. The selling prices and high percentage of direct reuse in the city indicate positive public acceptance of, and satisfaction with, direct TWW reuse. The recognized bird migratory pathway was pivotal to creating the circumstances that provide a unique example of how TWW can be used for environmental purposes in Jordan.

4.3 Best practice of DWWTPs

Regarding DWWTPs best practices, the Public Security Directorate (PSD) DWWTP was considered the best example of DWWTP design and operation in Jordan (**Photo 7**). The

WWTP selection process was based on a detailed analysis of the Public Security Directorate institutional settings, potential locations for the plant, and capacities - especially those related to the operation and maintenance of the selected system. The produced effluent meets Class A of JS 893 (2006), which is the highest class of effluent quality. The effluent is used to irrigate the Directorate's green areas, which encompass nearly 19 du of olive trees and some roadside ornamental plants. The irrigation scheme process reuses up to 100% of the produced TWW, which can save 4.500 m^3 of freshwater per month.

The DWWTP employs Sequencing Batch Reactor technology (SBR) with a design capacity of 150 m^2/d, which reflects the water used by around 2.500 PSD employees.

— Irrigation system —

A drip irrigation system is used to irrigate 18.500 m^2 of landscape and ornamental trees. There is the possibility to irrigate another 15.500 m^2 of green areas within the project borders. Furthermore, an 90.000 m^2 area outside of the project border could be developed into a green area that can be irrigated with TWW from the PSD DWWTP, but this depends on an agreement between relevant parties (Hayek, 2013).

Photo 7 Treated wastewater reuse at the PSD decentralized wastewater treatment plant (© Nabil Wakileh).

Drip irrigation is the optimal irrigation system, as it enables highly efficient water use based on the delivery of minute amounts of water at low pressure through numerous emission points.

The design of the irrigation system used in the areas around the PSD DWWTP complies with the Jordanian Standards for Wastewater Reuse. The design considered the peak monthly evapotranspiration rates based on actual weather conditions and rainfall at the location. The PSD DWWTP produces only small quantities of biosolids. These biosolids are managed via collection by tankers once every two months (collection could be even less frequent). The collected biosolids are then disposed at a dumping site.

Assessment of Bottlenecks Regarding the Sustainable Reuse of Treated Wastewater and Biosolids

5

Jordan will require an integrated water resource management approach that clearly positions wastewater in the water cycle to adequately prepare for climate change. Wastewater is the only water resource that is sustainable and increasing; therefore, this resource should be optimally utilized. The political situation in the region, which manifests itself in the influx of war refugees, has also increased the magnitude of the environmental, water and wastewater challenges within Jordan. Analyses related to the carrying capacity of Jordan must carefully consider which options can guarantee certain living standards for both citizens and refugees. Obviously, water and water-related aspects are central issues concerning human equality and dignity. Nevertheless, food security adds to the challenge, and demonstrates why food-water security should be one of the top priorities for the Jordanian Government.

Many countries in the MENA region face challenges related to scarce water resources, population growth, and climate change. TWW could be a viable solution to some of these problems, as it can be used instead of conventional water resources for diverse purposes. Many factors – such as regulatory, institutional, social, technical, and financial aspects – can influence the success of the substitution process.

5.1 Regulatory and institutional bottlenecks

Perhaps one of the main bottlenecks related to the use of TWW and biosolids in Jordan is institutional fragmentation, which jeopardizes the design and implementation of effective reuse schemes. This fragmentation is evident in that many of the involved stakeholders, e.g., MoA, MWI, Jordan Valley Authority (JVA), WAJ, MoEnv, MoH, have overlapping responsibilities and, more importantly, lack sufficient coordination (Seder et al., 2011). There is no clear structure for cooperation among these government organizations; as a result, resources are not effectively used as some tasks are repeated by several stakeholders.

A National Water Reuse Coordination Committee (NWRCC) was formed as per cabinet letter 57/11/6826, dated 21/5/2003, under the supervision of the secretary general of the WAJ. The members of the committee represented the Royal Court, MoH, MoEnv, MoA, National Center for Agricultural Research and Technology Transfer, JVA, Royal Scientific Society (RSS), Farmers Union, universities and the private sector. The committee was mainly tasked with establishing a coordination plan for the reuse directorate so that most of the overlap between Jordanian ministries could be removed. However, the committee was not active and hardly any improvement was noticed. Consequently, all of the actions and decisions related to reuse were left to the WAJ, a responsibility which did not result in successful reuse schemes. It is worth mentioning that although Jordanian regulations and standards permit restricted irrigation with TWW (i.e. direct reuse[2] scheme for vegetables that are cooked prior to consumption by humans), the WAJ has so far limited the direct reuse of TWW to fodder crops and fruit trees.

Farmers could experience significantly higher financial returns if they were granted licenses that reflected what is permitted in the current standards (i.e. restricted irrigation with TWW (Majdalawi, 2013). However, the lack of downstream control due to a low level of practical MoA involvement means that the reuse directorate published by the WAJ will not include revisions that would allow higher value crops to be irrigated with TWW. It can be assumed that the minimal engagement of the MoA in this regard could be due to a lack of awareness regarding the benefits of reusing TWW and biosolids. This is reflected in the MoA's instructions for the licensing, preparation, storage, handling and trading of fertilizers from 2011, as well as instructions in Article 4 of 2009 that prohibit the production of organic fertilizers from biosolids that stem from WWTPs. The ministry also apparently lacks relevant information on the benefits of biosolids land application. Moreover, decisions at the MoA are sometimes heavily influenced by different agricultural associations, most of which oppose the land application of biosolids. The main voiced concern is that the land application of biosolids will negatively affect the quality and reputation of agricultural products in the country. This opinion was publicly stated by the National Sludge Technical Committee, which was formed by the Cabinet in 2015. It is worth mentioning that the committee was formed to give technical advice on biosolids reuse possibilities, with particular emphasis on reuse in agriculture. The committee is chaired by the MoEnv and includes representatives from the MWI, MoA, and academia, among other stakeholders.

Other major bottlenecks are related to the existing technical standards, which especially hamper the implementation of small-scale treatment schemes. The currently technical standards for large-scale treatment systems also apply to small-scale systems, which impedes the widespread application of the latter due to high investment costs. Small-scale systems cause far lower pollutant loads to the environment than large-scale systems, a fact that has been alluded to in recommended modifications of existing standards from the DWWM Policy (MWI, 2016b). An additional bottleneck is that the quantity of TWW is sometimes discussed instead of its optimal utilization. The lack of a clear policy for crop patterns is considered an impediment to the optimal utilization of TWW and improvements in agricultural productivity (Olmstead, 2014; MWI, 2016a). In general, crop patterns are established by the MoA depending on several factors that are primarily related to the price of water. Although the MoA has made several attempts to guide farmers in establishing crop patterns,

[2] Treated wastewater is used for agricultural irrigation without blending with other water sources.

none of these attempts have been perceived as comprehensive enough. For example, the price of water was not a main part of the adopted approach, and this resulted in widespread mistrust among farmers.

Furthermore, the current irrigation water tariffs are considered extremely low, which does not support the optimum utilization of water and negatively affects water conservation. Treated wastewater pricing can influence both crop patterns and water distribution, as well as support the development of business models that focus on decentralized, small-scale treatment systems. However, the supply of TWW for irrigation will always compete with freshwater sources – such as groundwater – even if these resources are scarce. The competition is currently fierce because the fees for using freshwater in irrigation are very low; as a result, farmers who happen to live close to a source to freshwater have no incentive for switching to TWW. Consequently, not only the TWW tariffs, but also the freshwater tariffs and the entire tariff system, should be revised. It should be noted that the irrigation water tariff was established in 1994, and has remained constant ever since, even though the inflation rate from 1994 to 2011 was 81%. The current tariff is based on an increasing block rate that varies between 8 and 35 Fils per cubic meter (van den Berg et al., 2016).

These examples demonstrate that institutional fragmentation is one of the main challenges for the wastewater sector in Jordan. For this reason, the National Implementation Committee for Effective Integrated Wastewater Management (NICE) should have a stronger role in coordinating different institutions and supporting the decision-making process. Such communication is pivotal to ensuring a smooth flow of knowledge between institutions.

5.2 Technical and financial bottlenecks

Although Jordan is a pioneer in using TWW for agricultural production, the country still faces some technical and financial challenges related to the increased demand for wastewater collection and treatment services. This includes the lack of economically viable services for scattered communities in rural areas and the rapidly expanding peri-urban areas. This issue is particularly relevant due to the current refugee situation, with 700.000 registered refugees from Iraq and Syria, 90% of which live outside of camps, severely straining Jordan’s carrying capacity (MWI, 2018). The lack of wastewater collection and treatment services presents a real barrier against the full utilization of wastewater and, perhaps more importantly, the prevention of potential groundwater contamination. The high investment costs associated with conventional wastewater collection systems hindered the expansion of sanitation services to such communities. The Wastewater Master Plan published by the International Resources Group (IRG, 2013) provides a snapshot of sanitation and wastewater treatment in Jordan and justifies the need for investments in wastewater collection. Jordan does not currently have codes for non-conventional sewage networks and the country has a lack of experience in these types of systems.

When discussing challenges related to the expansion of services to rural and developing areas, it is important to note that the absence of adequate storm water drainage systems renders treatment plants inoperable during extreme rainfall events, which have been predicted to increase in frequency and intensity due to climate change. Jordan has already experienced economic and environmental costs from the damage caused to treatment plants during extreme weather events.

With respect to DWWM systems, the lack of well-established business models is the main bottleneck hindering the widespread use of such systems. This, however, cannot be considered in lieu of policy and institutional aspects, as business models will develop if TWW is proactively directed to higher value uses. For instance, aquaculture could be considered if regulations permit such end use. Various effective low-cost treatment technologies have to be developed to support novel business models; in this way, the science-policy interface must be strengthened to drive the implementation of these types of technologies. Additional barriers to the development of successful business models include the lack of certification systems for DWWTPs and a shortage of skilled personnel for the O&M of such systems.

It is also important to consider how existing capacities could support the implementation of different irrigation systems. For instance, subsurface irrigation systems would not require such strict effluent standards with respect to pathogens and organic pollutants, which are relevant to solutions that focus on potential odor concerns. However, subsurface irrigation systems are rarely used in Jordan, and there are very few instances when they have been used to distribute TWW.

5.3 Cultural and social bottlenecks

The indirect reuse of TWW is generally accepted in Jordan, but the public is much more resistant about direct TWW reuse. It is well recognized that Jordan is a water scarce country that will run out of freshwater resources at current consumption levels, and this knowledge may be the main reason why the general public is accepting indirect TWW reuse. However, in the case of farmers, profits are more important than acceptance. For instance, farmers do not always conform to Jordanian standards even though monitoring programs are in place to ensure compliance in terms of water quality and the type of irrigated crops. Some farmers use TWW discharged into streams for unrestricted irrigation before mixing the treated effluent with freshwater in reservoirs. This irrigation practice is considered illegal and violates the Jordanian Standard JS 893 (2006). It has been suggested that farmers mainly disregard the current standard due to a lack of knowledge about which practices are permitted and which practices are prohibited.

There is clear resistance to biosolids reuse for agricultural production. Biosolids reuse has still not been introduced to the public, with the resistance towards biosolids reuse coming from different institutions, as discussed earlier. Moreover, farmers do not want to jeopardize the reputation of their products, even if they feel that biosolids reuse could be beneficial and safe.

Local opinion is critical to wastewater treatment projects, as small-scale wastewater management schemes usually face the most resistance from local communities who are concerned about the site at which the facility will be built. This may stem from a lack of trust between the public and the government with respect to the capacity of a WWTP to achieve sufficient levels of treatment, especially in terms of odors.

Moreover, communities are usually doubtful of future governmental plans for treatment plants. In many instances, the local community believes that the WAJ will connect neighboring towns to the treatment plant that is to be installed in their neighborhood. This would negatively affect the reputation of the town in which the treatment plant is located. Local communities commonly fear that the value of land in areas surrounding the treatment plant will decrease, and this concern has increased resistance to the development of wastewater treatment services.

In fact, the lack of social acceptance towards wastewater reuse in Jordan has halted the implementation of many sanitation service projects, some of which have focused on wastewater reuse. In some cases, the attitudes towards a project became so aggressive that the Ministry of Interior Affairs had to interfere to stop violence and solve conflicts. Lack of awareness among the general public as well as conflicts of interest between land owners and the government seem to be the main bottlenecks for small-scale sanitation and reuse projects.

Policy Measures that would Ensure the Long-Term Sustainability of Wastewater and Biosolids Reuse

6

The recognition of the WHO 2006 guidelines for the safe reuse of TWW in agriculture is an important step to addressing the regulatory and institutional bottlenecks related to wastewater reuse (WHO, 2006d; WHO, 2006c; WHO, 2006a; WHO, 2006b). Evidently, Jordan has adapted the guidelines through its National Irrigation Water Quality Standards (JS 1766/ 2014), which recognize various types of irrigation water, including surface water, as potential contamination sources that need to be regulated. Specifically, surface water was found to be polluted (Al-Mashagbah, 2015) by different sources including agricultural drainage, dead animals, and runoff, among others. Undoubtedly these contamination sources might also deteriorate the quality of TWW that has undergone secondary or tertiary treatment (as is the case in Jordan). In the case of TWW the public will usually blame the WWTP even if other contamination sources decreased the TWW quality. The provisions of JS 1766/2014 will help to integrate TWW into the water cycle, and the standard – once in effect – will support better acceptance of this high-quality water resource.

It should be noted that the WHO guidelines - which were developed in 2006 – have still not been implemented at a national scale in any country. The integral approach proposed by WHO Guidelines (2006) cannot be implemented without a detailed management and safety plan. Obviously, management plans can be expected to vary from country to country, as well as within the same country, depending on different variables. In the Jordanian context, the extent of coordination between different stakeholders should be clearly defined when such a Sanitation Safety Plan (SSP) is developed and implemented.

Some agricultural inputs might exert a larger influence on the safety of agricultural products than irrigation water quality. For instance, it was found that high-quality irrigation water might get re-contaminated due to manure application (agricultural input). This contamination may subsequently contaminate agricultural products and present a health risk for farmers and consumers (Halalsheh et al., 2018b). This finding demonstrates that SSPs must be developed, as well as implemented, for different points of the agricultural value creation chain to ensure that high-quality irrigation water is constantly used.

This chapter discusses the appropriate steps for developing SSPs and presents an institutional framework that would ensure safe agricultural production at the farm level in Jordan. In the proposed framework, irrigation water qualities (TWW or other sources) cannot be assessed without considering other external inputs and parameters that lie downstream of WWTPs. Therefore, the proposed framework presents farm level control measures and specifies which authority – with reference to the legal mandate – is responsible for each of these measures.

6.1 Sanitation safety planning

Implementation plans, or SSPs, prioritize risks and utilize limited resources to minimize the most severe risks and progressively improve a certain societal problem. More information can be found in the WHO SSP Manual (WHO, 2016). The development process for SSPs closely mirrors that of Water Safety Plans (WSP) (Davison et al., 2005). Sanitation safety plans comprise three main components:

1. **System description,** which describes the whole process and usually includes a flow chart that carefully delineates the system.
2. **Hazard analysis,** which identifies all of the potential hazards (biological, chemical, physical, and radiological agents). Moreover, this component will describe hazard sources, along with possible hazardous events, and provide an assessment of each risk (Davison et al., 2005); and
3. **Control measures**, which are the actions or activities that will be applied to minimize hazards.

The proposed control measures entrust the MoA with a greater role in mitigating the risks that exist downstream of wastewater treatment. As such, laws of the MoH, MoA, WAJ, and MoEnv will regulate how TWW is used for different purposes. Overlaps between different bodies may have resulted in some confusion regarding assigned responsibilities; hence, increasing coordination is critical to developing good SSPs. For instance, the MoA and MoH are still discussing who is responsible for controlling and assuring the quality of irrigated crops. The MoA currently monitors imported crops for pesticide residues, but is reluctant about being in charge of controlling local non-processed food. The MoH, however, argues that crop quality control is part of the MoA's legal responsibilities.

Overlaps in the responsibilities assigned to each ministry are apparent, and consequently, Jordanian ministries must improve coordination to adequately, and efficiently, control the quality of agricultural products. Moreover, it is expected that lack of capacities at both ministries are behind reluctance to take the lead in controlling locally produced crops. As such, institutional, infrastructural and human capacities at both ministries need to be strengthened. Recently, the Jordanian component of a WHO/UNDP project on adaptation to climate change improved the ability of the Jordan Food and Drug Administration (JFDA) to recognize pathogenic contamination of crops. On the other hand, the MoA has the capacity to monitor pesticide residues in crops, both imported and locally produced.

6.2 Technical and financial measures

Although Jordan has already made considerable progress in the provision of sanitation services, the current flux of refugees and impending climate change impacts will require decentralized solutions to adequately serve the rapidly expanding urban areas as well as hot spots within rural communities. Even though most technologies that are applied in CWWTPs can also be used in decentralized- and semi-centralized systems, options that minimize biosolids production and are characterized by low operation and maintenance requirements should be preferred.

It should be noted that no single technology can be applied to all wastewater treatment cases and, as such, the selection of a technological solution should be made using a sustainability matrix that weighs the characteristics of alternatives based on the criteria suggested in the DWWM Policy (MWI, 2016b). The assessments should always include relevant experts, whose judgments should consider how the technology fits the Jordanian context and how it will be perceived by the general public. Furthermore, a wastewater treatment technology should never be selected without considering reuse irrigation systems. For instance, a sub-surface irrigation system might be preferable for house onsite wastewater management. This is particularly true if the treated effluent is stored in a collection tank before being pumped and reused for irrigation. Effluent storage during summer months is associated with an increased risk of pathogenic re-contamination, which could be eliminated by applying a sub-surface drip irrigation system. In any case, irrigation system selection criteria have to be added to the selection matrix.

Moreover, a certification process – which is currently under development by NICE – will ensure proper selection and operation of technological solutions. The planned certification scheme will provide a certification framework for all WWTPs with a capacity of up to 5.000 PE, and shall describe procedures for certifying O&M staff in Jordan. Furthermore, it will list specifications for the materials, design and construction, and performance testing. The certification process will also specify the minimum written documentation that the manufacturer will pass on to the owner. It should be noted that WWTPs with capacities under 5.000 PE were selected in order to be in line with the National Water Strategy 2016 – 2025 (MWI, 2016a) and the National Strategic Wastewater Master Plan (IRG, 2013).

In Jordan, ownership and maintenance for decentralized systems are transferred to individual homeowners or small communities. This leads to a fragmentation of the responsibilities for operation and maintenance, which can result in overburdening the owners. Alternatively, business models should be created in which ownership of decentralized and centralized facilities are under one roof and a cluster of multi-sized treatment systems are operated and maintained by a single competent enterprise. The resulting costs are passed on in the form of wastewater charges to all connected citizens (both in metropolitan and rural areas). This business model can be described using the term "*central management of decentralized infrastructures*".

However, governmental support of small-scale DWWTPs is currently limited to locations at which groundwater quality is threatened, due to leakage from cesspools. The situation may change in the near future, especially because governmental subsidies could be indispensable to the ability of the WAJ to provide expanding peri-urban areas with high-quality, reliable sewage networks and treatment systems. Until the current situation changes, any suggested business model should not contain subsidies, but rather consider technologies that could utilize different waste streams to produce energy and/or recover other resources to facilitate a circular economy. Value creation could provide cost recovery in the sanitation sector; for instance, biological material that has been subjected to anaerobic digestion could create energy as well as compost – which could be returned to the soil to reduce the need for chemical fertilizers and soil amendments. At the global level, Drechsel et al. (2018) estimated that capturing all of the nutrients from current stocks of cattle, chicken, pig and sheep manure would yield an amount that is more than twice the world's current consumption of N, P and K. In Jordan, such possibilities have to be further investigated and explored, and accordingly, a new regulatory framework has to be established.

In conclusion, realistic standards have to be established through the development of SSPs at catchment or sub-catchment levels, with the aim of achieving significant cost savings. At the same time, the potential for value creation from various waste streams should be investigated.

6.3 Cultural and social measures

Combining wastewater treatment with agricultural irrigation has been commonplace in Jordan for several decades. Almost all of the wastewater treated receives at least secondary treatment. This means that the effluent quality mostly covers *Class C* as defined in JS 893 (2006). Moreover, large reuse schemes are still limited to the indirect reuse of *'mixed water'*, meaning that effluent from CWWTPs is mixed with surface water. Apparently, this part of the current wastewater management approach is generally accepted by the public. In contrast, direct reuse is handled far stricter in the agreements between the WAJ and farmers, as even tertiary TWW can only be used to irrigate fodder crops and fruit trees. A main reason for this restriction is the societal perception of water originating from WWTPs, which partly stems from the fact that public awareness programs have so far ignored promoting direct reuse of TWW.

The assurance of the water quality is the responsibility of the treatment plant operator, as well as the reliable external monitoring bodies. However, if levels of confidence in operators and authorities are in general low additional measures, such as monitoring done by independent supervisory bodies, and transparent communication with the water users, are necessary to create confidence in TWW quality (DWA, 2019).

Hence, the government should invest in public awareness programs that focus on disseminating relevant knowledge about wastewater treatment and reuse. For instance, Jordanian society accepts greywater reuse more readily than TWW reuse despite the fact that raw greywater might be as polluted as domestic wastewater. This is best reflected in the current reclaimed greywater use standards (JS 1776/2013), which permit the use of treated greywater for unrestricted irrigation.

7

Recommendations

The severe water scarcity in Jordan effectively makes wastewater treatment and reuse an attractive option for preserving and extending available water supplies. The reuse of properly TWW into national water resources management has clear benefits for public health, groundwater, the environment and economic development. Treated wastewater may provide a significant renewable and reliable water source, and will contribute to the conservation of freshwater resources. Furthermore, it constitutes a valuable source of water and nutrients in agricultural schemes, therefore, TWW can also be valuable in terms of reduced chemical fertilizer use and increased agricultural productivity. However, these benefits can only be realized if the Jordanian government takes actions to improve the current situation and overcome existing obstacles.

Increasing the production of TWW

Currently, approximately 163 MCM/year of TWW is generated in Jordan (MWI, 2018). This is primarily achieved by sewer-bound CWWTPs serving bigger cities and densely populated areas. Increasing the amount of TWW can only be achieved by extending the access of the population to treatment plants to rural and peri urban areas. Due to economic reasons, a combination of channel-bound systems with non-channel-bound solutions of all size classes should be prioritized, leading to the formation of clusters from centralized, semi-centralized and decentralized wastewater treatment solutions.

Consolidation of DWWTPs and reuse systems

Within the WAJ, the main obstacles to extend decentralized wastewater infrastructures and reuse systems are staffing constraints and uncertainties for trouble-free operation.

From a technical point of view, not all available decentralized technologies are easy to operate and maintain. As a result, NICE is currently developing a certification scheme for smaller plants that will ensure the safe reuse of TWW after implementation. The planned certification shall provide a framework for WWTPs with capacities of up to 5.000 PE, and will also describe the certification procedure for personnel involved in the operation and maintenance of such WWTPs in Jordan. The certification shall specify the materials, designs and construction, and performance testing for DWWTPs and treatment plants for greywater. Moreover, it will describe the minimum written documentation that a manufacturer must hand over to the owner.

The control and management of DWWTPs must be managed by an independent unit under the umbrella of MWI/WAJ. An official database (inventory) should be created and maintained listing all existing DWWTPs, monitoring plans and performance data as it is an important tool for central management of decentralized infrastructures. It should be noted; however, operation, maintenance and monitoring should be outsourced and could be covered by existing private companies or associations that already operate CWWTPs.

Moreover, DWWTPs are currently obligated to comply with the irrigation standard JS 893 (2006), which does not meet the specific requirements of decentralized systems. The increase in decentralized technologies in Jordan makes this a concerning finding. For this reason, the current standard should be updated or a new standard set for DWWTPs, as described in the DWWM Policy (MWI, 2016b), should be implemented.

Optimizing CWWTPs

Regarding CWWTPs in Jordan, the responsible ministries should plan further investigations that evaluate the performance of certain WWTPs that are producing an effluent which does not comply with (JS 893, 2006) (see 2. Centralized Wastewater Treatment Plants). The results of these studies can then be used to make recommendations for improving the performance of these facilities. Increasing the quality and secure delivery of TWW will also create high quality reuse options.

Decreasing water transfer losses

Approximately 80% or more than 131 MCM/year of TWW in Jordan is discharged into wadis and blended (mixed) with rain water/freshwater to be mainly used in the Jordan Valley for unrestricted irrigation (indirect reuse).

Transfer and storage of TWW by river (wadi) runoff causes losses through infiltration and evapotranspiration. Consequently, the amount of TWW that reaches the irrigation fields in the Jordan Valley may be well below the total available amount.

Reducing these losses could be a measure to optimize irrigation efficiency. To this end, the magnitude of these water transfer losses should be investigated with solutions being proposed and evaluated if required.

Increasing direct reuse

An additional optimization measure could be the reduction of indirect reuse in favor of a direct reuse of TWW in the vicinity of the WWTPs. Unnecessarily strict restrictions (e.g. high limits in JS 893/2006) of TWW reuse should be abandoned. For example, direct effluent reuse in irrigation is currently mainly applied to fodder crops and fruit trees. Moreover, unrestricted irrigation is only allowed after mixing TWW with other freshwater resources. These restrictions might be attributed to institutional fragmentation, which has resulted in a low level of MoA involvement in processes that lie downstream of WWTPs.

Adjustment of water tariffs

Even though wastewater is already actively reused in irrigation in Jordan, the current system is still far from achieving the maximum benefits. It is important to point out that the agricultural sector is highly subsidized by the government; therefore, the current water tariffs should be reconsidered.

The tariffs for all other freshwater resources should also be reconsidered, particularly in the case with the recent National Water Strategy 2016 – 2025 due to basing the tariff calculations on water allocation models. The reconsideration of tariffs would also support the development of successful business models.

Enforcement of sanitation safety planning

Sanitation safety planning for different catchment areas, which are in accordance with the IWRM principles presented in the National Water Strategy 2016 – 2025, would consider all of the agricultural inputs, prioritize hazards and define specific control measures (actions) that would minimize associated risks (MWI, 2016a). An example of this is the regular fecal contamination of underground water resources – a direct result of the lack of wastewater treatment in some areas – which requires urgent action to safeguard public health, groundwater resources and the environment.

Enforcing SSP would also provide the basis for new standards and would be beneficial in terms of savings in wastewater treatment investments, which have earlier been ineffective due to downstream contamination sources.

Moreover, SSPs would also improve coordination among wastewater management stakeholders, consequently reducing the current burden on the WAJ and ensuring that each member is responsible for their legally defined tasks.

Making biosolids a resource

The Jordanian government is aware of the importance of managing biosolids and recognizes this as a short-term priority. As a matter of priority, investments should first be made in programs that fully demonstrate the benefits of such reuse. An example would be in applications that do not pose a health risk to the population such as restoration of degraded or saline soils to afforestation.

For the recovery of resources from wastewater in the context of a circular economy, scientific knowledge and technical know-how from around the world should be exchanged to establish new criteria or guidelines for the sustainable management of biosolids in Jordan. Accordingly, it is recommended to check the consistency of JS 1145 (2016) for the reuse and disposal of biosolids.

In addition, appropriate sludge stabilization procedures, standardized sampling and analytical techniques and adequate monitoring and enforcement guidelines should be established to optimize the biosolids management in Jordan.

Strengthening social acceptance

Public awareness programs have thus far failed to promote TWW reuse due to community acceptance. The government should therefore invest in public awareness programs that focus on wastewater treatment and reuse ensuring to address cultural and social concerns. All relevant stakeholders should participate from the initial stages of the implementation of reuse projects to further stimulate acceptance. Moreover, any wastewater reuse initiative must have effective safety measures in place, such as, frequent monitoring of effluent quality and control measures in the case of deviations to prevent negative externalities to either the environment or public health. Based on the results presented in Chapter *2. Centralized Wastewater Treatment Plants,* the current control mechanisms are not working properly. It is of concern, that almost 40% of the CWWTPs are still operating although they do not meet the limits specified in Standard JS 893 (2006).

SDG Goal 6

The recommendations listed in this section could serve as a first basis to assist Jordan in achieving the SDG Goal No. 6 for sustainable development, described by the United Nations.

The recommendations aim at improving water quality by reducing pollution, eliminating dumping, halving the proportion of untreated wastewater and substantially increasing safe reuse of TWW. It also aims to significantly increase water-use efficiency across all sectors and ensures sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity.

التوصيات

إن شح مصادر المياه في الأردن جعل من إعادة استخدام المياه المستصلحة خيارا مجديا وذلك للمحافظة على مصادر المياه المتاحة وتوسيع نطاق استخدامها، و يعد دمج إعادة استخدام المياه مع إدارة مصادر المياه جزءا لا يتجزأ من عملية التحكم في التلوث البيئي والاستخدام الامثل للمصادر المتاحة، بالإضافة الى الفوائد التي تعود على البيئة والصحة العامة والتنمية الاقتصادية. وتعتبرالمياه المستصلحة مصدرا مهما للمياه المتجددة والتي يمكن إعادة استخدامها في القطاع الزراعي، للمحافظة على مصادرالمياه العذبة. والذي من شأنه أن يقلل استخدام الأسمدة الكيماوية وزيادة الإنتاجية الزراعية. ومع ذلك، لا يمكن تحقيق هذه الفوائد إلا إذا اتخذت الحكومة الأردنية الإجراءات اللازمة للتغلب على العقبات وتطوير الوضع الراهن.

زيادة كميات المياه العادمة المعالجة

يتم حاليا معالجة حوالي 163 مليون متر مكعب من المياه العادمة في السنة (الجدول 3). و ذلك من خلال شبكات الصرف الصحي المشبوكة على محطات معالجة المياه العادمة المركزية التي تخدم المدن الكبرى والمناطق المكتظة بالسكان. لا يمكن تحقيق زيادة كمية المياه المعالجة إلا عن طريق توسيع وصول شبكات الصرف الصحي للسكان في المناطق الريفية وشبه الحضرية.ولكن لأسباب اقتصادية، يجب علينا إعطاء الأولوية لشبك المنازل على شبكات الصرف الصحي او الحفر الامتصاصية المصمتة اومحطات المعالجة اللامركزية، مما يؤدي إلى إيجاد مجموعات من الحلول لمعالجة مياه الصرف الصحي المركزية وشبه المركزية واللامركزية.

أنظمة المعالجة اللامركزية وإعادة الاستخدام

تتمثل العقبات الرئيسية التي تعترض توسيع البنى التحتية اللامركزية لمياه الصرف الصحي وأنظمة إعادة الاستخدام في قيود التوظيف والشكوك التي تحول دون تشغيل الأنظمة بطريقة مثالية خالية من المشاكل.

من الناحية الفنية، يمكن القول أنه ليس كل التقنيات والأنظمة اللامركزية المتاحة سهلة التشغيل والصيانة. لهذا السبب، تقوم حاليا اللجنة الوطنية التنفيذية للإدارة المتكاملة للمياه العادمة (NICE) بتطوير خطة لإصدار الشهادات للمحطات الصغيرة التي ستساعد على ضمان إعادة الاستخدام الآمن للمياه العادمة المعالجة،هذا و توفر شهادات الاعتماد إطارا لمحطات معالجة مياه الصرف الصحي بسعة تصل إلى 5.000 مكافىء سكاني، كما تصف هذه الدراسة إجراءات إصدار الشهادات للعاملين في تشغيل وصيانة محطات معالجة مياه الصرف الصحي في الأردن.و يجب أن تحدد المواد والتصاميم والبناء واختبار الأداء لمحطات معالجة مياه الصرف الصحي ومحطات معالجة المياه الرمادية. علاوة على ذلك، سوف تحدد الوثائق المكتوبة التي يجب على الشركة المصنعة تسليمها إلى المالك.

يجب تنظيم محطات المعالجة اللامركزية (DWWTPs) وإدارتها بواسطة وحدة مستقلة تحت مظلة WAJ/MWI، بحيث يتم إنشاء قاعدة بيانات رسمية للاحتفاظ بجميع المعلومات والبيانات المتعلقة بمحطات معالجة مياه الصرف الصحي اللامركزية وخطط المراقبة وبيانات الأداء الحالية. ومن الجدير بالذكرأنه يجب الاستعانة بمصادر خارجية للتشغيل والصيانة والمراقبة ويمكن أن يتم ذلك بواسطة الشركات الخاصة الحالية أو الجمعيات التي تشغل بالفعل محطات المعالجة المركزية.

علاوة على ذلك، فإن محطات المعالجة اللامركزية (DWWTPs) ملزمة حاليا بالامتثال للمواصفة الاردنية لإعادة الاستخدام (893/2006)، التي لا يفي بالمتطلبات المحددة للأنظمة اللامركزية. إن الزيادة في التقنيات اللامركزية في الأردن تجعل هذا الأمر مثار قلق. لهذا السبب، يجب تحديث المعيار الحالي أو تطبيق مواصفات قياسية جديدة لـ (DWWTPs)، كما هو موضح في سياسة إدارة المياه العادمة اللامركزية (MWI/2016a).

تحسين محطات المعالجة المركزية (CWWTPs)

فيما يتعلق بـ CWWTPs في الأردن، ينبغي على الوزارات المسؤولة أن تخطط لمزيد من التحقيقات التي تقيم أداء بعض محطات معالجة مياه الصرف الصحي التي تنتج مياه عادمة معالجة لا تتوافق مع المواصفة الأردنية (893/2006) ويمكن بعد ذلك استخدام نتائج هذه الدراسات لتقديم توصيات لتحسين أداء هذه المرافق.و تحسين نوعية لمياه العادمة المعالجة وأستخدامها بشكل آمن التي من شأنها أن تخلق أيضا خيارات إعادة استخدام ذات جودة عالية.

تقليل الفاقد من المياه

يتم تصريف حوالي 80٪ أو أكثر من 131 مليون متر مكعب في السنة من المياه المعالجة في الأردن إلى الوديان وخلطها بمياه الأمطاروالمياه العذبة لاستخدامها بشكل رئيسي في وادي الأردن لأغراض الري غير المقيد (إعادة الاستخدام غير المباشر).

يؤدي نقل وتخزين المياه العادمة عبر الوديان إلى حدوث خسائر(فاقد) من خلال الارتشاح والتبخر. نتيجة لذلك، قد تكون كمية المياه التي تصل إلى حقول الري في وادي الأردن أقل بكثير من إجمالي الكمية المتاحة.

يمكن أن يكون تقليل هذه الخسائر مقياسا لتحسين كفاءة الري. تحقيقا لهذه الغاية، ينبغي التحقيق في حجم الفاقد الناتج عن نقل المياه، وإذا لزم الأمر، يتم اقتراح الحلول التقنية وتقييمها.

زيادة نسبة إعادة الاستخدام المباشر

يمكن أن يمثل أحد تدابير التحسين الإضافية في الحد من إعادة الاستخدام غير المباشر لصالح إعادة الاستخدام المباشر لمياه المعالجة بالقرب من محطات معالجة مياه الصرف الصحي. يجب إعادة النظر في القوانين الصارمة التي تحد من استخدام المياه المعالجة. على سبيل المثال، يتم إعادة استخدام المياه المعالجة المباشرة في الري حاليا بشكل أساسي على محاصيل الأعلاف وأشجار الفاكهة. علاوة على ذلك، لا يسمح بالري غير المقيد إلا بعد خلط المياه المعالجة (TWW) بموارد المياه العذبة الأخرى، يمكن القول أن هذه القوانين فرضت بسبب توزيع المسؤوليات والمهام بين المؤسسات الحكومية المعنية مما أدى إلى انخفاض مستوى مشاركة وزارة الزراعة في النشاطات التي تحصل بالقرب من محطات معالجة مياه الصرف الصحي.

تعديل تعرفة المياه

على الرغم من إعادة استخدام المياه العادمة في الري، فإن النظام الحالي لا يزال بعيدا عن تحقيق أقصى الفوائد المرجوه.و من المهم الإشارة إلى أن القطاع الزراعي مدعوم بشدة من قبل الحكومة؛ لذلك، ينبغي إعادة النظر في تعريفة المياه الحالية.

خطط سلامة الصرف الصحي

تطوير واعتماد إطار مؤسسي لوضع خطط سلامة الصرف الصحي والتنفيذ اللاحق لـهذه الخطط لمناطق التجمعات المائية المختلفة وفقا لمبادئ إدارة مصادر المياه المتكاملة (IWRM) والمبينة في الاستراتيجية الوطنية للمياه (2016-2025)، وعند تطوير خطط السلامة للصرف الصحي يجب أخذ مايلي بعين الاعتبار: جميع المدخلات الزراعية، و أولويات المخاطر و الإجراءات الرقابية التي من شأنها أن تقلل من المخاطر. سيكون هذا النهج أساسا لتحديد تكلفة تقنيات معالجة المياه العادمة وإعادة استخدامها،بالإضافة الى توفير استثمارات في معالجة مياه الصرف الصحي، والتي كانت غير فعالة سابقا بسبب تلوث مصادر المياه، وتزويد خدمات الرعاية الصحية التي بدورها ستقلل العبء الحالي على سلطة المياه ويضمن أن كل عضو مسؤول عن مهامه المحددة قانونيا.

أهمية الحمأة

تدرك الحكومة الأردنية أهمية إدارة المواد الصلبة الحيوية (الحمأة)، يجب أولا الاستثمار في البرامج التي تظهر فوائد إعادة الاستخدام بالكامل، على سبيل المثال في التطبيقات التي لا تشكل خطرا صحيا على السكان مثل استعادة التربة المتدهورة أو المالحة للتشجير.

من أجل استرداد الموارد من مياه الصرف الصحي المعالجة في سياق الاقتصاد الدائري، ينبغي تبادل المعرفة العلمية والدراية الفنية من جميع أنحاء العالم

لوضع معايير أو مبادئ توجيهية جديدة للإدارة المستدامة للمواد الصلبة الحيوية في الأردن. وفقا لذلك، يوصى بالتحقق من تطابقها مع المواصفة الاردنية لإعادة استخدام المواد الصلبة الحيوية والتخلص منها (1145/2016).

بالإضافة إلى ذلك، ينبغي وضع إجراءات مناسبة لمعالجة الحمأة، وأخذ العينات والتقنيات التحليلية،بالإضافة الى مبادئ توجيهية مناسبة للرقابة والإنفاذ لتحسين إدارة المواد الصلبة الحيوية في الأردن.

تعزيز القبول المجتمعي

فشلت برامج التوعية العامة من أجل القبول الثقافي والاجتماعي، لمبدأ إعادة استخدام المياه العادمة المعالجة؛ وبالتالي، يتعين على الحكومة الاستثمار في برامج التوعية العامة التي تركز على معالجة المياه العادمة وإعادة استخدامها. يجب على جميع أصحاب المصلحة المعنيين المشاركة منذ البداية في تنفيذ مشاريع إعادة الاستخدام لرفع مدى القبول. بالإضافة إلى ضرورة وجود تدابير فعالة للسلامة لإي مبادرة بإعادة الاستخدام ومنها مراقبة نوعية المياه المستصلحة بشكل دوري واتخاذ التدابير الرقابية اللازمة لمنع الآثار السلبية على البيئة و الصحة العامة. وتبين من خلال الدراسة كما هو موضح في الفصل الثاني،أن آليات المراقبة الحالية في محطات معالجة المياه العادمة المركزية، لا تعمل بشكل فعال، ولذا فإن حوالي 40٪ من محطات معالجة مياه الصرف الصحي لا تحقق معاييرإعادة الاستخدام (الري أو التصريف في الجداول والوديان والمسطحات المائية) المحددة في المواصفة القياسية (893/2006).

تحقيق الهدف السادس من أهداف التنمية المستدامة (SDG 6)

من الواضح أن التوصيات الواردة في هذه الدراسة ستساعد الأردن على تحقيق الهدف السادس من أهداف التنمية المستدامة، التي أدرجتها الأمم المتحدة، ويهدف إلى تحسين نوعية المياه عن طريق الحد من التلوث، والقضاء على التصريف غير القانوني للمياه العادمة، وخفض نسبة المياه العادمة غير المعالجة وزيادة إعادة استخدام مياه الصرف الصحي بشكل آمن. كما تهدف إلى زيادة كفاءة استخدام المياه بشكل كبير في جميع القطاعات وضمان استدامة إمداد للمياه العذبة والحد بشكل كبير من عدد الأشخاص الذين يعانون من ندرة المياه.

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9. Definitions and Terminology

Biosolids

Sewage sludge which has been adequately treated (sludge stabilization) and processed which can be utilized as fertilizer to improve and maintain productive soils and stimulate plant growth (WWAP, 2017).

Centralized Wastewater Treatment Plant (CWWTP)

Managed systems consisting of a collection of sewers and a single treatment plant used to collect and treat wastewater from specific service areas (WWAP, 2017).

Circular economy

An economy which balances economic development with environmental and resource protection. It places emphasis on the most efficient use and recycling of resources, and environmental protection. A circular economy features a low consumption of energy and other resources, low emission of pollutants, minimum waste production and high efficiency. It involves applying a cleaner production in companies, as well as eco-industrial park development and integrated resource-based planning for development in industry, agriculture and urban areas (WWAP, 2017).

Decentralized Wastewater Treatment Plant (DWWTP)

Decentralised wastewater systems collect, treat, and reuse or dispose of wastewater at or near its point of generation. With reference to the Jordanian Decentralized Wastewater Management Policy (MWI, 2016b), decentralized wastewater treatment systems are defined as follows: "*Domestic wastewater treatment plants for small residential groups with a design capacity below 5.000 Population Equivalent*"

Direct reuse

Reuse schemes when TWW is used for agricultural irrigation without blending it with other water sources.

Disinfection

Removal and inactivation of harmful microorganisms to raise the quality of the TWW before irrigation (ISO 16075-1, 2015).

Domestic wastewater

Composed of blackwater, greywater and potentially other types of wastewater derived from household activities and residential settlements (WWAP, 2017).

Fodder crops

Crops not for human consumption such as pastures and forage, fiber, ornamental, seed, forest, and turf crops (ISO 16075-1, 2015).

Greywater

Wastewater generated from a washing machine, bathtub, shower or bathroom sink, collected separately from a domestic wastewater flow. It does not include wastewater from toilets (WWAP, 2017).

Indirect reuse

Reuse schemes when TWW is used for agricultural irrigation after blending with other water sources (mainly surface water).

Primary treatment

Removal of a portion of the suspended solids and organic matter from raw wastewater (WWAP, 2017).

Reclaimed water

Treated wastewater that can be reused under controlled conditions for beneficial purposes (WWAP, 2017).

Restricted irrigation

Use of reclaimed water for non-potable applications in settings where public access is controlled or restricted by physical or institutional barriers (ISO 16075-1, 2015). JS 893/2006 must be applied and TWW quality should meet JS 893/2006 in order to be used for irrigation in agriculture.

Secondary treatment

Removal of biodegradable organic matter (in solution or suspension), suspended solids, and nutrients (nitrogen, phosphorus, or both) (WWAP, 2017).

Sewage

Wastewater and excrement (blackwater) conveyed in sewers (WWAP, 2017).

Sludge

The nutrient-rich organic materials resulting from the treatment of domestic sewage in a wastewater treatment facility (WWAP, 2017).

Tertiary treatment

Removal of residual suspended solids (after secondary treatment), further nutrient removal and disinfection (WWAP, 2017).

Treated wastewater

Wastewater which has undergone any kind of primary, secondary and possibly tertiary treatment (DWA, 2019).

Unrestricted irrigation

Use of reclaimed water for non-potable applications in settings where public access is not restricted (ISO 16075-1, 2015). Blended water (TWW mixed with rainwater/ freshwater) must meet the Irrigation Water Quality Guidelines (JS 1766:2014) in Jordan.

Water reuse

Use of reclaimed water under controlled conditions for beneficial purposes, such as agricultural or landscape irrigation etc.; synonymous to water reclamation (ISO 16075-1, 2015).

Wastewater management

Includes the prevention or reduction of pollution at the source , the collection and removal of contaminant from wastewater streams, and the beneficial use and/or disposal of treated wastewater and its by-products (WWAP, 2017).

Wastewater Treatment Plant (WWTP)

Facility designed to treat wastewater by a combination of physical (mechanical) unit operations and chemical and biological processes, for the purpose of reducing the organic and inorganic contaminants in the wastewater (ISO 16075-1, 2015).

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Policy Measures that would Ensure the Long-Term Sustainability of Wastewater and Biosolids Reuse

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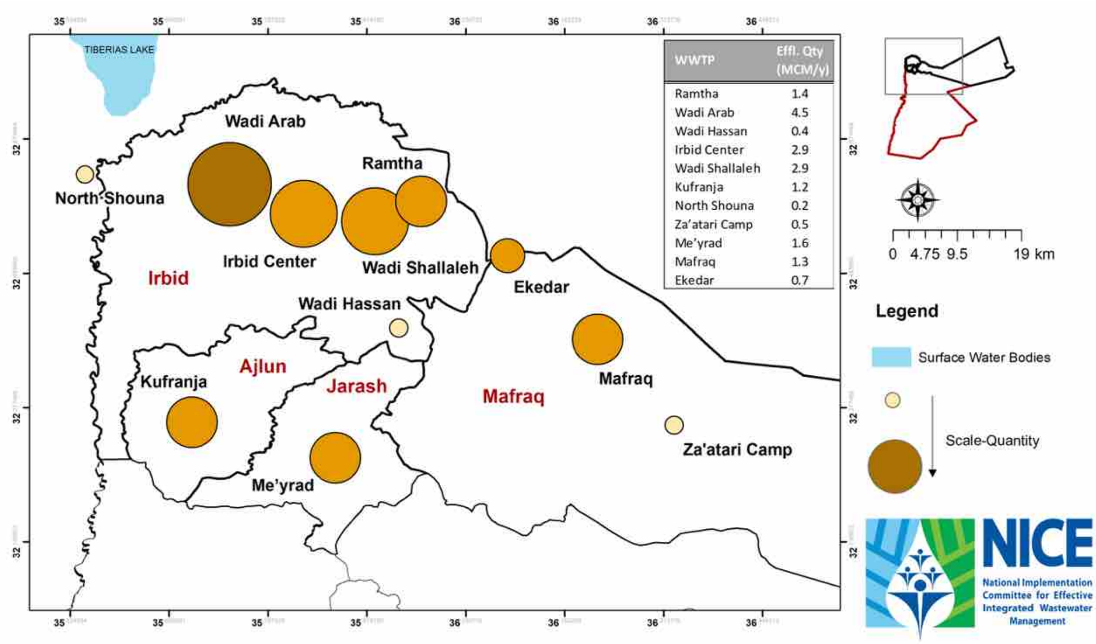
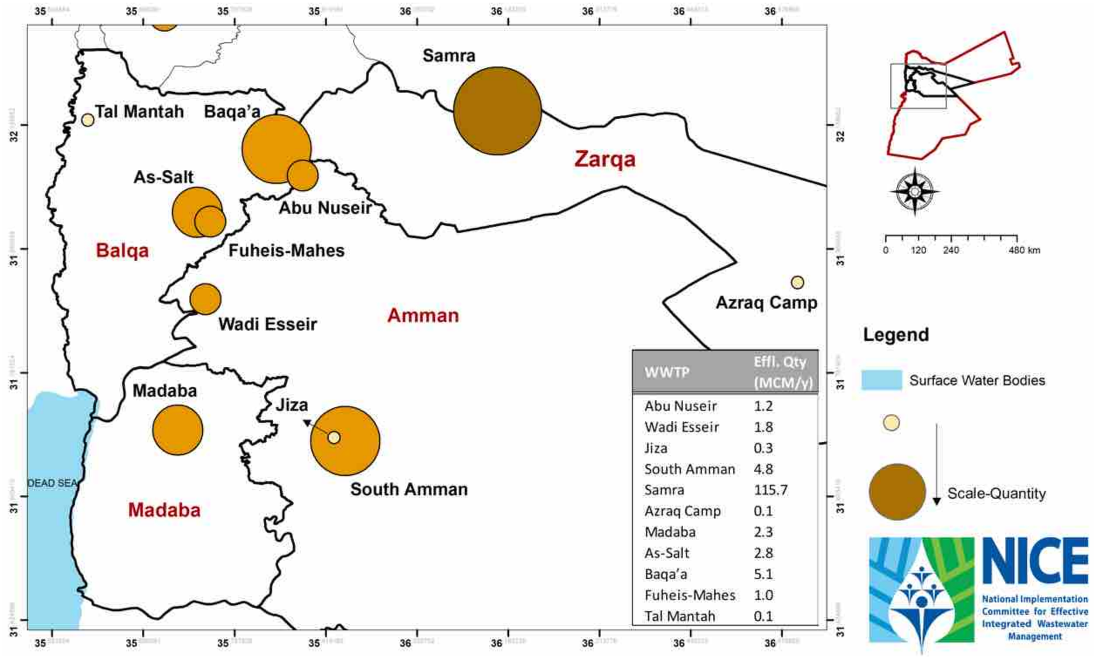
11. Annexes

11.1 Quantities of treated wastewater produced by CWWTPs in Jordan

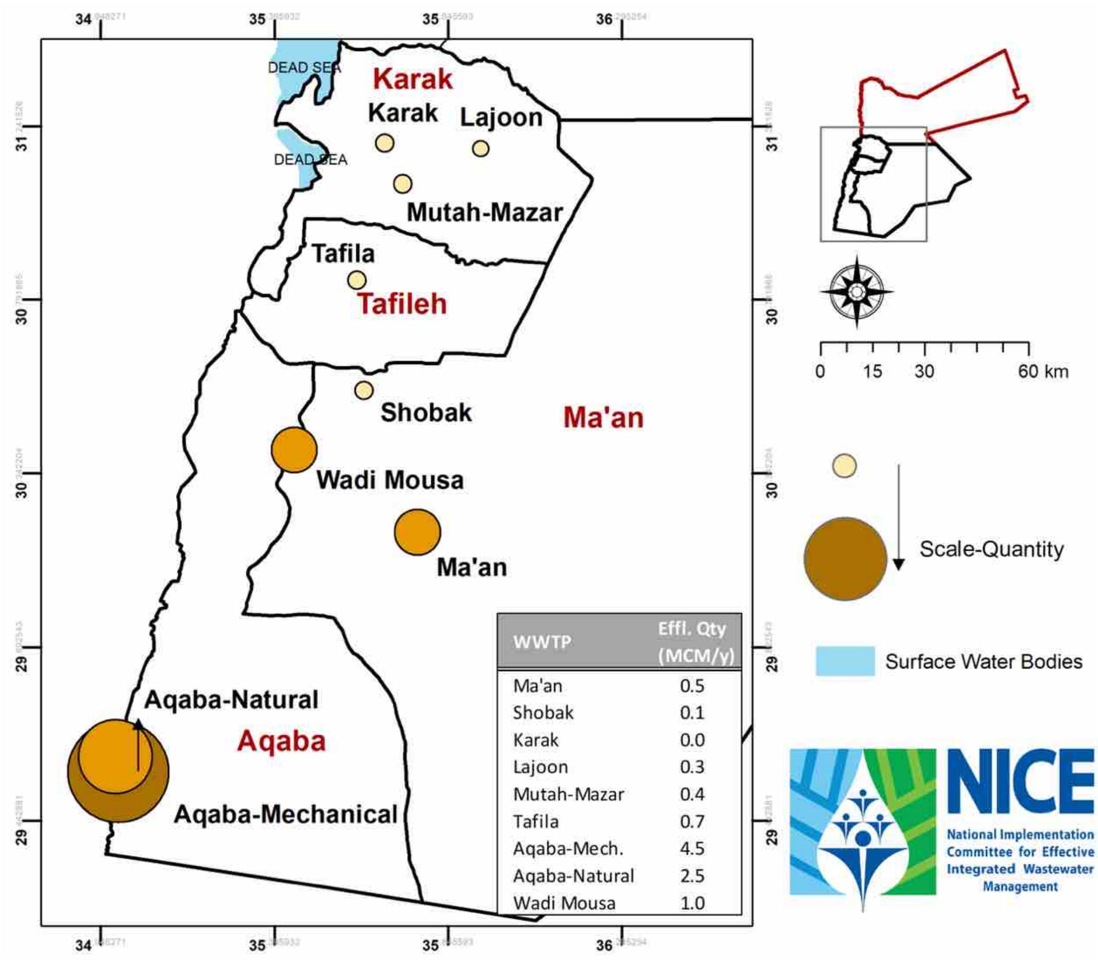


Annex Figure 1 Average quantity of treated wastewater produced by centralized wastewater treatment plants in the Northern Governorates.



WWTP	Effl. Qty (MCM/y)
Abu Nuseir	1.2
Wadi Esseir	1.8
Jiza	0.3
South Amman	4.8
Samra	115.7
Azraq Camp	0.1
Madaba	2.3
As-Salt	2.8
Baqa'a	5.1
Fuheis-Mahes	1.0
Tal Mantah	0.1

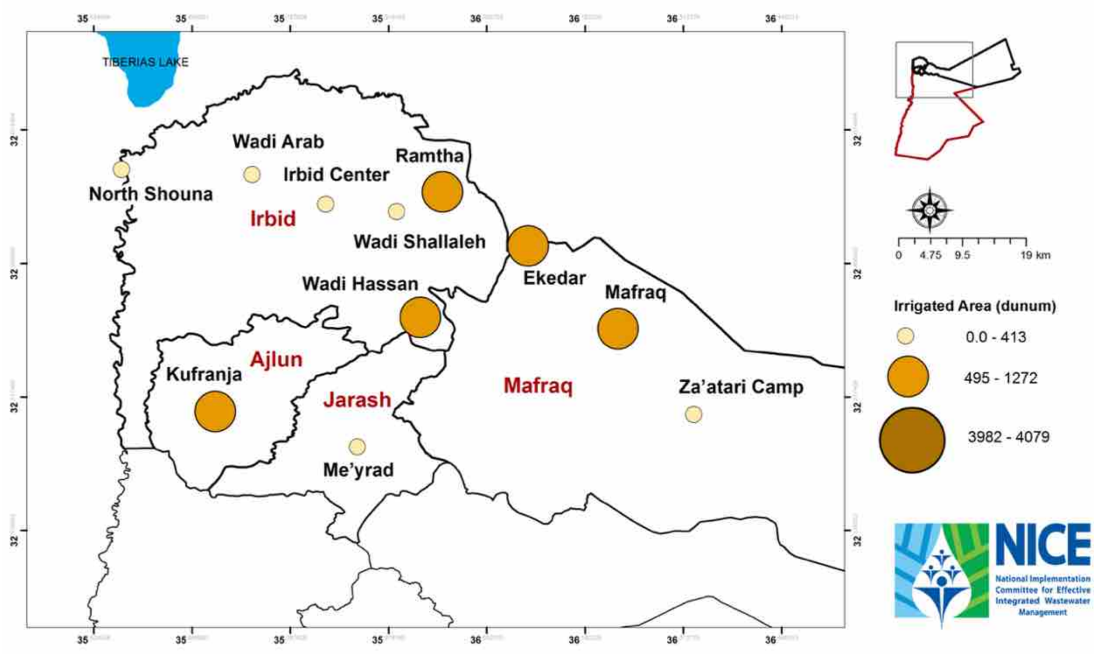
Annex Figure 2 Average quantity of treated wastewater produced by centralized wastewater treatment plants in the Middle Governorates.



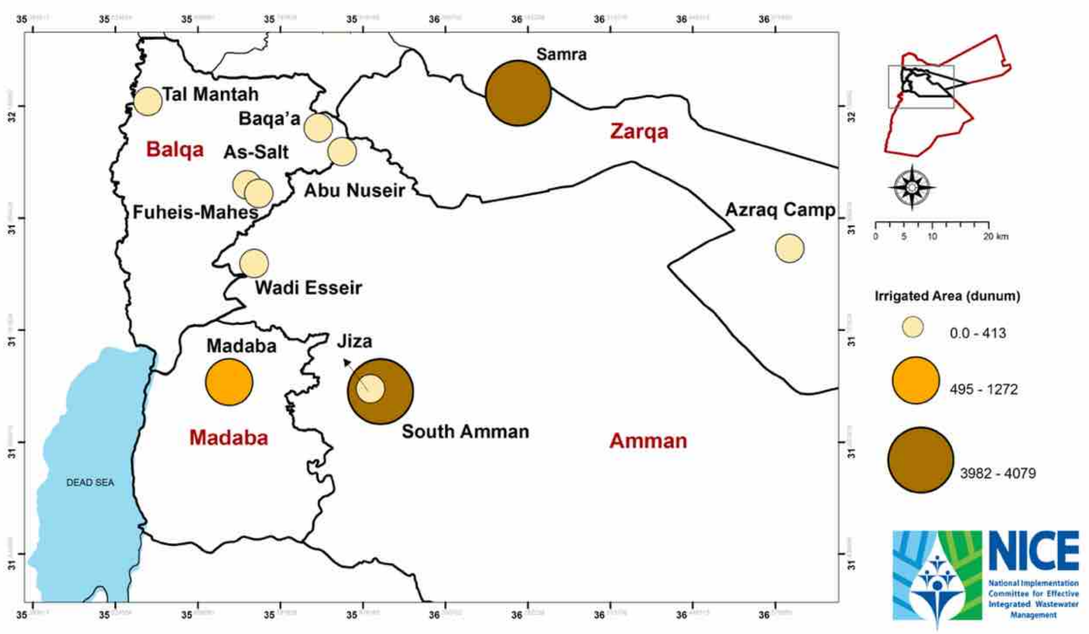
WWTP	Effl. Qty (MCM/y)
Ma'an	0.5
Shobak	0.1
Karak	0.0
Lajoon	0.3
Mutah-Mazar	0.4
Tafila	0.7
Aqaba-Mech.	4.5
Aqaba-Natural	2.5
Wadi Mousa	1.0

Annex Figure 3 Average quantity of treated wastewater produced by centralized wastewater treatment plants in the Southern Governorates.

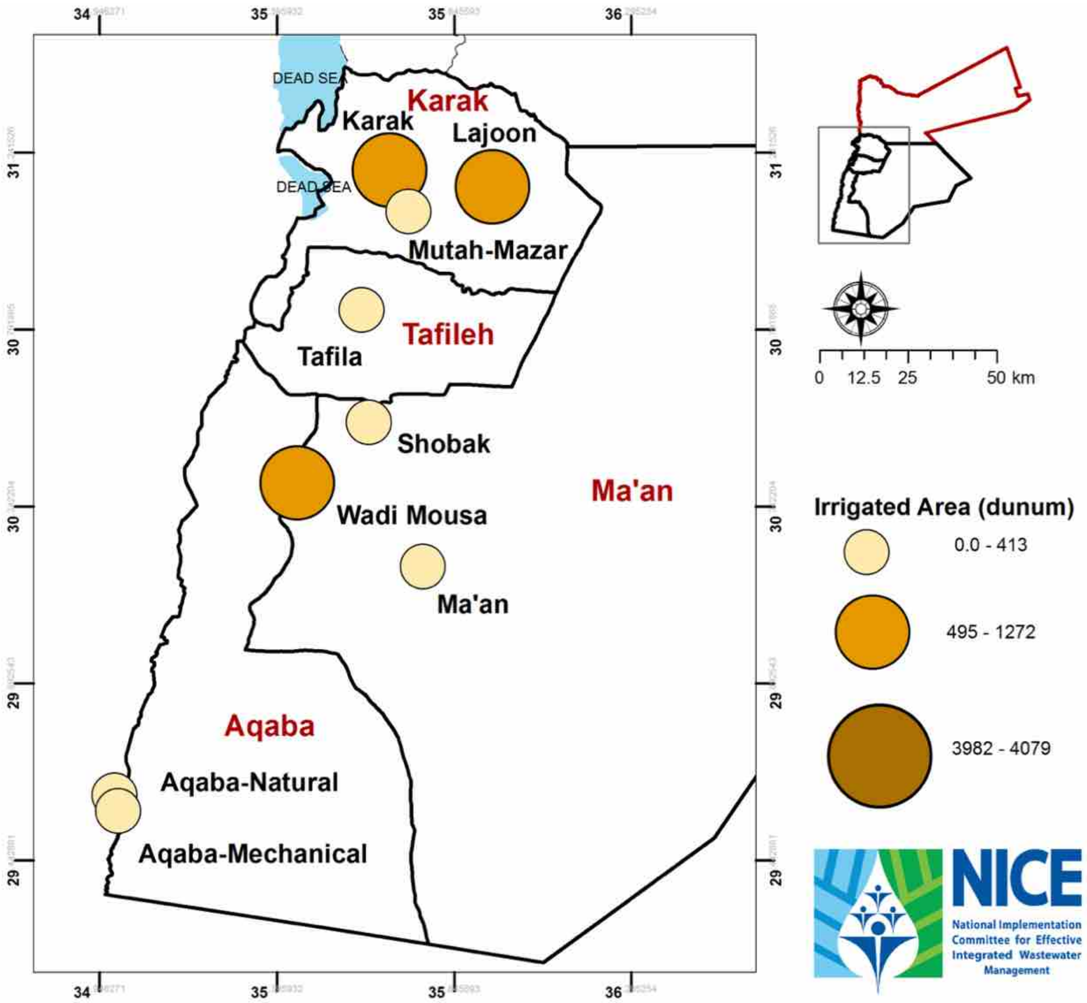
11.2 Total area of land irrigated with wastewater from CWWTPs



Annex Figure 4 Total area of land irrigated with treated wastewater from centralized wastewater treatment plants in the Northern Governorates.



Annex Figure 5 Total area of land irrigated with treated wastewater from centralized wastewater treatment plants in the Middle Governorates.



Annex Figure 6 Total area of land irrigated with treated wastewater from centralized wastewater treatment plants in the Southern Governorates.