

Wastewater Treatment and its Reuse in Jordan

Ahmad M. Abu-Awwad¹

¹ Department of Land, Water and Environment, Faculty of Agriculture, The University of Jordan, Amman, Jordan

Received on 1/7/2021 and Accepted for Publication on 29/8/2021.

ABSTRACT

The prospective agriculture development, in Jordan, is tied up by severe water scarcity that induces imbalances and shortages of water supply for various uses, especially under high population growth rates, natural and non-voluntary migration, and climate change. This paper provides highlights on the wastewater treatment plants (WWTPs) expansion, development, and treated wastewater reuse for the current and past 100 years in Jordan, examples of inefficient utilization of some WWTPs effluent and some of its constituents (such as Nitrogen and Phosphorus). It also suggests the necessary measures in the near future and long-term for the effective use of treated wastewater that improve and increase the reuse of treated wastewater in agricultural irrigation.

Keywords: Jordan, WWTPs, treated wastewater reuse, development, efficient utilization.

INTRODUCTION

Jordan is an arid to semi-arid country, with a total land area of approximately 89,342 km² with more than 92% of the land area receiving an annual average rainfall of less than 200 mm (MWI, 2016). Rainfall ranged from 600 mm in the northwestern part of the country to less than 50 mm in the southeastern deserts. The annual precipitation of the country is estimated to be 8,165 million cubic meters (MCM), from which 93.5% are lost by evaporation while 2.1% is considered floods and 4.4% flows as groundwater recharge (MWI, 2017). The population of Jordan was 10.203 million in 2020 (JDOS, 2020), increased to 10,313,797 as of Friday, August 6, 2021, based on Worldometer elaboration of the latest United Nations data, with a recent average growth rate (2020) of about around 1.05% per year down from 1.08% in 2019 (<https://www.worldometers.info/world-population/jordan-population/>).

Jordan is one of the most water-scarce countries in the world; it is ranked the second poorest country in water resources in 2017 and has the lowest levels of water availability per capita with only 145 m³ per capita/year which appears to be diminishing each year and is expected to reach almost 80 m³ in the year 2025 (MoEnv, 2014; MWI, 2017; Hadadin *et al.*, 2009). The last figure falls below the annual benchmark level of 1000 m³ per capita which is often used as an indicator of water scarcity (FAO, 1995). As a result, the available water resources are being seriously overexploited.

The country's renewable water supply currently only meets about half of the population's water demands, with groundwater being used twice as quickly as it can be recharged; and is one of the countries most affected by rising temperatures, and it is predicted to get worse. The dead sea is shrinking, and many houses only get up to 24 hours of water a week.

(Reference: <https://www.usaid.gov/jordan/water-and-wastewater-infrastructure>)

Water demand outpaces the available renewable water supply to the extent that the groundwater table is dropping all over almost the whole country. This occurred as a result of population growth, higher living standards and exacerbated by abrupt refugee inflow, expansion of the agricultural sector, and global climate change, the gap between water supply and demand is becoming bigger and wider creating Jordanian water resources scarcity (MWI, 2019; and Al-Kharabsheh and Ta'any, 2005). So, Jordan has experienced an imbalance in the population-water resources equation. The deficit is being covered through the mining of groundwater resources at 130% of their safe yields and the exploitation of non-renewable groundwater (Abu-Awwad, 2011).

Irrigation with unconventional sources of water, such as treated wastewater (TWW), is a critical factor for sustaining food security, particularly considering global climate change, which has resulted in severe constraints on freshwater resources for agriculture. TWW has significant irrigation potential and has been increasingly used in many arid and semi-arid regions around the world, including China, the Middle East, Mediterranean countries, Australia, North and South America, and Africa (Grattan *et al.*, 2015).

The use of TWW in agriculture is a valuable practice that is receiving renewed attention from the Jordanian government with the increasing scarcity of freshwater resources. Several crops are grown using blended TWW such as citrus, bananas, vegetables, and cereals such as corn, barley, and wheat (FAO 2003).

Wastewater reuse in agriculture involves the further use of TWW for crop irrigation. This type of reuse is considered an efficient tool for managing water resources and helps in alleviating the country's water-scarce, stemming from the need for a regulated supply that compensates for water shortages caused by seasonality or the irregular availability of other water sources for crop irrigation throughout the hydrological year (Angelakis, 2015).

The use of TWW in agriculture is the best possible strategy for addressing water scarcity and nutrient deficiency in agricultural systems in the face of climate change. The inclusion of organized wastewater treatment and recycling in water resource management systems reflects the increasing scarcity of water sources to meet societal demands, technological advancement, public acceptance, and improved understanding of public health risks.

Definitions

Wastewater is any water that has been adversely affected in quality by an anthropogenic influence. It, therefore, includes liquid waste discharged from domestic houses, industrial, agricultural, or commercial processes (<http://en.wikipedia.org/wiki/Wastewater>)

Treated Wastewater in wastewater (sewage) that has been treated and purified and is as biologically clean as standard drinking water. However, unless very extensive levels of tertiary treatment are performed, reclaimed water would still contain high levels of nitrogen and phosphorus that make treated wastewater unsuitable for drinking.

Reclaimed wastewater is treated wastewater mixed with freshwater.

Restricted reuse according to JS 893/2006 is the irrigation of all crops except salad crops and vegetables that may be eaten uncooked (including tomato, cucumber, pepper, cauliflower, onion, carrot, radish, lettuce, parsley, mint, watercress, herb, strawberry, watermelon, melon, sugarcane, and others). The General definition of restricted irrigation also can be defined as the use of low-quality TWW in limited areas and for specific crops only (restrictions are imposed based on the type of soil, the proximity of the irrigated area to potable aquifer, irrigation method, crop harvesting technique, and fertilizer application rate); simple and low cost (in general only applicable to a small amount of wastewater, used in specific locations, where areas and crops are well defined and unlikely to change).

Unrestricted reuse is the use of TWW to grow all crops including those are eaten raw by humans.

History of wastewater reuse

Wastewater reuse is not a new concept; the first evidence of wastewater reuse was found among the ancient Greeks, who used public latrines that flushed wastewater through sewer systems towards a storage chamber (María and Inés, 2017). Additionally, Greek and Roman civilizations used domestic wastewater at the perimeters of major cities (Athens and Roma). Wastewater was transported to the agricultural fields to be used as fertilizers for crops and orchards (Cooper, 2001). Between the years 1550 and 1700, the direct use of wastewater on the agricultural fields was extended to farms in Germany, Scotland, and England where the first sewage farms were established (Tzanakakis *et al.*, 2014). Beginning in 1800, soil irrigation with wastewater was adopted in many fast-growing cities in Europe and United States. For example, the practice was considered legal in cities such as London, Paris, and Boston and was considered a solution for the treatment and disposal of large volumes of wastewater (Tzanakakis *et al.*, 2007). Paris was the first large city to irrigate peri-urban fields with wastewater. However, wastewater disposal schemes in agricultural fields continued to be widely adopted by major European cities and the United States until the early 20th century (Drechsel *et al.*, 2010; Asano *et al.*, 2007).

Recently, wastewater reclamation and reuse have become the best option for saving and protraction available water resources and become an integral factor in fostering the optional planning and effective use of water resources (Saidan, 2020). It used to be said that “the solution to pollution is dilution.” When small amounts of sewage are discharged into a flowing body of water, a natural process of stream self-purification occurs. Densely populated communities generate such large quantities of sewage, however, that dilution alone does not prevent pollution. This makes it necessary to treat or purify wastewater to some degree before disposal. The construction of centralized sewage treatment plants began in the late 19th and early 20th centuries, principally in the United Kingdom and the United

States. Instead of discharging sewage directly into a nearby body of water, it was first passed through a combination of physical, biological, and chemical processes that removed some or most of the pollutants. Also beginning in the 1900s, new sewage-collection systems were designed to separate stormwater from domestic wastewater, so that treatment plants did not become overloaded during periods of wet weather.

<https://www.britannica.com/technology/wastewater-treatment>. (Accessed 3 July 2021).

After the middle of the 20th century, increasing public concern for environmental quality led to broader and more stringent regulation of wastewater disposal practices. Higher levels of treatment were required. For example, pretreatment of industrial wastewater, to prevent toxic chemicals from interfering with the biological processes used at sewage treatment plants, often became a necessity. Wastewater treatment technology advanced to the point where it became possible to remove virtually all pollutants from sewage. This was so expensive, however, that such high levels of treatment were not usually justified <https://www.britannica.com/technology/wastewater-treatment>. (Accessed 3 July 2021).

Wastewater treatment plants became large, complex facilities that required considerable amounts of energy for their operation. After the rise of oil prices in the 1970s, concern for energy conservation became a more important factor in the design of new pollution control systems. Consequently, land disposal and subsurface disposal of sewage began to receive increased attention where feasible. Such “low-tech” pollution control methods not only might help to conserve energy but also might serve to recycle nutrients and replenish groundwater supplies.

Wastewater treatment in Jordan

History of wastewater treatment in Jordan

The utilization of TWW within Jordan has been made possible by the development and evolution of a sound legislative and legal foundation. The first law regarding the

operation of municipal sewer systems was first established in 1955, and the original public health standards were first enacted in 1971. Today there are several sets of standards and guidelines for wastewater, sludge, soil, and crops. The existing standards and laws that directly apply to TWW reuse are Law No.18/1988 and its amendments, the Jordan Standard No. 202/2007 for Industrial Wastewater Discharges, Jordanian Standard 893/2006 for Discharge of Treated Domestic Wastewater, and Jordanian Standard No. 1145/2006 regarding the use of sludge (ACWUA, 2011).

The first wastewater treatment was practiced in Jordan in a limited way since 1930 in Salt City. Some treatments were done by using primitive physical processes, where the septic tanks and cesspits were utilized to discharge greywater to the garden. These processes resulted in negative environmental impacts, especially groundwater pollution (MWI, 1998). Modern technology used to collect and treat wastewater was introduced in the 1960s when Jordan's first WWTP was built in 1968 in Ain Ghazal which uses the conventional activated sludge process. The system consisted of a sewage network that runs by gravity to the lowest point in Amman, where the treatment plant was located. The plant now serves as a pre-treatment plant for the As-Samra WWTP. The treated wastewater was discharged to Sail Al-Zarqa (MWI, 1998).

Wastewater reuse is not a new phenomenon in Jordan. It is inevitable that any available water, irrespective of its actual quality, will be used in arid and semi-arid environments. Recognizing this reality, Jordan has worked to manage irrigation with wastewater since 1969 and has expanded such use ever since. Original wastewater reuse came about as a result of urban development in various areas of Jordan.

Jordan has undergone an impressive transformation in the last 70 years, evolving from a predominantly agricultural country to an Arab country with the highest literacy rate; an outstanding level of education and health care; a strong Information Technology (IT) sector; and an increasingly influential role in the global economy. Nowadays, Jordan continues to focus on sectoral reform and institutional change. Jordan's points of focus are becoming more

streamlined, and the Kingdom is now concentrating on reuse activities to ensure the highest possible impact and efficiency.

The construction of other treatment plants started in the early 1980s. Since the year 1980 and during the International Drinking Water and Sanitation decade (1980-1990), the Government of Jordan carried out significant and comprehensive plans with regards to the different issues of wastewater management primarily related to the improvement of sanitation. About 75% of the urban population and 52% of the total population of Jordan gained access to wastewater collection and treatment systems. This led to raising sanitation levels to protect public health and the environment and minimize surface and groundwater pollution (MWI, 1998).

Jordan prepared a long-term plan to treat wastewater in 1982. Before that, the kingdom had a few sanitary sewers and one wastewater treatment plant in Amman. In its initial phase, the long-term plan saw the construction of the As-Samra wastewater stabilization ponds (WSP) in 1985. The original WWTP at As-Samra was completed in 1985, with a treatment capacity of 68,000 m³/day. The TWW is discharged from the WWTP into the Zarqa River, whose bed, in the mid-1980s, was nearly dry.

Pre-treated water from the Ain Ghazal pre-treatment plant, the West Zarqa pumping station, and the Hashimiyya pumping station was being supplied to the WSP. The WSP was overloaded very quickly, and its effluents were not able to meet the Jordanian domestic wastewater discharge standards. The effluents caused major environmental and health concerns when the water was used for irrigation or discharged into rivers and other water bodies. With USAID's funding in 1997, efforts were made to study the possibility of constructing the As-Samra WWTP at the same site of the As-Samra WSP. The As-Samra WWTP was built to replace the old, overloaded As-Samra Wastewater Stabilization Ponds.

Construction of the As-Samra WWTP was undertaken between 2003 and August 2008, for \$169m. The facility is

acknowledged for being one of the first projects in Jordan to be built on a build, operate, and transfer (BOT) basis and one of the first to receive a grant from USAID. With a peak flow of 840,000 m³ each day, the facility treats an average flow of 267,000 m³/day of wastewater, serving a population of 2.2 million living in the Greater Amman and Zarqa areas. An expansion of the facility began in 2012 and the plant was officially opened in October 2015. It increased the plant's average treatment capacity to 365,000 m³/day. It was implemented along with the Wastewater Network Project of the Jordan Ministry of Water and Irrigation.

(<https://www.water-technology.net/projects/as-samra-wastewater-treatment-plant-jordan/>)

In the year 2000, there were only 17 treatment plants in operation in Jordan. Out of these, 6 plants used WSP, one used an aerated pond, while the remaining 10 plants used activated sludge or attached growth processes or a

combination of both. At that time, WSP treated about 85 percent of collected wastewater in Jordan [about 80 MCM per year, (Ammary, 2005)]. However, in 2015, the number of treatment plants increased significantly and reached 32 and the volume of treated wastewater was 147 MCM (MWI, 2015).

Characteristics of WWTPs in Jordan

There are 32 WWTPs as of 2019 distributed in the urban centers of Jordan (Table 1), treating more than 173.9 MCM/year, or about 98% of the collected wastewater (MWI, 2019). It is expected to treat 240 MCM/year by 2025 (MWI, 2016). More than 90% of TWW is used in agricultural activities. About 61% of the population has access to wastewater collection and treatment systems (JDOS, 2016). Figure 1 presents constructed, upgraded, and under design for upgrade wastewater treatment plants in Jordan.

Table 1: Wastewater treatment plants (MWI Annual Report, 2019)

No.	Treatment Plant	Influent MCM/Year	Effluent MCM/Year	Reclaimed Wastewater used MCM/Year	Percentage of Reclaimed Wastewater used
1	Khibet As-Samra	120.72	117.1	117.1	100
2	South Amman	4.86	4.72	2.316	49.09
3	Abu Niser(*)	1.35	1.31	0.082	6.29
4	Wadi AL-Sir	1.74	1.71	1.705	100
5	Aljeza and Talbeah	0.30	0.29	0.292	100
6	Madaba	2.78	2.53	2.531	100
7	Central Irbid	3.30	3.10	0.000	0.00
8	Wadi Arab	5.14	4.98	0.000	0.00
9	Shalalah	3.61	3.43	0.000	0.00
10	Wadi Hassan	0.41	0.38	0.385	100
11	Jerash	0.44	0.42	0.424	100
12	Mafrq	1.45	1.29	1.292	100
13	Ramath	1.66	1.50	1.501	100
14	Kufranjah	1.30	1.25	1.249	100
15	Al-Marad	1.20	1.16	1.160	100
16	North Shunah	0.17	0.15	0.000	0.00
17	Al-Kydar	0.84	0.82	0.820	100
18	Salt	3.59	3.19	3.188	100
19	Fuhas and Mahes	1.17	1.15	1.149	100
20	Ein Al-Basha	5.39	5.12	5.119	100

21	Tal Al-Montah	0.16	0.15	0.000	0.00
22	Karak	0.55	0.54	0.536	100
23	Al-Lajoun	0.31	0.30	0.128	42.11
24	Old Natural Aqaba	2.76	2.22	2.223	100
25	Mechanical Aqaba	4.51	3.9	3.900	100
26	Mu'atah, Mazar and Al-Adnaneh	0.60	0.55	0.099	17.96
27	Ma'an	0.95	0.92	0.651	71.00
28	Wadi Musa	1.04	1.02	1.016	100
29	Shubak (Tanks)	0.05	0.00	0.000	0.00
30	Al-Mansourah	0.002	0.00	0.000	0.00
31	Tafelah	0.843	0.79	0.000	0.00
32	AL-Za'atri	0.62	0.55	0.550	100
33	Al-Share'a Pump Station (cleaning of filters)	0.088	0.088	0.088	100
	Total	173.93	166.63	149.500	89.72

(*) Converted to a lift station and the water entering it will be transferred to Al Samra station.

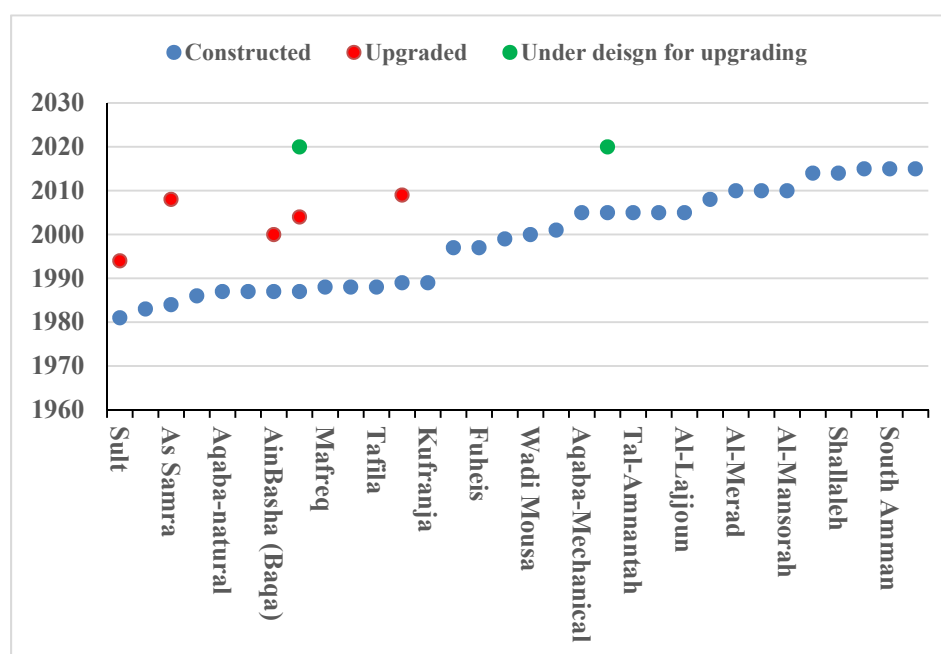


Figure 1: Constructed, upgraded, and under design for upgrade wastewater treatment plants in Jordan

The most widely technologies used in WWTPs in Jordan are the activated sludge (AS) process with a share of 60%. Followed by the wastewater stabilization pond (WSP) process with a share of 19%. While the trickling filter (TF)

and AS process, Membrane Bioreactor (MBR) and TF process, and oxidation sludge (OS) process were evenly having the same use share of 6%, respectively (Saidan *et al.*,2020).

On the other hand, TWW reuse is regarded as a fertilizer source because it contains several nutrients in various forms that are necessary for agricultural production and soil fertility, thereby reducing the need for costly commercial fertilizers (Noah *et al.*, 2002). Furthermore, the TWW reuse conserves the sources of natural water, minimizes the outflow of TWW into freshwater ecosystems, and enriches the soil with useful nutrients (Ganjegunte *et al.*, 2018).

According to Jordan's water strategy which was formulated in 1998 (Water for Life: Jordan's Water Strategy 2008-2022), TWW is considered as a non-conventional water resource that cannot be treated as "waste" but as an important source for agricultural crop irrigation (MIW,

2001; and Taha and Haddadin, 2005). Moreover, the government of Jordan has regulated and developed standards for TWW reuse. Jordanian standards for reclaimed domestic wastewater (JS893/2006) are based on reuse categories. It determines the standard, regulations, and guidelines that are required for water reuse. It is purposely set to specify the conditions that the reclaimed domestic wastewater discharged from wastewater treatment plants (WWTPs) should meet to be discharged or used in various fields such as artificial recharge of groundwater aquifers and irrigation purposes. Table 2 presents the Jordanian standards for reclaimed domestic wastewater for irrigation purposes

Table 2: Jordanian standards for reclaimed domestic wastewater for irrigation purposes, (ISM, 2006)

Standards and properties	Maximum permissible limits			
	Cut flowers	Cooked vegetables, parks, playgrounds, and roadsides within cities	Fruit trees, external roadsides, and green landscapes	Field crops, industrial crops, and forest trees
BOD5	30	30	200	300
COD	100	100	500	500
DO	>2	>2	-	-
TSS	15	50	200	300
pH	(6-9)	(6-9)	(6-9)	(6-9)
NO3	45	30	-	-
T-N	70	45	45	70
E.coli	<1.1	100	1000	-
Intestinal Helminthes Eggs	≤1	≤1	≤1	≤1
FOG	2	8	8	8

Examples of inefficient use of TWW

Even though Table 1 indicates that the percentage of reclaimed wastewater used in some WWTPs is 100%, it is

- As of 2019 **Ramtha and Madaba WWTPs** effluent was treated and sold to the farmers under the direction of the Ministry of Water and Irrigation

not the case for most if not all WWTPs in which treated wastewater was used in the vicinity of the WWTP (as an example: Ramtha, Madaba, South Amman WWTPs).

(MWI) "Jordan Water Authority". Based on the agreements between the farmers and the MWI, the sale price is JD0.05/cubic meter/dunum on daily basis for 365 days/year, totaling JD54.75/1095

m³/dunum (JD0.05 x 3 x 365). The effluent is supplied (at 3 m³/day/du) to the farmers' farms on daily basis, regardless of the crop types and their needs.

Based on field reconnaissance visits, during 2018 and 2019, and discussion with farmers and WWTPs personnel. The details of treated effluent reuse from Ramtha and Madaba WWTPs were as follows: the total planted area of irrigated fodder crops (alfalfa (annual and perennial), ryegrass, barley, and corn) using TWW from Ramtha and Madaba WWTPs was 737.7 and 1528 dunum, respectively. It is worth mentioning that the cultivated area was the maximum area that could be irrigated during the peak crop water requirement. The unused (excess) effluent represents 50 to 55% of the total effluent supply, which is wasted and disposed of (**Figure 2**) to the environment (USAID, 2019).

- **South Amman WWTP** - is an activated sludge system, which started operating in October 2015. Constructed for \$121 million, the plant's treatment capacity stands at 52,000 m³/day (18.98 MCM/year). Proposed expansion design capacity is 72,000 m³/day (26.28 MCM/year):

- Influent entered South Amman WWTP was 4.86 MCM (MWI annual report, 2018)
- The effluent coming out from South Amman WWTP was 4.72 MCM (MWI annual report, 2018)

- The WWTP is presently (2020) emitting an effluent quantity of approximately 19,000 m³/day (6.9 MCM/year).

- Effluent reused was 2.316 MCM/year (MWI annual report, 2018)

Currently, there are 21 signed agreements between the MWI and farmers, Cooperative and Charities societies to cultivate an approximate area of 7,132 du (713.2 ha) for fodder production irrigated by using TWW from South Amman WWTP, which would require approximately 5.7 MCM/year. However, only 984 du out of the 7,132 du presented in the agreements were planted as reported by the MWI/JVA, on 30 October 2019. Even though, the planted area is relatively limited to 984 du the effluent quantities supplied were 1,917,295 m³/year, during 2019. It is worth mentioning that the measured planted area as reported by the Monitoring and Evaluation Team from the University of Jordan on 5 April 2018 was 1,738.7 du. The reason behind the reduction in the planted area could be attributed to the farmers' limited experience in irrigated agriculture as opposed to their experience in growing rainfed crops.



Effluent Disposed from Ramtha WWTP to the Wadi



Effluent Drained from Farmers' Fields to the Wadi

Figure 2: Wasted excess (unused) TWW disposed into the

As of 2021, the excess, unused effluent is dumped temporarily in a quarry pit (actually several pits, (Figure 3) just outside of the WWTP.



- **Central Irbid, Wadi Arab, and Shalalah WWTPs** – About 11.5 MCM TWW is not used and disposed into Jordan river, just because its quality microbial (*E. coli*) content is not in line with JS893/2006. It is worth mentioning that the MWI with the assistance of donors (USAID, KfW, etc) is in the process of solving this issue and transferring the excess TWW to Jordan valley, where it is most needed free some fresh water for domestic use.

Key finding

- **Case studies for six WWTPs (Ramtha, Madaba)** revealed that only 45 to 50% of the TWW supplied to farmers farms, based on the agreements signed between farmers and MWI, is beneficially used to irrigate fodder crops and 50 to 55% of the diverted TWW is wasted to the environment. Thus, about 20 MCM TWW was not used from the six WWTPs (Ramtha, Madaba,

south Amman, central Irbid, Wadi Arab, and Shalalah).

- **Using TWW for non-potable uses has many benefits.** It is a direct substitute for treated drinking water, is generally less expensive than standard potable water where water resources are scarce, and contains higher levels of nitrogen and phosphorus, which help fertilize plants. In arid and semi-arid areas where water resources are scarce and expensive to use, reusing TWW for productive purposes is economically sound and helps prevent contamination to existing freshwater sources.

Recommendations

- There is an urgent need for the necessary measures for efficient utilization of treated wastewater that optimize and maximize treated wastewater reuse for agricultural irrigation.
- Use as the determining factor of TWW – TWW use chain from production to storage should benefit the intended water use, including technical aspects, farming and irrigation techniques, risks, benefits, and constraints.
- Sustainable TWW use should adopt a holistic and multidisciplinary approach associating the resource-use bottom-up approach, cho the TWW model specifically adapted to TWW reuse, and consider the irrigation system (water-soil-plant-people) as an integral part of the TWW use process.
- Promote water efficiency in irrigation and higher economic returns for irrigated agricultural products, improve the efficiency of bulk irrigation water delivery and on-farm irrigation systems in the vicinity of the TWWPs, substitute freshwater with TWW, provide quality water from WWTPs, destined for agricultural use, managed to ensure food safety.
- Reduce and substitute groundwater abstraction used for agriculture in the highlands by using TWW, and enforcement of existing regulations strengthened.

REFERENCES

- Abu-Awwad, A. M. (2011). Optimizing Model for Cropping Pattern Areas Irrigated by Treated Wastewater in Wadi Musa. *Jordan Journal of Agricultural Sciences*, 173(797), 1-28.
- ACWUA, (2011). Arab Countries Water Utilities Association. Safe Use of Treated Wastewater in Agriculture Jordan, Case Study.
- Angelakis, A.; Snyder, S (2015). Wastewater treatment and reuse: Past, present, and future. *Water* 2015, 7, 4887-4895.
- Atef Al-Kharabsheh & Rakad Ta'any (2005) Challenges of Water Demand Management in Jordan, *Water International*, 30:2, 210-219, DOI: 10.1080/02508060508691861
- Asano, T.; Burton, F.; Leverenz, H.; Tsuchihashi, R.; Tchobanoglous, G. (2007). *Water Reuse: Issues, Technologies, and Applications*; McGraw Hill Professional: New York, NY, USA, 2007.
- Cooper, P. (2001). The historical aspect of wastewater treatment. In *Decentralised Sanitation Reuse: Concepts, System, and Implementation*; IWA Publishing: London, UK, 2001; pp. 11–38
- Drechsel, P.; Scott, A.; Sally, R.; Redwood, M.; Bachir, A (2010). *Wastewater Irrigation and Health: Assessing and Mitigating Risk in Low-Income Countries*; International Water Management Institute, Edose.; Earthscan: London, UK, 2010
- Grattan, F. J. Diaz, F. Pedrero, Vivaldi G.A. (2015). Assessing the suitability of saline wastewater for irrigation of Citrus spp.: Emphasis on boron and specification interactions. *Agric. Water Manage.*, 157, pp. 48-58.
- FAO (Food and Agriculture Organization of the United Nation), (2003). *Users manual for irrigation with treated wastewater*. Cairo 2003.
- FAO (1995). *Water Resources, Development and Management Service, MENA Regional study report*, 1995.
- Ganjegunte, G.. Ulery, A. . Niu, G. and Wu, Y. (2018). Organic carbon, nutrient, and salt dynamics in saline soil and switchgrass (*Panicum virgatum* L.) irrigated with treated municipal wastewater. *Land Degrad. Dev.*, 29 (1) (2018), pp. 80-90
- Hadadin, N. Qaqish, M. Akawwi, E. and Bdour, A. (2009). Water shortage in Jordan – Sustainable solutions. <https://www.usaid.gov/jordan/water-and-wastewater-infrastructure>
- <http://en.wikipedia.org/wiki/Wastewater>
- <https://www.britannica.com/technology/wastewater-treatment>. Accessed 3 July 2021
- <https://www.water-technology.net/projects/as-samra-wastewater-treatment-plant-jordan/>
- <https://www.worldometers.info/world-population/jordan-population/>
- JDOS. Jordan Department of Statistics, 2020
- JDOS. Jordan Department of Statistics, 2016
- Maria Fernanda Jaramillo ID and Inés Restrepo, (2017). Wastewater Reuse in Agriculture: A Review about Its Limitations and Benefits. *Sustainability*, 9, 1734.
- MoEnv (2014). Jordan's Third National Communication on Climate Change. Submitted to The United Nations Framework Convention on Climate Change (UNFCCC), funded by GEF and UNDP," Ministry of Environment, Amman, Jordan, 2014.
- MWI, Jordan Ministry of Water and Irrigation, (2019). *The Amended Guideline of the Water Resources Protection for the Year of 2019*.
- MWI (1998). *Wastewater Management Policy*; Ministry of Water and Irrigation: Amman, Jordan, 1998.
- MWI (2017). *Jordan Water Sector Facts and Figures*. Ministry of Water and Irrigation, Amman, Jordan.
- MWI, Jordan Ministry of Water and Irrigation, (2018). *Annual Report of Water Authority*.
- MWI (2016). *Jordan's Water Strategy 2016–2025*; Ministry of Water and Irrigation: Amman, Jordan, 2016.

- Noah A. (2002). Improving Desert Environment through Water reuse. Evolution of Sanitary Drainage in Combating Pollution. Head of Laboratory, Wastewater Treatment Work Middle Eastern. [Http://www.watermagazine.com/secure/jc/Desert.htm](http://www.watermagazine.com/secure/jc/Desert.htm).
- Saidan, M. N. Al-Addous, M. Al-Weshah, R. Obada, I, Alkasrawi, M. and Barbana, N. (2020). Wastewater Reclamation in Major Jordanian Industries: A Viable Component of a Circular Economy. *Water* 2020,12, 1276.
- Taha, s. and N. Haddadine. (2005). Jordan Ministry of Water and Irrigation. Potential for reuse of treated wastewater in Jordan.
- Tzanakakis, V.; Paranychianaki, N.; Angelakis, A (2007). Soil as a wastewater treatment system: Historical development. *Water Sci. Technol. Water Suppl.* 2007,7, 67–75.
- Tzanakakis, V. E., Koo-Oshima, S., Haddad, M., Apostolidis, N., and Angelakis, A. N. (2014). “Chapter 24: The history of land application and hydroponic systems for wastewater treatment and reuse,” in *Evolution of Sanitation and Wastewater Management through the Centuries*, eds A. N. Angelakis and J. B. Rose (London: IWA Publishing), 459–482.
- USAID Jordan Water Infrastructure Project 2019

معالجة مياه الصرف الصحي وإعادة استخدامها في الأردن

أحمد محمد أبو عواد¹

¹ قسم الأراضي والمياه والبيئة ، كلية الزراعة ، الجامعة الأردنية ، عمان ، الأردن

تاريخ استلام البحث: 2021/7/1 وتاريخ قبوله: 2021/8/29.

الملخص

ترتبط التنمية الزراعية المرتقبة في الأردن بندرة المياه الحادة التي تؤدي إلى اختلالات ونقص في إمدادات المياه لمختلف الاستخدامات في ظل معدل النمو السكاني المرتفع، والهجرة الطبيعية وغير الطوعية، وتغير المناخ، وتسلب هذه الورقة الضوء على التوسع في محطات معالجة مياه الصرف الصحي وتطويرها وإعادة استخدام مياه الصرف الصحي المعالجة حالياً وخلال المائة عام الماضية في الأردن، وتوجد أمثلة على الاستخدام غير الفعال لمخلفات بعض محطات معالجة مياه الصرف الصحي، وبعض مكوناتها كالنيتروجين والفوسفور. وتقتصر التدابير الضرورية في المستقبل القريب وطويلة الأمد للاستخدام الفعال لمياه الصرف الصحي المعالجة التي تعمل على تحسين وزيادة إعادة استخدام مياه الصرف الصحي المعالجة للري الزراعي.

الكلمات الدالة: الأردن، محطات معالجة مياه الصرف الصحي، إعادة استخدام مياه الصرف الصحي المعالجة، التطور، الاستخدام الفعال.
