A framework for wastewater reuse in Jordan: from present status to future potential as indicated by the Wastewater Reuse Index (WRI)

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A Framework for Wastewater Reuse in Jordan: Utilizing a Modified Wastewater Reuse Index

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Abstract Pressing water scarcity in Jordan rapidly increases the demands of marginal water resources for the agricultural sector. Water management studies reveal that no single source could fully solve the nation's water shortage and many integrated actions are needed to ensure water availability, suitability and sustainability. Yet, among these options treated wastewater has the largest potential to augment water supply in the near future, thereby narrowing the gap between available freshwater and total demand. Indeed, treated wastewater could be a valuable source for irrigation in the agricultural sector and an increasing percentage of irrigated areas,

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especially in the Jordan Valley, are currently using treated wastewater. With a fast growing population and expansion of the irrigated areas to meet food demand, the pressure on water resources in Jordan remains of imminent importance. Hence, an urgent call to analyze the current and potential role of treated wastewater seems justified. Under the umbrella of the project on the Sustainable Management of Available Water Resources with Innovative Technologies (SMART) funded by the German Federal Ministry for Education and Research in Germany, an investigation has been carried out in the Jordan Valley to estimate the current wastewater reuse quantities and the potential to increase its utility for agricultural production. In general, the reuse as percentage of total treatment is applied for national and international comparisons. Yet, this index is of limited use for policy decisions as it does not reflect potentialities of wastewater use. Therefore, this study introduces a wastewater reuse index (WRI) that reflects the actual proportion of wastewater reused from the total generated wastewater. We found that the WRI in Jordan steadily increased from 30% in 2004 to 38 in 2007. Efficient use of treated wastewater requires the application of new technologies in Jordan like dwellings connected to the sewer system, decentralization of treatment plants to rural and urban settlements and prevention of high evaporation rates from stabilization ponds.

Keywords Wastewater · Reuse · Water reuse index · Agriculture · Irrigation · Jordan valley

1 Introduction

Jordan represents a typically water-constrained economy that is daily confronted with decisions on its water use. With a fast growing population and an expanding agricultural sector, the demand for alternatives of fresh water resources remains imminent. Moreover, climate change is expected to affect the country negatively as temperature increases while precipitation most likely becomes erratic (Abdulla et al. 2009) An important strategy for the Jordanian government is to meet the water demand for the agricultural sector by producing more treated wastewater (e.g. Al-Omari et al. 2009).

The basic principle using collected wastewater is that their treatment can adjust the quality to serve the end-users (e.g. Al-Khashman 2009): irrigation, artificial recharge, potable water supply, toilet flushing, and industrial water supply. Reuse of wastewater has been practiced in many areas worldwide for thousands of years and is motivated by two strong economic incentives (Abu-Madi 2004): to decrease the water scarcity in the region, and/or avoid the cost of the deterioration of water resources and the environment caused by untreated or partly treated wastewater.

Reducing the agricultural demand for fresh water in the region is not easy, but non-conventional water sources can assist in reducing the overall water quantities/percentage utilized by the agricultural sector. Wastewater is, therefore, an important additional source as it can be treated and reused not only by the agricultural sector for crop irrigation but also for landscape irrigation, groundwater recharge, and even some recreational purposes (Aydın and Gür 2002; do Monte 2007; Mekala and Davidson 2008).

2 Measuring Wastewater Reuse

Water scarcity has made wastewater reuse more prominent in technical and policy literature as well as in national and international professional meetings. Several indicators are being used to quantify achievements and progress in wastewater reuse (Scott and Faruqui 2004; Gabriel 2005). The common practice is to use an index where wastewater reuse is divided by wastewater treatment. In this study we argue that an appropriate indicator should take into account all wastewater production, both collected and uncollected, so as to provide a sufficient measurement of potential reuse. Figure 1, shows the use of both approaches for Jordan. The highest value, 90.1%, is calculated using the reported volume of treated wastewater. The lower value, 39.7%, is the ratio of wastewater reuse to the estimated generation of wastewater (assumed to be 80% of water withdrawals; Nayif Saider, Ministry of Water and Irrigation, Jordan (MWI). Personal communication). As can be seen in the figure, using treatment in the denominator provides a misleadingly high estimate of the current reuse rate.

Given the potentially large gap between actual and apparent reuse, as shown in Fig. 1, we argue that it is important to base measurements of wastewater reuse on complete wastewater generation including on-site and low-cost means of reuse, in order to properly capture the potential (FAO and WHO 2003). Currently available measures of reuse are based on collected urban wastewater and typically omit wastewater that does not pass through conventional collection and treatment. This limits the ability to estimate potential, and makes international comparison difficult. Therefore, we propose to use the wastewater reuse index (WRI), which represents the ratio between actual wastewater reuse and total available wastewater, in mathematical terms defined as (Fig. 2) :

$$WRI = {}^{R \times 100}/_{G}, \text{ whereby } 0 \leq WRI \leq 100 \tag{1}$$

Where, R is total wastewater reused and G is total wastewater generation.

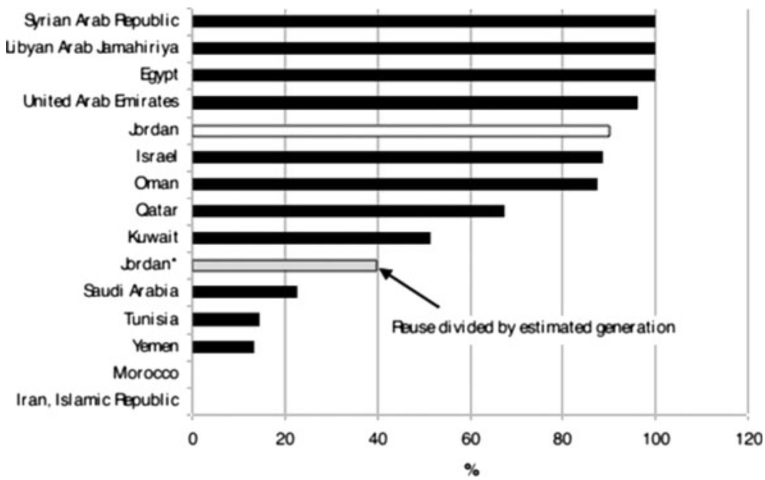

Fig. 1 Wastewater reuse as percentage of treatment in the MENA region, 2003–2007 (Data from AQUASTAT, accessed 16 December 2008)

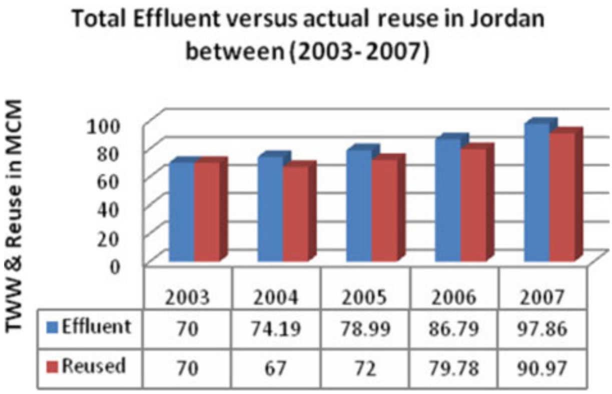

Fig. 2 The total effluent versus actual reuse in Jordan between (2003–2007) in MCM/year

We consider this as an improvement with respect to the traditional reuse index that identifies the reuse as a percentage from total wastewater treated

$$\mathrm{RI} = \mathrm{R} \times 100 / \mathrm{T}, \tag{2}$$

Where, R is total wastewater reused and T is the Total wastewater treated hence, not reflecting the future potential according to the available wastewater volume.

The WRI, therefore, offers standard criteria enabling water resource managers and policy makers to put a figure in the gap between achievements at different junctures, and thus recognizes water saving efforts such as low water consumption and reducing losses.

In the following, all quantities are listed in million cubic meter (MCM) per year. The relevant variables are as follows:

Since the wastewater generation in Jordan is considered 80% of the water distributed to the municipals, then:

$$G = 0.8 \times V, \tag{3}$$

where V is the total water volume distributed and G is the total wastewater generation.

Furthermore,

$$C = {}^{X \times G}/_{100}, \tag{4}$$

where C refers to the amount of wastewater collected and X represents the collection as percentage of the total wastewater production. And,

$$T = {}^{Y \times C}/_{100}, \tag{5}$$

With T representing the amount of wastewater treated and Y, the treatment as a percentage of the total collections. Then,

$$R = {}^{Z \times T}/_{100}, \tag{6}$$

where R is the amount of wastewater treated and Reuse Z the percentage of total treatment, Finally, we use the WRI as in Eq. 1 which is equivalent to:

$$Z \times X \times Y/_{10000}, \tag{7}$$

Table 1 shows the estimated results and compares them with the traditional wastewater reuse index (RI), which is identified as a reuse percentage of wastewater treated. The WRI for all of Jordan in 2006 was 34.8% while it was 45% at the Jordan Valley research area. It is clear that the WRI is quite low in Jordan, even though there is a slight increase in subsequent years. We observe that important efficiency gains can be obtained in the production of reused wastewater as currently only 50% of the total generated wastewater is being collected, of which 25% is lost in the process. In general the following measures are recommended to increase the efficiency of the process:

1. More dwellings would need to be connected to the sewer system. Currently approximately 61% of dwellings in Jordan (Ministry of Water and Irrigation, Jordan (MWI) 2007) are connected to the sewer network system, while the rest of dwellings are disposed of in cesspools.
2. Decentralized Wastewater treatment (WWT) could help to increase reuse since many rural areas and some cities have no WWTP due to hilly terrain and lack of investment and there is some unaccounted loss from the network.
3. Finally, reduce the high evaporation from the stabilization pond and lagoons at the WWTP.

2.1 International Comparison

Because of a paucity of international data, it is difficult to carry out a true international comparison for the indicator we are proposing. As is clear from the method used here, if sensible estimates of wastewater generation can be constructed, then it

Table 1 WRI data (Ministry of Water and Irrigation, Jordan (MWI) 2007)

Symbol	Values	2004	2005	2006	2007	2006
		For Jordan				For JV
G	Total wastewater generation (MCM/ year)	220.62	225.6	229.04	240.7	200.4
C	Amount of wastewater collected (MCM/ year)	101.79	107.36	110.91	113.8	103.5
T	Amount of wastewater treated (MCM/ year)	74.2	78.99	86.79	77.87	79.49
R	Amount of wastewater reused (MCM/year)	67	72	79.78	90.97	72.69
X	Collection as percentage of total production (%)	46.14	47.59	48.42	47.29	64.00
Y	Treatment as percentage of total collection (%)	72.90	73.57	78.25	68.41	77.00
Z	Reuse as percentage of total treatment (%) (RI)	90.30	91.15	91.92	116.80	91.00
	Water reuse index (%) (WRI)	30.40	31.92	34.83	37.79	45.00

is possible to improve on the estimates of wastewater generation and use those for a preliminary comparison. The discussion in this section will use the measures that have been adopted in the resources cited.

In the Middle East there is a significant effort to meet an ultimate objective of reusing at least 50 to 70% of the total wastewater volume (EPA 2004). In Israel during the drought year of 1990–91, agricultural allocations were severely cut and the proportion of wastewater reuse (which constituted a safe supply) rose to over 24% of total allocations (Shelef and Azov 1996). In normal years, Israel reuses more than 65% of its total domestic sewage production (Friedler 2001). Some nations evaluate reuse through the comparison of water reuse potential with total water use. In the United States, municipal water reuse accounted for 1.5% of total freshwater withdrawals in 2000. In Tunisia, recycled water accounted for 4.3% of available water resources in 1996. In Israel, it accounted for 15% of available water resources in the year 2000. The volume of treated wastewater compared to irrigation water resources is 7% in Tunisia, 8% in Jordan, 24% in Israel, and 32% in Kuwait. Approximately 10% of the treated effluent is being reused in Kuwait, 20–30% in Tunisia, 85% in Jordan, and 92% in Israel (Kamizoulis and Bahri 1999).

3 Wastewater and Reuse in Jordan

In Jordan, the agricultural sector consumes about 64% of available water per year with one-third of this amount consumed in the Jordan Valley, of which about 50% is reclaimed water (treated wastewater TWW). All in all, agriculture consumes less than 20% of the total amount of freshwater available in the Jordan Valley. Of the 22 WWTPs in Jordan only three receive TWW from septic tanks and not through the wastewater network. In 2006 the total effluent was 87 MCM, of which 91.9% was reused by agriculture after mixing it with fresh water during its inflow in the wadis (blended water). Jordan wants to increase the amount of TWW by improving the sewer network. As such TWW is vital to the water balance and allows to reallocate the fresh water used in agriculture to domestic use (data Ministry of Water and Irrigation 2006/2007).

The effluent from the 22 operating WWTP in Jordan is used primarily for agriculture purposes in the immediate vicinity, while surplus TWW flows along wadis where it either evaporates, or, is captured in water bodies like dams and ponds. It is known that farmers alongside the wadis are illegally pumping the effluent to irrigate their crops thwarting the intended destination and intended reuse of that water. However, the volumes of these illegal flows are unknown.

In the year 2006, the amount of water supplied was about 925 million cubic meters (MCM) while the actual demand was 1512 MCM: the municipal uses represented around 32%, irrigation around 63%, and industry uses around 5% of the total consumption. According to the Ministry of Water and Irrigation, Jordan (MWI) assumption "the wastewater (WW) generated is assumed to be 80% of the total volume" this means (WWG = 230 MCM/year) that only, approximately, 111 MCM reaches the Wastewater Treatment Plants (WWTP). Several reasons are cited for this loss, the most important being that only approximately 61% of the total households are connected to the sewer system. This means that approximately 39% of Jordanian households are not connected to the sewer network system. In other words, there is a considerable amount of the influent lost without recycling or reuse. Most of the non-connected households depend on cesspools, which can lead to groundwater contamination.

3.1 Irrigated Area in the Jordan Valley (JV)

The Jordanian Highland consumes around 300 MCM of fresh ground water per year for irrigation, whereas total consumption per year in the Jordan Valley is 220 MCM of which only approximately 100 MCM is fresh water. That means that the Jordan Valley uses approximately 42% of the total available fresh water for irrigation purposes while 58% of the total fresh water is consumed in the Highland. The Jordan Valley consumes almost 90 MCM freshwater and 90 MCM treated wastewater. The Middle Jordan Valley consumes nothing of the available fresh water being totally dependent on blended water.

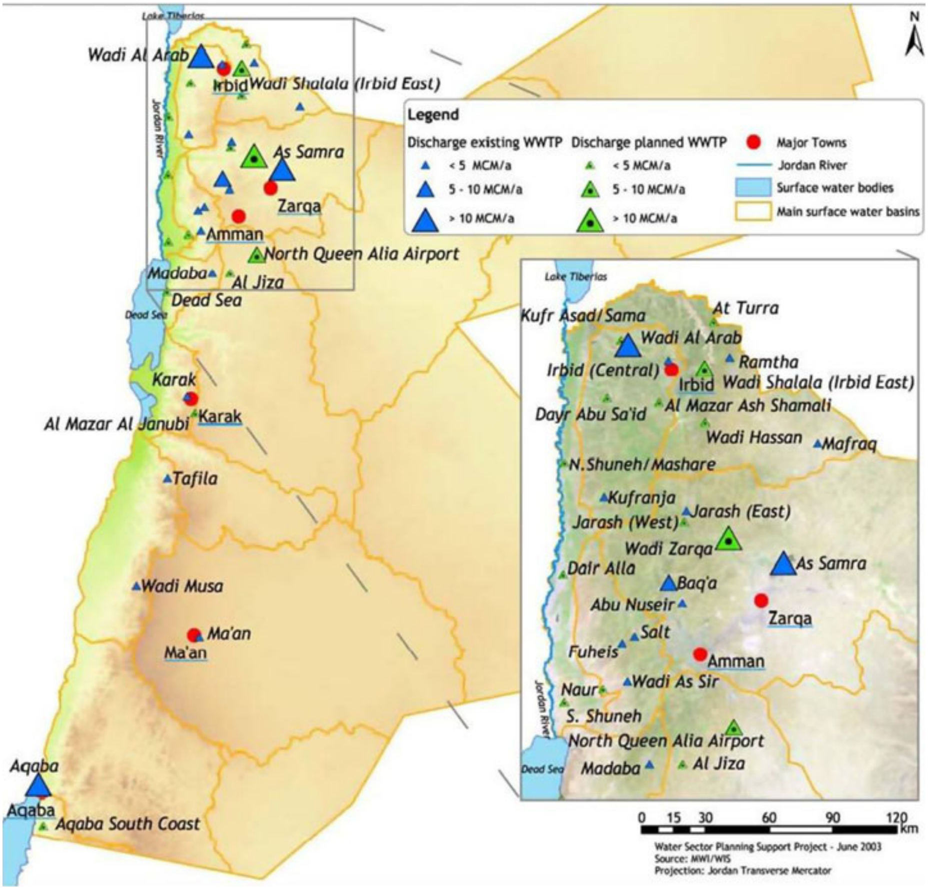

Fig. 3 Centralized and decentralized WWTP in Jordan

The objective of this study is to quantify the gap between achievements in wastewater reuse and real consumptions so as to provide a better insight into the problem of reuse efficiency, through using the wastewater reuse index (WRI). We argue that this index provides a clear picture of the quantities of influents and effluents, as well as the potential reuse of effluents presently.

Generally there are two types of Wastewater Treatment Plants (WWTPs) in Jordan; one is the centralized WWTP recognised as a governmental institution, while the other is the decentralized WWTP such as those installed at airports, universities and private companies. There are 22 governmental (87 MCM in 2006) and 23 private WWTPs (less than 3 MCM in 2006) (Fig. 3).

Governmental WWTPs receive sewage water from the public sewage network system that fall under the jurisdiction of the Water Authority of Jordan (WAJ). Private WWTPs handle wastewater drained from local premises with no connection to the public network and are not part of the WAJ mandate.

In this paper, only the centralized governmental WWTPs was considered due to the fact that it has a significant mandate to treat and reuse effluents compared to the effluents from the decentralized (private) WWTPs.

3.2 Sewage System in Jordan

There are 39% of households using private cesspools for discharging sewage water, which indicates a huge variation in the share of dwellings connected to the public sewage network system among the governorates. The highest percentage of connection (80%) is in Amman governorate whereas the Karak governorates have the lowest percentage (13%). The Amman Governorate, which receives the biggest share of municipal potable water (more than 40%), has almost 78% of its dwellings connected to the public sewage network system (Table 2).

3.3 Influents and Effluents of WWTP's

The total municipal water distribution for domestic use according to the data of the Ministry of Water and Irrigation, Jordan (MWI) was approximately 286.3 MCM in 2006; as shown in (Table 3), where approximately 110.9 MCM was received as

Table 2 Water supply for different sector and the actual demand, Ministry of Water and Irrigation data (2006/2007)

Demand requirements	Ground water	Surface water	Treated wastewater	Total
	MCM			
Domestic	214.0007	79.75	0	293.751
Rural area	0.745	7		7.745
Industry & remote areas	44.894	3.527	0	48.421
Agriculture	244.81	176.366	90.97	512.146
Agriculture (high land)		77.46		77.46
Total supply demand	504.4497	344.103	90.97	939.523
Actual demand				1512
Deficit				572.477

Table 3 Municipal water consumption for each governorate in Jordan (MWI 2006)

Governorate	2004	2005	2006	Consumption 2006
	m^3/year			%
Amman	118,536,066	119,869,739	121,953,318	42.6
El Zarqa	37,687,744	38,447,913	40,324,912	14.08
IRBID	32,754,703	34,376,280	34,195,729	11.94
MAFRAQ	16,903,277	17,482,806	17,604,297	6.15
El Balqa	20,177,343	21,274,250	21,168,767	7.39
KARAK	11,030,435	11,023,232	11,466,121	4
TAFILA	3,070,173	3,496,374	3,705,131	1.29
MA'AN	7,068,872	7,107,804	7,452,019	2.6
JERASH	4,362,633	4,081,985	4,135,507	1.44
AL-LAJJOUN	3,101,994	3,649,708	3,643,033	1.27
MADABA	6,057,704	6,172,765	6,369,242	2.22
AQABA	15,020,565	15,012,503	14,285,763	4.99
Total	275,771,509	281,995,359	286,303,839	

Ministry of Water and Irrigation (MWI), Water Authority of Jordan (WAJ)

influents at the WWTPs (Table 4). Meanwhile, in the mid eighties, the MWI assumed that 80% (or 229 MCM) of domestic water will be generated as wastewater. This

Table 4 Influents and effluents of Wastewater Treatment (WWT) Plants, 2006 (MWI 2006)

WWTP	Influent		Effluent	
	MCM/Year	%	MCM/Year	%
AS-SAMRA W.S.P	81.84	73.79	58.78	67.72
AQABA MECH	2.46	2.22	2.64	3.04
AQABA W.S.P	2.27	2.05	2.28	2.63
RAMTHA W.S.P	1.28	1.15	1.23	1.42
MAFRAQ W.S.P	0.68	0.61	0.64	0.73
MADABA W.S.P	1.67	1.51	1.49	1.72
MA'AN W.S.P	0.97	0.87	0.86	0.99
IRBID	2.32	2.09	2.23	2.58
JERASH	1.21	1.09	1.18	1.36
KUFRANJA	1.24	1.11	1.06	1.22
ABU-NUSIER	0.84	0.76	0.81	0.93
SALT	1.58	1.42	1.42	1.64
BAQA'	4.01	3.61	3.81	4.39
KARAK	0.59	0.53	0.55	0.63
TAFILA	0.37	0.33	0.33	0.38
WADI AL SEER	0.99	0.89	0.89	1.03
FUHIS	0.61	0.55	0.58	0.67
WADI ARAB	3.64	3.28	3.52	4.05
WADI HASSAN	0.4	0.36	0.39	0.45
WADI MOUSA	0.61	0.55	0.63	0.73
TALL-MANTAH	0.1	0.09	0.09	0.1
AKADER	1.05	0.95	1.15	1.33
AL-LAJJOUN	0.18	0.17	0.23	0.27
TOTAL M.C.M (per year)	110.91		86.79	

means that 48.42% of the generated wastewater from domestic use does not reach WWTPs due to the following reasons:

1. Approximately 61% of dwellings (Table 5) in Jordan are connected to the sewer network system, while the remaining use cesspools;
2. Some municipal water is lost to illegal water abstraction;
3. Technical loses due to leakage in the water supply networks estimated around 25–40%, according to WAJ; and,
4. Percolation of cesspools to groundwater (40% of the dwellings drain their wastewater into cesspools).

It is estimated that the total amounts of wastewater subject to deep percolation to groundwater are significant, due to the above reasons (El-Naqa and Al-Shayeb 2008). In the long term this could cause serious groundwater contamination.

Table 5 Total subscribers to water and sanitation system in Jordan, 2006 (MWI 2006)

WAJ directorate	Total subscribers to water (number of persons)	Total subscribers to sanitation (number of persons)	Served % per directorate	Served % per governorate
Amman	409222	328230	80	80
Irbid	78840	41581	53	
Al Kourah	11475	0	0	
Al Ramth	11466	4917	43	
Bani Kinanah	10726	2	0	
Bani Obiead	15644	5093	33	
North Ghor	10768	0	0	37
Al Zraqa	83483	57675	69	
Al Risyafa	33398	25580	77	71
Maádaba	15352	7336	48	
Theiban	4388	2	0	37
Al Salt	21662	11765	54	
Ain Albasha	16671	14399	86	
Al Fuhis	5215	4290	82	
South Shouna	6082	0	0	
Maadi	6207	0	0	55
Al Karak	16238	4340	27	
Ghor Al safi	3856	0	0	
Al Qaser	4978	0	0	
South Mazar	9622	45	0	13
Al Tafila	11990	2359	20	20
Maán	8939	1900	21	
Wadi Mousa	6330	2059	33	
Al Shoubak	2078	0	0	23
Al Mafraq	25368	4915	19	
North Badia	7712	0	0	15
Ajloun	15202	4739	31	31
Jarash	20882	7252	35	35
Al Aqaba	23275	16904	73	73
Total	897069	545383	61	61

MWI/WAJ 2008

As'samra WWTP receives 73.8% of the total amount of influents and is the largest WWTP in Jordan and in the Middle East; Al Zarqa and Amman are its largest suppliers (Table 5). The effluent of this WWTP is also the main supplier of reclaimed water for the King Talal Reservoir (KTR) that is being used for the agricultural sector in the Jordan Valley (JV).

3.4 Effluents Outlet

The net effluents (Table 6) refer to the actual effluent passing through the WWTPs and equals the gross effluent of each WWTP minus the amount of water consumed by agriculture at the premises and vicinities of the WWTPs (licensed consumption).

There is a significant amount of effluents that come from Assamra, Baq'a, Wadi Arab and Irbid as can be seen from (Table 6), but only effluents coming from Assamra and Baq'a are used in irrigation. This means that approximately 6 MCM per year is not utilized; the effluent from the North treatment plant like Irbid has poor quality and is rejected for use in the Jordan River.

There are three dams (King Talal Reservoir (KTR), Shu'aeb, and Kafrain) that receive effluents from some WWTP. Since these effluents run through wadis and are mixed with fresh surface water it becomes blended water. All amounts of water stored in these dams are designated for the agricultural use in the Jordan Valley.

Table 6 Net effluent exiting WT Plants, (MWI 2006)

WWTP	Effluent	Water consumption before the outlet	Net effluent[a]
	(MCM/ Year)		
As'samra	69.65	20	49.65
Aqaba	4.2	4.2	0
Ramtha	1.18	1.18	0
Mafraq	0.6	0.6	0
Madaba	1.57	1.57	0
Ma'an	0.87	0.22	0.65
Irbid	2.25	0	2.25
Jerash	1.22	0	1.22
Kufranja	1.22	0.63	0.59
Abu-Nusier	0.83	0	0.83
Salt	1.47	0.05	1.42
Baq'a	4.08	0.49	3.59
Karak	0.55	0.64	0
Tafila	0.37	0.12	0.25
Wadi Al-Seer	1.12	0.07	1.05
Fuhais	0.61	0	0.61
Wadi Arab	3.7	0	3.7
Wadi Hassan	0.27	0.27	0
Wadi Musa	0.71	0.71	0
Tall Al-Mantah	0.1	0	0.1
Al-Akader	1.16	1.16	0
Al-Lajjoun	0.17	0	0.17
Total (MCM/year)	97.9	31.91	66.08

[a]Net effluent is the effluent minus water amounts consumed in premises and vicinities of WT Plants

The total effluent water draining into these dams is around 58 MCM annually, of which 55 MCM is received by KTR alone. KTR is considered a vital water source for agriculture sustainability in the middle Jordan Valley, it being the principal recipient of effluents (53 MCM/year) mainly from As'samra, Baq'a, Jerash and Abu-Nusier WWTP's. In addition, many springs and stormwater runoff accumulate into KTR.

Farmers in the middle Jordan Valley depend entirely on the KTR as a source of irrigation water. They do not receive any surface water from King Abdulla Canal (KAC). Furthermore, they have to share this limited resource with new development areas (DAs) recently connected to the KTR system (DA 19, 20, 21) (Fig. 4).

In addition, farmers alongside Wadi Al-Zarqa' use TWW for uncontrolled cultivation. No data and relevant information about the cultivated areas along wadi Zarqa, nor crop patterns, nor the actual amount of water consumption is presently available.

3.5 Wastewater Reuse for Agricultural Irrigation

The collected wastewater must be treated to adjust its quality to the following end-users: irrigation, artificial recharge, potable water supply, toilet flushing, and industrial water supply. Reuse of wastewater has been practiced in many areas worldwide for thousands of years. In most cases it is used for unrestricted irrigation. Reclaimed wastewater can be used for all crops even for those that are consumed raw or uncooked. The reuse of WW in agriculture has been practiced worldwide in developed as well as in development countries such as in Australia, Federal Republic of Germany, India, Mexico, Tunisia, China, Guatemala, India and United States of America (Buechler and Mekala 2006).

Rural and suburban areas without large-scale wastewater collection and treatment systems commonly depend on septic systems. Wastewater is collected in a tank, and then distributed to the surrounding soil through perforated pipes. Septic systems work effectively only in very low density development. In higher-density developments, septic systems can severely impair groundwater quality.

Compared to conventional systems (the centralized WWT), an alternative collection systems such as adapting new technologies is less expensive and require less excavation. Reduced excavation means that less polluting sediment is disturbed into streams. This alternative sewer system tends to resist leakage better than conventional gravity collection systems.

This can lead to an increased amount of treated wastewater in Jordan through applying new technologies such as decentralized wastewater treatment system (On-site and/or cluster system used to collect, treat, and disperse or reclaim wastewater from a small community or service area.) or by using composting toilet systems (a technology that uses a biological process to degrade human waste into a humus-like end-product, sometimes called biological toilets, dry toilets and waterless toilets) that contain and control the composting of excrement, toilet paper, carbon additive, and, optionally, food wastes. Unlike a septic system, a composting toilet system relies on unsaturated conditions (material cannot be fully immersed in water), where aerobic bacteria and fungi break down wastes, just as they do in a yard waste composter. Properly sized and operated, a composting toilet breaks down waste to 10 to 30% of its original volume. The resulting end-product is a stable soil-like material called "humus", which in countries such as the United States must be either buried or removed by a licensed seepage hauler. In other countries, humus is

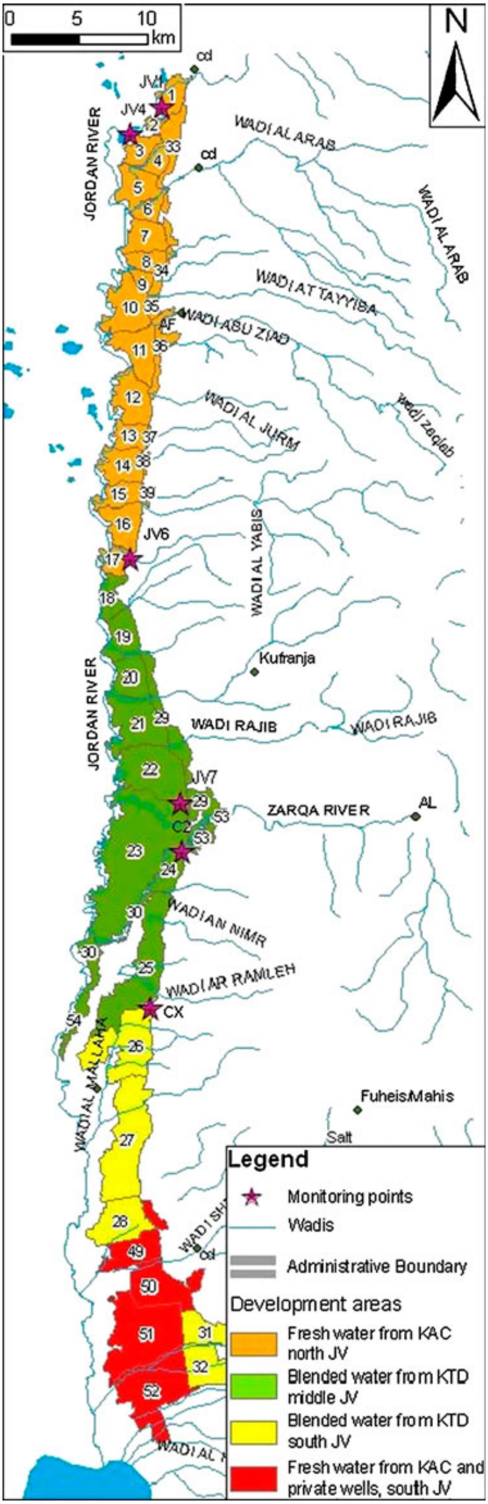

Fig. 4 Development areas in the Jordan Valley

used as a soil conditioner on edible crops. The primary objective of the composting toilet system is to contain, immobilize or destroy organisms that cause human disease (pathogens), thereby reducing the risk of human infection to acceptable levels without contaminating the immediate or distant environment and harming its inhabitants. A secondary objective is to transform the nutrients in human excrement into fully oxidized, stable plant-available forms that can be used as a soil conditioner for plants and trees.

4 Conclusion and Recommendations

In this paper we introduced a wastewater reuse index (WRI) which is defined as the ratio of actual wastewater reused to total generated wastewater. We argue that the WRI better reflects the potential for wastewater use as compared to the commonly used ratio of reuse to total treatment.

Representing Jordan as a case study, we argue that the wastewater reuse index is a useful measure for estimating the potential for wastewater reuse and that it can be used for policy guidance. We observed that the WRI in Jordan increased steadily from 30% to 38% between 2004 and 2007. As such, the WRI indicates that there is considerable scope for expanding wastewater reuse, which prompted a more detailed look at the constraints on wastewater treatment and reuse in different areas in the study area within the Jordan Valley. The appropriate approach to increase wastewater treatment depends on local conditions. In some cases the appropriate response is to increase the number of dwellings connected to the sewer system. In others, particularly in hilly or rural areas, a better option is to adopt technology such as composting toilet or decentralized wastewater treatment plant.

The decentralized approach to wastewater collection and treatment offers a new means of addressing wastewater management. Common to all of these options is on-site wastewater treatment by means of low-cost treatment systems, combined with direct use of the treatment products (water, compost, and biogas). This approach can sustainably meet wastewater management requirements.

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