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Quantity not quality: promoting sustainable wastewater practices in Jordan

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Abstract

Jordan, the second most water-scarce country in the world, is gradually increasing its reliance on treated wastewater for its water supply; more than 90% of treated wastewater is used either in agricultural or industrial activities in Jordan. However, in Jordan, all treated wastewater plants are constructed upstream of dams, the latter being used to store treated wastewater. Most dams in the country were originally constructed to collect freshwater through rainfalls. Mixing this source of freshwater with treated wastewater decreases the dams' water quality. This study examines the effects of mixing freshwater with treated wastewater in dams by comparing water samples from the outflows of selected wastewater treatment plants and different dams with historical hydrochemical data of dam water before the diversion of treated wastewater. This study finds that the quality of dam water, in which freshwater has been mixed with treated wastewater, notably decreases. Hence, this study formulates policy recommendations on how to ensure a sustainable water supply that ensures the quality necessary to different water uses, making the suggestion of a separate storage system in dams.

Keywords: Dams; Hydrochemical analysis; Jordan; Treated wastewater; Water quality

Introduction

Jordan is among the most water-scarce countries in the world (Hussein, 2017a), which poses a challenge to social and economic development as water is an essential element for households, industry, and agriculture (MWI, 2017). Jordan's decision-makers have been long pressured to find a sustainable solution to the water crisis and have been forced to favor larger quantities of water over higher quality. Historically, water scarcity in Jordan can be attributed to several factors including climate change, limited precipitations, mismanagement, transboundary nature of most surface water resources, and rapid

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population growth (Hussein, 2017b, 2018a, 2018b). This is coupled with the issue of non-revenue water lost through leakage, theft, or under-billing, which costs approximately half a billion dollars per year (USAID, 2019), adding to the growing national debt which reached 42.1 billion dollars in 2019 (CEIC Data, 2019). Further, in recent history the region has been affected by war, and a dramatic increase in the number of refugees from neighboring countries, especially Syria and Iraq, has exacerbated existing shortages (MWI, 2017). In fact, Jordan hosts more than 1.3 million Syrian refugees (Jordan Times, 2019), with each costing the water sector around 440 JOD per year (MOWI, 2015: p. 22).

However, most importantly, the Jordan River basin, which is the region's most important source of water, sits between Jordan, Israel and Palestine. At a domestic level, policy-makers have had to mitigate regional conflict by prioritizing set agendas to engender peace between the two countries. A condition of the 1994 Wadi Arabah peace treaty was that Jordan shares this major water source with Israel, and the aforementioned regional conflicts further burden Jordan's existing water crisis resulting in Jordan's share of the basin being inadequate to meet needs. Jordan remains vulnerable to any interruption to its transboundary flows and limited water supply, and increasing population means that the water shortage is affecting water and wastewater treatment system operations (Yorke, 2013: p. 8).

The most obvious objective of current policy-makers under these conditions is to resort to treating wastewater as this relies on recycling what the country already possesses and does not infringe on the peace treaty nor require them to resume old political contentions. Instead, technology has been utilized to secure the source of water in compliance with the environmental restrictions. Applying wastewater treatment technology to available water is a quick, safe, and guaranteed solution that avoids political confrontation. However, it should be communicated to policy-makers that there has been a failure to respond to the water challenge before it posed a threat against domestic stability. Within its political margins, Jordan has no sovereignty over its water since its surface and underground resources originate at the borders and are shared in zones of conflict such as the Yarmouk River, which is shared with Syria, and the Jordan River, which is shared with Israel and the Palestinian National Authority (Yorke, 2013: p. 17).

One of the most effective solutions underlined in those two strategies in order to mitigate the issue of water scarcity is to increase the reliance on treated wastewater for industrial and agricultural uses. The Ministry of Water and Irrigation of Jordan has been pursuing projects and initiatives, such as the Disi Project and the Red Sea – Dead Sea Canal Project, aiming at increasing the water quantity in the country (Hussein, 2017c).

Treated wastewater reuse goes in the direction of increasing water quantity; however, this paper argues that a focus on the quality of the water produced, especially for the latter solution, should be further considered.

Typically research in this area focuses on the technical aspects of how to increase water production and on the issue of social and cultural acceptability of using treated wastewater, rather than on the impact that the decreased quality of treated wastewater mixed with fresh dam water has on farmers and other local consumers. This paper aims to stimulate a policy dialogue on how to improve water quantity while ensuring higher water quality for the various water uses in Jordan. This paper sheds light on the deterioration in quality of the fresh rainfall water after it runs off and is merged with the treated wastewater in dams. This formulates policy recommendations on how to ensure a sustainable water supply that ensures the suggestion of a separate storage system in dams according to the end uses of the targeted water.

Background

Wastewater collecting systems were first introduced into Jordan in 1930 in the city of Salt. Some treatments utilized basic physical processes without doing a chemical treatment, however, septic tanks and cesspits often discharged graywater (sullage) to gardens, resulting in groundwater pollution. Modern technology to collect and treat wastewater was introduced in the late 1960s, when the first collection system and treatment plant was built at Ain Ghazal, an archeological site on the Zarqa River in East Amman, utilizing the conventional activated sludge process. The system consisted of a gravity-led sewage network that ran from the Zarqa River basin area to Ain Ghazal. The treatment plant was designed to handle an average flow of 60,000 m^3/day with a 5 days' biological oxygen demand (BOD5), and loading of 18,000 kg/day, for a population of around 300,000. It was designed to have an effluent standard of BOD5 20 mg/L, and the treated effluent was discharged into the Zarqa River (MWI, 2017). Since 1980, the government has promoted wastewater management primarily in relation to improving sanitation services. About 75% of the urban population and 52% of the total population (at that time) gained access to wastewater collection and treatment systems. This has raised the sanitation level, improved public health, and strengthened pollution control of surface and groundwater in the areas served by wastewater facilities. Currently, there are 16 treatment plants serving most of the country's major cities and towns. Ten of these are conventional mechanical treatment plants and six employ waste stabilization ponds. Two other treatment plants are currently under construction. Nevertheless, the treated wastewater is currently mixed with freshwater from rainfall, and the mixed water is stored in the dams before being pumped for agricultural and industrial purposes. In fact, most of the treated wastewater plants in Jordan are upstream of the dams. In the Jordan Valley, an agricultural area in Western Jordan that follows the Jordan River down to the Dead Sea, the majority of mixed water is used for agricultural purposes, however farmers are struggling to use this water due to the negative effects it has on the soil and agriculture. This, in turn, will affect Jordan's political economy and reduces the quantity and quality of produce exported to neighboring countries, since Jordan's fruit and vegetable exports were estimated at €651 million in 2015, and thousands of tons of produce used to be exported to neighboring countries such as Lebanon and Syria. In addition, Jordan is currently seen as the prime exporter of produce to the Gulf that consumed over 80% of Jordan's produce in 2015 (Bureau Leeters, 2016: pp. 15–16).

Many of the countries in the region are described as water deficient, however many of Jordan's bordering countries have been able to take significant steps to close the gap between demand and supply and contribute proactively to national economic growth, despite the geopolitical situation. The best example is Israel, where the industrial revolution, agricultural development, and population growth has drastically increased the country's water demand. In response, a national campaign was launched to develop their water system, focusing on wastewater as one of the main valuable resources.

The Kingdom of Saudi Arabia (KSA) faces similar challenges with water shortage and has undergone significant socio-economic developments with a huge population growth since the 1970s, now reaching 30 million. This caused a substantial increase in their water demand and they took great steps in water desalination and water depletion. However, to bridge the gap of the greater demand, special attention has recently been attributed to wastewater with the aim to achieve 100% use of treated wastewater by 2025.

These ambitious plans that put wastewater reuse at the forefront of combatting the high water demands put pressure on Jordan to follow suit. To confront its water problems, Jordan must create infrastructure to raise levels of regional cooperation to protect and coordinate the use of shared resources and find new supplies (Yorke, 2013: pp. 8–9).

While other countries in the region have found solutions to face the water shortage, Jordan has had to cope with the scarcity of water by initiating more wastewater reuse plans and trying to make them more efficient. Jordan has also had to provide a bigger water supply to all sectors, including farming and industry, to generate economic growth and allow Jordan to cope with its environmental/water limits.

Methodology and study parameters

This section primarily defines the dams selected for this study, their water inflows, and their catchment areas. The next section presents the materials and methods undertaken for the study followed by a section that analyzes the data and discusses the tradeoffs of mixing treated wastewater with freshwater in dams. The paper concludes by providing sustainable policy recommendations for future action.

Analyses were conducted at the Laboratory of Water, Energy, and Environment Centre (WEEC) at the University of Jordan according to the *Standard Methods of the American Public Health Association* (Rice *et al.*, 2012). Many parameters that reflect the water quality, including Ca, Mg, Na, and K and electrical conductivity (EC) were measured in this study. These parameters and methods are shown in Table 1.

The evaluation of water quality in the Zarqa River is based on the chemical indices: electrical conductivity (EC), sodium adsorption ratio (SAR), sodium percentage (Na %) and magnesium hazard (MH) and Kelley's ratio (KR). Sodium (or alkali) hazard in irrigation water is determined by the absolute and the relative concentration of cations and expressed in terms of SAR or the sodium absorption ratio. In that respect, there is a significant relationship between the SAR values in irrigation water and the sodium absorption rate by the soil, wherein the higher sodium and lower calcium and magnesium values in irrigation water indicate that the cation–exchange complex may become saturated with sodium, but if there are large enough quantities of magnesium and calcium in the soil this will counter the effects of the sodium and help to maintain good soil properties. SAR value is an indication of the availability of soil pore water to plant roots, high SAR values and excess sodium concentrations in irrigation water affect the soil properties and reduce its permeability and infiltration rate (Allison *et al.*, 1968; Weiner, 2012).

$SAR = Na\sqrt{(Ca + Mg)}/2$ (ions units meq/liter) (Karanth, 1987)

Figure 1 shows the key basins of surface water in the north of Jordan, and the five dams examined in this paper. Dams receive their water from rainfall flood flows and spring discharge within their catchment area. In addition to these good quality water sources, wastewater treatment plant effluents constructed within the watersheds of these dams discharge the treated wastewater into the hydrologic

Table 1. Base and flood flow for dams' natural situation (MOWI, 2015).

Dam	Flood flow MCM/yr	Base flow MCM/yr	Total MCM/yr
King Talal Dam	37.49	33.4	70.89
Kafrain Dam	1.35	12	13.35
Shuieb Dam	1.77	8	9.77
Ziglab Dam	2.2	8.3	10.5
Wadi Arab Dam	6.48	24.9	31.38

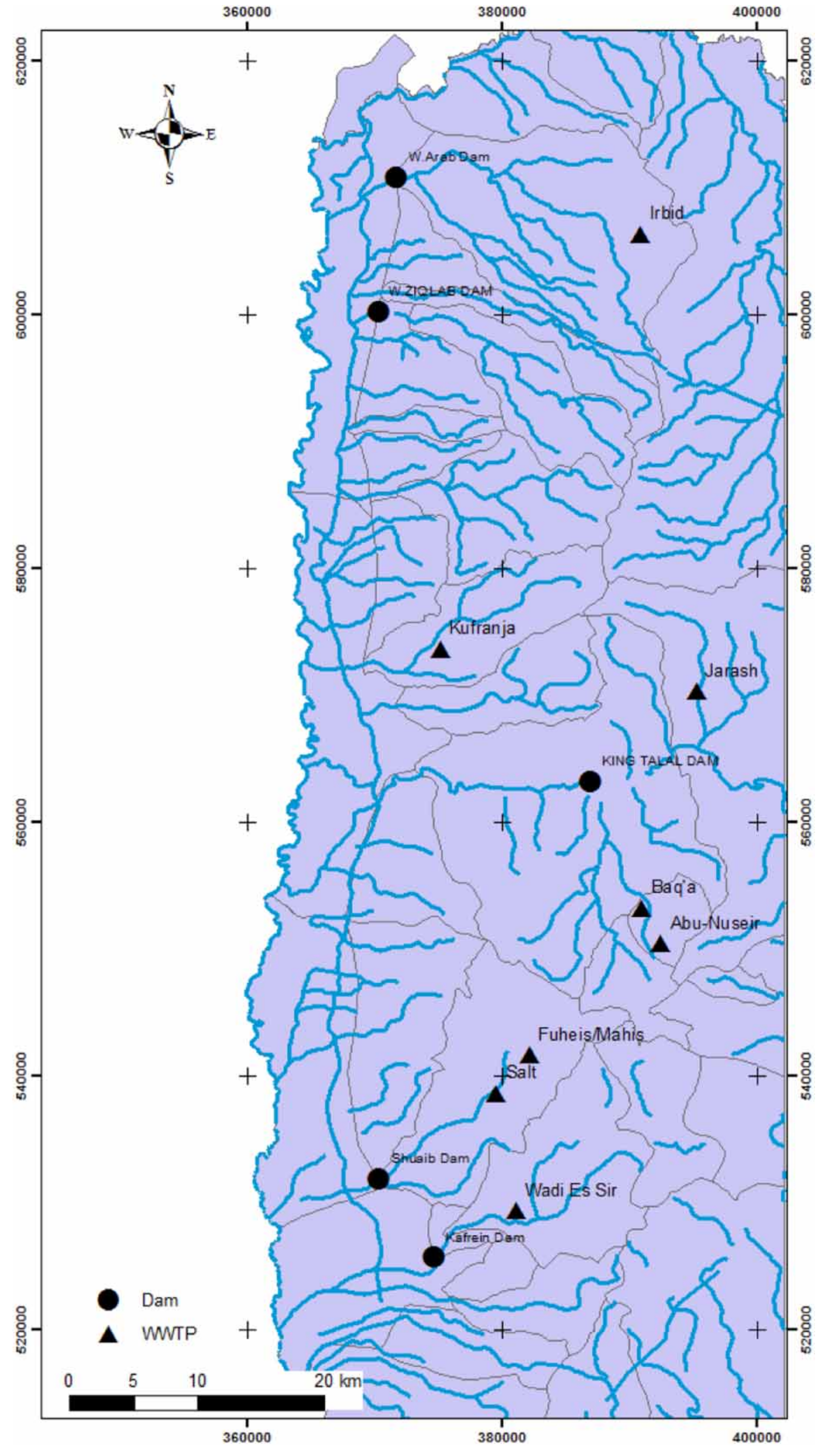

Fig. 1. Location map of the main dams and wastewater treatment plants within their catchment areas.

system reaching the dams. Table 1 shows the total base and flood flows in million cubic meters (MCM) of the dams.

Study locations

Jordan has built several dams of various storage capacities in order to store water for domestic, agricultural, and industrial uses, as well as to control floods, improve drainage, and collect water from rivers and streams. This article details the King Talal Dam (KTD), which is an earth-fill dam that began operating in 1978, with a capacity of around 85 MCM and a dimension of 7.50 km long and 450 m wide (area of 33.75 km^2), making it one of the largest dams in Jordan (RSS reports, 1984–2005; Numayr, 1999). KTD was constructed within the Zarqa River Basin and receives its major inflow from runoffs of the Zarqa River and its main springs, and discharges 40 km northwest of Amman. Other inflows to the KTD come from other small springs as well as treated wastewater from the Al-Samra, Jerash, and Baqa'a sewage treatment plants, and various industrial plants between Amman and Zarqa. These plants contribute to about 50% of the water reaching the dam.

This paper also explores the Wadi Al-Arab Dam (WAD) in the catchment area of Yarmouk, measuring approximately 267 km². The average rainfall in this catchment area ranges from approximately 500 mm over the highlands in the west of Irbid, to 350 mm in the North Shuna in the Jordan Valley, and has an overall average of 372 mm/year. The north-western parts of the catchment bordering the Hermon Mountains have a rainfall of more than 1,000 mm/year decreasing to 250 mm/year in the south-eastern area of the catchment (Salameh *et al*., 2018). The average total water discharge of the valley is around 31.4 MCM/year, with a base flow of around 25 MCM/year. The WAD was built in 1987 with a total capacity of 20 MCM to collect flood water and base flows mainly for irrigation purposes in the Jordan Valley. Waters originating within the catchment area's valley only filled the dam during very wet years such as 1991/92. In other years, the dam served as a storage reservoir for water pumped from the King Abdullah Canal (KAC) in the Jordan Valley during floods (Salameh *et al*., 2018).

A wastewater treatment plant was built for Irbid, a city northwest of Amman, in the upper areas of the Wadi Al-Arab area. Although the treatment plant's waste is supposed to evade the dam, floodwaters can still enter the premises of the treatment plant and also the effluents along the WAD in the dam's reservoir, adversely affecting the quality of its water (Alfarra *et al*., 2012). Additionally, some areas of Irbid that are located within the drainage basin area of the WAD still release their untreated wastewaters in the tributaries that flow into the dam, thus deteriorating the quality of the dam's water.

The Shuaib Dam (SD), which is located in Wadi Shuaib to the west of Amman, was built in 1968 with a capacity of 2.3 MCM. Wadi Shuaib has a drainage area of approximately 180 km^2 from the west of Suweileh region at an elevation of 1,200 m above sea level down to 200 m below sea level. The valley's natural annual flood flow is around 1.8 MCM, whereas the annual base flow is around 3.9 MCM. In addition to the flood and base flows, the SD also receives effluents from Al-Salt, Al-Fuhais, and Mahis wastewater treatment plants (Salameh *et al*., 2018). Al-Salt wastewater treatment plant started operation in the early 1980s, initially with a capacity of 3,000 m^3/day and since 1997 has a capacity of up to 7,600 m^3/day (Ammary, 2007). The Al-Fuhais and Mahis wastewater treatment plants, on the other hand, began operating in the late 1990s with a capacity of 2,400 m^3/day.

Wadi Kafrain is a valley encompassing several towns and villages including Wadi Al-Sir and Na'ur, and has a flow of around 6.4 MCM/year, comprising a flood flow of 1.6 MCM/year and a base flow of

4.8 MCM/year. The Wadi Kafrain Dam (WKD) was constructed in the upper part of Wadi Kafrain in 1968 with a capacity of 3.8 MCM. The dam's water comes from the base and flood flows of Wadi Kafrain in addition to the treated wastewater flow from the Wadi Al-Sir wastewater treatment plant. Wadi Al-Sir treatment plant was built in 1997 and is supposed to treat up to approximately 4,000 m^3/day.

The final dam dealt with in this paper is the Wadi Ziglab Dam (WZD), located in Wadi Ziglab, west of Irbid, and which was constructed in 1966 with a total capacity of 4.3 MCM. This dam's water is used for irrigation in the Jordan Valley area. The catchment area of Wadi Ziglab is around 106 km^2 and extends from the Jordan Valley eastwards towards the highlands. The total average discharges of the Wadi Ziglab catchment area is around 10.5 MCM/year with a flood flow of around 2.2 MCM/year and base flow of about 8.3 MCM/year. The hydrologic situation in the catchment area has not changed much since the 1960s, however the area has been affected by increased urbanization and climatic changes, although these are not yet strongly reflected in the flow regime of this valley (Salameh *et al*., 2018).

Materials and methods

Water samples were collected from ten sites along the targeted dams and streams. Also, historical hydrochemical records for each dam before the diversion of the treated wastewater were collected and compared with the new data. Surface water samples were collected from the different locations using a 2 liter-capacity PVC water sampler in January and May 2017. The bottles were also washed with sampled water before they were filled. The bottles were kept in an icebox until they were transported to the laboratory.

The pH of the water was determined with a pH meter equipped with a standard hydrogen electrode and reference electrode. Although pH usually has no direct impact on consumers, it is one of the most important operational water quality parameters. Careful attention to pH control is necessary at all stages of water treatment to ensure satisfactory water clarification and disinfection. For effective disinfection with chlorine, the pH should be less than 8.5 standard units (SU).

The temperature of the water was measured *in situ* with a portable thermometer. Cool water is generally more palatable than warm water, and temperature impacts on the acceptability of a number of other inorganic constituents and chemical contaminants that may affect the taste. Further, higher temperatures enhance the growth of microorganisms and may increase taste, odor, color, and corrosion problems.

Electrical conductivity (EC) measures the water's ability to conduct an electric current and depends upon the number of ions or charged particles in the water. It is measured by passing a current between two electrodes (a known distance apart) that are placed into a water sample. The unit of measurement for EC is expressed in either microsiemens per centimeter (μS/cm) or millisiemens per centimeter (mS/cm). EC in the collected water samples was measured *in situ* using a calibrated portable EC meter.

Water samples were analyzed for different chemical parameters including cations (Ca^{2+}, Mg^{2+}, Na^+, and K^+) and anions (Cl^-, $SO4^{2-}$, HCO_3^-, and NO_3^-). The concentrations of cations and anions were determined at the laboratory according to the *Standard Methods* (Rice *et al*., 2012).

Alkalinity in water results from the presence of the hydroxides ($OH-$), carbonate (CO_3^{-2}), and bicarbonates (HCO^{-3}) of elements such as calcium, magnesium, sodium, potassium, and ammonia. The alkalinity in wastewater helps to resist changes in pH caused by the additions of acids. Nitrogen and phosphorus, essential to the growth of microorganisms, plants, and animals, are known as nutrients. As nitrogen is an essential building block in the synthesis of protein, nitrogen data are required to evaluate the treatability of water by biological processes.

Phosphorus is also essential to the growth of algae and other biological organisms. Due to the noxious algal blooms that occur in surface water, there is presently much interest in controlling the amount of phosphorus compounds that enter surface waters in domestic and industrial waste discharges and natural runoff. The sulfate ion occurs naturally in most water supplies. Sulfur is reduced biologically under anaerobic conditions to sulfide which, in turn, can combine with hydrogen to form hydrogen sulfide. Chlorine is widely used as an important disinfectant and bleach. In particular, it is widely used in the disinfection of swimming pools and is the most commonly used disinfectant and oxidant in water treatment. Chlorination is employed primarily for microbial disinfection; chlorine also acts as an oxidant and can remove or assist in the removal of some chemicals. A disadvantage of chlorine is its ability to react with natural organic matter to produce trihalomethanes.

For analysis of the concentrations of major cations, we started with calcium as it is the fifth most abundant element in the Earth's crust. It is an important element for plant growth, and the main sources of calcium in natural water come from streams flowing over limestone, $CaCO_3$, gypsum and other calcium-containing rocks and minerals (Nikanorov & Brazhnikova, 2009).

Sodium (Na^+) is the sixth most abundant element in the Earth's crust after calcium. Nearly all sodium compounds are readily dissolved in water, it naturally leaches from rocks and soils, and sodium is an important element in determining the suitability of water for irrigation (Priyadarshi, 2005). Magnesium (Mg^{2+}) is one of the most abundant elements in the Earth's crust and is never found free in nature. It is classified as a secondary nutrient, but it has a major effect on crop and animal production (Kirkby & Mengel, 1976).

Potassium (K^+) is also one of the most abundant elements in the Earth's crust. It is an important element since it is one of the essential nutrients for plants and animals; it is also naturally leached from rocks and soils (Hem, 1985).

Kelley's ratio can be used to determine the suitability of water for irrigation. The measurement of the concentration of Na^+ against Ca^{2+} and Mg^{2+} is known as Kelley's ratio (Kelley, 1963):

$$\text{Kelley's ratio } (KR) = Na^+/Ca^{2+} + Mg^{2+} \text{ (ion units meq/liter)}$$

A Wilcox diagram can be used to determine the suitability of water for irrigation (Wilcox, 1955). This diagram represents a plot of the sodium absorption ratio (SAR) on the Y-axis against EC on the x-axis. According to the Wilcox diagram, water can be classified into four types based on EC and four types based on SAR. The classifications based on EC (or salinity hazard) are: C1 (low salinity hazard), C2 (medium salinity hazard), C3 (high salinity hazard), and C4 (very high salinity hazard); whereas the second classifications based on SAR (or sodium hazard) are: S1 (low sodium hazard), S2 (medium sodium hazard), S3 (high sodium hazard), and S4 (very high sodium hazard).

Results and discussion

Historically in Jordan, the collected water in the selected dams was of low salinity and contained only small concentrations of pollutants, such as nitrate. However, water that has been collected from a stream contains a higher concentration of different pollutants which is a result of the contamination from the outflow of the wastewater treatment plants discharging their flows into streams feeding the selected dams. This is shown in the water samples from the dams before and after the diversion of the treated water into them. In fact, the analysis shows that the treated wastewater contains many pollutants that adversely affect the water quality of the dams. Figure 2 shows the electrical conductivity of the different water samples. It is very clear that the increase in the salinity is due to the process of merging the two kinds of water.

Based on the data of the current study, the maximum EC values were observed in the streams that feed the selected dams compared to the values recorded in the water of dams before and after diversion of the effluents from wastewater treatment plants.

Figure 3 demonstrates the comparison between the concentrations of the measured parameter from the collected water samples before the dams (streams) and within the selected dams (before and after diversion of the effluents from wastewater treatments plants).

The concentration of the measured cations and anions (mg/L) in the present work (Figure 3) showed that there were differentiations in the water quality of the collected water samples. The analysis data of the Ziglab Dam (ZD) showed different trends, due to there being no wastewater treatment plant discharging into the dam. This indicated that the water quality of ZD is in a good condition compared to the water quality of the other dams.

Another method for determining the suitability of water for agricultural use is by calculating the sodium percentage (Na%) (Wilcox, 1955), as sodium concentration reacts with soil, thus reducing its permeability (Todd, 1980). The percentage of sodium values in the collected water samples indicate that most of the water samples are in the 'good to permissible' category for irrigation use, except three samples which fall below the 'unsuitable' category.

The Wilcox diagram (Figure 4) describes the potential of water for agriculture use, and recommends using water with lower SAR and lower electrical conductivity. As shown in Figure 4, water in the streams leading to the selected dams have higher records of salinity (salinity hazards), compared to the salinity values in the dams before and after diversion.

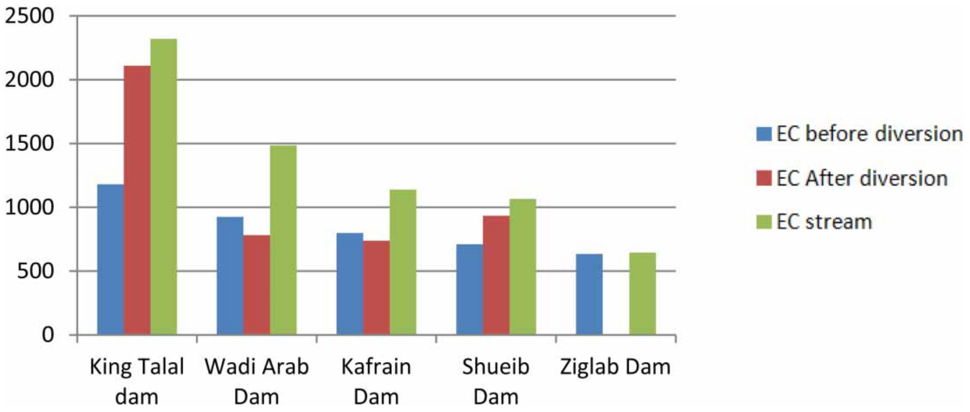

Fig. 2. Comparison between the electrical conductivity in streams before the dams, water of the dams before and after diversion of the effluents from wastewater treatment plants.

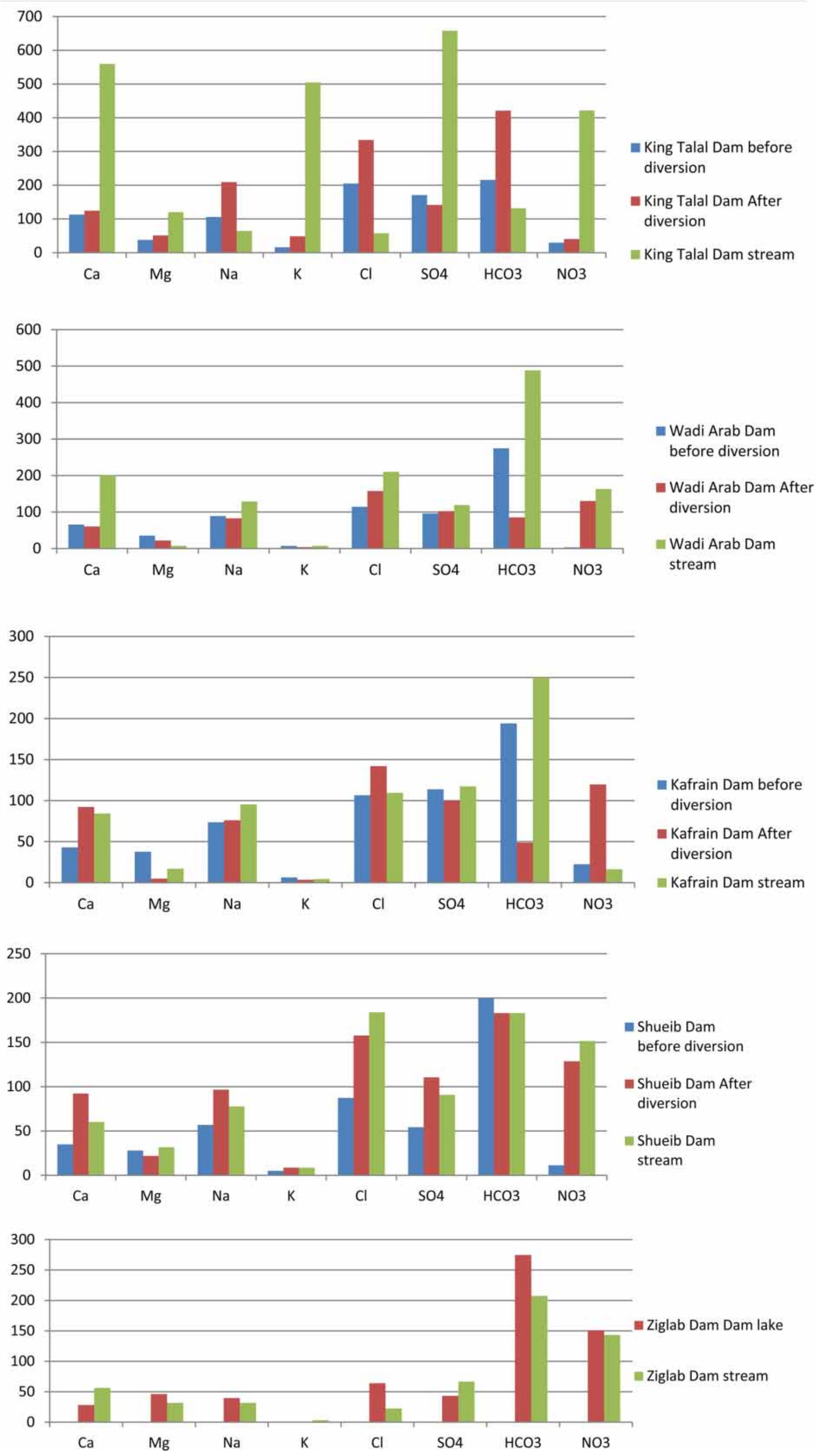

Fig. 3. Comparison between concentrations of measured parameters before and after diversions.

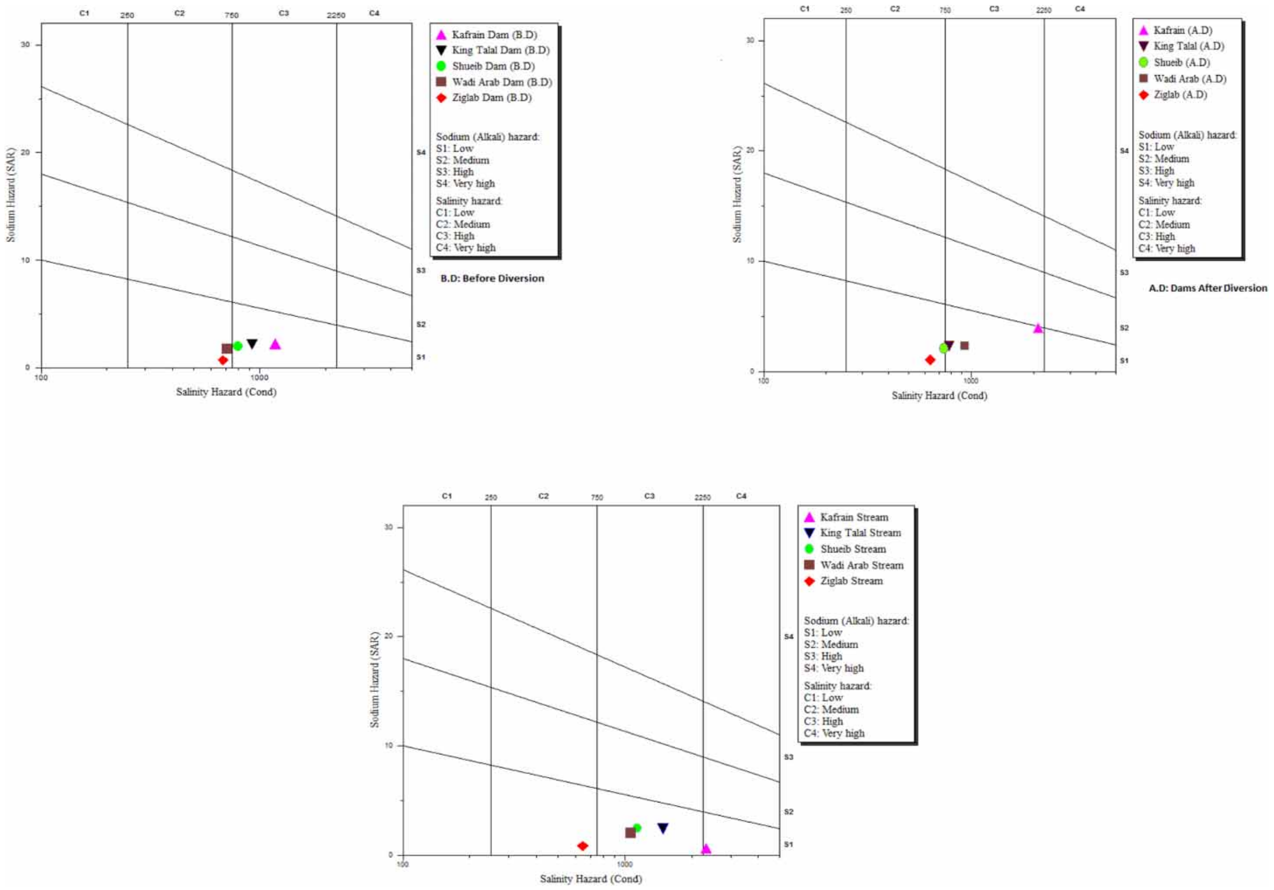

Fig. 4. Wilcox diagrams for water samples from different water types within the targeted dams.

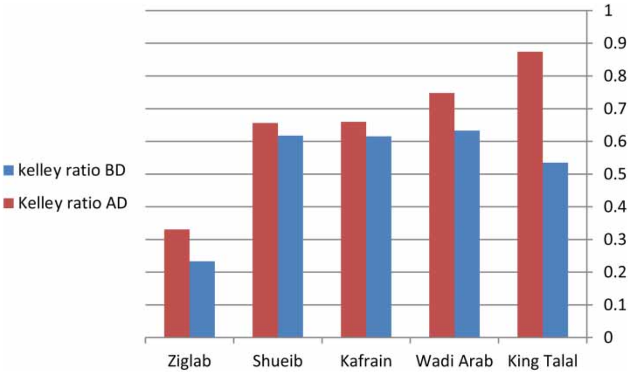

Fig. 5. Water samples from different water types within the targeted dams according to Kelley's ratio.

Kelley's ratio

Kelley (1940) suggested that the sodium problem in irrigational water could be determined by applying a ratio now known as 'Kelley's ratio' (KR), which reveals that water having a ratio of more than 1 is generally unfit for irrigation. In irrigation water, if the value of KR is more than 2 it means an extra value of sodium exists in the water and the water is not suitable for irrigation. If the KR value is in the range 1–2 that means the water is under the category of marginal, whereas if the KR value is less than 1 it means that the water is suitable for irrigation (Kelley, 1940).

It is noticed that after merging, the water has higher KR values but is still suitable for irrigation, as shown in Figure 5 below.

Samples collected from dam water before and after the diversion of the treated flows was plotted using KR. Figure 5 shows that the ratio becomes higher when the treated effluent is discharged into the dams, meaning the water becomes unfit for agricultural uses.

Conclusion and recommendations

As shown in the chemical analysis of the 'Results and discussion', stream water containing high levels of pollutants from wastewater treatment plants is discharged into the flow of the selected dams and while it increases the quantity of water in the dams, it decreases the quality of the water. Given the necessity to ensure both quantity and quality of water, freshwater in dams should be protected from any source of pollution that might affect its quality, including treated wastewater. In fact, treated wastewater has lower EC values, lower ion concentrations, and is lower in SAR values, and KR. The treated wastewater actually has better hydrochemical parameters than the stream water, which has lower water quality due to the wastewater that flows directly into it.

The overall decreased quality of the mixed water in the dams makes the use of the water for consumption impossible. By considering the major quality changes which have taken place in the waters of dams that were originally designed to store flood and base flows of valleys and streams, it becomes clear that this policy has deprived the country of tens of millions of cubic meters of good quality flood and base flows annually, which can be used for high quality usages such as drinking.

The mixing of these waters with treated wastewater rendered the water only useful for irrigation purposes. While the quality of the mixed water improved compared to quality of the treated wastewater, it is a pressing issue that the good quality of flood and base flow has deteriorated in a country keen to obtain higher quality water for drinking purposes. Providing high quality drinking water is the first priority for Jordan, as emphasized by King Abdullah II in the 'National Water Strategy of Jordan, 2016–2025'.

Therefore, this study suggests further research on the topic, in order to evaluate the possibility of building separate storage systems in the dams for treated wastewater and for pure freshwater. The latter could still be used for drinking purposes, while the former, if mixed with parts of pure freshwater to reach a good enough quality water for irrigation, could still be used for agricultural and industrial purposes.

Jordan's geopolitical situation, stability, and food supply are most affected due to the fact that Jordan has become an obvious recipient for refugees from all over the region. Therefore, the availability of water for drinking, irrigation, and industry has become extremely challenging, and the lack of resources and ability will have an impact on the country's economic growth. Therefore, Jordan's decision-makers face the dilemma of how to generate water supplies that meet the population's demand, incorporating or at least balancing it with socio-economic development plans. The unimaginable growth of the population due to regional conflicts, teamed with the subsequent decreasing quality of water caused by mixing treated wastewater and freshwater, is directly harming the agriculture sector, which produces 25% of exports and €651 million annually (Bureau Leeters, 2016: p. 8).

Therefore, despite Jordan's national efforts to work on water scarcity and treated wastewater, and despite the unilateral efforts by individual countries in the region, there should be joint regional efforts to work on wastewater projects. As Jordan has a unique position as the neutral ground in a highly conflicted region, it could initiate bilateral arrangements with bordering countries to learn from their breakthrough technologies.

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