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RESEARCH ARTICLE

APPLYING THE QUALITY AND POLLUTION INDICES FOR EVALUATING THE WASTEWATER EFFLUENT QUALITY OF KUFRANJA WASTEWATER TREATMENT PLANT, JORDAN

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ABSTRACT

In Jordan, reclaimed wastewater has become a significant component of water resources due to acute water scarcity and increased water demand for different purposes. The vast majority of the reclaimed wastewater is used for restricted and unrestricted agriculture, with agriculture being one of the main economic activities in the country. The purpose of this study is to assess the quality of the wastewater effluent from the Kufranja Wastewater Treatment Plant (WWTP) and its suitability for irrigation and discharge into streams, wadis, or water bodies using the water quality index (WQI) and the water pollution index (WPI). The WQI and WPI were calculated using 15 physiochemical and biological parameters in total. The results of WQI and WPI based on the Jordanian standards for the reuse of reclaimed wastewater showed that the wastewater effluent of Kufranja WWTP falls within the category of "good quality" for the irrigation of industrial crops, field crops, and forest trees, while it falls within the category of "unsuitable quality or highly polluted water" for other irrigation uses. Moreover, the Kufranja WWTP effluent is of "unsuitable quality or highly polluted water" for discharging into streams, wadis, or water bodies. The findings from this study show that the Kufranja WWTP performed well during the year of study, where the average removal efficiency (EFF%) for BOD_5, COD, and TSS was 95.1%, 95.6%, and 96.0%, respectively. The WQI results in this study revealed that *E. coli* has the greatest contribution to the WQI values, followed by PO_4^{3-}, pH, and SAR, implying that the previous parameters are to blame for the deterioration of the effluent quality of the Kufranja WWTP and its inappropriateness for most uses. Therefore, further advanced treatments are required to reduce the loading of these parameters.

KEYWORDS

Water Quality Index, Water Pollution Index, Reclaimed Wastewater, Wastewater Reuse, Irrigation Water, Kufranja WWTP - Jordan.

1. INTRODUCTION

Jordan is among the world's three most water-poor countries; its water resources are extremely limited, and the country is facing an extreme water shortage given that available water resources are insufficient to meet the country's water demand (MWI, 2020a). Jordan's water scarcity has been exacerbated by a number of factors, including population growth, climate change (e.g., fluctuating and scarce rainfall and high evaporation rates), the hosting of many refugees, a lack of alternative water resources, and water resource mismanagement, in addition to the need for economic development. The annual per capita of renewable water resources in Jordan has decreased from 3,600 m^3 in 1946 to less than 100 m^3 in 2017, far below the globally identified benchmark water poverty level of 500 m^3 per capita (MWI, 2017).

Water supply in Jordan comes from three major resources: groundwater (~53%), surface water (~32%), and treated wastewater (~15%) (MWI, 2020a). The scarcity of water resources is one of the most significant challenges to Jordan's economic development, particularly in the agricultural sector. Jordan's water crisis has become critical amid local and international concerns that have issued warnings about expectations of a doubling of the expected demand for water in the years ahead, especially if the refugees remain in Jordan. Therefore, the country's high usage of water resources and the growing demand for water for different purposes need to be accompanied by efficient management and planning in order to balance current water needs and ensure the sustainability of water resources for future generations. The gap between water supply and demand has recently widened as Jordan's water deficit surpassed 40 million cubic meters in 2021 (MWI, 2020-2022).

The continuous increase in water demand caused an increase in competition between the agricultural, domestic, and industrial sectors over limited water resources, which led to a decrease in the availability of freshwater (MoE, 2020). Therefore, seeking alternative water sources (e.g., treated wastewater) is very important and just as important as conserving and protecting limited water sources from any source of pollution (Abualhaija and Shammout, 2022). Treated wastewater in Jordan is one of the most important unconventional water sources. Its importance derives from its significant contribution to offsetting the acute water deficit and narrowing the large gap in the Jordanian water budget. Jordan has 33 wastewater treatment plants (WWTPs) distributed among the country's urban areas; these plants treat more than 186 MCM of wastewater each year. The population growth in Jordan (including the refugees) caused an increase in the amount of treated wastewater from 110 MCM in 2010 to 187 MCM in 2020, which led to exceeding the design capacity of some WWTPs and affecting their performance (MWI, 2020a).

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More than 90% of treated wastewater in Jordan is reused in agriculture (MoE, 2020). Wastewater reuse has many environmental, economic, and socio-economic benefits. The environmental benefits include diminishing the pollution of freshwater resources and wastewater-receiving water bodies, while the economic benefits include the large quantities of water provided by reusing wastewater, which helps in preserving freshwater resources and thus alleviates water scarcity in Jordan (Abdulla et al., 2016; FrankWater, 2017). In addition, treated wastewater is rich in nutrients, which reduces the need for chemical fertilizers used in agriculture and thus increases production, employment, and exports and brings socio-economic benefits (Bahadir et al., 2016; FrankWater, 2017).

However, many challenges hamper the reuse of treated wastewater in a broader and better way. The most significant of these challenges is the quality of treated wastewater, where the quality of treated wastewater in most of Jordan's WWTPs has not met the recommended standards for most agricultural uses and is only suitable for restricted agricultural uses (MoE, 2020). Accordingly, the discharge of wastewater effluents from these WWTPs into water bodies can lead to pollution and pose health risks. Therefore, it is very important to carry out continuous studies on the quality of the wastewater and determine its suitability for various uses and discharge into streams, wadis, and water bodies.

Water resources in Jordan are affected by many anthropogenic-induced sources of pollution, including urban, industrial, and agricultural pollutants, in addition to wastewater effluents from WWTPs, which alter the chemical, physical, and biological properties of the water in these resources and thereby lead to a deterioration in their quality and ecosystem (Al-Omari et al., 2019; Breulmann et al., 2022; Lin et al., 2022). Accordingly, surface and groundwater quality must be continuously studied and monitored, and sources of pollution must be effectively monitored, controlled, and managed. This study is significant because it will provide important and helpful information to the decision-makers and relevant institutions to better understand the status of wastewater quality, which helps them to adopt effective strategies and achieve appropriate management and optimum use of wastewater effluents in order to protect the surface and groundwater from the pollution that may occur as a result of the discharge of wastewater effluents, thus preserving the environment and public health, and providing renewable and sustainable water sources for irrigation and other uses.

Therefore, the main objectives of this study are to evaluate the wastewater effluent quality of the Kufranja WWTP and its suitability for irrigation and discharge into streams, wadis, or water bodies by applying the water quality index (WQI) and the water pollution index (WPI) and to determine and highlight key parameters that affect the effluent quality, in addition to assessing the performance of the Kufranja WWTP based on the hydraulic and organic loads and removal efficiency (EFF%) of the biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), and total suspended solids (TSS).

2. Materials and Methods

2.1 Study Area

Kufranja wastewater treatment plant (WWTP) is located in Wadi Kufranja, northern Jordan in the city of Ajloun, about 68 km northwest of the capital of Jordan, Amman (Figure 1). It serves four major cities (Ajloun, Kufranja, Anjra, and Ain-Janna) with a total population of about 91,400 (YWC, 2022). Kufranja WWTP began operating in 1990 with a design capacity of about 1900 m^3/day. It was working on a trickling filter system. The hydraulic load became greater than the plant's design capacity as the population increased. Consequently, the Jordanian government has recently expanded and optimized the Kufranja WWTP, where its design capacity becomes about 9000 m^3/day, and it works on the activated sludge system (MWI, 2020b).

Kufranja WWTP is situated in Wadi Kufranja, upstream of the Kufranja Dam. Kufranja Dam was constructed in 2016. It is a concrete-face rock-fill dam with a storage capacity of about 7.6 MCM (Abualhaija and Mohammad, 2021). Wadi Kufranja is the main tributary to the Kufranja Dam. Its water sources are primarily spring waters and precipitation discharged from the surrounding area, as well as the wastewater effluent flowing from the Kufranja WWTP. In 2021, for the protection of the water sources of the Wadi Kufranja and the Kufranja Dam against any possible pollution resulting from the discharge of wastewater effluent from the Kufranja WWTP, the Jordanian Ministry of Water and Irrigation established a large 8-km pipeline to transport effluent from the Kufranja WWTP to the Rajeb region to irrigate forest trees. In this way, the Jordanian government prevented the discharge of wastewater from the Kufranja WWTP into the Wadi Kufranja and Kufranja Dam.

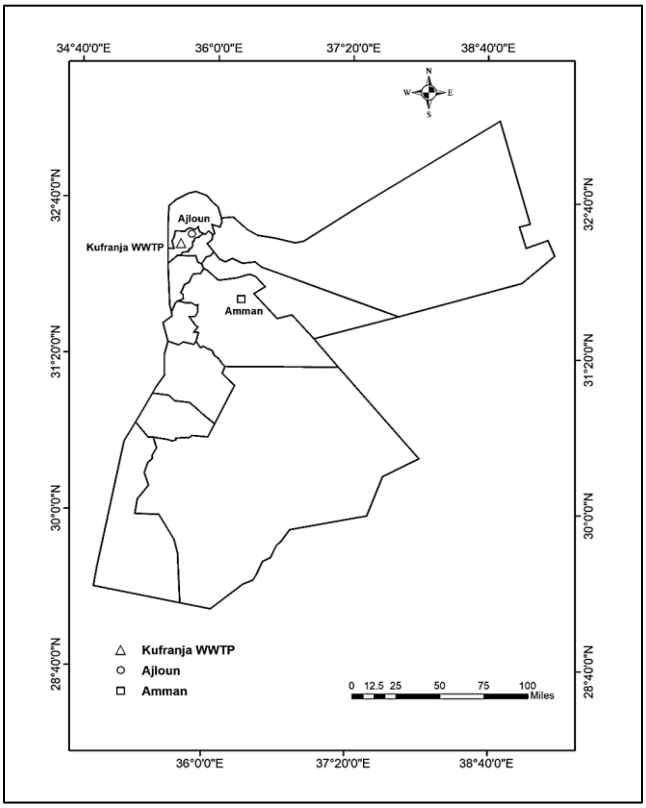

Figure 1: Location map of the Kufranja WWTP in Jordan.

2.2 Sample Collection and Analytical Methods

Table 1: Analytical and reference methods of the physicochemical and biological parameters.

Test	Unit	Reference Method (Rice et al., 2012)
pH and TDS	SU and mg/l	Portable waterproof meter (instruments: Hanna, HI98194)
BOD_5	mg/l	OxiTOP Respirometric method (5210D)
COD	mg/l	Clased Reflux colorimetric method (5220D) (instrument: Spectrophotometer (DR 3900 Hach))
TSS	mg/l	Solids (2540D)
Cations and Anions	mg/l	Ion Chromatography (4110C) (instrument: DIONEX ICS-5000+ DP) equipped with the column (CS12A-4*250) for cation tests; the column (AS14A- 4*250) was used for anions tests with a conductivity detector
T. Kj-N	mg/l	Macro-Kjeldahl method (4500-NorgB)
TN	mg/l	Calculation
Bicarbonate	mg/l	Titration method with the calibrated pH meter (2320B) (instrument: sensodirect 150 Lovibond)
SAR	Unitless	Calculation
E. Coli	MPN/100 ml	Enzyme Substrate Test method (9223B)

Samples from the effluent of the Kufranja WWTP were collected three times during 2019. Polyethylene bottles were used to collect the samples, which were rinsed three times with effluent water to remove contamination. After that, the bottles were filled with the targeted water and stored in an icebox until analysis. The analyzed physicochemical and biological parameters were as follows: hydrogen ion concentration - pH (SU), biochemical oxygen demand - BOD_5 (mg/l), chemical oxygen demand - COD (mg/l), total dissolved solids - TDS (mg/l), total suspended solids -

TSS (mg/l), nitrates - NO_3^- (mg/l), total Nitrogen - TN (mg/l), phosphate - PO_4^{3-} (mg/l), chloride - Cl^- (mg/l), bicarbonate - HCO_3^- (mg/l), sodium - Na^+ (mg/l), magnesium - Mg^{2+} (mg/l), calcium - Ca^{2+} (mg/l), sodium absorption ratio - SAR, and *Escherichia coli* - *E. coli* (MPN/100ml). All the analyses were carried out following the Standard Methods for the Examination of Water and Wastewater (Rice et al., 2012). All the analytical and reference methods are illustrated in Table 1.

2.3 Calculation of the Water Quality Index (WQI)

A number of quality indices have been developed and used to assess the suitability of water for various uses, in particular for drinking and irrigation (Abbasi and Abbasi, 2012; Abualhaija et al., 2020; Brown et al., 1972; Hossain and Patra, 2020; Meireles et al., 2010; Pryce et al., 2022). WQI is expressed as an index number that describes the overall quality of water and its appropriateness with regard to any intended use, where the WQI encompasses vital water quality parameters at a specific location and time. It converts complex and important data on water quality into understandable and usable data for decision-makers, relevant institutions, and the general public of a nation (Falowo et al., 2017). The computation of the WQI was performed based on the weighted arithmetic index method (Brown et al., 1972). The WQI was applied in this study to evaluate the quality of wastewater effluent for the Kufranja WWTP based on Jordan's standards for reclaimed domestic wastewater (JSMO, 2021). All the 15 analyzed physicochemical and biological parameters (pH, BOD_5, COD, TDS, TSS, NO_3^-, TN, PO_4^{3-}, Cl^-, HCO_3^-, Na^+, Mg^{2+}, Ca^{2+}, SAR, and *E. coli*) were included in the calculations of the WQI model.

The WQI was calculated from the following equation (Brown et al., 1972):

$$WQI = \sum_{i=1}^{n} W_i Q_i / \sum_{i=1}^{n} W_i \quad (1)$$

Where W_i denotes the unit weight of the i^{th} parameter, Qi denotes the water quality rating of the i^{th} parameter, and (n) denotes the number of the involved parameters in the calculation.

The water quality rating (Q_i) was calculated according to equation (2):

$$Q_i = 100\,[(V_i - V_{id})/(S_i - V_{id})] \quad (2)$$

V_i is the experimental or analyzed value of the i^{th} parameter at a certain sample location; V_{id} refers to the typical value of the i^{th} parameter in pure water; the typical value for all parameters is zero (0), except for pH, which is 7. S_i denotes the standard allowable value for the i^{th} parameter.

The Wi is conversely proportional to the standard value (Si) for each parameter, as shown in the following formula:

$$W_i = K/S_i \quad (3)$$

Where K is the constant of proportionality and is computed following the below equation:

$$K = 1/\sum\left(\frac{1}{Si}\right) \quad (4)$$

Water quality is classified into five categories based on WQI values as presented in Table 2, where the lower the WQI value, the better the water quality, and the higher the WQI value, the poorer the water quality (Brown et al., 1972; Chaterjee and Raziuddin, 2002; Tyagi et al., 2013).

2.4 Calculation of the Water Pollution Index (WPI)

The WPI was calculated based on an integrated model that was developed by (Hossain and Patra, 2020). WPI is an integrated approach since it transforms all parameters into a single, comprehensible, usable value for categorizing water quality. The WPI model does not use (weights/assigned) parameter values like other models, but it can handle a wide range of variables because it is flexible for (n) parameters (Hossain and Patra, 2020). The WPI model was used in this study to evaluate the pollution load of the wastewater effluent from the Kufranja WWTP and the suitability of the effluent for irrigation uses and for the discharge to streams, wadis, or bodies of water. WPI was calculated based on Jordanian standards for reclaimed domestic wastewater (JSMO, 2021). Similar to the WQI model, all the analyzed physicochemical and biological parameters in this study were involved in the computation of WPI.

The WPI was calculated using the following equation (Hossain and Patra, 2020):

$$WPI = \frac{1}{n}\sum_{i=1}^{n} PLi \quad (5)$$

Where Pli is the pollution load of the i^{th} parameter; (n) represents the number of all parameters.

The calculation of the pollution load (PLi) was performed using equation (6):

$$PLi = 1 + \left(\frac{Ci - Si}{Si}\right) \quad (6)$$

Where Ci is the laboratory-analyzed concentration of the i^{th} parameter, Si denotes each parameter's standard or maximum acceptable limit.

The calculation of PLi for the pH parameter is based on the pH value and the following equations (Hossain and Patra, 2020):

$$PLi = \frac{Ci - 7}{Si_a - 7}, \text{ If the pH} < 7. \quad (7)$$

$$PLi = \frac{Ci - 7}{Si_b - 7}, \text{ If the pH} > 7. \quad (8)$$

Where Si_a denotes the lowest permissible pH value for the intended use, Si_b denotes the highest allowable pH value for the intended use. The classifications of water quality based on WPI results are divided into four categories, as shown in Table 2 (Hossain and Patra, 2020).

Table 2: Classification of water quality based on the WQI and WPI values (Brown et al., 1972; Hossain and Patra, 2020).

WQI value	Category	WPI value	Category
< 25	Excellent water quality	< 0.5	Excellent water quality
26 - 50	Good water quality	0.5 - 0.75	Good water quality
61 - 75	Poor water quality	0.75 - 1	Moderately polluted water
76 - 100	Very Poor water quality	> 1	Highly polluted water
> 100	Unsuitable for the intended use		

2.5 Standards for Wastewater Use in Jordan

In the present study, the latest edition of the Jordanian standards for reclaimed wastewater (JS 893/2001) (JSMO, 2021) has been used, which is the fourth edition after the earlier three editions in 1995 (JS 893/1995), 2002 (JS 893/2002), and 2006 (JS 893/2006). The Jordanian standards for reclaimed wastewater depend mainly on many relevant international guidelines, such as those of the World Health Organization (WHO) and the Food and Agriculture Organization (FAO) (Ulimat, 2012). The latest version of the Jordanian standards for reclaimed wastewater (JS 893/2021) is divided into three main sections: (1) standards governing the discharge of reclaimed wastewater into streams, wadis, or water bodies; (2) standards governing the use of reclaimed wastewater for artificial recharge of groundwater aquifers; and (3) standards regarding the use of reclaimed wastewater for irrigation purposes.

Regarding the section on the reusing of reclaimed domestic wastewater for irrigation, the Jordanian standards (JS 893/2021) classified this section into four classes, namely: class A, class B, class C, and class D. Class A includes the allowable limits for the irrigation of parks, playgrounds, and the sides of roads inside the cities. Class B includes the permissible limits for the irrigation of fruit trees, the sides of roads outside the cities, and green areas. Class C includes the acceptable limits for irrigating industrial crops, field crops, and forest trees. Finally, Class D contains the acceptable limits for the irrigation of cut flowers (JSMO, 2021).

3. Results and Discussions

3.1 Effluent Quality Parameters of the Kufranja WWTP

All the results of the physicochemical and biological analyses of the wastewater effluent from the Kufranja WWTP are presented in Table 3. The mean pH value was 7.98 (SU), indicating that the effluent of the Kufranja WWTP is alkaline. The mean pH value was within Jordanian standards for reclaimed wastewater for irrigation in all classes A, B, C, and D (Table 3) (JSMO, 2021). The mean effluent BOD_5 and COD values were 32.0 mg/l and 59.5 mg/l, respectively. The mean BOD_5 value is within Jordan's allowable limits for reusing reclaimed wastewater for irrigation of class B and class C crops but failed to meet the limits of the permissible standards for irrigating class A and class D crops. The mean COD value was within the allowable limits of classes A, B, and C for irrigation and did not meet the class D standards. The average TDS value for the Kufranja WWTP effluent was 810 mg/l, meeting the permitted irrigation standards for all classes A, B, C, and D. While the TSS value was 21.7 mg/l, it met the irrigation standards for classes A, B, and C and exceeded the standards for class D.

Table 3: The mean values of physicochemical and biological parameters and the Jordanian standards for reclaimed domestic wastewater (JSMO, 2021).

Parameter	Unit	The results of this study (Mean value)	Jordanian permissible limits for the reuse of reclaimed wastewater for irrigation according to the uses				Jordanian permissible limits specified for the discharge of reclaimed wastewater into streams, wadis, or water bodies
			Class A (Parks, playgrounds, and sides of roads inside the cities)	Class B (Fruit trees, sides of roads outside the cities, and green areas)	Class C (Industrial crops, field crops, and forest trees)	Class D (Cut flowers)	
pH	SU	7.98	6-9	6-9	6-9	6-9	6-9
BOD_5	mg/l	32.0	30	100	200	15	60
COD	mg/l	59.5	100	200	300	50	150
TDS	mg/l	810	1500	1500	1500	1500	1500
TSS	mg/l	21.7	50	100	100	15	60
NO_3^-	mg/l	2.33	16	16	16	16	20
TN	mg/l	36.7	70	70	70	70	70
PO_4^-	mg/l	8.00	10	10	10	10	5
Cl^-	mg/l	215	500	500	500	500	500
HCO_3^-	mg/l	191	400	400	400	400	400
Na^+	mg/l	138	230	230	230	230	200
Mg^{2+}	mg/l	19.3	100	100	100	100	60
Ca^{2+}	mg/l	93.9	230	230	230	230	200
SAR	Unitless	3.39	9	9	9	9	6
E. coli	MPN/100ml	2.50E+05	100	1000	---	1.1	1000

The anion and cation average concentrations in the wastewater effluent from the Kufranja WWTP were 2.33 mg/l for NO_3^-, 8.0 mg/l for PO_4^-, 215 mg/l for Cl^-, 191 mg/l for HCO_3^-, 138 mg/l for Na^+, 19.3 mg/l for Mg^{2+} and 93.9 mg/l for Ca^{2+}, respectively. All concentrations of anions and cations in this study are within the Jordanian allowable limits for the reuse of reclaimed wastewater for irrigating crops in all classes A, B, C, and D (Table 3). The total nitrogen (TN) average concentration was 36.7 mg/l and met the standards for all classes A, B, C, and D. The average value of the sodium absorption ratio (SAR) was 3.39, which conforms to the allowable standards for all classes A, B, C, and D. The mean count of *E. coli* was 2.50 E+05 MPN/100 ml, which is higher than Jordan's standards for reusing reclaimed wastewater for irrigation of classes A, B, and D crops. The Jordan permissible limit of *E. coli* for class C was not specified.

3.2 Evaluation of the Kufranja WWTP Effluent and Its Suitability for Irrigation Purposes

The results of the WQI calculation using the Jordanian standards for the reuse of reclaimed wastewater for irrigation (classes A, B, C, and D) (JSMO, 2021) showed that the WQI values were 5,087 for class A, 102 for class B, 45.5 for class C, and 13,904,055 for class D (Table 4). Based on water quality classifications according to the WQI values (Table 2), the WQI values for classes A, B, and D fall into the category of "unsuitable water quality for irrigation use." In contrast, the WQI value for class C belongs to the category of "good water quality for irrigation." This means that wastewater effluent from the Kufranja WWTP is suitable for irrigating industrial crops, field crops, and forest trees but cannot be used to irrigate playgrounds, parks, roadsides inside and outside of cities, green areas, fruit trees, or cut flowers (Table 4). The results of the WQI for the wastewater effluent from the Kufranja WWTP in this study are in line with those published (Ibrahim, 2019).

The computed values of WPI based on Jordan's standards for reclaimed wastewater for irrigation (classes A, B, C, and D) (JSMO, 2021), were 167 for class A, 17 for class B, 0.54 for class C, and 15,145 for class D (Table 4). According to the classification of water quality for irrigation uses shown in Table 2, the WPI values of classes A, B, and D fall within the "highly polluted water" category. In comparison, the calculated WPI value of class C was within the category of "good water quality" for irrigation, indicating that the effluent from Kufranja WWTP can be used only to irrigate crops in class C. The wastewater effluent quality classifications for the Kufranja WWTP using the WQI model are similar to those based on the WPI model. Hence, the WQI model results are consistent with the WPI model results.

Most of the treated wastewater effluents from the WWTPs in Jordan are used in restricted agriculture due to their exceeding the Jordanians' allowable standards for unrestricted agriculture (MoE, 2020). Consequently, the quality of the effluents from Jordan's WWTPs (including the Kufranja WWTP effluent quality) must be improved and treated adequately to expand their uses in restricted and unrestricted agriculture and other uses (e.g., industrial uses), thereby reducing the enormous pressure and overexploitation of freshwater resources and contributing to alleviating the problem of water scarcity in the country as well as protecting the public health, water environment, and ecosystem.

3.3 Suitability of the Kufranja WWTP Effluent for Discharge into Streams, Wadis, or Water Bodies

Table 4: Values of WQI and WPI of the wastewater effluent from Kufranja WWTP based on the Jordanian standards of reclaimed wastewater for irrigation uses and discharging into streams, wadis, or water bodies (JSMO, 2021).

Jordanian standards that used for the calculation of WQI and WPI.		WQI value (This study)	Category of the water quality based on WQI values	WPI value (This study)	Category of the water quality based on WPI values
The Jordanian standards for the reuse of reclaimed wastewater for irrigation (Class A, B, C, and D)	Class A (Parks, playgrounds, and sides of roads inside the cities)	5087	Unsuitable for the irrigation use	167	Highly polluted water
	Class B (Fruit trees, sides of roads outside the cities, and green areas)	102	Unsuitable for the irrigation use	17	Highly polluted water
	Class C (Industrial crops, field crops, and forest trees)	45.5	Good water quality for irrigation	0.54	Good water quality
	Class D (Cut flowers)	13904055	Unsuitable for the irrigation use	15145	Highly polluted water
Jordanian standards for the discharge of reclaimed wastewater into streams, wadis, or water bodies		124	Unsuitable for the discharge into streams, wadis, or water bodies	17.2	Highly polluted water

Quality and pollution indices (WQI and WPI) were applied and calculated based on the Jordanian standards specified for the discharge of reclaimed wastewater to streams, wadis, or waterbodies (Table 3) in order to determine the appropriateness of the quality and pollution load of wastewater effluent from the Kufranja WWTP for discharge into streams, wadis, or waterbodies (JSMO, 2021). Is the Kufranja WWTP's effluent a potential source of pollution if it is discharged into the Wadi Kufranja and Kufranja Dam?

The results in Table 4 showed that the calculated WQI value based on the allowable limits for discharge purposes was 124, while the WPI value was 17.2. Classifications of water quality based on WQI and WPI values have shown that the WQI value falls within the category of "unsuitable water quality." In contrast, the WPI value belongs to the category of "highly polluted water" (Table 4). Therefore, the wastewater effluent from the Kufranja WWTP cannot be discharged into streams, wadis, or other water bodies due to its high pollution load and inappropriate quality.

The calculations of the WQI in the present study revealed that the most significant actual contribution to the WQI value calculated for most irrigation classes (A, B, and D) and calculated for discharging purposes into streams, wadis, or water bodies comes from *E. coli*, followed by PO_4^{3-}, pH, and SAR, indicating that the parameters mentioned above degraded the effluent quality of the Kufranja WWTP. As a result, the users of this water must take the necessary and appropriate precautions to protect their health and environment. Accordingly, additional treatment should be implemented at the Kufranja WWTP to reduce loads for these parameters.

3.4 Performance of the Kufranja WWTP

Kufranja WWTP was expanded and optimized in 2016. Its design capacity was raised to 9000 m³/day, with an actual influent of 3562 m³/day in 2019 (MoE, 2019). This means that in this study (2019) the Kufranja WWTP was not hydraulically overloaded. The designed biochemical organic load (BOD_5) of the Kufranja WWTP after its expansion and optimization is about 2500 mg/l/day. In contrast, the actual load in the year of study was about 765 mg/l/day (MoE, 2019), indicating that Kufranja WWTP was also not organically loaded.The results in Table 5 indicate that the mean removal efficiency (EFF %) of BOD_5, COD, and TSS at the Kufranja WWTP was 95.1%, 95.6%, and 96.0%, respectively, which are higher than those (92.5%, 87.3%, and 88.6%) documented for the same treatment plant in 2005 (Table 5) (Abdulla et al., 2016). Furthermore, the removal efficiency of BOD_5 was higher than that reported in 2012 (88%), which indicated that the Kufranja WWTP performed well during the study year (Ulimat, 2012).

Table 5: The removal efficiency (EFF%) of BOD_5, COD, and TSS at the Kufranja WWTP and the results of previous related studies.

Study	BOD_5 (mean value)			COD (mean value)			TSS (mean value)		
	In mg/l	Out mg/l	EFF %	In mg/l	Out mg/l	EFF %	In mg/l	Out mg/l	EFF %
This study	650.5*	32.0	95.1	1349.7*	59.5	95.6	540*	21.7	96.0
2005 (Abdulla et al., 2016)	1195	90.0	92.5	2051	260	87.3	804	92.0	88.6
2011 (Ulimat, 2012)	--	--	88	--	--	--	--	--	--

* (MWI, 2019)

The elevated removal efficiency of BOD_5, COD, and TSS for the Kufranja WWTP during this study compared to the previous studies can be attributed to the expansion and optimization of the Kafranja WWTP in 2016, and the operation of the new high-efficiency treatment system (activated sludge system) rather than the old one (trickling filter system).

4. Conclusions

Treated wastewater in Jordan has become an increasingly important source. It is reused for irrigation and other purposes according to its quality and compliance with the allowable standards for reclaimed wastewater. Therefore, this study presents the WQI and WPI approaches in evaluating the effluent quality of the Kufranja WWTP in Jordan and its suitability for irrigation and discharge into streams, wadis, and water bodies. The results of WQI and WPI in this study based on the Jordanian standards for the reuse of reclaimed wastewater (JS 893/2001) showed that the wastewater effluent of Kufranja WWTP falls within the category of "good quality" to irrigate crops in class C, while it belongs to the category of "unsuitable quality or highly polluted water" for the irrigation of crops in other classes (classes A, B, and D), which indicates that the wastewater effluent of Kufranja WWTP can only be used to irrigate industrial crops, field crops, and forest trees.

Concerning the suitability of the wastewater effluent of Kufranja WWTP for discharge into streams, wadis, or water bodies, the calculations of the WQI and WPI revealed that the Kufranja WWTP effluent is categorized as "unsuitable quality or highly polluted water" for discharge purposes and cannot be discharged into streams, wadis, or water bodies. Therefore, there is an important and urgent need to improve and continuously monitor the quality of wastewater effluent in Jordan in order to: (1) conserve freshwater resources from any possible pollution resulting from the discharge of wastewater to these sources and thus protect the aquatic ecosystem and public health; (2) expand its uses in agriculture, groundwater recharge, and other uses, which reduces the enormous pressure on freshwater sources in the country; and (3) provide renewable and sustainable alternative water sources for irrigation and other uses, hence providing a window for water managers and decision-makers to manage and alleviate water shortage issues.

The results of this study revealed that the largest contribution to the calculated WQI values comes from *E. coli*, followed by PO_4^{3-}, pH, and SAR, which implies that the aforementioned parameters impacted and degraded the effluent quality of the Kufranja WWTP. Consequently, some additional treatment is required to reduce the load of these parameters. During the study period, Kufranja WWTP was not hydraulically or organically overloaded. The average removal efficiency (EF %) of BOD5, COD, and TSS was 95.1%, 95.6%, and 96.0%, respectively. This means that the Kufranja WWTP is performing satisfactorily. However, further treatment processes and special measures should be adopted to improve the Kufranja WWTP's effluent quality. The application of the water quality index (WQI) and the water pollution index (WPI) will always be useful in assessing the quality of wastewater effluent and its suitability for irrigation and other uses. The outcomes of this study could provide valuable and beneficial data for water managers, decision-makers, and related institutions to understand the current state of the treated wastewater quality for better use and sustainable management, especially during acute water scarcity in Jordan.

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Conflicts of Interest

The author declares no conflict of interest.

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