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Assessment of Urban Wastewater Reuse for Irrigation – Environmental Feasibility and Sustainable Development – A Case Study in El Jadida

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ABSTRACT

Morocco, like other arid and semi-arid countries, faces a growing water shortage, necessitating the exploration of alternative solutions. This study investigates the potential use of untreated urban wastewater for irrigation and environmental impact mitigation, focusing on El Jadida as a case study. Throughout the year 2023, from January to December, a comprehensive characterization of physico-chemical, heavy metal, and biological parameters of this unconventional water source was conducted to account for seasonal variations, particularly between rainy and sunny periods. Samples were collected at the inlet of the El Jadida wastewater pre-treatment plant (WWTP) to assess the city's net pollution levels. Results indicate high values for chemical oxygen demand (COD = 741 mg/L), biological oxygen demand (BOD_5 = 344 mg/L), organic load (BOD_5/COD ratio = 2.2), and biodegradability, suggesting a strong need for biological treatment. Despite compliance with discharge standards, concentrations of heavy metals such as mercury (Hg), cadmium (Cd), aluminum (Al), manganese (Mn), and fluoride ions (F^-) exceed Moroccan irrigation water quality thresholds by 90%, 66.7%, 21.8%, 33.3%, and 86.1%, respectively. Therefore, advanced chemical treatment is highly recommended to mitigate environmental impact and ensure safe reuse for irrigation. The novelty of this study lies in evaluating the suitability of El Jadida's wastewater for irrigation and environmental impact mitigation, underscoring the critical need for effective treatment solutions to enhance water sustainability in Morocco. Future research will focus on optimizing water treatment processes.

Keywords: urban wastewater reuse, irrigation, environmental feasibility, sustainable development, heavy metals, water sustainability.

INTRODUCTION

Water is undeniably one of the world's most essential resources, it is a crucial element for the social, economic, and environmental development of our planet. However, its current distribution remains unequal, creating numerous challenges for stockholders, users, and service providers (Pandeya et al., 2021). Access to sustainable, profitable, and equitable water services is becoming increasingly complex, requiring sophisticated resources. While global water crises are often linked to a shortage of this resource, in other regions, poor management leads to its scarcity (Zhang et al., 2021).

The water quality degradation in semi-arid and arid regions, particularly on rural land, poses major environmental problems. Morocco is considered as one of the country experienced water stress (Zouhri et al., 2024). This degradation is exacerbated by the overexploitation of aquifers, leading to high mineralization that alters freshwater ecosystems (Ez-zaouy et al., 2022). Several factors threaten and degrade water quality (Bahir and Ouhamdouch 2020), including population growth (Huang et al.), industrial pollution (Cheng and Xu, 2023; Ji and Ma, 2022; Faouzi et al., 2023), and climate change (Galliari et al., 2021), increasing the degree of salinity, particularly in coastal regions (Zamrsky et al., 2020). Besides, rapid industrialization, population growth, and anthropogenic activities in North Africa (Haouas et al., 2023) in Morocco, have led to increased water consumption and pollution, affecting the quality of tropical river ecosystems (Qalmoun et al., 2022; Bounoua et al., 2020). Climate change is exacerbating these problems by altering rainfall patterns and causing more extreme and unpredictable weather conditions, impacting on water availability and quality (Abdelmajid et al., 2021).

On the other hand, characterizing the composition of wastewater, including industrial, domestic, and clinical sources, at the inlet of wastewater treatment plants (WWTPs) is crucial to ensure their safety and proper operation through informed decision-making and precautionary measure. Essential parameters such as temperature (T), pH, electrical conductivity (EC), dissolved oxygen (DO), total suspended solids (TSS), chemical oxygen demand (COD), biochemical oxygen demand (BOD_5), heavy metals and bacteriological content play a vital role in understanding the nature of wastewater and selecting appropriate treatment methods (Assal et al., 2024; El Fadili et al., 2022d; Ben Ali et al., 2023). This enables the selection of suitable treatment processes in WWTPs, guaranteeing effective treatment and minimizing environmental impact. This approach facilitates the recovery and reuse of water for a variety of purposes, including irrigation and industrial processes, thereby reducing the demand for freshwater resources. WWTPs not only mitigate pollution by removing contaminants, but they also recover valuable resources such as biogas for energy production and nutrients for fertilizers. By ensuring that only safe water is discharged into natural water bodies, WWTPs help preserve biodiversity and prevent the proliferation of harmful algae. Consequently, they play a key role in mitigating climate change through energy-efficient processes and by being designed to withstand extreme weather events, thus ensuring a sustainable and safe water supply for future generations (Nguyen et al., 2022).

The present study contributes to the field by conducting a comprehensive year-long assessment of El Jadida's wastewater quality, emphasizing its suitability for various applications, notably irrigation and environmental impact mitigation. By meticulously analyzing physicochemical, heavy metal, and biological parameters, including seasonal variations, this research aims to inform robust decision-making processes and precautionary measures. The findings not only underscore the need for effective wastewater treatment strategies but also advocate for water conservation efforts essential for sustainable development in Morocco.

Overall, this work highlights the novelty of an in-depth investigation of wastewater quality over one year, its implications for multiple applications and its contribution to decision making and environmental management.

MATERIALS AND METHODS

Description of the study area

Located on the Atlantic coast, El Jadida benefits from a temperate climate characterized by mild winters and hot summers, temperatures ranging from 17 °C to 30 °C, and humidity levels up to 90%. El Jadida is estimated to have 846.659 inhabitants in 2023, and covers an area of 3.357.85 km², resulting in a population density of 252 inhabitants/km². The current industrial zone, created in 1976, covers an area of 117 ha and includes 90 industrial units (Johari et al., 2022). Companies in the industrial zone cover a wide range of industrial and service-related activities (food processing, textiles and leather, para-chemistry, etc.). The city generates nearly 200000 m^3 of wastewater daily.

The sampling

The current study required the collection of well-distributed water quality data over time in order to characterize and assess the possible environmental impacts of El Jadida's wastewater. The raw wastewater samples selected for analysis were taken from the primary sewer upstream of the El Jadida wastewater treatment plant, as shown in Figure 1. All samples were collected from the primary sewer over one year considering monthly sampling frequency (January to December 2023). A monthly sampling frequency was observed at the designated sampling point. Samples were collected and stored at 4 °C in

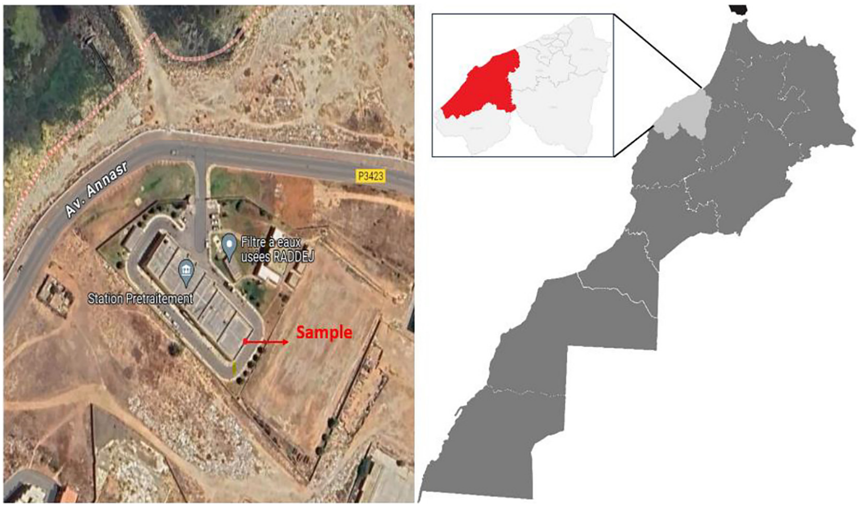

Figure 1. Location map of sampling sites in the primary sewer upstream of the El Jadida wastewater treatment plant

aseptic containers compliant with NF EN 25667-1 and ISO 5667 standards, protected from light to prevent any physicochemical contamination (Tenodi et al., 2020, El Fadili et al., 2022a). Samples for heavy metals were collected separately and some drops of nitric acid were added to prevent the precipitations.

Physical and chemicals wastewater analysis

The samples were collected every hour for 24 h on the scheduled sampling date, using analysis parameters compliant with the methods prescribed by the NF EN ISO 5667-1 standard. They were collected in sterile containers, and all measuring equipment used was pre-calibrated according to the manufacturer's instructions. Temperature, pH, electrical conductivity, and dissolved oxygen were measured using a portable multi-parameter instrument (a Multi 3630 manufactured by WTW (Germany)). Samples were then stored at 4 °C in the dark during transport to the laboratory, where they were analyzed to the same standard as mentioned above. Analyses of TSS, BOD_5, COD, nitrogen and phosphorus compounds, and the other remaining parameters were carried out using the methods recommended by AFNOR standards as presented in Table 1.

Table 1. The parameters and analytical methods

Parameters	Method used	Method of reference
Sampling liquid discharges	Automatic sampler	NM ISO 5667
Temperature	Probe thermometer	NM 03.7.008
pH at 25 °C	Electrometric measurement	NM ISO 10523
Electrical conductivity at 25 °C	Electrical conductivity	NM ISO 7888
TSS	Membrane filtration	NM EN 872
COD	Méthode spectrométrique	NF T 90-101
BOD_5	OXITOP DBO_5 HACH	Respirometry
Total Kjeldahl nitrogen	Digestion and distillation method	NM ISO 5663
Total phosphorus (P)	Spectrometric method	NM ISO 6878
Sulfates SO_4	Nephelometric method	NF-T 90-040
Free sulfide (S^{2-})	Spectrometric method	DIN 38405
Oils and grease Heavy metals	Rodier method Atomic absorption spectrometry (AAS)	Rodier method NF EN ISO 12020
Coliforms	Membrane filtration	NM ISO 9308-2
faecal streptococci	Membrane filtration	NM ISO 7899-1
Salmonella spp/5000ml	Membrane filtration	NM ISO 19250
Cholera vibrios spp/5000ml	Membrane filtration	NM 03.7.051

To determine the concentrations of heavy metals, atomic absorption spectroscopy (AAS)-Agilent AA Duo spectrometer was employed. This analytical technique is highly sensitive and accurate for quantifying heavy metals in various matrices of wastewater.

Irrigation quality indices

The water used for irrigation could significantly influence soil conditions and crop yields (El Fadili et al., 2022a). The feasibility of using the generated wastewater for agricultural purposes was evaluated based on irrigation quality indices, various indices were computed to assess the suitability of wastewater for irrigation.

- Sodium adsorption ratio (SAR)

$$SAR = \frac{\mathrm{Na^+}}{\sqrt{(\mathrm{Ca^{2+}}+\mathrm{Mg^{2+}})/2}} \quad (1)$$

- Magnesium hazard ratio (MHR)

$$HR = \frac{\mathrm{Mg^{2+}}}{(\mathrm{Ca^{2+}}+\mathrm{Mg^{2+}})} \times 100 \quad (2)$$

- Permeability index (PI) – the soil permeability hazard is assessed based on the below Equation (Doneen, 1962)

$$PI = \frac{(\mathrm{Na^+}+\sqrt{\mathrm{HCO_3^-}})}{(\mathrm{Ca^{2+}}+\mathrm{Mg^{2+}}+\mathrm{Na^+})} \times 100 \quad (3)$$

- Kelly's ratio (KR) – is computed based on the following Equation:

$$KR = \frac{\mathrm{Na^+}}{\mathrm{Ca^{2+}}+\mathrm{Mg^{2+}}} \quad (4)$$

A harmful influence on soils appears when KR of water used for irrigation is more than 1 (Szabolcs and Darab, 1964). All ionic concentrations are expressed in meq·L^{-1}.

RESULTS AND DISCUSSION

Physical parameters: temperature, pH, electrical conductivity, and TSS

Domestic and industrial wastewater from the city of El Jadida were collected by a network of sewers before being conveyed to the treatment plant. This untreated water has variable physicochemical characteristics, influenced by various factors such as the composition of the effluent, the intrinsic composition of water, and the absence of specific pre-treatment for industrial effluent (Table 2).

Wastewater temperature ranges from 17.8 to 26.5 °C, with an average of 22.2 °C as shown in Figure 2a. These values are within the admissible limits defined by Moroccan pollution standards for discharging of effluent, thus favoring the bacterial growth necessary for the biological degradation of organic pollutants during subsequent treatment. pH values range from 6.8 to 7.7, with an average of 7.2, as illustrated in Figure 2b. This range of values is in line with general discharge limits (Faouzi et al., 2023). A neutral pH is optimal for bacterial growth, a key element in the biological degradation of organic pollutants that will take place during the subsequent treatment of this water.

The electrical conductivity of collected wastewater samples shows great variability, ranging from 2410 to 7460 µS·cm^{-1}, with an annual average of 5079 µS·cm^{-1}, as illustrated in Figure 2c. This range can be explained by the high salinity of drinking water and the absence of mixing between domestic and industrial

Table 2. Summarizes the detailed findings related to the physicochemical analyses conducted on raw wastewater samples collected at the inlet of the El Jadida WWTP during the study period

Month	T (°C)	pH	Conductivity (µS·cm^{-1})	Dissolved oxygen	COD (mg·L^{-1})	BOD_5 (mg·L^{-1})	TSS (mg·L^{-1})
January-23	18.8	7	7460	0.01	917	401	188
February-23	18.8	7.7	7230	0	722	304	122
March-23	20.4	7.6	6600	0.1	847	363	245
April-23	22.3	7.2	6660	0	709	310	192
May-23	21.8	7.4	4330	0.01	110	363	21
June-23	26.5	7.4	4520	0.1	934	412	304
July-23	25.5	7.2	4090	0	639	281	238
August-23	26	7.1	4260	0	660	235	250
September-23	25.2	7.1	4300	0	754	338	337
October-23	22.6	6.8	5080	0	709	301	232
November-23	20.7	7	4010	0	949	421	300
December-23	17.8	6.9	2410	0.01	950	407	213

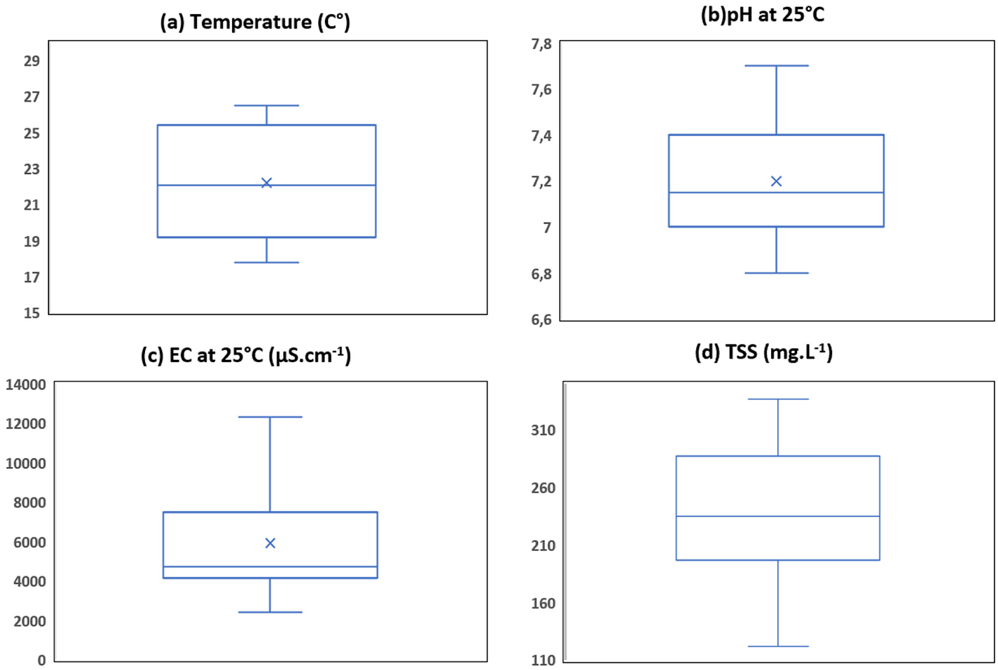

Figure 2. The boxplots for (a) temperature, (b) pH, (c) conductivity and (d) TSS

effluents, as shown by Chaimaa Merbouh and Hamza El Fadili in their study (Merbouh et al., 2022; El Fadili et al., 2022a). The study area is characterized by drinking water rich in mineral salts, which has a direct impact on the composition of domestic wastewater. Industrial discharges and the absence of specific pre-treatment in factories before discharging their effluents into the urban sewer network also contribute to the increase in raw wastewater conductivity. It is important to note that the average conductivity observed exceeds the direct discharge limits defined by Moroccan regulations. The suspended solids shown in Table 1 content of wastewater collected prior to the treatment plant shows notable variability, oscillating between 122 and 337 mg·L^{-1}, with an average of 236 mg·L^{-1} represented in Figure 2d. This average value exceeds the 100 mg·L^{-1} set as the limit value under order no. 3286.17 of September.

In comparison with other studies, the TSS concentrations observed in El Jadida remain lower than those of Efui Holaly Gbekley's study, which was measured on the Adétikopé effluents in Togo in 2023, ranging from 408 to 2080 mg·L^{-1} (Gbekley et al., 2023). Similarly, the TSS values measured in the study by Chaoui A. on the Zaio wastewater treatment plant in Morocco, sampled in 2023, revealed an average concentration of 389 mg·L^{-1} (Chaoui et al., 2023), higher than that measured in this study.

Dissolved oxygen, biochemical oxygen demand, and dissolved oxygen demand

Nevertheless, it is crucial to point out that the TSS concentrations observed at El Jadida surpass those reported in Chaimaa Merbouh's (2023) study of discharges into the Nfifikh River in Morocco. This study shows an average TSS concentration ranging from 206.58 to 121.58 mg·L^{-1} (Merbouh et al., 2022). Despite this, our results remain superior to those of Merbouh for several major reasons. Firstly, the effluents analyzed in our study come from the collection of domestic and industrial wastewater, which explains the high TSS content. Secondly, the water taken by Merbouh from the Nfifikh River undergoes dilution by the river water itself, which leads to a reduction in TSS concentrations. Dissolved oxygen, biochemical oxygen demand (BOD_5) and dissolved oxygen demand (DOC):

Raw wastewater from domestic and industrial activities is characterized by a particularly low dissolved oxygen (DO) content, generally fluctuating between 0.01 and 0.1 mg·L^{-1} (O_2). On average, this concentration barely exceeds 0.05 mg·L^{-1}, as shown by data from El Jadida (Kouali et al., 2022). This lack of oxygen can be explained by two major phenomena: on the one hand, oxygen deficiency favors the development of anaerobic fermentation, a biological process that degrades organic matter in the absence of oxygen. This phenomenon, which generates unpleasant odors, is illustrated in Table 1, which shows the monthly variation in DO in the city's wastewater. Oxygen depletion in raw wastewater is also due to the cellular respiration of microorganisms present in the effluent. These microorganisms, proliferating thanks to abundant organic matter, consume the oxygen available for their growth and metabolism. The greater the quantity of organic matter, the higher the oxygen demand, inevitably leading to a drop in DO concentration.

Wastewater analysis reveals high concentrations of organic matter, as evidenced by the 5-day COD and BOD_5 values presented in Figure 3. COD values ranged from 610 to 949 mg·L^{-1} (O_2), with an average of 741 mg·L^{-1} (O_2, well above the authorized limits for direct wastewater discharge as defined by Moroccan regulations (Faouzi et al., 2023). Similarly, BOD_5 values range from 235 to 421 mg·L^{-1}, with an average of 344 mg·L^{-1}, indicating a particularly high biodegradable organic matter content.

These high COD and BOD_5 concentrations are due to significant domestic and industrial inputs. Discharges of foodstuffs, household products, and pharmaceuticals from domestic sources, as well as wastewater from agri-food, chemical, and textile activities, contribute significantly to the organic matter load of wastewater. Sewage system management problems, such as leaks, overflows, and inadequate treatment, can also aggravate the situation. COD and BOD_5 values do not comply with Moroccan discharge standards. The biodegradability ratio R = DBO_5/DCO varies from 1.7 to 2.8 as shown in Table 3, with an average of 2.2. The wastewater evaluated in this study can be considered of domestic origin and biodegradable, which may require biological treatment before discharge into the receiving environment to avoid an accumulation of the organic load in a confined space.

Table 3. COD/BOD_5 monthly wastewater ratio for the city of El Jadida

Date	COD/BOD_5 ration	Biodegradability index
January-23	2.3	Highly biodegradable
February-23	2.4	Highly biodegradable
March-23	2.3	Highly biodegradable
April-23	2.3	Highly biodegradable
May-23	1.7	Highly biodegradable
June-23	1.8	Highly biodegradable
July-23	2.3	Highly biodegradable
August-23	2.8	Highly biodegradable
September-23	2.2	Highly biodegradable
October-23	2.4	Highly biodegradable
November-23	2.2	Highly biodegradable
December-23	2.3	Highly biodegradable

Nutrients

Abundant and irregular wastewater discharges can lead to the proliferation of photosynthetic algae in the aquatic environment. This phenomenon is mainly due to excessive inputs of nutrients, particularly nitrogen and phosphorus, which can lead to eutrophication.

Analysis of the physicochemical parameters of wastewater discharges revealed high concentrations of Kjeldah nitrogen, as shown in Figure 4,

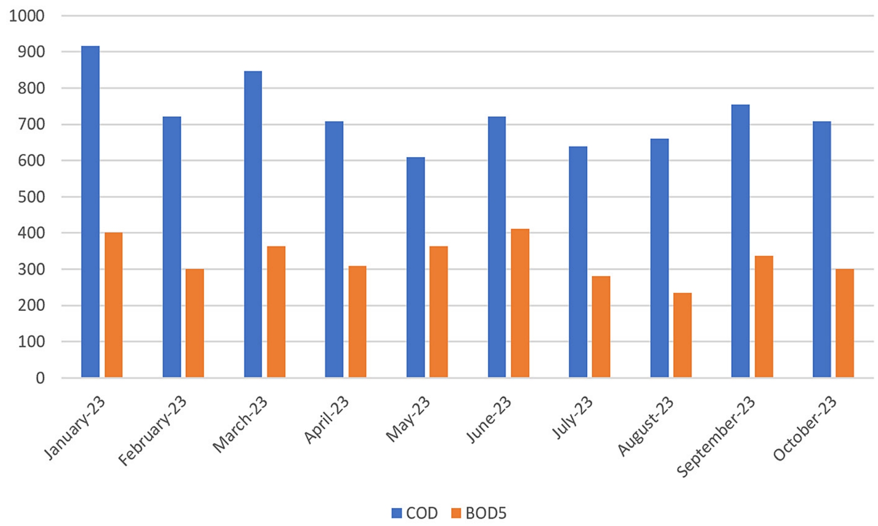

Figure 3. Monthly variations in COD and BOD_5

ranging from 41 to 115 mg·L^{-1} with an average of 78 mg·L^{-1}, and, ranging from 15 to 24 mg·L^{-1} with an average of 20 mg·L^{-1}. These values far exceed the regulatory limits set by the Moroccan standard (Zhou et al., 2022).

Sulfate SO_4 and Free sulfide S^{2-}

Sulfate is an essential nutrient for the growth of plant and animal tissues. Its ability to be reduced and oxidized by chemical and microbiological pathways makes it an important link in the global sulfur cycle. In this study, as the graph shows in Figure 5b, sulfate levels remained within the range specified by the Moroccan discharge standard, from 66 to 485 mg·L^{-1}, with an average of 183 mg·L^{-1}. However, as shown in Figure 5a, free sulfide ranges from 0.4 to 2.3 mg·L^{-1}, with an average of 1 mg·L^{-1}, exceeding the discharge limits set by the Moroccan standard (Oliveira et al., 2020).

This non-compliance is limited mainly between April and June, possibly due to discharges from certain industries such as paper mills, tanneries, or chemicals such as detergents, bleaching agents, and preservatives. All these factors may explain the increase in sulfide levels, which must be treated to preserve aquatic life after discharge into the sea and protect infrastructure against corrosion.

Heavy metals

The heavy metals content in treated wastewater was examined in this paper and compared with the permissible limits of reject set by the decree n° 2-04-553. As observed in Table 4, the measured concentrations of all heavy metals complied with the Moroccan discharge standards.

To ensure precise quantification of heavy metal concentrations, we employed atomic absorption spectroscopy (AAS) using an advanced spectrometer (Anwar et al., 2024). This analytical

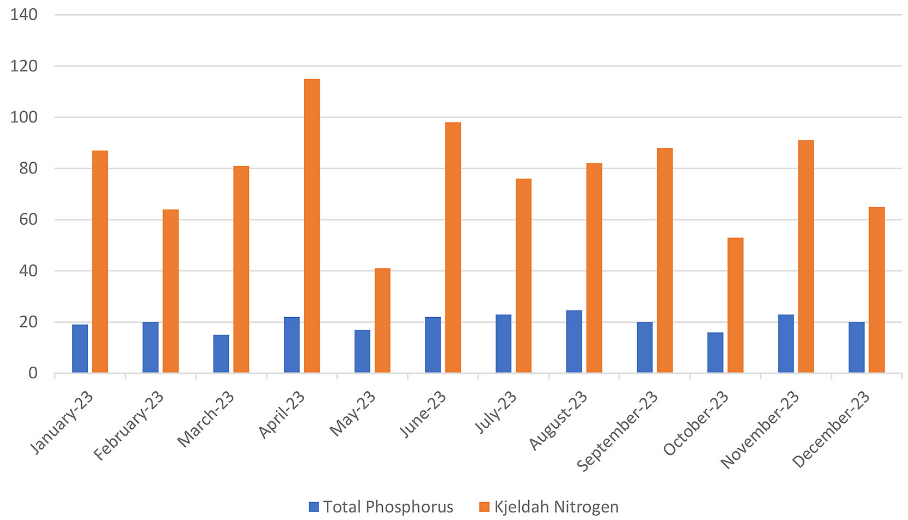

Figure 4. The monthly variation of total phosphorus and nitrogen

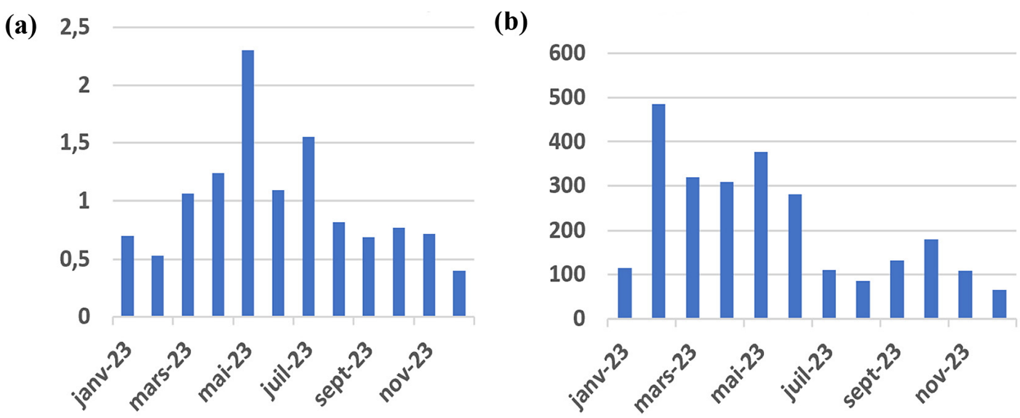

Figure 5. The monthly variation of (a) Free sulfide, and (b) sulfate.

Table 4. Heavy metal concentrations and discharge limit values according to Moroccan standards

Parameter	Reject value*	Limit value**
Mercury	< 0.01	0.01
Cadmium	0.03	0.25
Arsenic	0.05	0.1
Barium	< 0.01	1
Hexavalent chromium	< 0.01	0.2
Copper total	1	2
Zinc total	0.49	5
Selenium	< 0.01	0.1
Fluoride	7.2	20
Cyanides	0.06	0.5
Cobalt	< 0.01	0.5
Iron total	0.55	5
Manganese	0.3	2
Silver Ag	< 0.01	0.1
Total Tin	< 0.01	2.5

Note: *Heavy metal content in effluents from the city of El Jadida, **Discharge limit values in accordance with Moroccan standards for liquid

technique offers exceptional accuracy and sensitivity, enabling us to accurately determine even trace levels of heavy metals in wastewater (Iqbal et al., 2022). Other parameters, such as fluoride, and cyanides, have also been analyzed, as they may present risks to human health and the environment if thresholds are exceeded. Meeting discharge limits is crucial, and this analysis confirms all elements were within the acceptable range according to Moroccan liquid discharge standards (Achkir et al., 2023; Touzani et al., 2023).

Bacteriological parameters

In the course of this study, we observed that September had the highest biodegradability rate of the year 2023. As a result, it was selected for the biological and microbiological analyses.

These analyses revealed concentrations of total coliforms, fecal coliforms and fecal streptococci of 7.0×10^6/100 ml, 2.8×10^5/100 ml and 4.0×10^4/100 ml, respectively. These parameters serve as indicators to determine the origin of fecal contamination, which is established by calculating the quantitative ratio R = FC/FS. According to the criteria defined by Borrego and Romero (Borrego et al., 1983), contamination of animal origin is characterized by an R ratio of less than 0.7, while contamination of human origin has an R ratio of over 4. Mixed contamination of predominantly animal origin is characterized by an R-ratio of between 0.7 and 1. Uncertain origin corresponds to an R-ratio of between 1 and 2, while mixed contamination of predominantly human origin is characterized by an R-ratio of between 2 and 4. In the case of our effluent, the FC/FS ratio is 7 greater than 4, indicating human fecal pollution (Arab and Arab, 2017).

Our microbiological analysis revealed the absence of Salmonella and Vibrio cholerae, which is a favorable indicator of the quality of our discharges.

Evaluation of examined water suitability for irrigation

Several factors collectively influence the quality of irrigation water, encompassing parameters such as pH, temperature, alkalinity, and salinity (El Fadili et al., 2022b). In this context, Wilcox's diagram, along with multiple indices (SAR, MHR, %Na, KI, and PI), were simultaneously calculated to evaluate the suitability of the analyzed water for irrigation, considering both its anionic and cationic composition. The obtained results are depicted in Table 5. Firstly, the pH values fell within the recommended range for agricultural purposes, ranging from 6.5 to 8.5.

Sodium plays a vital role in irrigation water. Yet, if its levels exceed those of Ca^{2+} and Mg^{2+}, it can notably decrease soil permeability by saturating soil cation exchange complexes (Tran et al., 2021). In this context, several irrigation parameters were introduced. The results showed that generated wastewater is not suitable for irrigation. For example, SAR (12.7) was more than the permissible limit of 10, SAR, KR, and PI values exceeded the allowable values of 10, 1, and 60, respectively. In terms of metallic pollution, the most studied heavy metals in wastewater exhibited values higher than the limits set by the Moroccan and FAO (Soumbara and El Ghini, 2023)

Table 5. The calculated irrigation quality indices

Samplers	MHR	PI	%Na+	KR	SAR
Before treatment	46.7	68.5	69.9	2.2	12.7

Table 6. Heavy metal and ions concentrations and water quality standards for irrigation in Morocco

Parameter	Reject value*	Limit value**
Mercury	< 0.01	0.001
Cadmium	0.03	0.01
Arsenic	0.05	0.1
Aluminum	6.39	5
Copper total	1	2
Zinc total	0.49	2
Selenium	< 0.01	0.02
Fluoride	7.2	1
Cyanides	0.06	1
Cobalt	< 0.01	0.5
Iron total	0.55	5
Manganese	0.3	0.2

Note: *Heavy metal and ions content in effluents from the city of El Jadida. **Discharge limit values according to Moroccan irrigation water quality standards

(Canton, 2021), the Table 6 compares the heavy metal concentrations measured at the inlet to the wastewater pre-treatment plant (WWTP) with the permissible limits set by the Moroccan standard for irrigation water.

The analysis reveals that the heavy metals and ions concentrations of Hg, Cd, Al and Mn exceed the authorized thresholds. Even if the other heavy metals comply with the standard, the irrigation water as a whole remains non-compliant with Moroccan regulations (Sahraoui et al., 2024).

CONCLUSIONS

This work aims to assess the degree of pollution, characterize El Jadida's wastewater, and evaluate its suitability for discharge into the natural environment and for reuse in irrigation. the wastewater was evaluated exhaustively based on its physicochemical, heavy metal, and biological parameters.

As a results, the physicochemical parameters studied, including COD, BOD_5, suspended solids and electrical conductivity, indicate non-compliance by exceeding the thresholds set by Moroccan wastewater quality standards. The COD and BOD_5 values were three times higher than the prescribed limits, while suspended solids and conductivity were almost 1.5 times and twice higher, respectively. Additionally, Analysis reveals that the heavy metals concentration such as Hg, Cd, Al, and Mn, along with ion of Fluoride (F^-), exceed authorized thresholds. authorized by the Moroccan standard for irrigation water quality, while the other heavy metals (As, Cu, Zn, Se, Co, Fe, etc.) comply with the standard. Overall, the irrigation water does not comply with the Moroccan regulations. The bacteriological parameters show that although Salmonella and Vibrio cholerae are absent, which is a favorable indicator of water quality, the concentrations of total coliforms, fecal coliforms, and fecal streptococci exceed the threshold limits of the irrigation water quality standard and consequently these waters do not require bacteriological treatment.

Finally, effective regulation of physicochemical, biological, and heavy metal parameters requires a combination of biological and chemical treatment. Based on the results of our research into wastewater quality monitoring, its treatment is urgently required to mitigate adverse effects on human health and the environment, thereby promoting sustainable water management practices amidst climate change and water scarcity challenges in Morocco. This critical initiative lays the foundation for future studies focusing on reclaiming treated water for sustainable agricultural practices, thus advancing water sustainability efforts in the region.

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