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Impact of Domestic Wastewater on Physico-Chemical and Biological Parameters of Rice Canal Water in Sukkur and Larkana, Pakistan

Ambreen Aziz*, Maira Tunio, Noor-Us-Sehar, Altaf Hussain Lahori

Department of Environmental Sciences, Sindh Madressatul Islam University, Karachi, Pakistan

Corresponding author E-mail: aaziz@smiu.edu.pk; environmentalistambreen@gmail.com

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Abstract: The aim of present research work was to assess the physical parameters (temperature, turbidity, and color), chemical characteristics (pH, TDS, TSS, DO, COD, BOD, calcium and magnesium hardness, total hardness, iron, free and total chlorine, chloride, and alkalinity), and biological parameters (fecal coliform) from various sampling points along the Rice Canal in the Sukkur and Larkana, regions of Pakistan. The results showed pH values ranging between 6.5-8.5, DO 1.12-2.11 mg/L, BOD from 114-298 mg/L, and COD from 51 to115 mg/L. Calcium hardness ranged from 124-126 mg/L, magnesium hardness ranged between178-202 mg/L, and total hardness between 304-317 mg/L. Iron concentrations ranged from 0.01-0.06 mg/L, while free chlorine and total chlorine were 0 mg/L. Chloride ranged from 4-86 mg/L, alkalinity from 118-138 mg/L, and fecal coliform counts were 15 and 13 CFU, respectively. The resultant values were compared with Sindh Environmental Quality Standards (SEQs) and World Health Organization (WHO) guidelines for water quality, and it was observed that several parameters exceeded SEQs, and WHO limits, indicating potential risks to local biodiversity, groundwater quality and on public health in the region. The findings of the present study will not only help in reducing pollutants at source of wastewater discharge into rice canal water, but also support to achieve Sustainable Development Goals#6 Clean Water and Sanitation.

Keywords: Water quality parameters, pollution load, SEQs and WHO guidelines, rice canal, SDGs.

Introduction

Fresh water availability is a major global challenge, with approximately one-third of the world's drinking water sourced from rivers, dams, lakes, and canals (Shinde 2025; Sidibe et al., 2026). These water bodies also serve as common recipients of domestic and industrial wastewater, causing significant pollution load as water bodies are supposed to be the major and natural pollutants sink (Vörösmarty et al., 2010; Mumtaz et al., 2026). Population growth, rapid industrialization, commercialized agricultural and increased water consumption have intensified pressure on freshwater resources. It was estimated that by 2025, around 1.0-1.3 billion people would be living in water-stressed regions (Schlosser et al., 2014). In developing countries, the demand for freshwater is increasing day by day due to inadequate wastewater management (Mokaya et al., 2004; Mishra, 2023). Globally, mega-cities generate substantial volumes of wastewater, often ranging from 30-70 m^3 per person per year (Edokpayi et al., 2017). In the absence of effective treatment facilities, untreated effluents are discharged into surface waters, degrading water quality and posing risks to ecosystems and human health (Booth et al., 2004; Anas et al., 2026). Contaminated water is linked to various waterborne diseases, and its unsafe use undermines efforts to achieve Sustainable Development Goals (SDGs) related to clean water and sanitation (Talib et al., 2019; Izah & Ogwu, 2025).

Pakistan faces significant challenges in ensuring access to safe drinking water. Since independence, increasing population and urbanization have strained water resources, while industrial and agricultural effluents have further degraded water quality (Mangi et al., 2016; Qian et al., 2025). The country is now classified as water deficient, ranked third globally by International Monetary Fund (IMF) of water scarcity. The Indus Basin Irrigation System (IBIS), the world's largest single irrigation network, covers 17.2 Mha and relies on rivers including the Indus, Kabul, Jhelum, Ravi, Chenab, Beas and Sutlej (Khan et al., 2025). However, unregulated wastewater discharge and poor water management threaten, both surface and groundwater quality (Sohag & Syed 2014; Qureshi et al., 2015). Previous studies have highlighted health risks associated with consumption of contaminated water, including diarrhea, cholera, dysentery, and arsenic contamination in Larkana groundwater (Okonko et al., 2008; Jabeen et al., 2015; Mangi et al., 2016; Kori et al., 2018). In an earlier study, Akber et al. (2022) assessed the physicochemical and microbiological characteristics of water from Rawal Dam. Choudhary et al. (2026) revealed that recent advances in sewage treatment technologies and sustainable sludge management practices are effective in reducing the pollution load in irrigation water.

The current study focuses on the rice canal system along with Sukkur and Larkana, Sindh, Pakistan. Larkana, situated on the right bank of the Indus River, experiences hot summer and mild winter, with an average annual rainfall of over 240 mm, and a population of approximately 1.4 million, accounting for 28.7% of the province population. Both sides of canal are densely populated, generating domestic wastewater that is often discharged untreated into the canal. This has resulted in significant pollution load of surface and groundwater, threatening public health and agricultural sustainability. Despite the critical importance of water quality in the region, there is limited literature on the pollution load in rice canal water near Sukkur and Larkana. Current knowledge gaps include the impact of domestic wastewater effluents on the physicochemical and biological parameters of canal water. Addressing these gaps is critical for a comprehensive understanding of pollution dynamics, and ensuring safe irrigation practices. The present research aims to evaluate the physical parameters including (temperature, turbidity, and color), chemical characteristics (pH, TDS, TSS, DO, COD, BOD, calcium and magnesium hardness, total hardness, iron, free and total chlorine, chloride, and alkalinity), and the biological parameter (fecal coliforms) of water from both sides of the rice canal Sukkur and Larkana. The study seeks to assess the pollution loads from domestic wastewater and compare the results with SEQS and WHO guidelines, and to avoid unsustainable practices for safe irrigation system and public health practices in future.

Materials and Methods

Water Sample Collection

The canal water sample were collected and stored in a sterile sample bottle as per guidelines of American Society for Testing and Materials (ASTM) throughout the rice canal watershed. The sampling was conducted at Sukkur and Larkana from the upstream (starting point) and downstream (ending point) of the rice canal at the time of pre-monsoon season normally starting in April in Pakistan. A total of 30 samples were randomly collected to avoid any ambiguity. A random sampling method was applied to ensure that the collected samples represented the water quality of the canal without bias. These samples were taken at intervals of about 5-10 km along the canal. Water was collected at 20-30 cm below the surface at every sampling point to eliminate surface contaminants, and to get a homogeneous sample. In addition, the samples were taken 50-100 meters away from sewage outlets and industrial drains, which gave enough time to mix wastewater with canal water. This assisted in assessing the real level of pollutant spread in the canal system. The samples (1-2 liters) were gathered in clean and sterilized polyethylene bottles. The samples were stored and transported in iceboxes at about 4 ℃ to avoid any chemical or biological alterations before analysis. The collected water samples were analyzed in accordance with the National Environmental Quality Standards (NEQs) and Sindh Environmental Quality Standards (SEQs) using standard procedures for water and wastewater analysis. The sampling points and study area map is shown in Figure 1.

Water Sample Analysis

The sample area was lengthy enough and to ensure that pH, temperature, and specific conductivity stabilized, the samples were collected after sufficient flushing time. To investigate the incursion of pollutants into the rice canal water system or surface water, these samples were obtained from a substantial distance from the sewage and industrial drains, after the wastewater had mixed with unpolluted or less polluted surface water. The pH and temperature in water samples were measured by using a pH meter and thermometer. Turbidity was determined by using an electronic turbidity meter (Akber et al., 2022). Total alkalinity, total hardness, DO, BOD, and COD were measured by the titration method (Northcutt et al., 2004; Omer, 2019). To address biological pollutant load, particularly fecal coliforms, Nutrient Agar and selective media MacConkey were used. Initially, the microbial community was analyzed, followed by the use of mixed cultures to grow microorganisms. These were then inoculated onto selective media, namely MacConkey agar, as well as Nutrient agar to isolate different microorganisms present in the canal water samples (Atlas, 2010). The body of water was used for both drinking and farming (Huq et al., 2008), making it necessary to monitor the contaminant load, which was determined using NEQs, SEQS and WHO guidelines. Overall, investigated pollution profile of rice canal water sample is presented in Table 1.

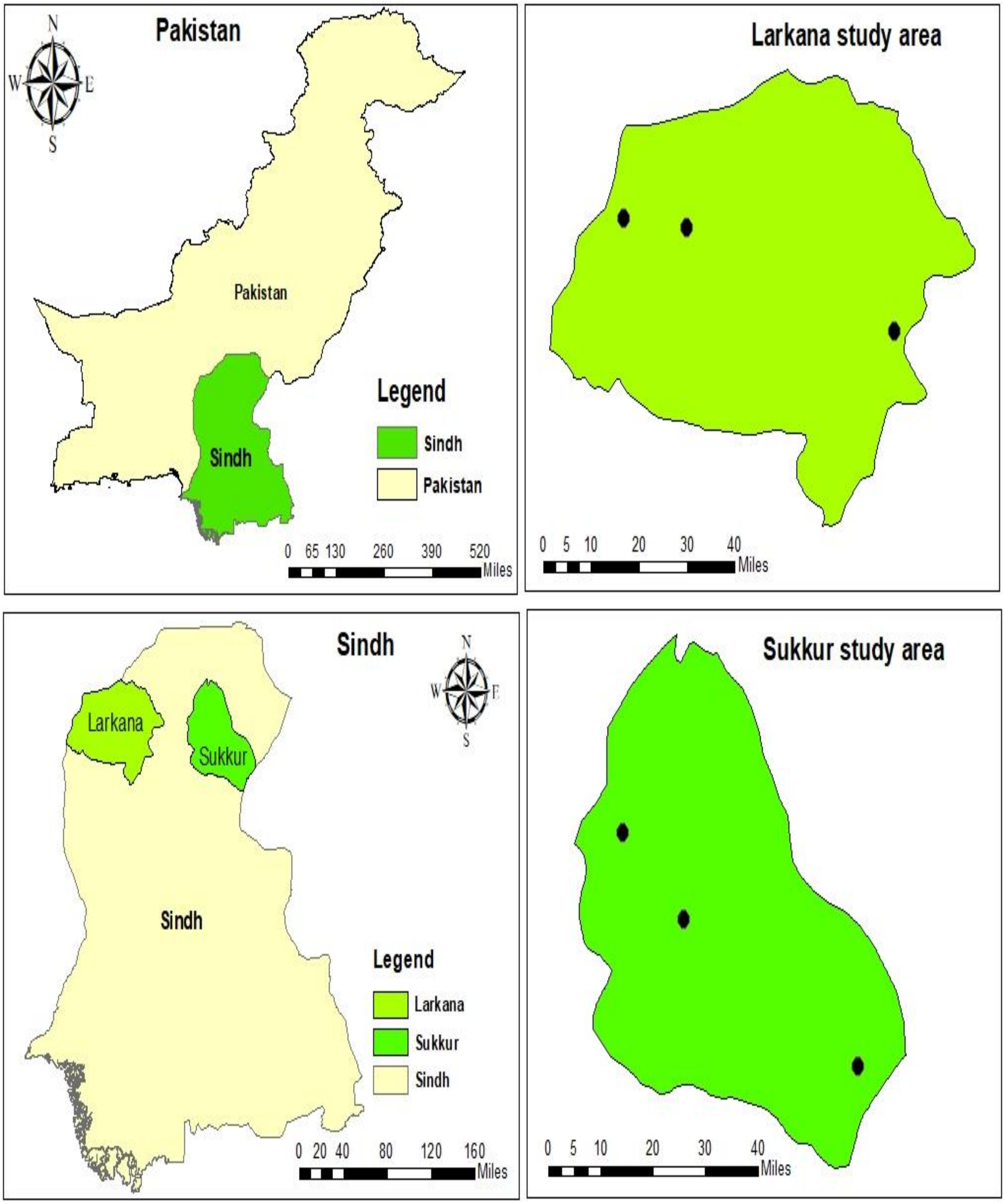

Fig. 1 Location map of the study area.

Table 1. Pollution profile of collected water samples with SEQs and WHO guidelines.

	Parameters	**Testing Unit**	**SEQs Standard**	**WHO Guidelines**
Physical Parameters	**Temperature**	˚C	-	-

	TURBIDITY	NTU	<5 NTU	<5 NTU
	Color	TCU	≤15 TCU	≤15 TCU
Chemical Parameters	**pH**	-	6.5-8.5	6.5-8.5
	TDS	mg/L	<1000	<1000
	TSS	mg/L	-	-
	DO	mg/L	-	-
	COD	mg/L	-	-
	BOD	mg/L	-	-
	Hardness in calcium	mg/L	-	-
	Hardness in magnesium	mg/L	-	-
	Total Hardness	mg/L	<500	-
	Iron	mg/L	-	-
	Free chlorine	mg/L	-	-
	Total chlorine	mg/L	-	-
	Chloride	mg/L	<250	250
	Alkalinity	mg/L	-	-
Biological Parameters	**Fecal Coliform**	CFU/100 mL	0 CFU/100 mL	0 CFU/100 mL

Statistical Analysis

The mean data of parameters was used in the present work by using Excel 2013. All the graphs were prepared by using OriginPro.16. Prism 5 software was used to make the scatter dot plot among physicochemical and biological parameters of rice canal Sukkur and Larkana.

Results and Discussion

Physical Parameters Profile

The maximum temperature of in the Sukkur samples was observed as 25.5˚C, while the lowest temperature in the Larkana samples was recorded 25.2 ˚C (Fig. 2). The lower turbidity was detected by 163 in Larkana irrigation water samples, whereas the maximum turbidity was noted as 210 NTU in Sukkur samples. Study revealed that water was more turbid at Sukkur sampling point, while Larkana had the low level of turbidity. SEQs allows <5 NTU in fresh waters, while obtained values are higher than permissible limit (Akber et al., 2022; Basurto-Cedeño et al., 2026). During the present study, recorded values of color ranged from 9.54-11.2 TCU. The maximum value was determined at rice canal Sukkur and the lowest value was noted at rice canal Larkana. Abbas et al. (2020) found that most of the physical and chemical properties of water were within the permissible limits as compared to Food and Agricultural Organization (FAO), United State Environmental Protection Agency (USEPA), and World Wide Fund for Nature (WWF) for agriculture water.

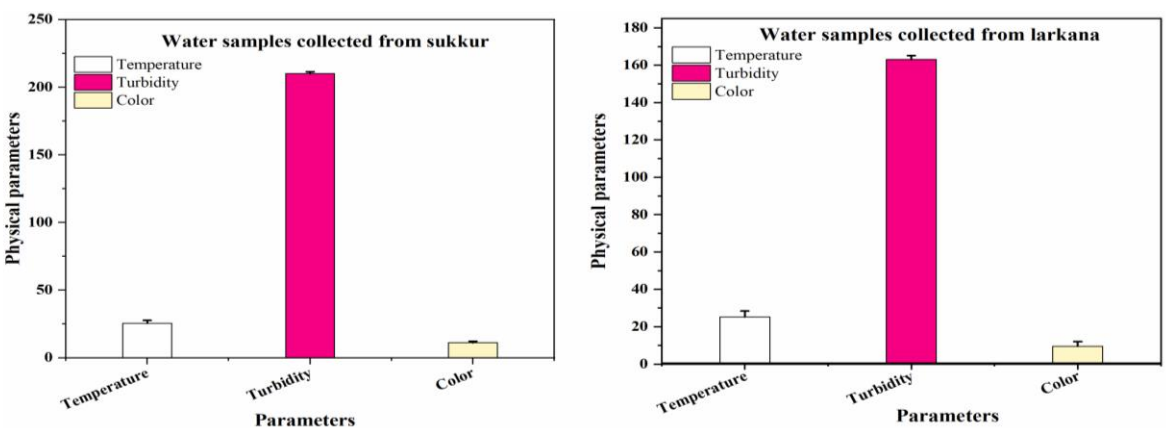

Fig. 2 Physical parameters profile of wastewater.

Chemical Parameters Profile

According to SEQs standard limit for TDS has been considered 3500 mg/L for inland waters. During this study TDS values were obtained between 210-230 mg/L. TDS values were high at Sukkur location of the rice canal. Results reveal that obtained values from the rice canal are in permissible limit. The present study helped us to know the level of suspended particles in the rice canal (Fig. 3). After conducting tests, the TSS values were recorded as 201 mg/L and 129 mg/L at Sukkur and Larkana, respectively. The maximum value of this parameter was found at rice canal Sukkur location, while the minimum value was recorded at rice canal Larkana.

According to the parameter limits of SEQs, TSS value should be under 200 mg/L. Suspended particles at the Larkana site are under the permissible limit as for Sukkur, it is one digit elevated than the given limit. The pH ranges between 8.18 ± 8.25 (alkaline) in the study area (Table 1). This comes in the WHO range of pH (6.5-8.5). This may be due to intrusion of sewage to the shallow groundwater (Gautam et al., 2026). High variation was not recorded in pH values. According to SEQs, pH of inland waters should be in the range of 6 to 9. Obtained values between 6 and 9 as well as recorded values of samples are suitable according to the NEQS (6.5-8.5). According to the irrigation water quality guidelines for Pakistan, these recorded values (6.5-8.4) are suitable. The average concentration of DO from rice canal Sukkur was observed as 1.12 for Larkana and 2.11 mg/L for Sukkur. The maximum value was found at rice canal Larkana and the minimum value was noted at rice canal Sukkur.

The BOD level of rice canal ranged from 114-298 mg/L. The desirable limit of BOD as per SEQs is 80 mg/L for inland waters. Obtained values are much higher than the permissible value. The maximum value was determined at rice canal Sukkur which was 298 mg/L and the lowest value 114 mg/L was noted in rice canal Larkana. A high value of BOD at the location of rice canal Sukkur shows the result of the dumping of domestic waste into the water due to increasing urban population located near the rice canal. The high level of BOD shows the low level of DO in the water.

This study has found higher value of COD at rice canal Sukkur, while low value was measured at rice canal Larkana. The chemical oxygen demand (COD) ranged from 51-115 mg/L. As per SEQs, the obtained value for COD should be 150 mg/L in a freshwater body. Obtained results are under the permissible limit of SEQs. It was expressed in milligrams per liter (mg/L), which indicates the mass of oxygen consumed per liter of solution. The noted values of the conducted study on rice canal ranged from 124-126 mg/L. The results of the present study show that the hardness of the samples is under permissible limit. The hardness that occurs due to the presence of magnesium in water is known as magnesium hardness. Hardness in magnesium was detected from the water samples of the rice canal. The obtained values of the water samples ranged from 178 to 202. The maximum value was determined at rice canal Sukkur, while the lowest value was measured at rice canal Larkana. The total hardness of canal water ranged from 304-317 mg/L while desirable limit as per SEQs is <500 mg/L.

The total hardness of water was due to the presence of bicarbonate, sulfates, chloride, and nitrates of Ca and Mg. It was observed that water was classified as soft when hardness was lower than 75 mg/L, while moderate hardness ranged from 75-150 mg/L. Hardness values between 150-300 mg/L were considered hard water, and water was classified as very hard when the hardness value exceeded 300 mg/L. In the present study, samples from locations of the rice canal were tested to determine iron levels. The recorded values ranged from 0.01-0.06 mg/L. The maximum value was observed at Sukkur rice canal, while the minimum value was recorded at the Larkana rice canal. According to SEQs the limit for iron in inland waters was 8.0 mg/L. The results indicated that level of iron in water samples was within permissible limit.

The results of chlorine concentration in the study area samples were recorded. During the tests, free chlorine was not detected in any of the samples. According to SEQs, the permissible limit for chlorine in water has been considered 1.0 mg/L. Therefore, the water was considered permissible, as chlorine was not detected. Total chlorine refers to the residual chlorine present in water, including both free and combined forms. In the present study, samples were collected from different locations of the rice canal to determine total chlorine levels. It was found that total chlorine was not detected in any of the samples. In addition, chlorides were measured at two different locations of the rice canal. The recorded values ranged from 54-86 mg/L. The maximum value was observed at the Sukkur rice canal, while the minimum value was recorded at the Larkana rice canal.

According to SEQs, the permissible limit for chloride has been recorded 250 mg/mL. The results indicated the chloride levels in the canal water were within permissible limits. Alkalinity refers to the presence of various components in water that contribute to its alkaline nature. Alkalinity elevated levels may create various health issues (Pickering et al., 2026). During the present study, alkalinity was determined for two different locations of the rice canal and the range of alkalinity of the samples was between 118-138 mg/L. The maximum value was determined at rice canal Sukkur and the minimum value was found at rice canal

Larkana. Abbas et al. (2020) revealed that the total dissolved solids were found above the permissible limit as specified by FAO, USEPA and WWF for agriculture water. Furthermore, majority of the tested physical and chemical properties of water samples were within the allowable limits as compared with FAO, USEPA, and WWF for irrigation water. Saffan et al. (2024) stated that low quality of irrigation water affects negatively the most of soil structure and health.

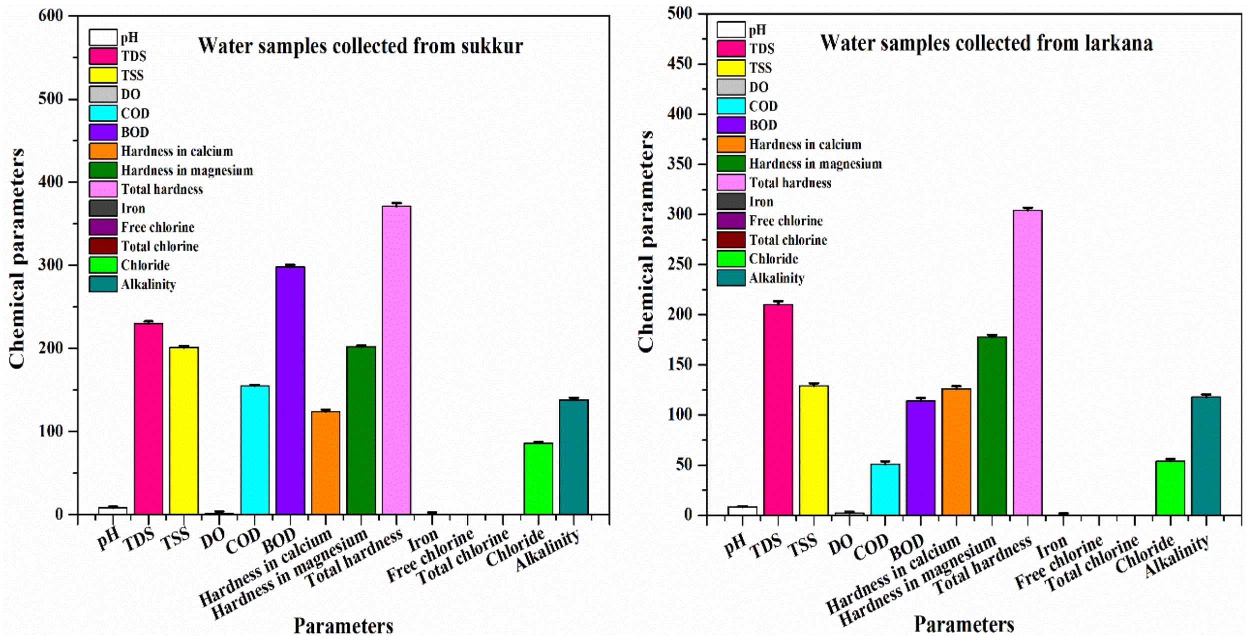

Fig. 3 Chemical parameters profile of wastewater.

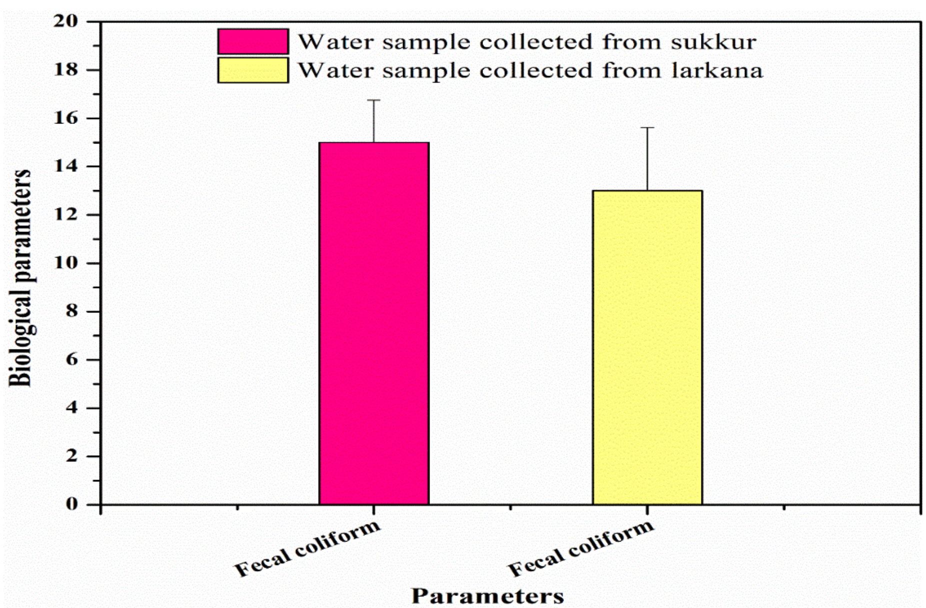

Fig. 4 Biological parameters profile of wastewater.

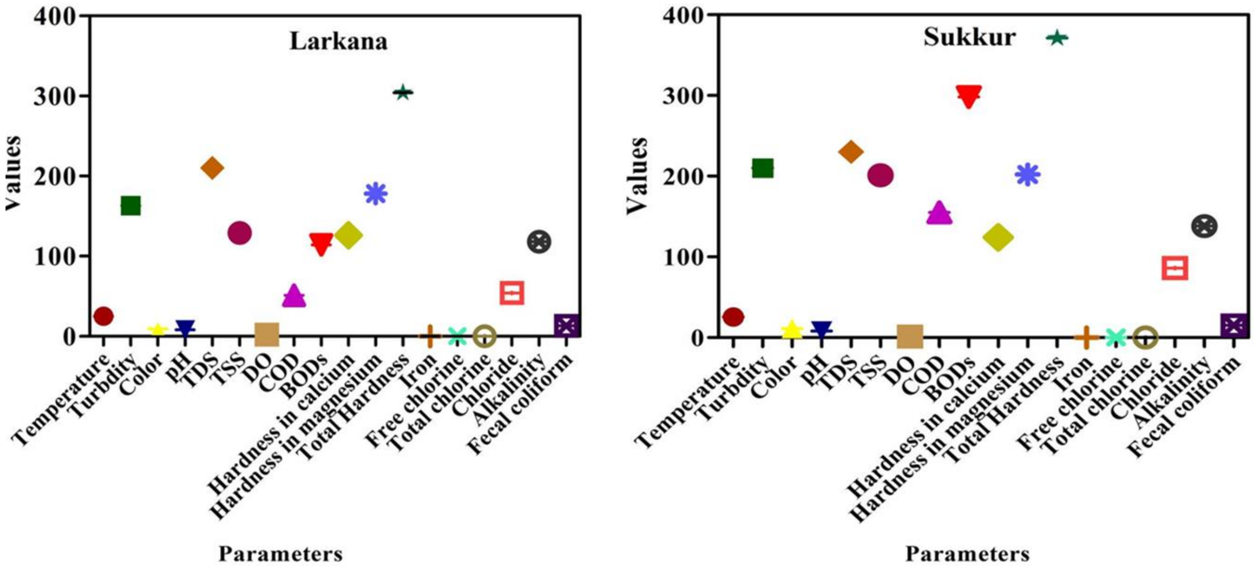

Fig. 5 Scatter Dot Plot among physicochemical and biological parameters of rice canal from Sukkur and Larkana.

Biological Parameters Profile

Maximum fecal coliform number of colonies in Sukkur water sample was observed as 15, whereas the lowest fecal coliform was found up to 13 as compared to WHO and SEQs (Fig. 4). According to WHO guidelines and SEQs, there should be 0 presences of microorganisms in 100 ml of drinking water. The water of rice canal is also used for bathing, washing, swimming, and to irrigate the rice crops in summer season and wheat, barley, mustard in winter season, sometimes local people also use this water for domestic purpose, which was harmful for their health.

The presence of microbes make the water unhealthy for human consumption. Serious health issues take place including diarrhea, dysentery, cholera, and other intestinal disturbance due to the consumption of contaminated water (Khanna & Bhushan, 2026). Steele et al. (2005) reported the presence of fecal coliforms in the irrigation water samples.

Scatter Dot Plot among Water Parameters

The data in Figure 5 revealed that the maximum concentration of temperature, turbidity, color, pH, TDS, TSS, DO, COD, BOD, calcium and magnesium hardness, total hardness, iron, free and total chlorine, chloride, alkalinity, and fecal coliform were found in Sukkur irrigation water samples as compared with Larkana irrigation water samples. It could be due to direct discharge of domestic wastewater and solid material dumping directly in the water body of Sukkur irrigation water, where the less accumulation of pollutants may be due to long distance and dilution factor of pollutants in the Larkana water samples (Igbinosa & Okoh 2009; Gadhi et al., 2026).

Conclusion

The present study demonstrates that, although wastewater reuse can support agricultural water demands, untreated domestic effluent and agricultural runoff remain contributors to severe pollution in the rice canal system. The analysis revealed that the physical, chemical, and biological characteristics of water samples from the Sukkur irrigation network, particularly near the Sukkur Barrage, are highly contaminated, primarily due to direct discharge and accumulation of untreated domestic wastewater. These findings have important implications for both public health and agriculture. The use of polluted irrigation water may lead to the accumulation of harmful contaminants in soils and crops, potentially degrading crop quality and posing health risks to consumers through the food chain. While, wastewater reuse may meet crop water requirements, it can adversely affect crop safety and productivity. These sources of contamination are likely multi-factorial, including inadequate sanitation infrastructure, untreated municipal wastewater, and industrial discharge. Recommended actions include implementing effective wastewater treatment before irrigation discharge, enforcing regular monitoring of water and soil, developing and following safe wastewater reuse guidelines, and promoting public awareness to reduce indiscriminate waste disposal. Future research should focus on the long-term accumulation of organic and inorganic pollutants in soils, as well as their phyto-availability and transfer into major crops such as rice, wheat, cotton, maize, sunflower, and vegetables, to better assess risks to food safety and human health.

Conflict of Interest Statement

The authors declare that they do not have any conflict of interest regarding the research work presented in this manuscript.

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