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Water quality analysis of old and new Phuleli Canal for irrigation purpose in the vicinity of Hyderabad, Pakistan

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ABSTRACT

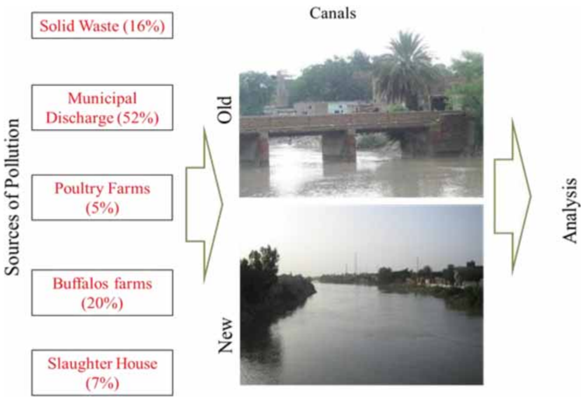
Irrigation-water quality plays an important role in agriculture productivity. In this study, water quality of the old and new Phuleli canal located in Hyderabad, Pakistan, was characterized for irrigation purpose. Water samples were collected from four different locations of both the old and new Phuleli canal. Twelve different irrigation-water quality standards were assessed under the study: pH, Electricity Conductivity, Biochemical Oxygen Demand (BOD), Total Dissolved Solids, Chemical Oxygen Demand (COD), Dissolved Oxygen, Calcium, Magnesium, Sodium, Potassium, Sodium adsorption ratio, Fecal Coliforms. The results showed that the Electricity Conductivity ranges from 910–3,090 MS/cm, Potassium 13–112 mg/l, BOD 61–285 mg/l, COD 97–361 mg/l and Fecal Coliforms 400–2,350 MPN/100 ml concentrations in water of both canals were higher than the National Environmental Quality Standards permissible limits. It was found that the water quality parameters were higher than the permissible pollution level of canal water for the use of irrigation in agriculture.

Key words: agriculture productivity, biological oxygen demand, chemical oxygen demand, irrigation water, wastewater, water quality

HIGHLIGHTS

- Water quality of the old and new Phuleli canal located in Hyderabad Pakistan was characterized for irrigation purpose.
- Twelve different Irrigation-water quality standards were assessed under the study.
- Twelve species were focused under the study.
- Irrigation water was highly contaminated, when it passed through the urban area.
- Due to high contamination, indirect method can be used for agriculture purposes.

GRAPHICAL ABSTRACT



1. INTRODUCTION

Indus River is one of the biggest sources of living for millions of people and other lives. It mainly provides water for domestic, drinking and agricultural activities of the countryside along its entire route (Clift 2002; Inam *et al.* 2007). The ratio of water pollution has constantly increased due to industrialization, urbanization (Usman *et al.* 2021) and climate change (Cheeseman 2016; Keerio *et al.* 2020b). Safe disposal of wastewater and sewage treatment plants are almost non-existent in all big cities of Pakistan. The Hyderabad, which is the second largest city of Sindh province of Pakistan, is also facing the same issue (Soomro *et al.* 2014). Wastewater of Hyderabad city and suburb areas is discarded into Phuleli canal without any pretreatment (Leghari *et al.* 2004). The Phuleli canal passes through the Hyderabad city, which has a population of about 2 million. The Phuleli canal is divided into two canals, namely old Phuleli and new Phuleli canal. The water of the Phuleli canal is used for agricultural, drinking and domestic purposes (Inam *et al.* 2007). The Phuleli canal also receives all of the sewerage of Hyderabad city, toxic, liquid waste of slaughter houses, poultries, and contaminated effluent of different industries (Sohag & Syed 2014; Soomro *et al.* 2014). Moreover, Phuleli canal also receives the effluent from Asia's largest cement factory, the Zeal Pak. There are a number of villages near to Phuleli canal and due to unrestricted disposal of solid waste and untreated wastewater into the old and new Phuleli canals, public health, environment, and groundwater quality is at great risk (Mastoi *et al.* 2014).

The quality of water in both old and new Phuleli canals may differ from one location to another location and may vary season to season. Therefore, the characterization of canal water would require the description of various constituents (Nag & Ghosh 2011). For sustainable crop production, irrigation water quality is the main concern (Suarez 2012; Chemura *et al.* 2014). Study was attempted to characterize canal water quality for ions concentration in different locations of Phuleli canal and to compare the values with permissible limits of the National Environmental Quality Standards (NEQS) for drinking and for agricultural use.

2. MATERIAL AND METHODS

2.1. Study area and sampling

The Old and New Phuleli canals are off taking from the Indus River on its left side from the Kotri barrage. The head reaches of these canals are running on the Eastern side of the city. The head reaches of both channels are being polluted from urban and industrial wastes (Figure 1). Eight samples were collected from different locations, which are mentioned in Table 1 and marked in Figure 1.

2.2. Sampling method

A plastic bottle of capacity 1.5 liters was used to collect the sample, the temperature of the water was measured at the time of sampling. Samples of both canals were started from 12 RD bypass Super Highway. Eight samples were collected from Old Phuleli canal, 12 RD bypass super highway to Bridge before Darya Khan pumping station. A random eight water samples were collected from the New Phuleli canal. A total of 16 samples were collected from various locations. All samples were properly labeled and the bottles were grouped separately for physical, chemical and micro-biological analysis. The samples were preserved and analyzed at the Institute of Environmental Engineering & Management (IEEM) laboratory MUET Jamshoro. Analyzed results were compared with NEQs to find the present status of water of Old and New Phuleli canal water.

2.3. Species selection

The targeted species were pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), Biochemical Oxygen Demand (BOD), Dissolved Oxygen (DO), Chemical Oxygen Demand (COD), Calcium (Ca), Magnesium (Mg), Sodium (Na), Potassium (K), Sodium Adsorption Ratio (SAR), and Fecal Coliforms. The sensory evaluation and American Public Health Association (APHA), 22nd edition methods, were followed for analysis.

3. RESULTS AND DISCUSSION

Results have been obtained through analysis of 12 different species of a total of eight points shown in Table 1 and sixteen samples were collected. Location of the sampling points and their descriptions can be seen in Figure 1. Samples were collected on two dates with different or varying frequencies. Eight samples were collected from four different locations of Old and New Phuleli canal on 7.11.2014 and the remainder on 23.11.2014 respectively. All 16 water samples (8 from Old and 8 from New Phuleli Canal) from different locations were collected and

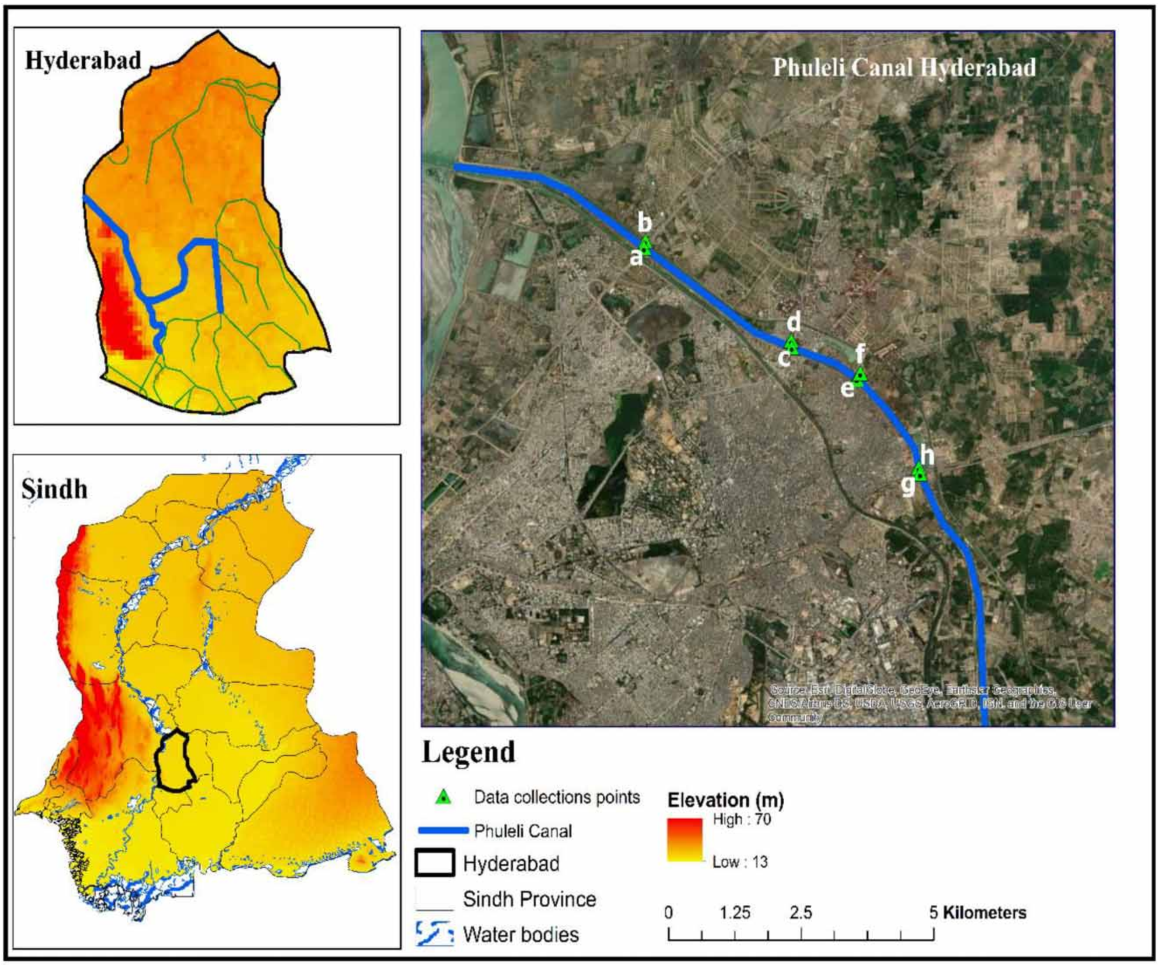


Figure 1 | Geographical features of the study area and location of the selected collection sites.

Table 1 | Sampling points of Old and New Phuleli Canals

Points	Old Phuleli Canal	Points	New Phuleli Canal
a	12 RD bypass Super Highway	b	12 RD bypass Super Highway
c	NHW Road	d	21 RD Hala Road Bridge
e	Ghangira Mori Bridge after WASA Pumping	f	Paretabad Road Bridge over wastewater
g	Bridge before Darya Khan Pumping Station	h	Channel Mori near Ghangira Mori

tested for physical, chemical and biological examination in laboratory. The selected species are listed in the Material and Methods section. The parameters tested are pH, EC, TDS, BOD, DO, COD, CA, Mg, Na, K, SAR, and Fecal Coliforms.

3.1. Physical characterization of old and new Phuleli Canal

The accurate pH and EC is important for biological processes (Aini *et al.* 2014). There is a relationship between pH and EC (Bruckner 2012). The pH is a logarithm of the reciprocal of hydrogen ion concentration. As ions carry negative or positive charges, EC should occur. The more basic or acid the water is, the higher the electrical EC. However, in this study small variation in pH and EC was observed in new Phuleli canal, the reason may be less dumping of waste in the new canal. In old Phuleli canal, less pH and EC variation was observed except at point four. However, at point four due to the dumping of city waste, suddenly the pH drops and ~65% EC was increased (Figure 2). It was observed that all pH values were within the limit of prescribed NEQs. The EC of

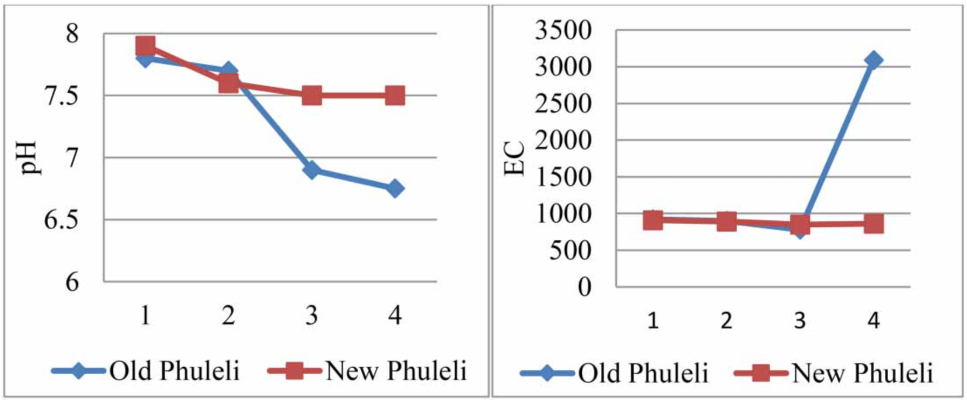


Figure 2 | pH and EC of old and new Phuleli Canal.

all samples were within permissible limits, except the sample collected from Darya Khan location (Point 4). At point four, high industrial effluents from the SITE area was discharged.

3.2. Chemical characterization of old and new Phuleli Canal

The poor water quality for irrigation has a negative impact on crop yield, quality, and public health of consumers (Qadir *et al.* 2007). The irrigation water quality problem can be categorized into four parts: 1. Salinity hazards, 2. Specific ion toxicity, 3. Infiltration and permeability problems, and 4. miscellaneous problems (Simsek & Gunduz 2007). The irrigation through a groundwater wells system has been increased. The tank and canal waters have very low saline and sodium hazards. The chemical composition of waters varies. The relative proportion of magnesium (Mg), sodium (Na) and chloride (Cl) raises with increasing salt content. Generally, Mg is more than Cl. Highly saline water may also contain a high amount of nitrate (Bhumbla 1977).

3.2.1. Total dissolved solids (TDS)

A total of nine chemical parameters are presented in Figure 3. The NEQs value of TDS for irrigation water is 1,000 mg/l. Location number four of Old Phuleli canal has higher TDS value (~1,550 mg/l) according to Figure 3(a). The value of the remaining locations of both canals was within the standard limits. The higher value of TDS is due to the effluent of wastewater discharged through Darya Khan Pumping Station. A high level of TDS can affect the irrigation facility, can lower the water conductivity of the soil and can pollute the soil surface. In addition, numerous bacteria and viruses can be attached to the solids and migrate. The elimination of TDS is related to the elimination of bacteria and viruses (Vinten *et al.* 1983; Ragusa *et al.* 1994; Jeong *et al.* 2016).

3.2.2. Biological oxygen demand (BOD)

BOD of wastewater is an important criterion for judging the suitability of wastewaters for irrigation. The seasonal changes in EC, soil pH, nitrate, and ammonium as affected by wastewaters with five levels of BOD was observed. The significance of the growing-season temperature on ammonium conversion (Nitrification) and other aerobic process in the soil, particularly under irrigation with wastes having higher oxygen demand (Nashikkar 1993). Organic matters act as nutrients for microorganisms. The BOD values at different location are shown in Figure 3(b). The permissible NEQs for irrigation are 80 mg/l. However, from our results it was found that the BOD value is higher than the permissible limit. The BOD value obtained at 4th location of the Old Phuleli canal is the highest amongst all the values. The reasons for the higher value have already been discussed above. The trend for both canals shows some interesting results. As it moves from the first point to the last point, BOD is increasing due to discharge of effluent from different points in canals and other solid waste from urban areas.

3.2.3. Dissolved oxygen (DO)

Oxygen supply to the root zone is important for plant health. Irrigating plants with two aeration systems oxygenated with DO from 3.5 to 6.5 mg/L, resulting in higher corn yield and biomass as compared with that grown with low DO water 0.3–4.5 mg/L (Yafuso & Fisher 2017). DO in water can cause microbial reduction as nitrate to nitrite and sulfate to sulfide. The DO for ammonium oxidizing bacteria should vary in the range from 0.5 to

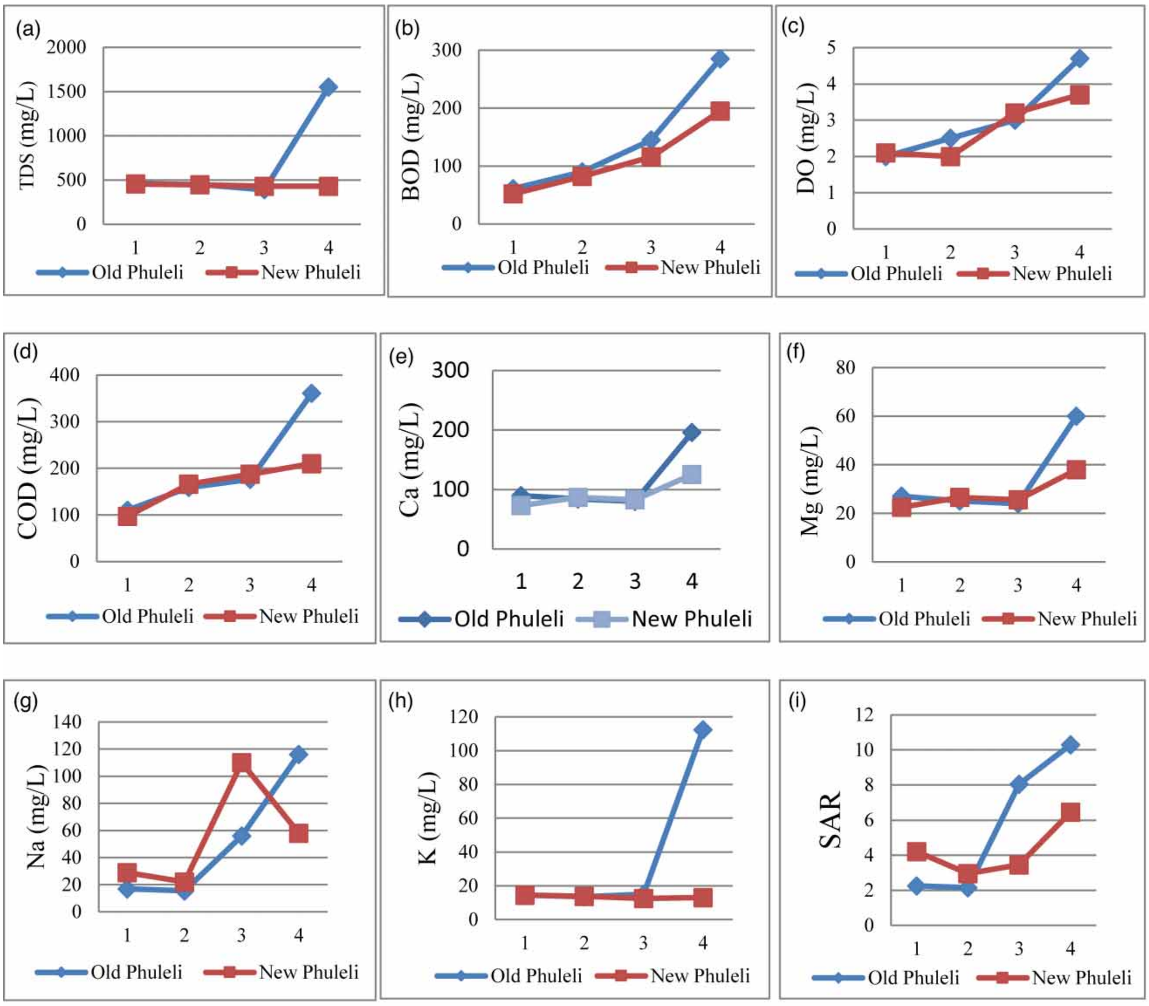


Figure 3 | Chemical characterizations of old and new Phuleli Canal. (a) Total Dissolved Solids (TDS), (b) Biological Oxygen Demand (BOD), (c) Dissolved Oxygen (DO), (d) Chemical Oxygen Demand (COD), (e) Calcium (Ca), (f) Magnesium (Mg), (g) Sodium (Na), (h) Potassium (K), and (i) Sodium Adsorption Ratio (SAR).

5 mg/L (Keerio & Bae 2020; Keerio *et al.* 2020a). However, in our results the DO concentration at point 1 was lower (~2 mg/L) and at point 4, 50% to 60% increase in DO was observed (Figure 3(c)). This shows that at Point 1, water was less polluted and there may be the presence of microbes, and they consume some oxygen as a substrate. As canal water crosses the urban area, high oxygen concentration was observed. The reason may be the activities of microbes were decreased such as Ammonia Oxidizing Bacteria (AOB) (Keerio & Bae 2020; Keerio *et al.* 2020a). However, regarding the plant and crops, DO between 3.5 to 6.5 mg/L is sufficient for high corn yield (Yafuso & Fisher 2017).

3.2.4. Chemical oxygen demand (COD)

Chemical oxygen demand (COD) is the chemical decomposition of organic as well as inorganic contents present in water and it was measured in mg/l. High COD indicates the presence of both biodegradable and non-biodegradable organic materials (Islam *et al.* 2019). If the BOD and COD ratio for non-treated wastewater is 0.5 or greater than 0.5, the wastewater is considered to be easily treatable through biological process. If the ratio is below 0.3, either the waste may have some toxic components or acclimated microorganisms may be required in its stabilization (Lee & Nikraz 2015). However, in this study the ratio between COD and BOD was 0.49 at New Phuleli canal point 2, 0.93 at New Phuleli canal at Point 4, and other results were laid in between these two values. At point 4 in both canals high COD value was found because a high concentration of physiochemical and biological values was found (Figure 3(d)).

3.2.5. Calcium (Ca)

Calcium is naturally available in the water body. It comes from the dissolution of rocks such as limestone, marble, calcite, gypsum, dolomite, fluorite, and apatite. Calcium is a determinant of hardness, because it can be found in water in the form of Ca_2^+ ions. Ca is an important part of plant protection systems. It is important for stability, membrane function, and for preventing solutes like amino acids and sugar from leaking from the cytoplasm; these activities help to prevent disease (Bateman & Lumsden 1965; Volpin & Elad1991; Elad *et al.* 2021). The maximum permissible range for irrigation is 10 mg/L. At Point 4 in both canals the calcium concentration was higher than the permissible range. At all remaining three points it was lower than the permissible range (Figure 3(e)).

3.2.6. Magnesium (Mg)

Mg is essential for photosynthesis (Elad *et al.* 2021). In most plants, Mg deficiency is manifested as chlorosis and leaf necrosis (Kirkby & Mengel 1976). Mg affects plant diseases, indirectly and directly, through interactions with other minerals; for example, Mn, Ca and K (Huber & Jones 2013). A large concentration of magnesium that restricts Ca absorption increases the severity of bacterial speck in tomato (Huber & Jones 2013; Elad *et al.* 2021). The concentration of Mg in Old and New Phuleli was observed with the NEQs limit except at Point 4, in the Old Phuleli canal. In terms of Mg, New Phuleli canal water can be used for irrigation purposes at all four points and Old Phuleli canal needs some treatment, especially at Point 4, before direct use for irrigation (Figure 3(f)).

3.2.7. Potassium (K)

When K existing at optimal concentration, it decreases plants' susceptibility to disease (Huber & Graham 1999). The canal water possesses potassium higher than the recommended guideline value of 10 mg/l. As per the analysis, the value of samples from both canals ranges between 13 and 112 mg/l. However, the concentration of K was 112 mg/L at Point 4 in Old Phuleli canal, approximately 92% higher than the standard value (Figure 3(g)).

3.2.8. Sodium adsorption ratio (SAR)

SAR is one of the important parameters to check the suitability of water used for agricultural purpose. It is also used to measure the sodicity of soil. It is determined by the concentrations of solids dissolved in the water (USDA 1954). If the sodium adsorption ratio is higher, it means the water is less suitable for irrigation (Dlamini *et al.* 2021). The SAR standard value is 8. In this study, the values of sample 3 and 4 of Old Phuleli canal were higher than the recommended guideline and other samples have values within the guidelines (Figure 3(i)) and can be calculated using Equation (1).

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

where: Na is Sodium, Ca is Calcium, and Mg is Magnesium.

3.3. Biological characterization of New and Old Phuleli canal

Coliforms are bacteria or organisms that are present in the environment (Panhwar *et al.* 2021a, 2021b). In biological characteristics, the Fecal Coliforms were targeted. The Fecal Coliforms in 100 ml of both canals at Point 3 and 4 of both canals were higher than the standard values (Figure 4). This study confirmed that the waters of both canals, which are used by millions of people, are heavily polluted with disease-causing bacteria. However, in other study, the irrigation water samples were analyzed for Total Coliform, Fecal Coliform and *Escherichia coli*. It was found that the samples of cabbage recorded the highest levels of microbial contamination. It was suggested that the water should be treated before using for irrigation. Peoples should confirm that vegetables are properly washed and cooked before consumption (Douti *et al.* 2021).

4. CONCLUSION

Direct use of wastewater for agriculture has been increasing due to urbanization, industrialization and wastewater dumping into irrigation canals without any treatment. For safe practices, wastewater should be treated at point sources before discharge into irrigation canals. The analyzed results at all selected locations of both canals indicate that the water quality is unfit for irrigation purpose, having a higher concentration of EC

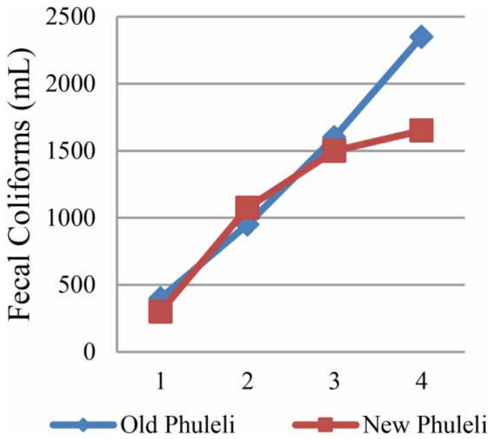


Figure 4 | Biological characterization of old and new Phuleli canal.

(3,090 mS/cm) and K than the permissible level for irrigation standards and National Environmental Quality standards (NEQs). However, the pH, DO and Na were within the permissible level of irrigation standards and NEQs. The samples from locations 2, 3, and 4 of both canals have a higher level of BOD and COD than the permissible level of irrigation standards and NEQs. The TDS concentration was within the permissible limit of irrigation standards and NEQs, except the fourth location (bridge near Darya Khan Pumping Station) of the Old Phuleli canal. In addition to the above for the fourth location of the Old Phuleli canal, high concentration of Mg and Ca was observed, higher than the permissible limit. Sodium adsorption ratio (SAR) and Fecal Coliforms were at higher concentrations than irrigation standards and NEQs at locations 3 and 4 of the Old Phuleli canal. Whereas, New Phuleli canal results were within the standards.

DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

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