Research Article

Wastewater Contaminants Characterization and Evaluation from Wali Muhammad Distributary, Multan, Punjab

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Abstract | Wastewater production and disposal have become issues of concern with the growing population and increase in overall water usage. About 4.36 billion m^3 (BCM) of wastewater is generated every year in Pakistan and not even 1% of the total wastewater gets treated before its disposal. The reported research aims to assess the concentration of contaminants in wastewater. Samples of wastewater were collected from Wali Muhammad Canal, Multan, and analyzed for heavy metals (HMs) including cadmium (Cd), copper (Cu), nickle (Ni), and zinc (Zn), along with basic physicochemical parameters including biological oxygen demand (BOD), chemical oxygen demand (COD), pH, electrical conductivity (EC), total solids (TS), total suspended solids (TSS), total dissolved solids (TDS), sodium (Na), calcium (Ca), potassium (K), magnesium (Mg), residual sodium carbonates (RSC), sodium adsorption ratio (SAR), carbonates (CO_3), and bicarbonates (HCO_3) by using standard analytical procedures. The contamination in the wastewater includes temperature, pH, EC, BOD, COD, TS, TDS, TSS, Na, Ca, Mg, K, SAR, RSC, CO_3, HCO_3, Cu, Ni, Cd, and Zn was 28.6 °C, 9.3, 2.47 $uScm^{-1}$, 304mg/L, 408mg/L, 19160 mg/L, 14290mg/L, 4880mg/L, 2.96mg/L, 37.6meL^{1}, 119.3meL^{-1}, 31.33mg/L, 1.46meL^{-1}, 2.50meL^{-1}, 7.06meL^{-1}, 7.16meL^{-1}, 0.154mg/L, 0.024mg/L, 0.054mg/L, and 4.45mg/L respectively. The disposal of untreated wastewater into the surface water bodies is damaging the whole ecosystem. The government should monitor the industries' wastewater disposal according to the nation's effluent standards, and make wastewater treatment plants for the elimination of hazardous contaminants.

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1. Introduction

Pakistan is the world's fourth-highest water user and ranks third amongst countries facing water shortages, as reported by the International Monetary Fund (IMF) (Ahmad, 2021). With the increase in overall water use, wastewater production and pollution load are also continuously increasing in Pakistan (Connor *et al.*, 2017). In Pakistan, approximately half of the two million wet tonnes of human waste produced each year end up polluting the water (Maqbool, 2022). A study found that 60 million people could be exposed to high levels of arsenic in groundwater on the Indus Plain (Podgorski *et al*., 2017). Water-borne illnesses are the main cause of morbidity and mortality (Manetu and Karanja, 2021). In Pakistan, 60,000 persons passed away in 2017 as a result of poor water and sanitary systems, with children under five making up half of those fatalities (UNICEF, 2020). It is estimated that poor water and sanitation, floods, and droughts cost Pakistan's economy 4.0 percent of its GDP, or around $12 billion annually (Young *et al*., 2019).

Multan (30.1575° N, 71.5249° E) releases 66×106 m^3 of wastewater and has an affluent potential of 5.17 m^3/sec (Khan *et al*., 2019). Seventy percent of houses and other users are served by the sewerage network of the Multan Water and Sanitation Authority (MWASA) (NESPAK, 2013). Multan Industrial Estate (MIE) Phase I contains 180 industrial units, the majority of which manufacture paper, textiles, leather, and pesticides. The district faces numerous environmental difficulties as a result of the untreated effluents from these companies (Murtaza *et al*., 2017). The effluents discharge of these industries enters into the water bodies that is the source of irrigation in urban areas for cultivation. The use of these crops by humans, produced with wastewater can lead to the depletion of nutrients in the human body and cause disabilities with malnutrition, immunological disorders, intra-uterine growth retardation, and upper gastrointestinal cancer (Khalid *et al*., 2018). Therefore, there is a need to explore alternative sources for irrigation, by focusing on the Sustainable Development Goal Clean water and Sanitation; target 6.3 which highlights safe water reuse in agriculture (Obaideen *et al*., 2022).

To analyze the impact of wastewater, a characterization study is required. Various physiological, biological, and chemical parameters were found to be exceeding their permissible limits in various wastewater characterization studies carried out for impact assessment in various cities of Pakistan and Multan (Khan *et al*., 2019). The qualities of wastewater should be thoroughly analyzed for the appropriate surveillance of its quality, management, and utilization. This research was conducted for the assessment of Multan's Wali Muhammad canal distributary's (30°9'16" N and 71°28'43" E) wastewater to estimate the severity of contaminants being released into the receiving environment.

2. Materials and Methods

2.1 Wastewater samples collection and preservation

Samples of wastewater were collected from Wali Muhammad Canal (30°9'16" N and 71°28'43" E), Multan (30.1575° N, 71.5249° E) in 500 ml capacity plastic bottles after washing with de-ionized water. For subsequent examination, water samples were acidified with 5% nitric acid and kept at 4 °C in the refrigerator.

2.2 Analysis of wastewater samples

The analysis of collected wastewater samples for the assessment of quality and heavy metals was performed by following the standard methods (Baird *et al*., 2017) in the Laboratory of Department of Soil and Environmental Sciences, MNS-University of Agriculture, Multan. The wastewater samples were analyzed for pH, chemical oxygen demand (COD), biological oxygen demand (BOD), electrical conductivity (EC), total solids (TS), total dissolved solids (TDS), total suspended solids (TSS), magnesium (Mg), sodium (Na), calcium (Ca), potassium (K), carbonates (CO_3), and bicarbonates (HCO_3), sodium adsorption ratio (SAR), residual sodium carbonate (RSC) cadmium (Cd), nickel (Ni), zinc (Zn) and copper (Cu). The analysis was done with the instruments along with the model presented in Table 1.

3. Results and Discussion

TS, TDS, and TSS are particularly essential characteristics because increased solids lead to specific ion toxicity, disease carriers, and viscosity of water bodies (Qadir *et al*., 2010). At a disposal facility, the values for TS, TDS, and TSS were 19160, 14290, and 4880mg/l, respectively (Table 2). Both the presence of soil and algae in the water body had an impact on the TSS value (Abdul-Aziz *et al*., 2020). Suspended solids volume rises when it rains because the soil from nearby gets into the wastewater course (Okoro *et al*., 2012). In wastewater, TSS is a particulate with a diameter greater than two microns (FELC, 2020). Algae, microorganisms, and inorganic substances formed the suspended solids. Water becomes cloudier as the amount of suspended solids increases (Wavelength, 2018). The elevation in suspended solids volume might also be attributed to organic particles from the degradation of the raw ingredients.

Table 1: List of parameters and method adopted for water quality analysis.

S. No.	Parameters	Units of measurement	Methods/Instrument
1	Potential of hydrogen (pH)	-	pH meter
2	Chemical Oxygen Demand (COD)	mg/L	Open reflux technique
3	Total Suspended Solids (TSS)	mg/L	Calculation formula
4	Sodium (Na)	mg/L	Flame photometer (PFP-7, Jenway UK)
5	Magnesium (Mg)	meL^{-1}	Atomic Absorption, Spectrophotometer, (Analytik Jena: NovAA 400P Germany)
6	Carbonate and Bicarbonate	meL^{-1}	Titration
7	Sodium Adsorption Ratio (SAR)	meL^{-1}	Calculation formula
8	Electrical Conductivity (EC)	$uScm^{-1}$	EC meter
9	Biochemical Oxygen Demand (BOD)	mg/L	5day BOD test.
10	Total Solids (TS)	mg/L	Gravimetric Determination method
11	Total Dissolved Solids (TDS)	mg/L	TDS meter (EZ9901)
12	Calcium (Ca)	meL^{-1}	Flame photometer (PFP-7, Jenway UK)
13	Potassium (K)	mg/L	Flame photometer (PFP-7, Jenway UK)
14	Residual Sodium Carbonate (RSC)	meL^{-1}	Calculation formula
15	Heavy Metals of Zn, Cd, Ni, Cu	mg/L	Atomic Absorption, Spectrophotometer, (Analytik Jena: NovAA 400P, Germany)

Table 2: Contaminants trends in wastewater.

Parameters	Min	Max	Mean	Std. Dev.	Permissible limit
Temperature (^{0}C)	28.00	29.00	28.667	0.577	=<3^{0}C
pH of wastewater (ph)	9.20	9.50	9.333	0.152	6-10
Chemical Oxygen Demand (COD)	400	416	408	8	150
Total Suspended Solids (TSS)	4870	4890	4880	0.01	150
Sodium (Na)	2.95	2.97	2.96	1.00	
Magnesium (Mg)	116	124	119.33	4.163	
Carbonate (CO^-_3)	7.00	7.20	7.0667	0.115	
Bicarbonate (HCO^-_3)	6.60	8	7.16	0.425	
Sodium Adsorption Ratio (SAR)	1.4191	1.5045	1.4641	0.0429	
Electrical Conductivity (EC)	2.45	2.50	2.47	0.02	
Biochemical Oxygen Demand (BOD)	303	305	304	1.00	80
Total Solids (TS)	19167	19171	19169	2.223E-03	150
Total Dissolved Solids (TDS)	14290	14298	14296	2.222E-03	3500
Calcium (Ca)	34.0	35.0	37.667	1.5275	
Potassium (K)	30.0	33.0	31.33	1.5275	
Residual Sodium Carbonate (RSC)	2.2167	2.8667	2.5056	0.3310	
Zinc (Zn)	4.4550	4.4590	4.4570	2.000E-03	5
Cadmium (Cd)	0.0546	0.0550	0.0548	2.082E-04	0.1
Nickle (Ni)	0.0244	0.0248	0.0246	2.000E-04	1
Copper (Cu)	0.1540	0.1544	0.1542	2.000E-04	1

The average BOD level in the wastewater samples was 304mg/L. The Environmental Protection Agency (EPA) of Pakistan has set a permissible limit for BOD of 50 mg/L (PNEQS, 2000). A low BOD number indicated adequate water quality, while a high BOD value indicated polluted water. BOD is a measure of how much dissolved oxygen bacteria require to decompose organic materials aerobically. In most aquatic habitats, BOD was utilized as an indicator to count the number of organic pollutants

(Lee and Nikraz, 2014). The COD level was 408 mg/L on average. It is a crucial indicator of water quality since it offers a way to determine whether sewage discharges will harm the ecosystem. COD is a measure of wastewater contamination intensity. It is described as the amount of oxygen necessary for the complete chemical oxidation of organic materials to produce CO_2, NH_3, and H_2O when done in acidic conditions with a potent oxidizing agent like potassium dichromate (Shah *et al*., 2014).

The pH of wastewater samples was 9.33, which was above the WHO guideline of 6.5 to 8.5 (Nazir *et al*., 2015) but below Pakistan's environmental protection agency's allowed level (PNEQS, 2000). pH is an important parameter that tells the acidity or basicity of wastewater. According to a study, wastewater that is slightly alkaline (7.2–7.6) improves the soil's ability to fix metal (Jiménez, 2006). The pH range, which is between 6 and 9, is fairly limited and crucial for the existence of the majority of biological life (Bai *et al*., 2011). Similar to this, determined that a pH range of 6 to 9 is ideal for macrophyte function (Shah *et al*., 2014).

Because the samples were taken at a sewage treatment facility in a residential neighbourhood, which may contain wastes such as soap, urine, and detergent produced by household activities, the pH of sewage wastewater revealed an alkaline value (Abdul Aziz *et al*., 2020).

The average temperature of the wastewater samples was 28.67 °C (Table 2), which is within the 20 to 32 °C range suggested by the WHO (Onuegbu *et al*., 2013). The EC of water is a measure of its ability to conduct electricity and is proportional to the concentration of ions in the water. The effluent has an EC value of 3450 us/cm, such value was greater than the 400 to 600 us/cm range recommended by the WHO for wastewater's electrical conductivity (Nazir *et al*., 2015). The conductive ions in wastewater could have been caused by dissolved compounds such as contaminants (Wilson *et al*., 2020). Conductivity may have increased as a result of dissolved ions being supplied to the channels at the point where distributary wastewater was released into an open wastewater channel. This was consistent with a prior study, which found that the electrical conductivity was increased when home effluents were discharged into open water systems (Mbui *et al*., 2016).

In the case of carbonates, bicarbonates, sodium absorption ratio and residual sodium carbonate were 7.06, 7.16, 1.46 and 2.50 meL^{-1}, respectively. The wastewater has the highest concentrations of calcium (37.6 meL^{-1}), potassium (31.33 mg/L), sodium (2.96 mg/L), and magnesium (19.33 mg/L) in terms of nutrients. Although potassium is found in soil in large proportions (around 3% of the lithosphere), its chemical form prevents bioavailability, necessitating the addition of potassium through fertilizers (Durán Álvarez and Jiménez Cisneros, 2014). Some crops require 185 kg of potassium per hectare to be grown. The reclamation of sodic soil is of special relevance to this parameter. The residual sodium carbonate and the sodium adsorption ratio were each 1.46 meL^{-1}. wastewater that varies in the key cation contents (K, Ca, Mg, and Na) that might impact soil base saturation. The sodium adsorption ratio (SAR) expresses the connection between sodium content and Ca plus Mg contents (Van der Hoek, 2014).

Prior to use in agriculture, wastewater must be analyzed for metals due to its toxicity, bioaccumulation, persistence, and biomagnification across food chains, which pose a risk to ecological systems and human health (Alengebawy *et al*. 2021). Copper is an important component of enzymes, a micronutrient for soil and irrigation water, and is necessary for the formation of haemoglobin (Dhaliwala *et al*., 2022). High copper levels, however, can result in diarrhea, vomiting, nausea, stomach cramps, and even death (Garg, 2022). Copper levels in the water were 0.154 mg/L due to industrial operations, plumbing fitting corrosion, livestock dung, and air deposition. Zinc concentration was 4.45 mg/L assessed in this study, though, its value was discovered to be below the acceptable level (5 ppm) (PNEQS, 2000). Moreover, anaemia, musculoskeletal pain, abrupt renal failure, and pancreatitis are all brought on by excessive zinc levels (Younas and Younas, 2022). The wastewater sample's cadmium concentration was 0.058 mg/L, according to the research. Children who are exposed to Cadmium over an extended period may experience cardiovascular, pulmonary, renal, skeletal, and kidney problems as well as stomach, lung, kidney, and prostate cancers (Rahimzadeh *et al*., 2017). A study conducted in Multan for the assessment of wastewater quality supports our findings of heavy metals present in the upper limit rather than zinc (Khan *et al*., 2019).

Conclusions and Recommendations

The quality of water is a major societal problem that is closely related to humanity's wellbeing. The demand for water is increasing day by day with the increase in population. Countries having sufficient water is now becoming deficient countries. Gray water is occasionally used to supplement blue water's needs. Heavy metals, which are hazardous to man and the biological environment, may be present in grey or wastewater invariables.

Novelty Statement

Water scarcity has become a global threat, and over-coming wastewater irrigation has become a trend in Pakistan. This water contains hazardous pollutants, which disturb the biota. Qualitative and quantitative analysis is necessary to evaluate the condition before irrigation. Measures should be taken for the treatment of wastewater before it enters nearby canals or rivers.

Author's Contribution

This work was carried out in collaboration among all authors. Author Tanveer ul Haq provided conception and design of the study. Author Hasnain Raza performed the research, statistical analysis, interpretation of the data and wrote draft of the manuscript. Author's Muhammad Imran and Nabeel Ahmad did critical revision of the Article for important intellectual content. Author Muhammad Bilal revised the article.

Conflict of interest

The authors have declared no conflict of interest.

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