Pak. J. Chem. 12(1-2): 24-36, 2022
ISSN (Print): 2220-2625
ISSN (Online): 2222-307X
Research article
DOI: 10.15228/2022.v12.i01-2.p04

Assessment of water quality and sediment contamination in Mehran University water treatment plant from kalri baghar (KB) feeder river Indus, Sindh, Pakistan

A. Ullah[1], S. S. Hassan*[1], A. Z. Zaidi[1], M. Y. Talpur[2]
[1]Environmental Engineering Department, US Pakistan Center for Advanced Studies in Water (USPCASW), Mehran University of Engineering and Technology, Jamshoro, 76062, Sindh, Pakistan
[2]Dr. M. A. Kazi Institute of Chemistry, University of Sindh, Jamshoro, 76080, Sindh, Pakistan
Corresponding Author email address: sshassan.uspcasw@faculty.muet.edu.pk, ssarahassan@gmail.com

ABSTRACT

The current article discusses the assessment and monitoring of the water and sediments of the Mehran University water treatment plant with exposure to chemical parameters and heavy metals. Water samples were collected from different sources such as raw water sources for Mehran, i.e., KB Feeder, Mehran water treatment plant, and Mehran University distribution system. This study sought to determine the concentration levels of chloride, alkalinity, hardness, TDS, fluoride, sulfate, and nitrate. Water samples were labeled with codes: S1, S2, S3, S4, and S5 for KB Feeder/Intake, Sedimentation tank outlet, Storage tank at a treatment plant, Mehran distribution tank, and IWRM Department, respectively. Titration methods determine the quantitative measure of chloride, alkalinity, and hardness. In comparison, total dissolved substances (TDS.) were determined with YSI. Probe and fluoride, sulfate, nitrate by UV-visible spectroscopy. The AAS technique used to analyzed iron, copper, lead, cadmium, and zinc metals in sediment samples. The observed water quality chemical parameters data were compared with reference values of WHO guidelines and found under WHO guidelines. The contamination and pollution factors of the sediment samples were considerable. This study reflects the water quality in the University premises with different departments, administration, and hostels.

Keywords: Kalri Baghar Canal, Mehran University water treatment plant, water quality, sediment contamination, Pollution load index, Contamination factor

1. INTRODUCTION

Water is an essential need for humans, animals, marine life, agriculture, and industries [1]. The human body contains 60-70% of water [2]. Generally, the drinking water comprises groundwater (aquifers) and surface water (rivers, ponds, lakes, and reservoirs). However, in many places, rivers are the primary source of water for all of their users [3]. The water quality varies from place to place; it depends on the environment of flowing water. Even the quality of the same water changes when it flows from one location to another. If drinking water is contaminated, many waterborne diseases can get into the human body [4]. Drinking water pollution causes diseases like cholera, diarrhea, dysentery, hepatitis, and many others, which cause millions of deaths each year. The focus of this study is a water treatment plant located in the Jamshoro district, where several contaminants have polluted water resources, including Manchar Lake, Phuleli canal, and River Indus [5, 6]. It is reported that the contamination levels are higher than the guideline limits of WHO, Food and Agriculture Organization (FAO), and National Environmental Quality Standards (NEQS) [5, 6].

The source of water for Mehran University, Jamshoro, and its staff colony is the KB feeder (Kalri Baghar) canal that draws water from the Indus River from the right side of the Kotri barrage [7]**(Fig. 1).** The River Indus originates from Tibet, China, and flows across Pakistan before draining into the Arabian Sea (**Fig. 1**). The River plays a vital role in the country's economy [8] by supporting the world's most extensive contiguous irrigation system, the Indus Basin Irrigation System (IBIS). Based on annual discharge and length, the Indus River is ranked as the world's twenty-third biggest and thirty-first longest River of the world, respectively [9]. The glacier and snow-melt largely contribute to the River flows. When water flows, a part of that water percolates into the ground and becomes acidic due to the dissolved geochemical contaminants. Besides natural contamination, water quality also deteriorates through untreated effluent disposal from industries, and therefore, water quality varies from site to site [9]. The effluent from industries contains many pollutants that can impair natural water resources. In rivers, some contaminants remain suspended, and some are dissolved in water. The quantum of water in the Indus River is highly variable, with high summers and low flows in the winter. From July to September, the peak flows cause floods, bringing devastation by inundating the adjacent areas, transporting sediments, and depositing fertile soil in the floodplains. The low periods not only have reduced flows, but during these periods, the pollutant concentration also increases, impairing the water quality further. The KB Feeder originates at the right side of the Kotri barrage [7].

The Kotri barrage is designed for 24500 m^3/s maximum flow [10]. The barrage is placed downstream of the Indus river, about 200 km from the Arabian Sea, where water quality is not pristine like the lower reaches of many other river basins. The upstream reaches of the Indus River are reported to be polluted through the discharge of domestic, industrial, and agricultural effluents. The water quality has deteriorated due to elevated releases of polluted matter into the River. The KB feeder supplies water to Mehran Water Treatment Plant (**Fig. 2**). The water treatment plant that supplies water to the Mehran University of Engineering and Technology (MUET) campus has a design capacity of one million gallons per

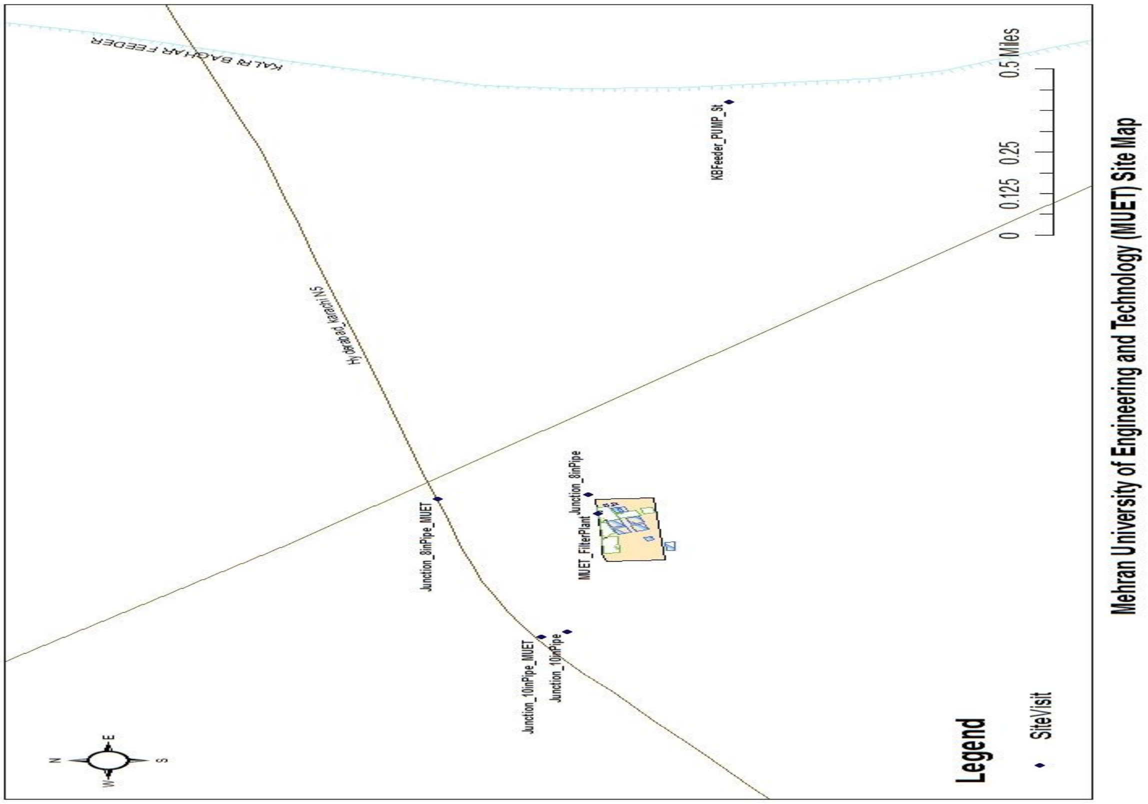


Figure 1 Map of KB Feeder and Water treatment plant

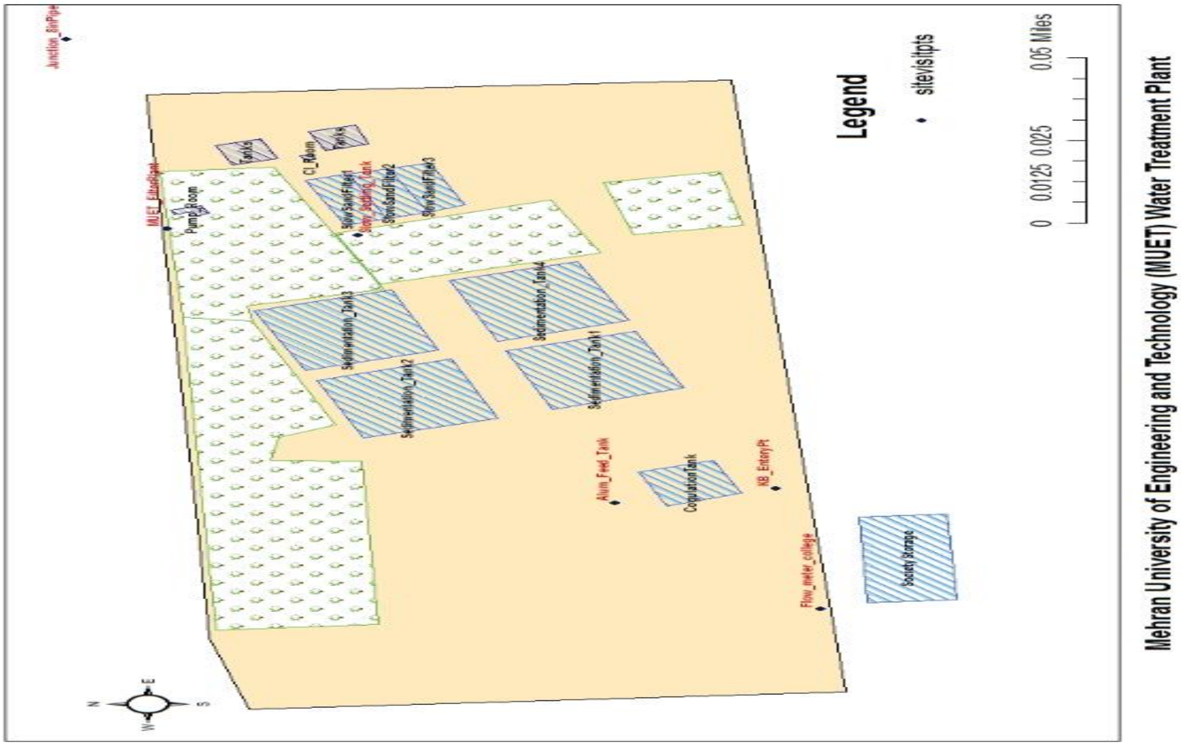
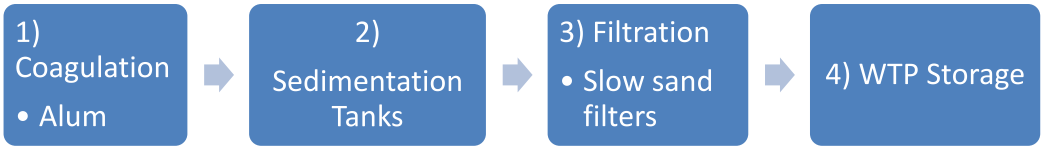


Figure 2: Map of MUET Water treatment plant

day (MGD). Except for a two to three weeks period when the KB feeder canal is closed for repair and maintenance in the winter, the supply continues to its total capacity throughout the year. Several small and big water storage tanks are built. Three primary storage other than, two at the treatment plant facility and another one at the Mehran University near foreign faculty, are installed on the campus. These tanks are used to store and distribute water on the university premises. As mentioned earlier, in the Jamshoro district, a greater extent of the freshwater ecosystem is affected by bad water quality. The water treatment plant study of Mehran university has recently raised awareness and the community's distress on drinking water contamination. In our reported studies (Part—I), we have discussed heavy metals in water samples from different locations, including the KB feeder, i.e., the raw surface water source, water treatment plant (WTP), and its water distribution network serving MUET, Jamshoro [11].

There are no systematic scientific studies conducted on water quality chemical parameters and sediments for these locations. Therefore, the 2nd part of this study is to evaluate water quality chemical parameters (chloride, alkalinity, hardness, total dissolved solids (TDS), fluoride, sulfate, and nitrate) at KB feeder, W.T.P., and water distribution network. Sediment samples from WTP were collected and analyzed for metals (iron, copper, lead, cadmium, and zinc). The water treatment train of the Mehran water treatment plant is illustrated in (**Fig. 2**).



Water treatment train of the Mehran water treatment plant

2. MATERIAL AND METHODS

2.1 Chemicals and reagents

Chemicals used for different analyzing methods are listed here: Manganese sulfate monohydrate, pH 6.86 buffer solution, sodium azide iodide (NaN_3), starch indicator, sodium thiosulfate, ethanol 95%, ammonia, barium chloride crystals, erichrome black-T indicator, EDTA, glycerol, hydrochloric acid, hydrogen peroxide, mercuric chloride, sodium chloride, nitric acid, perchloric acid, potassium chromate, sodium borohydride, sodium carbonate, sodium hydroxide, sodium sulfide inhibitor, stannous chloride (Tin II chloride), sulphanilic acid, sulphuric acid, brucine sulfate, distilled water, Mili-Q water, phenolphthalein indicator, ferrous sulfate, silver nitrate, SPADNS (red zirconium dye solution), potassium nitrate, lead nitrate, copper sulfate, iron chloride, zinc chloride, chromium sulfate, arsenic oxide, and cadmium sulfate.

2.2 Glassware cleaning

The sampling apparatus and glassware were first washed with a solution of detergent powder, followed by their rinsing in distilled water. After that, sampling glassware was further washed with de-ionized water several times to remove any remaining contaminants thoroughly. An oven may also be used for drying sediment samples and glassware at 100°C for a few hours and then cooled for performing laboratory experiments.

2.3 Sampling

Sampling and sample collection need to be performed very carefully to eliminate any chances of external contamination. If sampling is not done with the standard contamination-free methods, results will not be reliable. Therefore, sample collection, preservation, storage, and analysis were carried out subsequently without any delays.

2.4 Sample apparatus

The sampling apparatus comprises glass and plastic, i.e., polypropylene or fluoropolymer (e.g., PTFE). Polyethylene plastic bottles are preferred for sampling for inorganic chemical parameters analysis because of their less inert material. As for organic chemical parameters analysis, glass bottles are preferred for sampling because of minimal adsorption and leaching. The glass bottles for inorganic are not preferred because ions can bind with the active sides of a glass surface. The container must be cleaned and protected from contamination for sample collection and blank analysis.

2.5 Collection method

The samples were collected in 500 ml sampling polyethylene plastic bottles. The collection was done so that minimum interaction could occur with sampling containers. Before sampling, the bottles were cleaned and used very carefully to avoid contamination of the samples.

2.6 Sampling methods

Sampling plays a significant role in getting valid and reliable results without any bias. This study used the grab sampler method to use monthly sampling from the target locations.

2.7 Sampling frequency

Samples were collected every month from June 2016 to May 2017. In June, the samples were collected twice a single month with a gap of ten-fifteen days. This two-time sampling was required to ascertain the extent of variations in water quality within fifteen days. No apparent changes were found within fifteen days. It was decided to collect further samples after a twenty-five- to thirty-day period, which was assumed to be good enough to represent and analyze water quality changes throughout the year. The seasonal is also possible to be ascertained because year-round sampling was conducted.

Hence, a total of thirteen rounds of samples were taken, and in each round, five different locations were selected for sampling. Initially, eight sites were chosen for reduced to five locations after the second sampling round. This reduction in sampling location was made after observing negligible variations in the parameters' concentrations between a few locations. Each sample round is collected between 9:00 am to 1:00 pm and preserved and stored to avoid contamination at field locations within these four hours. These samples were analyzed in the following hours in the laboratory without any delay. Three bottles were collected from each location. Special care and full safety precautions were taken for sample handling and transportation to prevent contamination and any other accident.

2.8 Sampling sites and justification

Sampling sites were selected in such a way to cover all critical locations from the raw water source to the end-user location after the treatment of water. GPS coordinates of these sites were recorded and mapped. Before sampling, the checklist for sampling SOPs (standard operating procedures) was verified, and every needed item, equipment, and accessory was procured. Every sample was collected with complete standard protocols to prevent contamination. The sampling frequency of once a year was dictated by the annual maintenance of the water treatment plant only when the sediments could be collected. Sediment samples were collected, preserved, and analyzed without any delay to avoid contamination. The environment of the water treatment plant, condition of the treatment process, coagulation tank with bushes, and sedimentation tank maintenance was considered(excavation near sedimentation tank for removing sediments settled down).

2.9 Samples preservation, labeling, storage, and transportation

Before sampling, preservative chemicals must be taken along with sample preservation. Before adding preservatives, samples must be filtered with a vacuum filter assembly or pressure filter gun. After filtration, samples should be preserved for chemical parameters analysis of dissolved solids. Preservation must be done as soon as possible to avoid changes in samples due to environmental effects.

The labeling of the samples must be carried out at the sample collection location to avoid any mistakes. Labeling must contain the date of sampling, round of sampling, location of sampling, and parameters for which the sample is collected. After collection, labeling, and preservation, samples must be stored in an icebox for transporting to the laboratory as soon as possible. The icebox should be clean, and contamination must be avoided.

2.10 Handling of water Samples

The 500 ml pre-sterilized polyethylene bottles were previously soaked in nitric acid for 24 hours and then rinsed with distilled water. The bottles were handled carefully to avoid trapping air bubbles. The water samples were sealed with polyethylene plastic double zip lock bags with specific codes and labels and stored in a refrigerator at 4° C for further analysis.

2.11 Handling of sediments sample

The sample of settled sediments was collected from the sedimentation tank during the maintenance time of the water treatment plant at MUET, Jamshoro (WTP). The sedimentation tanks are closed for one to two weeks a year to remove the settled sediments from the sedimentation tank.

The sediment sample was taken by the auger, and the sample was collected in sample polyethylene bags and then enclosed into zipping lock bags with a proper label. These sediment samples were stored in the icebox immediately after sampling and stored in the refrigerator. Humidity in sediment samples may change the concentration due to the presence of some microbial contaminants. Therefore, it is recommended to store sediment samples refrigerated (< 6°C) as soon as possible before analysis.

2.12 Analysis methods

The chemical parameters like chloride, total alkalinity, total hardness, sulfate, nitrate, fluoride, and total dissolved solids were analyzed using international standard methods. The procedures for analyzing water quality chemical parameters in the laboratory are given below.

2.13 Equipment handling and calibration

The equipment required for the study of parameters must be calibrated before analyzing. According to the instrument's manual instructions and for accuracy of results, it is recommended that before the test, the equipment must be calibrated.

2.14 Analysis of chloride

Chloride is the common anion found in water and sewage. The official international method for analyzing chloride is APHA 4500B, also known as the Agentrometric method [12]. More explanation of the technique is explained in the subsequent sub-sections for both clear and turbid samples.

2.14.1 Procedure for clear samples

Place 100 ml of the sample or an aliquot containing not more than 10 mg chloride in a porcelain basin of about 300 ml capacity. If the pH of the sample is in the range of 7-9.5, it can be directly titrated. If the pH is not in the range, adjust the pH by using sulfuric acid or sodium hydroxide. Then add 1.0 ml potassium chromate indicator solution. Titrate the solution with Silver nitrate followed by continuous stirring till a slight perceptible reddish coloration persists. Conduct a blank by placing 100 ml of distilled water instead of a sample. For this method, 0.2 to 0.3 ml blank is generally used.

2.14.2 Procedure for colored and turbid sample

In a highly colored sample, pour 3 ml of aluminum hydroxide to calculate the volume of the sample in a beaker. Mix well and let it settle. The precipitates are filtered and washed with distilled water. Combine the filtrate and washings (get the pH within the range 7-9.5, if necessary) and titrate.

2.14.3 The formula for chloride calculation

If the normality of the $AgNO_3$ solution is exactly 0.0282 N, then chloride (mg/l) is calculated by using equation 1.

$$\text{Chloride } (Cl^{-1}) \text{ mg/L} = (\text{ml } AgNO_3 \text{for sample} - \text{ml } AgNO_3 \text{ for blank}) \times 1000 \quad \text{Equation (1)}$$

2.15 Analysis of alkalinity

The international standard method (APHA 2320B)[12] was used to measure the alkalinity of samples, which measures the capacity of an aqueous solution to neutralize an acid.

2.15.1 Procedure

Take 25 ml, 50 ml, or appropriate volume of drinking water sample from different sources in 250 ml capacity of the conical flask. Pour 50 ml distilled water to adjust the volume. Add the phenolphthalein indicator solution. When pink color appears, then titrates with 0.02 N sulfuric acids (pH 8.3) until the solution becomes colorless.

2.16 Total alkalinity

Put three drops of the mixed indicator to the solution inside which phenolphthalein alkalinity has been determined and titrate against 0.02 N sulphuric acids (to pH 4.6) until the light pink color appears.

2.17 Analysis of total hardness

Hardness is caused by calcium and magnesium ions. The international standard method determines the total hardness (US-EPA 130.2) [13], also known as the EDTA titrimetric method or titration method.

2.17.1 Procedure

Put 10ml volume of sample (filtered if necessary) within a conical flask and dilute to 20ml. Add 1-5 drops of indicator used as Erichrome Black-T before titration. Titrate with standard EDTA solution slowly, until reddish tings appear, and add the last few drops inside 3-5 seconds. The solution will be blue at the endpoint. After adding buffer, the whole titration procedure should be completed within 5 minutes.

2.17.2 Soft and hard water WHO guideline values

Soft water has a WHO guideline value of 0-20 mg/l. Whereas, for hard water, the WHO guideline value is 80-120 mg/l.

2.18 Analysis of sulfate

Sulfate naturally occurs in water due to leaching from gypsum and other common minerals. The international standard method for sulfate analysis is ASTM D516-16 [14]. It is also known as the Turbidimetric method. UV visible spectroscopy is used for detection.

2.18.1 UV-Visible spectroscopy

This equipment is used to detect sulfate and other parameters in water; for each parameter, the reagents may change. The blank solution and sample solution are both run simultaneously. Standard curves are prepared for concentration and absorbance.

2.18.2 Identity

In the number of minerals, sulfate naturally occurs, including epsomite ($MgSO_4 \cdot 7H_2O$), gypsum ($CaSO_4 \cdot 2H_2O$), and barite ($BaSO_4$). The water flows and dissolves minerals from mineral content. The everyday average sulfate intake by water, food, and the air is around 500 mg, whereas food also contributes as a source of sulfate. Though, in some areas, drinking water stores high levels of sulfate, the primary source for intake of sulfate in drinking water. This method was used successfully with drinking, ground, and surface waters. The turbid metric test method covers the determination of sulfate ion ($SO_4^{2-)}$ in 1 to 40 mg/l from water samples.

2.18.3 Apparatus and equipment

The presence of sulfate peak is determined in the range of 420 nm from the spectrophotometer device. Beakers, volumetric flasks, pipette, conical flasks, magnetic stirrer, and microbalance are used along with the device.

2.18.4 Procedure

A fixed volume of 25 ml of sample is taken in a conical flask. Then add 1.25 ml of conditioning reagent; 1.25ml is added to the flask sample, and the magnetic stirrer is used for constant stirring. Add Barium chloride 0.05 g and start a stopwatch. Absorbance was recorded on UV-spectrophotometer at 420 nm after 30 sec up to 4 min with an interval of 30 sec. The same procedure was used for blank and standard. The standard calibration curve was prepared to calculate the amount of sulfate.

2.18.5 Calibration

Different concentration of sulfate standards solution with 0.0, 2.0, 5.0, 10.0, 15.0, 20.0, 30.0, and 40.0 mg/l (ppm) and diluting with 100 mL deionized water in 100 ml volumetric flasks were prepared for calibration.

2.19 Analysis of nitrate

The international standard Brucine method or colorimetric method US-EPA 352.1 [13] was used to determine the nitrate in samples as nitrate is the end product of the aerobic stabilization of organic nitrogen.

2.19.1 Procedure

The simplest brucine method was followed through a UV-Visible spectrophotometer for the quantitative analysis of nitrate (NO_3^-). Transfer 12 ml of sample to 25 ml flask, add 2.0 ml NaCl solution and mix thoroughly. Added 10 ml of the sulphuric acid solution and 0.5 ml brucine reagent makeup volume up to 25 ml and left it for 20 min to develop color. Finally, take absorbance at 410 nm using a spectrophotometer. Use the same standard method for blank as well. Construct a calibration curve by standards to calculate the amount of nitrate. The absorbance for nitrate ion was observed at 410 nm by spectrophotometer.

2.19.2 Expected levels

Nitrate level (NO_3^-) is generally below 1 mg/l in unpolluted waters, and in freshwater, it ranges up to 0.1 to 4 mg/l. The nitrate level in sewage treatment plants is more than 20 mg/l.

2.20 Analysis of fluoride

Fluoride naturally occurs in soil, water, food, and minerals such as fluorapatite and fluorite. The international methods for analysis are SPADNS and Red Zirconium Dye Methods [15, 16].

2.20.1 method

In the reagent Red Zirconium Dye, Zirconium dye is added to the sample. Fluoride reacts with it. The dye strength depends on the fluoride concentration; lighter dye indicates higher fluoride concentration. Absorbance is measured at 570 nm. Standard samples are prepared and run, and absorbance value is obtained of known standards from the calibration curve. Run the samples and read the fluoride values of each sample by knowing their absorbance and reading their concentration from the calibration curve.

2.21 Sediments sample preparation for atomic absorption spectroscopy analysis

Sediments sample must be converted into liquid form so that they can also run efficiently, and the concentration of metals can be detected easily.

2.21.1 Sediments sample preparation

The sediment sample needs to be digested and converted into the liquid form for running in the atomic absorption spectroscopy. The international standard method for sediment digestion is acid digestion of solids by the US-EPA method-3050B [17]. For digestion, take 1-2 g of the wet sediment sample. For this purpose, the sediment sample is precisely weighed and put into the 250 ml volumetric flask. The first step is to heat the 10 ml sample of 1:1 HNO_3 at 95°C on a magnetic stirring hot plate without boiling. After cooling the sample, it is refluxed with repeating additions of concentrated $HNO_{3,}$ awaiting no brown smoke given off by the sample. Then the solution is allowed to evaporate until the volume reduces to 5 ml. Without allowing any losses, add 2 ml de-ionized water and take 3 ml H_2O_2 30 make up volume up to a maximum of 10 ml. In the second step, the mixture is refluxed through concentrated 10 ml of HCl for 15 min at 95°C. The digestate was filtered entirely using filter paper known as Whatman No. 41, then diluted to 100 ml with de-ionized water, and then analyzed for heavy metals using flame atomic absorption spectrometry model number AI-1200. The reagent blanks were monitored throughout the analysis, and they were used to correct the analytical results [18].

2.22 Analysis of metals by atomic absorption spectroscopy

2.22.1 Analysis of trace metals Fe, Cd, Pb, Cu, Zn.

Iron, cadmium, lead, copper, and zinc are toxic elements if their concentrations increase in sediments like lead is toxic even at a low concentration. The method used for Fe, Cd, Pb, Cu, and Zn is APHA 3111A [19], by using flame atomic absorption spectroscopy model AI 1200.

2.22.2 Instruments and apparatus

The atomic absorption spectroscopy method was used to analyze the metals in which gases are used (fuel gas Acetylene, Oxidant gas Air). The apparatuses include beakers, volumetric flasks, pipettes, conical flasks, and filter paper.

2.22.3 Procedure

The standard solutions are prepared for 2, 4, 6, 8, and 10 ppm. The samples are pre-concentrated after filtration. Set the AAS, flame beam, and hollow cathode lamp for excellent efficiency. The standard solutions of 2, 4, 6, 8, and 10 ppm are run for the calibration curve of analyzing metal. The absorbance was recorded by AAS, and a calibration curve determined the concentration. The pre-concentrated samples with acidic are run, and their absorbance is obtained. With the help of the calibration curve, the concentration is obtained against the absorbance [18].

Note: The samples are pre-concentrated after filtration, and their volume is reduced ten times by using a hotplate.

2.23 Pollution load index (PLI.)

The index values were collected to ascertain heavy metals' load index and contamination level. Pollution Load Index (PLI) is an assessment of sediment quality [20] (equation 2). The cumulative perspective is used for quantifying the PLI of all metals.

$$PLI = (CF_1 \times CF_2 \times CF_3 \times . . . \times CF_n)^{1/n} \qquad \text{Equation (2)}$$

Where CF_{metals} = factor for contamination of each metal.

2.24 Contamination factor

The contamination factor is the ratio of concentrations of each metal to the baseline value [20]. The Baseline or background value represents the level of metals in the soil before industrialization, as shown in equation 3.

$$CF_{metals} = C_{metals}/C_{background}$$

Equation (3)Where, C_{metals}= Concentration of metal

$C_{background}$= background concentration of metals.

3. RESULTS AND DISCUSSION

3.1 Variation in concentration of chloride in water

The chloride concentration in water varies throughout the year, while from Nov-Dec, 2016, and March-May, 2017, chloride concentrations remained high in water. According to the World Health Organization, the guideline limit for chloride is 250 mg/l [21], and the highest observed chloride concentration was about 200 mg/l, as shown in the radar graph (**Fig. 3)**. Therefore, these high concentrations are still within the safe limit and cannot be considered toxic. If the concentration exceeds the WHO guideline limit, the aesthetic quality of water may change.

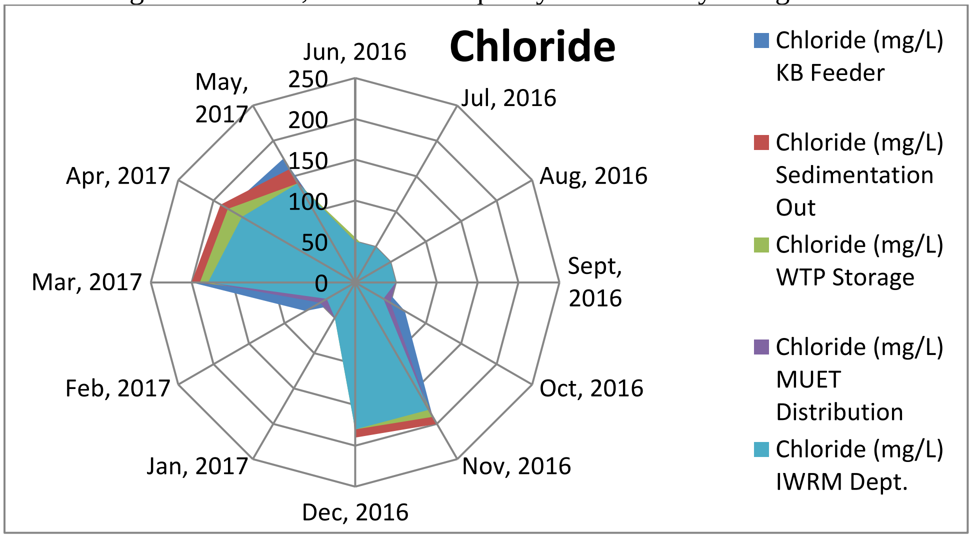


Figure 3: Variation in chloride concentration in water from June 2016 to May 2017

3.2 Variation in concentration of total alkalinity in water

Alkalinity is analyzed for samples from all locations, i.e., S1 to S5. For alkalinity, the samples were collected for the entire year, i.e., from June 2016 to May 2017. The alkalinity concentration from all sixty-five samples ranged from 5 to 95 mg/l. For all 65 samples, the average alkalinity and standard deviation are 31 mg/l and 28.07 mg/l, respectively. Although the average alkalinity value of 31 mg/l is above the minimum permissible of limit 20 mg/l and below the maximum permissible limit of 120 mg/l as suggested by WHO, the standard deviation shows a broader spread of data that indicates that many individual sample values are falling way below the minimum permissible limit. However, on the higher side, almost all samples comply with the higher permissible limit. Alkalinity concentration is shown in the radar graph (**Fig. 4**).

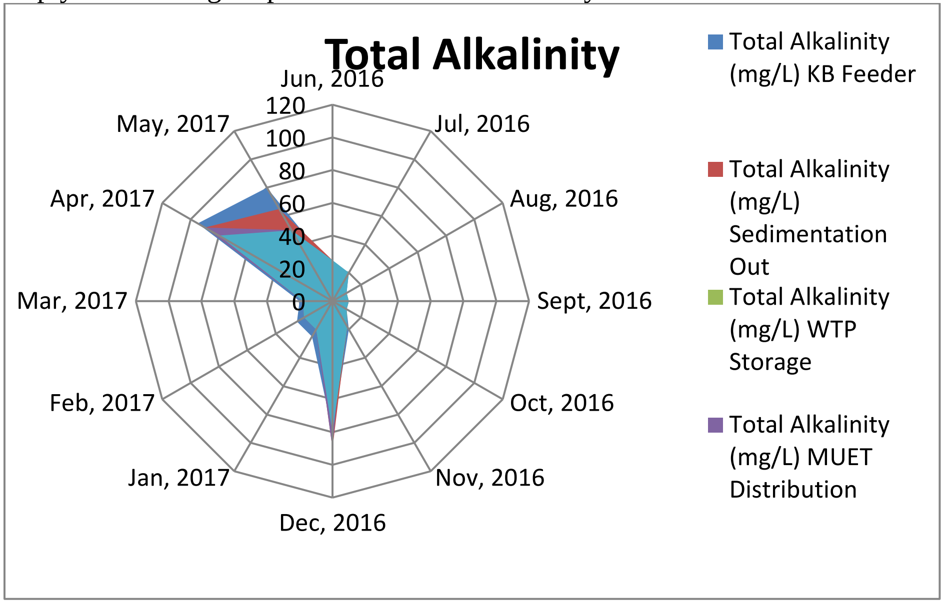


Figure 4: Variation in Total Alkalinity concentration in water from June 2016 to May 2017

3.3 Variation in concentration of total hardness in water

For total hardness, the water samples were collected from five locations, and each location sample was collected 13 times from June 2016 to May 2017. Total hardness concentration ranged from 50 to 240 mg/l, whereas the mean and standard deviation in the observed concentration of total hardness for 65 samples is 98.8 mg/l and 47.8 mg/l. In Nov 2016 and March 2017, the observed total hardness concentration was between 200 mg/ and 250 mg/l. WHO guideline limits for total hardness in drinking water are 200 mg/l. If the concentration increases the WHO guideline limits, the aesthetic property of water may change. Therefore, it is suggested that the total hardness in drinking water should be below 200 mg/l. The total hardness of each location for the entire year is reported (**Fig. 5**).

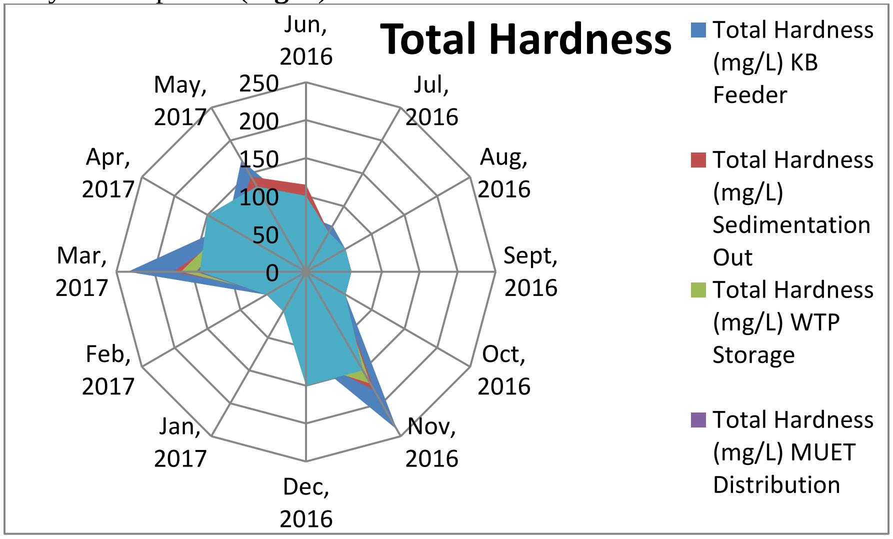


Figure 5: Variation in Total Hardness concentration in water from June 2016 to May 2017

3.4 variation in the concentration of total dissolved solids (TDS.) in water

Sometimes, only total dissolved solids are tested for analyzing the water quality in developing countries. If TDS concentration is found above the WHO guideline limits, the other parameters must be tested before the water is used for drinking. The WHO guideline limit suggested for total dissolved solids in drinking water is 1000 mg/l [22]. The observed concentration of total dissolved solids ranged between 114.3 mg/l to 737.1 mg/l for 65 water samples. The mean observed concentration and standard deviations are 371.9 mg/l and 229.48 mg/l, respectively. The highest concentrations of total dissolved solids were observed in Nov-Dec 2016 and March-May 2017, with concentrations ranging between 600-750 mg/l. However, the highest concentration of TDS. was still within safe limits, i.e., within WHO guideline limits (**Fig.6)**.

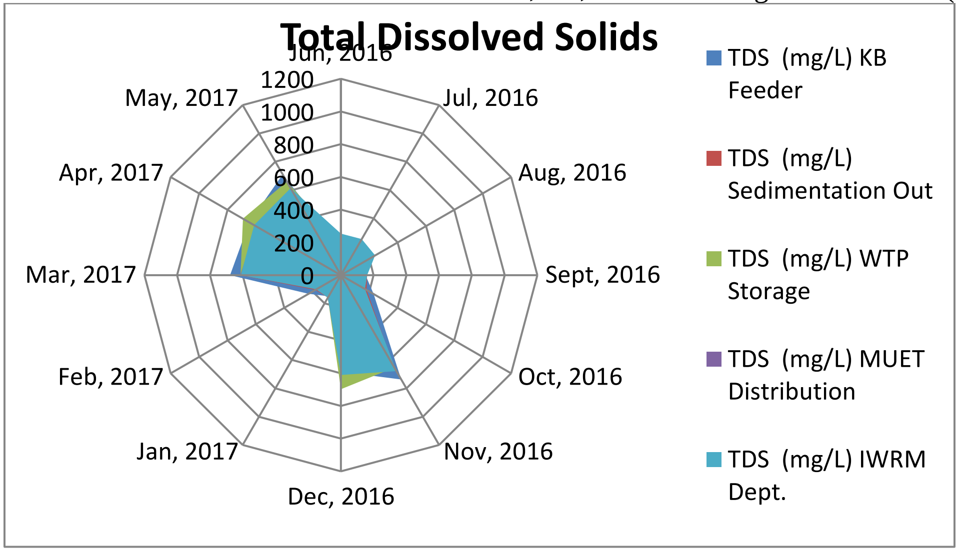


Figure 6: Variation in Total Dissolved Solids concentration in water from June 2016 to May 2017

3.5 Variation in concentration of fluoride in water

Fluoride is a contaminant that affects bones and skeletal structures. The world health organization declared that in the drinking water, fluoride concentration should not be greater than 1.5 mg/l. The observed fluoride concentration in the drinking water ranged between 0.039 mg/l to 0.46 mg/l. The mean and standard deviation values of 65 samples are 0.26 mg/l and 0.098 mg/l, respectively. **Fig. 7** shows the fluoride test, suggesting that the highest fluoride concentration was observed in Nov 2016 and May 2017, about 0.45 mg/l. The fluoride in the drinking water of Mehran University is within the WHO guideline limits, and therefore it is not hazardous.

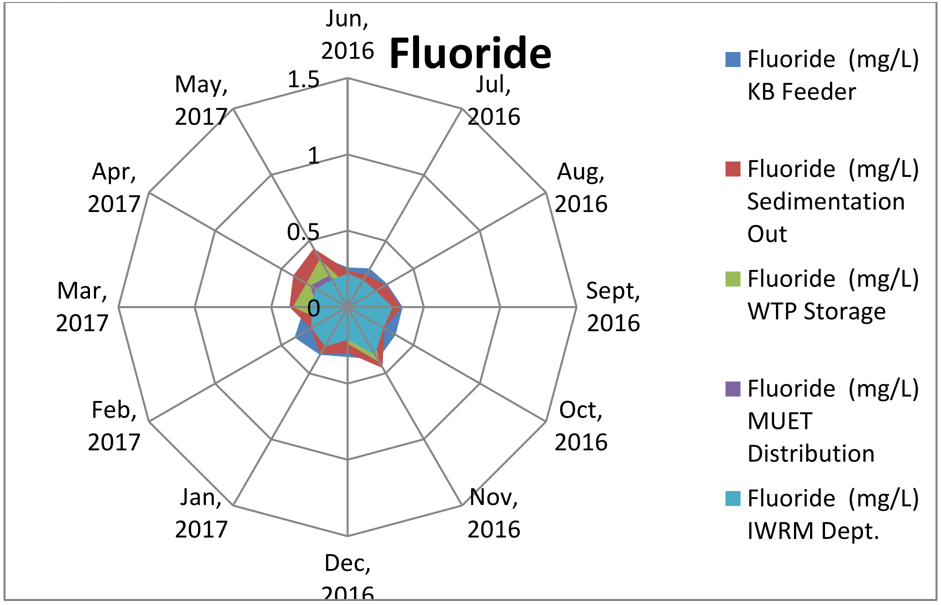


Figure 7: Variation in Fluoride concentration in water from June 2016 to May 2017

3.6 Variation in concentration of sulfate in water

The sulfate concentration in the drinking water can change the taste of water. If the concentration level increases, it may become hazardous to human health. The observed sulfate concentration in drinking water for 65 samples ranged between 23 mg/l to 75.73 mg/l. The mean and standard deviation for 65 samples is 47.24 mg/l and 12.15 mg/l, respectively. The world health organization suggested a safe limit of 400 mg/l for sulfate. The Mehran University drinking water contains sulfate within the safe range. The radar graph reports that sulfate's highest concentrations were observed in June 2016, Nov 2016, March 2017, and April 2017 (**Fig. 8)**.

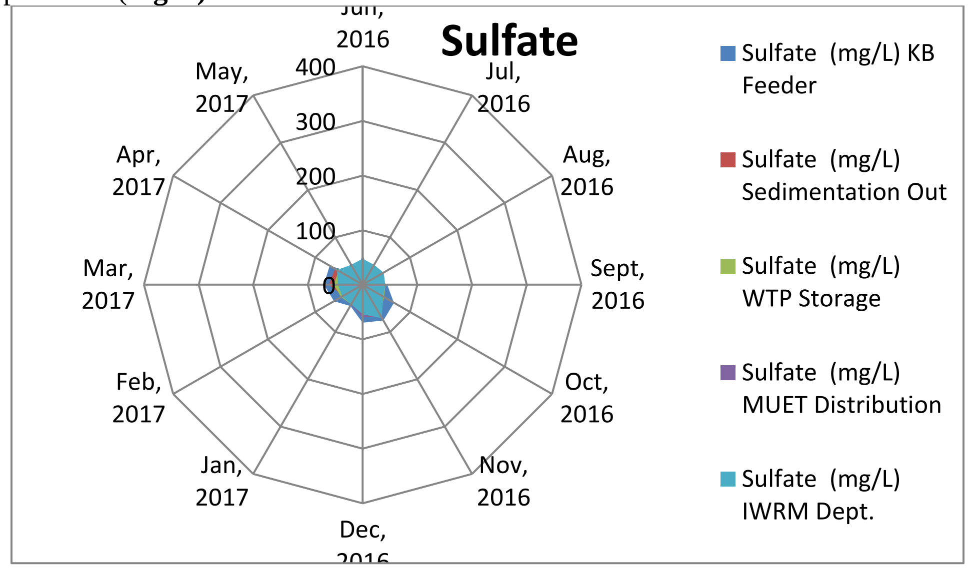


Figure 8: Variation in Sulphate concentration in water from June 2016 to May 2017

3.7 Variation in concentration of nitrate in water

Nitrate in the surface water is found in low concentrations. The drinking water with nitrate concentration is hazardous for human health, as surface waters are the primary source of drinking water. The natural concentration of nitrate was generally found low in surface waters. The highest concentration in surface water was found at KB Feeder in Nov 2016 and April 2017—16 mg/l and 15.3 mg/, respectively; here, as at the other four locations, nitrate was found in low concentrations. The WHO guideline limit is 50 mg/l for nitrate [22]. These observed values are within safe limits (**Fig.9)**.

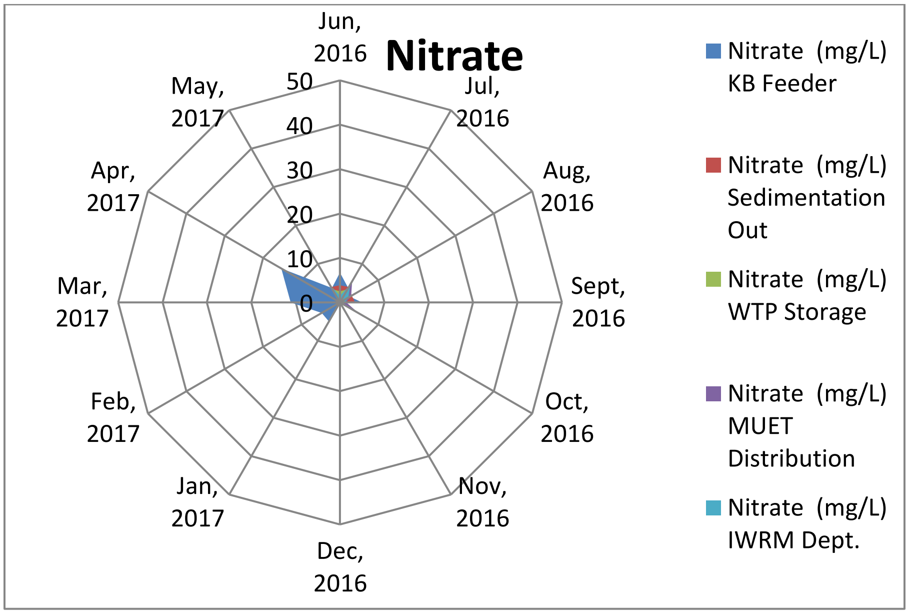


Figure 9: Variation in Nitrate concentration in water from June 2016 to May 2017

3.8 Heavy metals concentration in sediments

The mean values of metals are shown in **(Table 1).** The sediment sample is collected from the water treatment plant's sedimentation location. The guideline values from the Sindh Environmental Protection Act (SEPA), CEPA, and Wisconsin department of natural resources, US, were compared. A total of five samples were collected from the sedimentation tank for which the means, standard deviations, and ranges of metals in sediments were calculated. According to the standard guidelines, the observed metal concentrations of zinc, copper, iron, cadmium, and lead in the sediments are not toxic.

Table-1: The mean concentration of metals in sediments of Mehran water treatment plant.

Parameters	**mg/kg DS**		**Guidelines (mg/kg DS)**		
	Mean ± SD	Range	SEPA	CEPA	USEPA
Zinc	34 ± 4	30 – 38	150	123	120
Copper	7 ± 3	4 – 11	15	35.7	32
Iron	44 ± 6.2	37 – 49			
Cadmium	0.4 ± o.1	0.1 – 0.5	0.8	0.6	0.99
Lead	3 ± 1.2	1 – 4	50	35	36

*SEPA= Sindh Environmental Protection Act; CEPA=
*USEPA= United States Environmental Protection Act

3.9 Contamination factor and pollution load index in sediments

The contamination factors (C.) obtained for Zn, Cu, Fe, Cd, and Pb are shown in **(Table 2).** If CF is greater than 1, it represents low contamination; if CF is between 1 and 3, then it is moderately contaminated; if CF is between 3 and 6, then it is considered contamination, and if CF is greater than 6, then it is highly contaminated [23]. **Table 2** represents that sediments were low contaminated by iron and lead, whereas moderately contaminated by zinc, copper, and cadmium.

The pollution load index (PLI) was calculated, and its value is 0.433. If PL. is greater than 1, then pollution occurs; if PLI is less than 1, then it is unpolluted [24]. Less than 1 value of the pollution load index is obtained. Therefore, the sample is uncontaminated (**Table 2**).

Table-2: Contamination factor for all parameters.

Parameters	**Mean**	**Background values**	**Contamination factors(CFs)**
Zinc	34	20	1.7
Copper	7	4	1.75
Iron	44	3800	0.011579
Cadmium	0.4	0.3	1.333
Lead	3	9	0.333333

3.10 Correlation of parameters

Correlation between chemical parameters of water quality such as chloride, alkalinity, total hardness, fluoride, sulfate, nitrate, and TDS are shown in (**Table 3**), in which the level of significance is calculated. If a value is more significant than 0.5, then the parameter has a higher significance relationship with the corresponding parameter; if the value lies below 0.5, it has a lower significance level. The significant correlation between the two parameters indicates the interdependency of these water quality chemical parameters.

Table-3: Correlation of different chemical parameters.

	Chloride	Alkalinity	Total Hardness	TDS	F	Sulfate	Nitrate
Chloride	1						
Alkalinity	0.62	1					
Total Hardness	0.85	0.36	1				
TDS	0.97	0.65	0.83	1			
F	0.45	0.24	0.40	0.46	1		
Sulfate	0.54	0.25	0.53	0.46	0.32	1	
Nitrate	0.01	-0.01	0.25	0.07	0.16	0.16	1

4. CONCLUSIONS

Seasonal variations were observed in the pollutant concentrations. Still, a majority of the samples at various sampling locations satisfied the WHO guideline limits for chloride (250mg/L), total hardness (200mg/L), total dissolved solids (1000mg/L), fluoride (1.5mg/L), sulfate (400mg/L), and nitrate (50mg/L). Therefore, it is concluded that the drinking water of Mehran University is safe for drinking purposes as far as the chemical parameters are concerned because the concentrations of water quality parameters (chlorine, total hardness, total dissolved solids, fluoride, sulfate, and nitrate) are under the permissible guideline limits suggested by WHO. The pollution load index for sediments metal samples (Zn, Cu, Fe, Cd, and Pb) represents that sediments are unpolluted, whereas the contamination factor represents that the sediments metal samples are moderately contaminated. There is a further need to analyze bacterial contamination before declaring the drinking water safe for human consumption.

CONFLICT OF INTERESTS

Authors have declared that there is no conflict of interests

ACKNOWLEDGMENTS

The authors would like to thank "US.-Pakistan Centre for Advanced Studies in Water (USPCAS-W), Mehran University of Engineering and Technology (MUET), Jamshoro, Sindh 76062, Pakistan", for providing the financial support to carry out this research work and also thanks for providing a pleasant environment for research work. This research work reported under the "Mehran clean water" project was funded by USPCAS-W, MUET, Jamshoro, Sindh, Pakistan, and the University of UTAH, UTAH, USA.

REFERENCES

1. D. Pimentel, B. Berger, D. Filiberto, M. Newton, B. Wolfe, E. Karabinakis, S. Clark, E. Poon, E. Abbett, S. Nandagopal. *BioSci.* 54, 909**. (2004).**
2. WHO, Nutrients in drinking water. WHO Press, Geneva **(2005).** https://www.who.int/water_sanitation_health/dwq/nutrientsindw.pdf.
3. D. J. McCabe Rivers and Streams: Life in Flowing Water. Nature education Knowledge 2010;1(12):4.https://www.researchgate.net/publication/236596782_Rivers_and_Streams_Life_in_Flowing_Water .
4. M. Haseena, M.F. Malik, A. Javed, S. Arshad, N. Asif, S. Zulfiqar, J. Hanif. *Environ. Risk Assessm. Remed*. 1(3):16. **(2017).**
5. G.M. Mastoi, S.G.S. Shah, M.Y. Khuhawar. *Environ. Risk Assessm. Remed*. 141(1)287**. (2008).**
6. T.M. Jahangir, M.Y. Khuhawar, S.M. Leghari, M.T. Mahar, K.P. Mahar. *Arab. J. Geosci*. 8: 3259**. (2015).**
7. A.M. Phul, B.K. Lashari, K.Q. Laghari. *Mehran Univ. Res. J. Eng. & Technol*. 29(4)689. **(2010)**.
8. F. Jabeen. A.S. Chaudhry. *Environ. Risk Assessm. Remed*. 166 (1-4) 641. **(2010).**
9. A. Khan, A.M. Yousafzai, M. Latif, A. Rehman, Q. Khan, A. Zaib, A. Ullah, A.A. Sthanadar, I. Haq, A. Aziz. *Int. J. Biosci*. 4(2)28. **(2014).**
10. V.K. Dewani, I.A. Ansari, M.Y. Khuhawar, M. J. Kazi. *Chem. Soc. Pak*. 24(3):190.**(2002).**

11. A. Ullah, S.S. Hassan, A.K. Ansari, N.B. Jalbani, R.B. Mahar, Z. Ahmed, R. Z. Brohi, M.Y. Talpur. *Int. J. Environ.* Sci. Technol. 16(11)6785. **(2019).**
12. A. D. Eaton, L. S. Clesceri, A. E. Greenberg. *Am. Public Health Assoc.*, **(1995).**
13. US-EPA, E.P.A./600/4-79/020 **(1983).**
14. American Society for Testing and Materials (ASTM) Official method (2016). Standard Test Method for Sulfate Ion in Water (ASTM D516-16), ASTM International, West Conshohocken, PA.
15. American Water Works Assn, and Water Pollution Control Federation, 1985. Standard Methodsf or the Evaluation of Water and Wastewater, 16th ed. Washington, DC; American Public Health Assn, I985, 352-61.
16. HACH, Co: DR 100 Colorimeter Manual. Loveland, Colorado, 3-21.**(1983).**
17. Edgell, K., USEPA Method Study 37 – SW-846 Method 3050 1988, EPA Contract No. 68-03-3254. **(1988).**
18. M.S. Islam, S. Han, M.K. Ahmed, S. Masunaga. *J. Water Environ. Technol*. 2014; (12):109. **(2014).**
19. APHA/Awwa/W.E.F., Standards methods for examination of water and wastewater, 20th edn. American Public Health Association, Washington. **(1998).**
20. H.S. Kouchesfehani, S.N. Azizi. *J. Coast. Zone Manag*. 22 (2)1-7. **(2019).**
21. WHO drinking water standards, WHO's guidelines for drinking-water quality, are the international reference point for standard setting and drinking-water safety, Geneva. **(1993).**
22. WHO (1996). Guidelines for drinking-water quality, 2nd ed. Vol. 2, Geneva. **(1996).**
23. M.I. Ahamad, J. Song, H. Sun, X. Wang, M.S. Mehmood, M. Sajid, P. Su, A.J. Khan. *Int. J. Environ. Res. Public Health* 17(3)1070. **(2020).**
24. M. Shirani, K.N. Afzali, S. Jahan, V. Strezov, M.S. Sardo. *Sci. Rep*. 10:4775. **(2020).**

Received: 3rd March 2022 **Accepted: 19th March 2022**