Journal of Tropical Pharmacy and Chemistry

Journal homepage: https://jtpc.farmasi.unmul.ac.id

Assessment of Physico-Chemical Properties of Drinking Water in District Mardan, Khyber Pakhtunkhwa, Pakistan

Sayed Suliman Shah[1,*], Dawood Shah[1], Mujahid Islam[2], Wajahat Ali[3]

[1]Department of Chemistry, Government Degree College No. 2 Mardan, Abdul Wali Khan University Mardan, Khyber Pakhtunkhwa, Pakistan
[2]Department of Physics, Faculty of Physical and Numerical Sciences, Abdul Wali Khan University Mardan, Khyber Pakhtunkhwa, Pakistan
[3]Department of Forestry and Wildlife Management, The University of Haripur, Khyber Pakhtunkhwa, Pakistan
*Corresponding author: suliman191@yahoo.com

Abstract

The issue of water quality is becoming ever more serious as freshwater resources are severely degraded across the world. Water quality in rivers, streams, lakes, and subterranean aquifers is deteriorating, posing a threat to human life and ecological sustainability. A proper study of the physico-chemical properties of the water samples provide insight into the quality of life in a specific region, as poor water quality not only affects the aquatic life but the surrounding ecosystem as well. In the present study, 30 different water samples were collected from different regions of district Mardan and they were analyzed for their physico-chemical properties such as pH, total suspended solids, conductivity, total dissolved solids, nitrates concentration, sulphates concentration, chlorides concentration, dissolved oxygen, and biochemical oxygen demand. The results of the analysis show that most of the parameters have significantly higher values than the WHO permissible limits. From the analysis of water samples, the researchers have been able to designate the study area with poor water quality and to propose future advice for sustaining the water quality in the region.

Keywords: Water quality, Physico-chemical properties, Drinking water, Nitrates, Chlorides, BOD

Submitted: 20 May 2022 **Revised**: 18 August 2022 **Accepted**: 28 August 2022

DOI: https://doi.org/10.25026/jtpc.v6i2.436

1 Introduction

The prosperity of human communities has been inextricably related to the availability of water.The quality of our lives is directly or indirectly affected by the quality of the water that we use in our daily life [1]. Clean water is essential to health, economy, and communities, as its availability and cleanliness are among the basic human needs [2]. Almost, two-third (71%) of the earth's surface is concealed by water [3], but our water supplies are limited, as 97.5% of the earth's total water is saline and only 2.5% is considered freshwater, but over two-thirds (%) of the freshwater is locked in the polar ice caps and glaciers. This leaves only 0.5% in our rivers, lakes, and groundwater for agricultural, industrial, and for drinking purpose [4, 5].

However, water is not clean and safe for human consumption in many parts of the world. Freshwater resources and aquatic habitats are being significantly damaged around the world, therefore water quality is becoming extremely critical [6, 7]. The degradation of the water quality in rivers, streams, lakes, and underground aquifers is threatening human lives and the integrity of valuable ecosystems [8]. It is also jeopardizing the availability of clean water for human and environmental needs. Due to the increase in the human population, over construction, industrialization, and overuse of fertilizers, as well as natural contamination, the quality of the freshwater is under threat [9]. According to the World Health Organization (WHO), only 0.007% of the world's total water supply is safe for consumption, and this minuscule amount must be shared by more than seven billion people [10]. Even, this water is not evenly distributed around the world, as 1.2 billion people live in water-scarce areas such as the Southwestern United States, India, Spain, North Africa, Australia, and Northern China [11, 12]. Lack of access to clean water is responsible for the deaths of millions annually. Water pollution adds to a global "water crisis" by reducing the availibilty of freshwater resources to humans and ecosystems alike [13]. Freshwater scarcity is currently affecting both developing and developed countries, including India, China, and several African nations. According to a recent UN survey, water stress could affect two-thirds of the world's population by 2025. Water scarcity can take the form of physical scarcity, in which water supplies are limited and needs are not met, or economic scarcity, in which water is available but no means/infrastructure exists to supply it in the amount and quality required [14]. Every year, around 5 million people, mostly the poor and children die from water-borne diseases [15].

The physico-chemical and biological aspects of water quality can be used to analyze it for drinking. Natural and inorganic chemicals pollute water, causing environmental and human health issues. Diseases like cholera, diarrhea, typhoid, and parasitic worms are all hazards of consuming contaminated water. As a result, there is a growing focus on aspects of drinking water quality and guidelines, which are based on the establishment of drinking water criteria [16]. Water quality is mainly judged by its physico-chemical parameters such as pH, temperature, dissolved solids, suspended solids, total alkalinity, chemical oxygen demand, biological oxygen demand, and conductivity, etc. [17]. It is essential to know the quality of water for protecting our health and well-being that is why it must be tested for the presence of known and emerging contaminants.

The present study was thus carried out to estimate the quality of drinking water in district Mardan, Khyber Pakhtunkhwa Pakistan. In the present study, 30 different water samples were collected from different regions of district Mardan and were analyzed for physico-chemical properties such as pH, total suspended solids, conductivity, nitrates concentration, total dissolved solids, sulphates concentration, chlorides concentration, dissolved oxygen, and biochemical oxygen demand. The present study would help provide awareness among the people of Mardan district to control the factors that are degrading the water quality in the area.

2 Experimental

2.1 Description of Study Area

The district of Mardan is situated in Khyber Pakhtunkhwa Pakistan. The district is named after Pir Mardan Shah, a prominent religious figure. The district spans the latitudes of 34° 05' to 34° 32' north and the longitudes of 71" 48' to 72° 25' east (**Figure 1**). Swabi and Buner districts surround district Mardan to the east, on the west by Charsadda and Malakand area, on the north by Buner district and Malakand area, and on the north by Nowshera district. Mardan district is mainly divided into two main regions, the southwestern plains, and the northeastern hilly area. The northeastern area is almost bounded by hills while the southwestern plain is mainly composed of fertile soil that grows several crops. The streams and rivers of district Mardan generally flow from north to south, with the majority eventually draining into the Kabul River. Noteworthy streams of the Mardan district are Kalpani, Muqam Khawar, Baghiari Khawar, Naranji Khawar. The weather is extremely hot in the summer season (May to September) with maximum record temperature in June i.e. 43.5 °C (110.3 °F). However, the temperature decreases gradually after October. The coldest months are December and January with the mean minimum recorded temperature in January i.e. 0.5 °C (32.9 °F). Metrological data indicates that in the Mardan district, the average annual rainfall is 12.8 mm. The relative humidity varies significantly throughout the year, although the highest levels of humidity, 73.33 percent, were recorded in December. According to the 2017 consensus, the population of the Mardan district is 2,373,061.

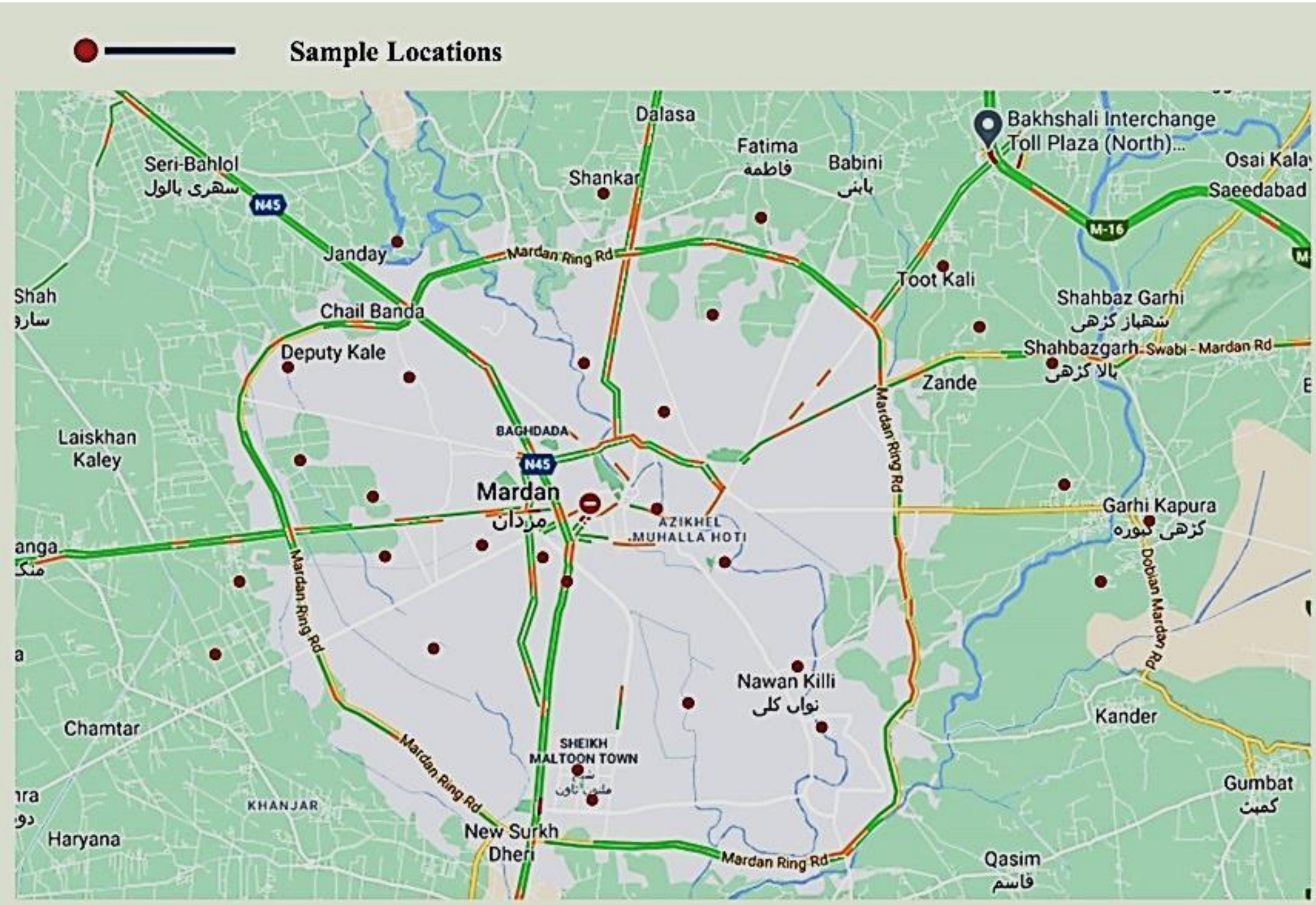

Figure 1. Map showing the study area.

2.2 Sample Collection

Thirty different samples of drinking water were collected on Feb 25, 2022 (collection day temperature, 21ºC) in well sterile and labeled plastic bottles from different regions of the Mardan district (**Table 1**). A pH metre (model MO00470009) was used to make on-site pH measurements. The samples were immediately brought into the laboratory and refrigerated before being analysed. All the instruments and equipment were sterilized and calibrated before the analysis of each and every parameter. The chemicals used in this experiment were of standard analytical grade (Merck and BDH). The stock solutions were prepared for each analysis in distilled water.

Table 1. Location of the collected water samples (drinking water) in district Mardan.

Sample ID	Location	pH of water samples
1	Gaju Khan	7.6
2	Kalpani Canal	8.3
3	Sheikh Maltoon Town	8.1
4	Saleem Khan	6.9
5	Saro Shah	6.8
6	Mayar	7.3
7	Sheikh Yaseen Town	7.2
8	Shankar Pond Water	6.7
9	Gari Kapura	8.1
10	Par Hoti	8.0
11	Manga Dargai	8.3
12	GDC No. 2 Mardan Tab Water	7.6
13	Khadi Kali	8.3
14	Kalo Khan	8.1
15	Thopo Chowk	7.9
16	Maho Dheri	8.1
17	Hoti Mardan	8.0
18	Mistri Abad	7.4
19	Bicket Gunj	8.7
20	Ghaznavi Colony	8.3
21	Tauheed Colony	6.9
22	Baghdada	6.3
23	Sharif Abad Water Tank	7.5
24	Pohan Colony	6.4
25	Serai	8.3
26	Makkah Colony	7.5
27	Meervas	7.9
28	Hazrat Umar Banda	7.1
29	Deputy Kaly	8.4
30	Mirzagano Kaly	8.1

2.3 Electrical Conductivity (EC)

A Digital Conductivity Meter (CM-180) was used to determine the electrical conductivity of the collected water samples.

2.4 Determination of Total Dissolved Solids (TDS)

Total dissolved solids (TDS) in samples was determined using the standard prescribed gravimetric method of American Water Works Association (AWWA), American Public Health Association (APHA), and World Health Organization (WHO) guidelines [18, 19]. A clean Petri dish was heated in an oven to 100 degrees Celsius, cooled in a desiccator, and weighed to a constant weight. Using pre-weighed filter paper, the water sample was filtered and placed in a clean conical flask. The filtrate was measured and poured into the petri-dish, which was then reheated in an oven at 180°C. After cooling in a desiccator, TDS is calculated from the solid residue obtained using equation 1.

$$\text{Total Dissolved Solids } (mg/L^{-1}) = \frac{(A-B)\times 1000}{\text{Volume of sample (ml)}}$$

Where A = weight of dried residue + evaporating dish (mg);
B = weight of the evaporating dish (mg).

(equation 1)

2.5 Determination of Total Suspended Solids (TSS)

Total Suspended Solids (TSS) in the collected water samples was determined using the gravimetric method. A pre-weighed filter paper was used to filter a measured volume of water samples. The filter paper was then heated up to 105 °C and then cooled at room temperature in a desiccator. TSS was calculated from the increase in mass of dry filter paper using equation 2.

$$\text{Total Suspended Solids } (mg/L^{-1}) = \frac{(A-B)\times 1000}{\text{Volume of sample (ml)}}$$

Where A = weight of the filter paper after filtration (mg);
B = weight of the filter paper before filtration (mg).

(equation 2)

2.6 Chlorides Determination

The concentration of chloride ions in the water sample was estimated using the standard prescribed method by Karl Friedrich Mohr, known as Mohr's method [20]. Using chromate ion as an indicator, a known volume of water was titrated against a standard solution of silver nitrate $AgNO_3$. Generation of brown-red Silver Chromate precipitate takes place when all chloride ions have reacted with the silver ions to form a white precipitate of Silver Chloride. The reactions can be written as equation 3.

$$Ag^+ + Cl^- \rightarrow AgCl$$
$$2Ag^+ + CrO_4^{-2} \rightarrow Ag_2CrO_4$$
(equation 3)

The stoichiometry and moles consumed at the endpoint were used to calculate the chloride concentration in the wastewater.

2.7 Sulphates Determination

Sulphates in water were determined using indirect EDTA titration. This experiment was conducted in four steps. In step number one, 40ml of the water samples were poured into glass bottles followed by the addition of few drops of concentrated HCl to build an acidic medium for effective precipitation of $BaSO_4$. Each bottle is then topped up with an excess of 0.0100 M $BaCl_2$ solution. The bottles were wrapped in aluminum foil and boiled on a hot plate for about an hour while being stirred. The bottles were taken off the hot plate, cooled, and capped before being set aside for 24 hours so that complete precipitation takes place. In the second phase, an EDTA standard solution was prepared by titrating it against a $ZnSO_4$ (0.05M) standard solution using Eriochrome Black T as an indicator and a PH 10 buffer. The endpoint was reached when the solution changed from pink to pure blue. In the third step, water hardness due to dissolved Mg^{+2} and Ca^{+2} was determined by titrating a portion of the water samples (20ml) against a standard solution of EDTA using Eriochrome Black T as an indicator and a buffer of PH 10. The concentration of Ca^{+2} and Mg^{+2} in water samples was determined using equation 4.

Concentration of Ca^{+2} or Mg^{+2} in water samples

$$= \frac{\text{EDTA concentration } (\text{mL}^{-1} \times \text{volume of EDTA used (L)}}{\text{Volume of water sample (L)}}$$
(equation 4)

Finally, in step 4, the excess, unprecipitated Ba^{+2} is determined by titrating the remaining samples (20ml) from step 1 with the standardised EDTA solution. The procedure is similar to step 3; however, a little more pH 10 buffer was added to counteract the effect of the acid added in step 1. The amount of excess Ba^{+2} was calculated by adding the total amount of metal in the precipitated samples' solutions and subtracting the amount of metal attributable to wa ter hardness estimated in step 3. The concentration of SO_4^{-2} in the sample can easily be calculated using equation 5.

$$SO_4^{-2} = \frac{(\text{Total amount of added } Ba^{+2}) - (\text{amount of excess } Ba^{+2})}{V_{SO_4^{-2}}}$$
(equation 5)

2.8 Nitrates Determination

A UV spectrometric approach was used to measure nitrate in wastewater. A 100 mg/L nitrate standard solution was prepared by dissolving 0.72 g anhydrous potassium nitrate in 1 L distilled water. Serial dilutions of nitrate stock solution were used to prepare calibration standards for nitrate in the range of 0.1–1.0 mg/L. A test tube stand was used to set up a series of reaction tubes, which were then put in a cold water bath. After pouring a measured amount of water (10ml) into the reaction tubes, the NaCl solution and sulphuric acid were added. The brucine-sulphanilic acid reagent was added, and the mixture was shortly heated in a boiling water bath. After allowing the samples to cool, the absorbance of each sample was measured in the UV spectrometer (model UV752D) at 410 nm in comparison to the reagent blank. The concentration of nitrate-nitrogen (NO3-N) in water samples was calculated using extrapolation from the calibration curve.

2.9 Dissolved Oxygen (DO) Measurement

Winkler's method was used to measure the amount of dissolved oxygen in collected drinking water samples. 0.1 M basic solution of sodium hydroxide and manganese peroxide was added to water samples, which results in the production of white precipitate which later on disappeared (due to its reaction with dissolved oxygen present in water samples) and the production of a brown precipitate occurred in the reaction mixture. The reactions may be represented as equation 6.

$$Mn^{+2} + 2OH \rightarrow Mn(OH)_2 \text{ (white precipitate)}$$
$$Mn(OH)_2 + \tfrac{1}{2} O_2 \rightarrow MnO(OH)_2 \text{ (brown precipitate)}$$
(equation 6)

The brown precipitate was dissolved 2 ml of concentrated sulphuric acid in the presence of iodine ions (I^-), and iodine (I_2) was released according to the amount of DO. Then, the released iodine (I_2) was titrated with sodium thiosulfate.

$$MnO(OH)_2 + 2I^- + 4H^+ \rightarrow Mn^{+2} + I_2 + 3H_2O + I_2 + 2S_2O_3^{-2} \rightarrow 2I^- + S_4O_6^{-2}$$
(equation 7)

The amount of dissolved oxygen in water samples was calculated using the equation 8.

$$DO\ (mg/L) = \frac{V_1 \times N \times E \times 1000}{[V_4 \frac{(V_2 - V_1)}{V_2}]}$$

V_1 = volume of titrant $Na_2S_2O_4$ (ml);
V_2 = total volume of water sample (ml);
V_2 = volume of sodium hydroxide and manganese peroxide added (ml);
V_4 = volume of analyte taken in titration;
E = equivalent weight of O_2;
N = normality of $Na_2S_2O_4$ solution.
(equation 8)

2.10 Biochemical Oxygen Demand (BOD)

BOD in the water samples was determined using standard procedure followed by [21]. 40 ml of each water sample was taken in two vials each. Each specimen was diluted up to 1 liter with distilled water and thoroughly shaken to make sure oxygen saturation. After this, dissolved oxygen was determined in one of the vials with the help of Winkler's method and the second vial is then wrapped and placed in darkness and tested 5 days later. By subtracting the second reading of dissolved oxygen from the first one, BOD is then determined.

3 Results and Discussion

The results obtained from the measurement of various parameters showed significant variation from sample to sample. Descriptive statistics for all physico-chemical parameters are presented in **Table 3**.

3.1 pH

The pH of water determines the solubility and biological availability of chemical elements such nutrients (phosphorus, nitrogen, and carbon) and heavy metals; lead, copper, cadmium etc [22, 23]. pH, for example, influences not only the amount and kind of carbon in the water, but also whether marine organisms can utilise it. Water can be harmed by pH levels that are too high or too low. When pH is high, it produces a bitter taste, deposits in water pipes and water-using equipment, and it reduces the efficacy of chlorine disinfection, necessitating the use of additional chlorine [24]. Pollution can impact the pH of water, harming the animals and plants that dwell in it. Water from an abandoned coal mine, for example, may have a pH of 2, which is very acidic (100,000 times more acidic than neutral water) and will kill any aquatic plant or animal that survives there. The values obtained from the water samples range from 6.3-8.4 (**Table 1**). The highest pH values were found in the water samples of Kalpani Canal, Manga Dargai, Khadi Kali, Ghaznavi Colony, Serai and Deputy Kaly as mentioned in the **Table 1**. This may due to the composition of the soil, bedrock, or other surroundings from which the sewage system is generated in these regions. Water with high alkalinity is a result of limestone-rich rocky areas. It includes carbonate, bicarbonate, and hydroxide compounds that dissolve in water and increase the pH level [25]. While, lowest pH values were found in the water samples of Pohan Colony, Baghdada, Tauheed Colony, Shankar Pond Water, Saro Shah and Saleem Khan. This may be due to the presence of agricultural soil and a large number of plants in these regions or caused by a high level of dissolved oxygen, high level of dissolved carbon dioxide and a large amount of decomposed plants [26].

Table 2. WHO water quality standards [27].

S. No.	Parameter	Standards
1	pH	6.5 - 9.2
2	Conductivity	400 μS/cm
3	Total Dissolved Solids (TDS)	500 mg/l
4	Total Suspended Solids (TSS)	5 mg/l
5	Chlorides as Cl^-	250 mg/l
6	Sulphates as SO_4^{-2}	250 mg/l
7	Nitrates as NO_3^-	10 mg/l
8	Biochemical Oxygen Demand (BOD)	2 mg/l

3.2 Electrical Conductivity

The potential of a solution to conduct electric current is measured by its conductivity coefficient (EC), which is strongly reliant on ionic species availability. The conductivity of water is greatly affected by inorganic ions. High EC values indicate that inorganic ions are abundant in water. The total dissolved solids (TDS) concentration is directly proportional to EC [28]. In other words, a high EC in wastewater suggests a high concentration of total dissolved solids. This shows that the concentration of diddolved ionic solutes in water bodies directly affect the conductance of electric current. Water dislodging with high EC can cause water imbalances in aquatic bodies and significantly decrease the concentration of dissolved oxygen in the surrounding water [29]. The result shows that the values of EC of the drinking water sample of the region range from 267.9-984. The results show that the EC values in the majority of the analyzed water samples are higher above the WHO's permissible limits (**Table 2**). The highest EC value is measured for the drinking water of Mayar while the lowest EC Is found in the water of Sheikh Maltoon Town. Despite the fact that some samples had low EC levels, the overall average (554.5 mg/l) was beyond safe limits **(Figure 2 (a))**. Therefore, planners and decision-makers must take immediate action to address the situation. Higher values of EC in the water of most regions may be due to the presence of inorganic dissolved solids including calcium, magnesium, sodium, chloride, sulphate, nitrate, phosphate, iron and aluminum ions [28].

3.3 Total Dissolved Solids (TDS)

TDS stands for total dissolved solids, which are both inorganic and organic substances in water that can pass through a 2-micron filter and are measured in milligrams per liter or parts per million [30]. In simple words, TDS is the number of cations and anions in water. Carbonate, bicarbonate, chloride, fluoride, sulphate, phosphate, nitrate, calcium, magnesium, sodium, and potassium are among the ions and ionic compounds that make up TDS, but any ion present in the water will contribute to the total. Pollutants, herbicides, and hydrocarbons are among the organic ions. TDS also includes organic compounds from the soil, such as humic and fulvic acids [31]. Total dissolved solids (TDS) are a measure of water purity and suitability for drinking and irrigation. TDS is also important in aquatic environments because organisms need those minerals for their bodies to proceed smoothly [32]. The results of the study show that the values of TDS of drinking water sample of the region range from 286-632 (mg/L) (**Table 3)**. It is clear from results that most of the tested water samples have TDS values higher than WHO permitted limits (**Table 2**). The highest TDS value is measured for the drinking water of GDC No. 2 Mardan Tab Water while the lowest TDS is found in the water of Ghaznavi Colony. Despite the fact that certain samples had the highest TDS readings, the overall average (444.2 mg/l) was below the permitted limits **(Figure 2 (b))**.

Table 3. Physico-chemical parameters of the drinking water samples from district Mardan

Sample ID	TDS (mg/L)	Conductivity (µS/cm)	TSS (mg/L)	Chlorides (mg/L)	Nitrates (mg/L)	Sulphates (mg/L)	DO (mg/L)	BOD (mg/L)
1	436	676	7.3	26.5	10.4	40.4	8.5	3.5
2	357	433.2	12.2	17.3	10.1	69.3	12.4	8.4
3	336	267.9	6.2	35.3	9.6	46.8	14.3	11.6
4	403	578	7.3	22.7	8.8	73.2	9.6	6.6
5	389	428.6	8.4	21.4	8.4	53.6	8.2	5.3
6	550	984	6.4	21.3	10.6	65.7	10.5	7.7
7	563	758	7	29.7	11.3	52.7	13.7	10.3
8	398	504	9.4	28.2	9.5	39.8	11.6	8.5
9	584	634	10.7	24.5	9.4	83.2	14.8	11.3
10	363	401	5.8	35.6	8.7	97.7	12.3	9.5
11	402	387	5.4	33.2	8.1	48.7	8.6	5.9
12	632	354	8.1	45.5	12.5	52.2	7.3	4.9
13	356	342	7.5	36.7	7	90.3	8.5	5.8
14	385	443	7.3	35.3	6.8	49.7	14.6	11.4
15	591	675	14.6	26.7	14.3	43.9	17.8	13.3
16	467	635	7.3	31.5	12.4	83.5	12.9	9.7
17	478	543	11.3	37.6	11.7	64.9	10.6	7.6
18	372	434	8.4	44.7	9.4	54.7	8.7	4.6
19	394	457.6	7.6	34.9	8.7	43.5	7.6	4.1
20	286	374	6.5	21.2	7.2	89.5	13.3	9.3
21	389	561.2	8.7	43.4	9.5	52.7	12.6	8.9
22	409	678	13	32.5	13.3	45.4	15.7	9.8
23	447	640	12.1	39.3	11.6	106.2	15.2	11.2
24	334	447	9.5	28.8	10.7	92.6	16.4	12.4
25	532	676	9.3	27.5	14.4	33.4	14.3	10.6
26	587	789	6.8	29.3	15.9	54.6	19.5	13.5
27	509	746	17.2	20.4	14.7	85.7	13.7	9.2
28	492	403	8.3	23.5	10.5	94.6	10.3	6.8
29	430	514	6.9	34.5	10.8	40.4	10.8	6.7
30	455	874	7.4	33.7	9.9	94.6	9.4	6.3

3.4 Total Suspended Solids (TSS)

TSS is a measure of particulate matter suspended in water. It's a term used to describe how much pollution is present in wastewater. TSS is also a good indicator of turbidity in water. Solids can be found drifting or floating in the water, ranging from sediment, silt, and sand to plankton and algae. Organic particles from decomposing materials may also have an impact on TSS concentrations. Decomposition of algae, plants, and animals causes tiny organic particles to break free and join the water column as suspended solids. Chemical precipitates are also classified as suspended solids. When it comes to water clarity, total suspended solids play a big role. The less pure the water is, the more solids there are in it. The maximum recommended TSS limit set by Pakistan Council of Research In Water Resources (PCRWR) is 5 mg/L . The TSS values of all the drinking water samples studied are shown in **(Figure 2 (c))**The TSS values for the drinking water from various locations of Mardan districts obtained in this study were found to be in between 5.4 – 17.2 mg/L (**Table 3)**. Mean value (8.8) and individual values of the TSS in the water samples are beyond WHO (WHO 1993) and PCRWR [33] acceptable limits. Higher values of TSS in the water of the region may be attributed to human activities, whether directly or indirectly, such as building and roads construction, industrial activities, agricultural activities and most importantly the domestic sewage.

3.5 Chlorides

Chlorides can be found in varying amounts in all natural waters. If the mineral content rises, the chloride content rises as well [34]. Unless the water is brackish or salty, the chloride ion is present in natural waters in relatively low concentrations, typically less than 100 mg/L. Water and beverages with high chloride concentrations have a salty taste, whereas water with concentrations over 250 mg/L has a discernible taste. Natural sources, sewage and industrial effluents, urban runoff containing de-icing salt, and saline infiltration are all sources of chloride in drinking water [35, 18]. In the study area the chloride concentration ranged from 17.3 mg/L to 45.5 mg/L with a mean value of 30.75 mg/L (**Table 3**). The chloride concentration is given in **(Figure 2 (d))**. The concentration of chloride in the drinking water of the study area has been found with in the WHO permitted limits. The presence of chlorine in drinking water is caused by the combined impact of silicate weathering, the usage of waste water for irrigation, and the indiscriminate use of fertilisers and other agro-chemicals.

3.6 Nitrates

Nitrate concentrations in groundwater are typically low, but they can reach high levels as a result of leaching or drainage from agricultural land, or pollution from human or animal wastes as a result of ammonia oxidation and other similar sources [18]. Nitrate (as NO_3^{-1}) levels in drinking water of the region ranged from 6.8 mg/L to 15.9 mg/L (**Table 3**). 16 samples of the drinking water from the region have nitrate concentration higher than the desirable limit as mentioned in **Table 2**. The mean nitrate concentration was 10.54 mg/L, which was higher than the maximum desirable limit. **(Figure 2 (e))** shows the concentration of Nitrates in water samples. This high level of nitrate is attributable to intensive cultivation and the indiscriminate application of nitrogenous fertilizer, which pollutes groundwater by leaching into it with percolating water.

3.7 Sulphates

Sulphates are natutally occuring compounds found in minerals, soil, and rocks. They can be found in the environment, including the air, groundwater, plants, and food [36]. The pharmaceutical industry is the primary commercial use for sulphate. Industrial waste and atmospheric deposition also contribute to sulphate contamination of water [37]. Sulphates concentration in the drinking water of the region ranged from 33.4 mg/L to 106.2 mg/L with an average value of 64.78 mg/L **(Table 3)**; **(Figure 2 (f))**, which lies below the WHO desirable limits (**Table 2**). Drinking water containing high levels of sulphates can cause intestinal irritation, diarrhoea, and, as a result, dehydration. When someone drinks water containing more than 250 milligrammes per litre (mg/L) of sulphate, they frequently experience a laxative effect [38, 39].

3.8 Dissolved Oxygen (DO)

Dissolved oxygen is the amount of oxygen gas (O_2) that is dissolved in the water of any source. If the amount of dissolved oxygen is high, the degree of self purification of water is high; in such cases, milder water treatment is required. However, if the amount of dissolved oxygen is less, all impurities would not be eradicated by the self-purification phenomenon and so in such cases, better purification methods are necessary. In this way, the value of dissolved oxygen in water is a useful measure of the condition of water (or the degree of pollution in water) [40]. DO levels of water are influenced by chemical, physical, and biochemical processes in the environment. The amount of dissolved oxygen in water is directly proportional to the amount of oxygen produced by photosynthesis and consumed by living organisms, especially bacteria. Furthermore, dissolved oxygen is influenced by a variety of factors, including water temperature, water movement, and salinity. The solubility of oxygen in water is directly proportional to ambient pressure and inversely proportional to water temperature and salinity [14]. Healthy water should generally have dissolved oxygen concentrations above 6.5-8 mg/L. However the concentration of dissolved oxygen in the study area ranged from 7.3 mg/L to 19.5 mg/L (**Table 3**) with an average value of 12.12 mg/L, which indicates that these water samples have sufficient amount of dissolved oxygen **(Figure 2 (g))**.

3.9 Biochemical Oxygen Demand (BOD)

Biochemical oxygen demand (BOD) is a measure of the amount of oxygen that would be needed by the microorganisms to decompose the organic and inorganic matter in water. The microorganisms transforms the pollutants into non-hazardous compounds and dissolved oxygen is consumed. The inorganic maater may include sulphites, sulphides, thiosulphates and ferrous iron. These pollutants are attacked by oxygen in presence of enzymes released by the microorganisms [41, 42]. The BOD test is used to assess how polluted a water is and how effective effluent treatment methods are. The amount of BOD in water has a big impact on DO. The greater the oxygen depletion in water bodies, the higher the BOD concentration. As a result, there is less oxygen available for higher species of sea life, resulting in the death of aquatic species [43]. The determined data for BOD is shown in table 3 indicating that the BOD ranged from 3.5 mg/L to 13.5 mg/L with an average value of 8.5 mg/L **(Table 3)**; **(Figure 2 (h))**, which lies above the WHO maximum permissible limits (**Table 2**). The presence of high BOD concentration in these drinking water samples indicates that these water are not suitable for drinking and proper measure should be adapted to combact this problem.

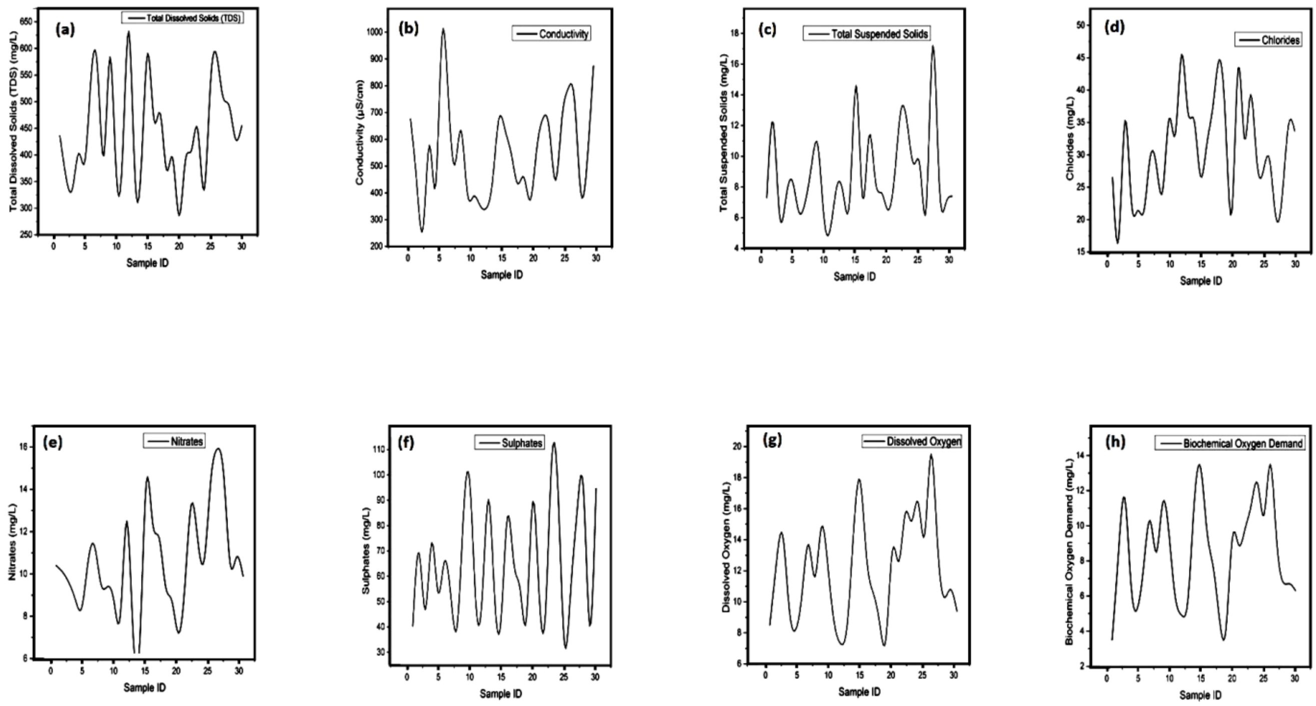

Figure 2. Graphical representation of the physic -chemical parameters of the drinking water samples of the study area.

4 Future Perspective

The stress on the water environment of the study as a result of increased industrialization, which aids urbanization, is becoming very high thus reducing the availability of clean water in the region. Polluted water is of great concern to the aquatic organism, plants, humans, and climate and indeed alters the ecosystem. The preservation of our water environment, which is embedded in sustainable development, must be well driven by all sectors. There is no proper way of solving the problem of water pollution but effective wastewater treatment has the tendency of salvaging the water environment, integrating environmental policies into the actor firms core objectives coupled with continuous periodical enlightenment on the present and future consequences of environmental/water pollution will greatly assist in conserving the water environment. **Figure 3** shows schematic illustration of the overall water treatment process and removal of waste unwanted material from water to make it suitable for drinking purposes. Moreover, pollution of water can be minimized by adopting the following general strategies:

- Taking baths from drinking water resources should be prohibited.
- Separate ponds and tanks should be reserved for water supply to animals.
- Domestic and farmyard sewage should be suitably treated before releasing them into water.
- Overuse of fertilizers and pesticides should be avoided.

- Hot water should be cooled before releasing from factories.
- Solid wastes should be recycled.
- Water hyacinth should be grown to remove heavy metals.
- Fat, oil, grease should not be poured into water.
- Household chemicals or cleaning agents should not be disposed into water bodies.
- Liquid or powder medications or any type of drug should no be discarded to freshwater resources.
- Ecosan toilets should be used, where human excreta is converted into fertilizers.
- Using phosphate-free soap or detergents in minimum quantity for cleaning and washing purposes.
- Disposal of plastic bags and other products made from plastic should be avoided.

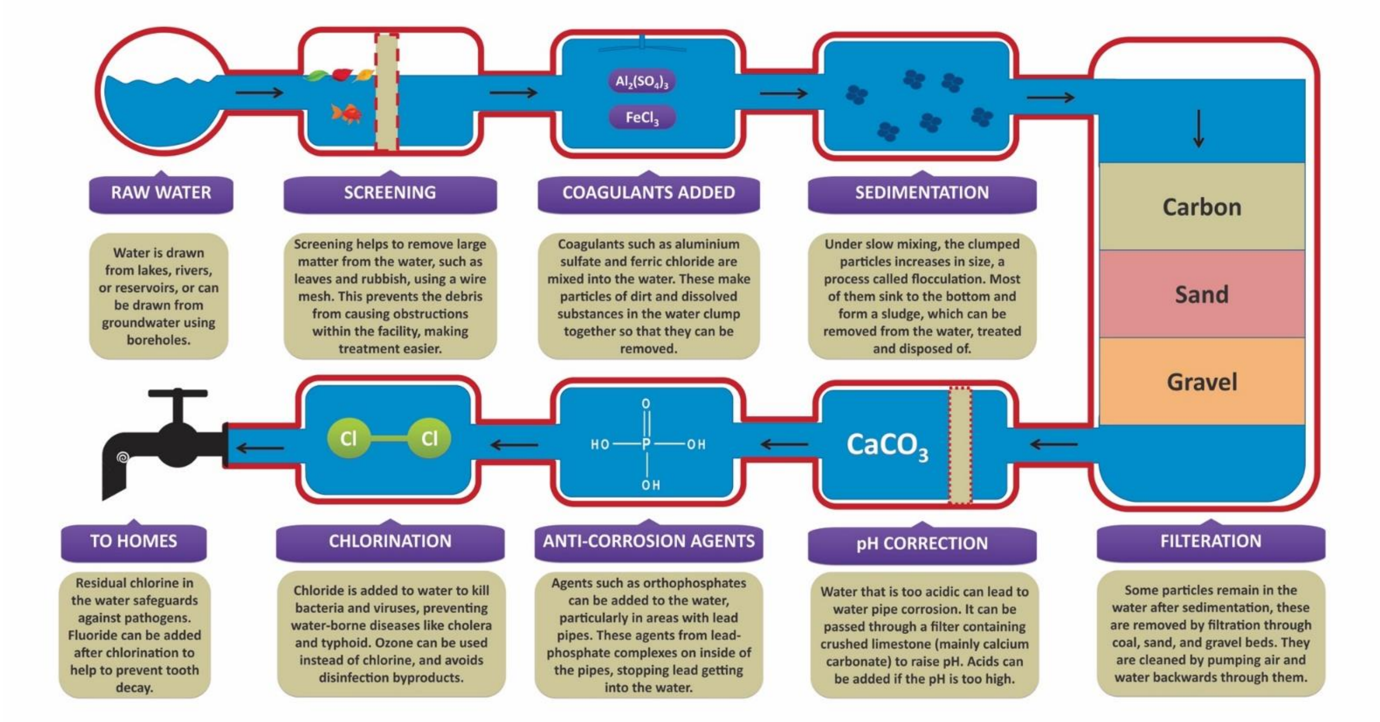

Figure 3. Schematic illustration of the overall water treatment process and removal of waste unwanted material from water to make it suitable for drinking purposes.

5 Conclusions

Water quality degradation is an issue of significant societal and environmental concerns. Many factors degrade the quality of water. The main aim of the current study was to evaluate the water quality of different water samples collected from different regions of district Mardan, Khyber Pakhtunkhwa, Pakistan. The study concluded that most of the water quality prameters including conductivity, TDS, TSS, Nitrates, Chlorides, Sulphates, and BOD in most of the water samples were found to be above the permissible limits of World Health Organization (WHO). The study has shown an alarming situation regarding the high values of the water quality parameters for the collected samples. It is significantly degraded by various factors. The relevant civic authorities should take urgent and effective steps to provide safe and healthy water to the large population of the district. The District Government should make consistent efforts to maintain the quality of drinking in the area as per the recommended standards of WHO.

6 Acknowledgments

We would like to express our deep and sincere gratitude to Professor Atiq Ur Rahman, Department of Chemistry, Government Degree College No. 2 Mardan, Khyber Pakhtunkhwa, Pakistan, for his generous guidance and intellectual support throughout the study.

7 Conflicts of Interest

All authors declare having no conflicts of interest regarding the publishing of this paper.

8 References

[1] Y. Rui, D. Fu, H. Do Minh, M. Radhakrishnan, C. Zevenbergen, and A. Pathirana, 2018. Urban surface water quality, flood water quality and human health impacts in Chinese cities. What do we know? Water, 10(3), 240.

[2] M. Khalifa, and S. Bidaisee, 2018. The importance of clean water. Scholar Journal of Applied Sciences and Research, 1(7), 17-20.

[3] E. R. Raut, and A. M. Sudame, 2020. Study of Physico-Chemical Parameters of Water Sample of Mahal Area of Nagpur City. International Journal of Engineering Applied Sciences and Technology, 4(12), 321–323.

[4] M. A. Ullah, M. Aslam, and R. Babar, 2019. Effect of Untreated Water Flow Rate at Certain Temperature on the Discharge of Treated Water. The Korean Journal of Food & Health Convergence, 5(6), 5-9.

[5] G. Liu, Y. Zhang, W. J. Knibbe, C. Feng, W. Liu, G. Medema, and W. van der Meer, 2017. Potential impacts of changing supply-water quality on drinking water distribution: A review. Water research, 116, 135-148.

[6] H. Iqbal, M. Ishfaq, A. Jabbar, M. N. Abbas, A. Rehaman, S. Ahmad, and B. I. Shagufta, 2014. Physico-chemical analysis of drinking water in district Kohat, Khyber Pakhtunkhwa, Pakistan. International Journal of Basic Medical Sciences and Pharmacy, 3(2), 37-41.

[7] J. Geist, and S. J. Hawkins, 2016. Habitat recovery and restoration in aquatic ecosystems: current progress and future challenges. Aquatic Conservation: Marine and Freshwater Ecosystems, 26(5), 942-962.

[8] M. T. Majeed, and S. Mumtaz, 2017. Happiness and environmental degradation: A global analysis. Pakistan Journal of Commerce and Social Sciences, 11(3), 753-772.

[9] C. P. Liyanage, and K. Yamada, 2017. Impact of population growth on the water quality of natural water bodies. Sustainability, 9(8), 1405.

[10] M. Flörke, C. Schneider, and R. I. McDonald, 2018. Water competition between cities and agriculture driven by climate change and urban growth. Nature Sustainability, 1(1), 51-58.

[11] R. Damania, S. Desbureaux, M. Hyland, A. Islam, S. Moore, A-S. Rodella, J. Russ, and E. Zaveri, 2017. Uncharted Waters: The New Economics of Water Scarcity and Variability. Washington, vol 2, World Bank, Washington, DC.

[12] P. Mehta, 2012. Impending water crisis in India and comparing clean water standards among developing and developed nations. Archives of Applied Science Research, 4(1), 497-507.

[13] J. Ganoulis, 2009. Risk Analysis of Water Pollution, 2nd ed, Wiley-VCH Verlag GmbH & Co. KGaA:Weinheim, Germany.

[14] T. E. Aniyikaiye, T. Oluseyi, J. O. Odiyo, and J. N. Edokpayi, 2019. Physico-chemical analysis of wastewater discharge from selected paint industries in Lagos, Nigeria. International journal of environmental research and public health, 16(7), 1235.

[15] M. Butt, and S. M. Khair, 2016. Cost of illness of water-borne diseases: a case study of Quetta. Journal of applied and emerging sciences, 5(2), 133-143.

[16] A. Al-Omran, F. Al-Barakah, A. Altuquq, A. Aly, and M. Nadeem, 2015. Drinking water quality assessment and water quality index of Riyadh, Saudi Arabia. Water Quality Research Journal of Canada, 50(3), 287-296.

[17] Z. Haftu, and S. Estifanos, 2020. Investigation of physico-chemical Characteristics and Heavy Metals Concentration Implying to the Effect of Local Geology on Surface Water Quality of Werii Catchment, Tigray, Ethiopia. EQA-International Journal of Environmental Quality, 40, 11-18.

[18] WHO 2004 Guidelines for drinking water quality, 3rd edn. World Health Organization, Geneva.

[19] Standard Methods for the Examination of Water and Wastewater 2005 21st edn, American Public Health Association/American Water Works Association/Water Environment Federation, Washington DC, USA.

[20] J. Meija, A. M. Michałowska-Kaczmarczyk, and T. Michałowski, 2016. Mohr's method challenge. Analytical and bioanalytical chemistry, 408(7), 1721-1722.

[21] A. K. Verma, and T. N. Singh, 2013. Prediction of water quality from simple field parameters. Environmental earth sciences, 69(3), 821-829.

[22] E. Kang, Y. Li, X. Zhang, Z. Yan, H. Wu, M. Li, and X. Kang, 2021. Soil pH and nutrients shape the vertical distribution of microbial communities in an alpine wetland. Science of The Total Environment, 774, 145780.

[23] A. Król, K. Mizerna, and M. Bożym, 2020. An assessment of pH-dependent release and mobility of heavy metals from metallurgical slag. Journal of hazardous materials, 384, 121502.

[24] J. Gao, F. Proulx, and M. J. Rodriguez, 2020. Synergistic effects of quenching agents and pH on the stability of regulated and unregulated disinfection by-products for drinking water quality monitoring. Environmental monitoring and assessment, 192(2), 1-14.

[25] A. Ram, S. K. Tiwari, H. K. Pandey, A. K. Chaurasia, S. Singh, and Y. V. Singh, 2021. Groundwater quality assessment using water quality index (WQI) under GIS framework. Applied Water Science, 11(2), 1-20.

[26] Y. Huang, D. Zhang, Z. Xu, S. Yuan, Y. Li, and L. Wang, 2017. Effect of overlying water pH, dissolved oxygen and temperature on heavy metal release from river sediments under laboratory conditions. Archives of Environmental Protection, 43(2), 28-36.

[27] WHO 1993 Guidelines for drinking water quality, 2nd edn. World Health Organization, Geneva.

[28] A. F. Rusydi, 2018. Correlation between conductivity and total dissolved solid in various type of water: A review. IOP conference series: earth and environmental science,118(1), 012-019.

[29] S. H. Ewaid, and S. A. Abed, 2017. Water quality index for Al-Gharraf river, southern Iraq. The Egyptian Journal of Aquatic Research, 43(2), 117-122.

[30] J. Peng, K. Kumar, M. Gross, T. Kunetz, and Z. Wen, 2020. Removal of total dissolved solids from wastewater using a revolving algal biofilm reactor. Water Environment Research, 92(5), 766-778.

[31] K. Sun, M. Rajabtabar, S. Samadi, M. Rezaie-Balf, A. Ghaemi, S. S. Band, and A. Mosavi, 2021. An integrated machine learning, noise suppression, and population-based algorithm to improve total dissolved solids prediction. Engineering Applications of Computational Fluid Mechanics, 15(1), 251-271.

[32] J. R. Olson, and C. P. Hawkins, 2017. Effects of total dissolved solids on growth and mortality predict distributions of stream macroinvertebrates. Freshwater Biology, 62(4), 779-791.

[33] S. Imran, L. N. Bukhari, and S. Gul, 2018. Water Quality Assessment Report Along the Banks of River Kabul Khyber Pakhtunkhwa 2018. Pakistan Council of Research in Water Resources, 45.

[34] C. N. Sawyer, and P. L. McCarty,1978. Chemistry for Environmental Engineering, 3rd ed, McGraw-Hill Book Co, New York.

[35] P. P. Adhikary, C. J. Dash, H. Chandrasekharan, T. B. S. Rajput, and S. K. Dubey, 2011. Evaluation of groundwater quality for irrigation and drinking using GIS and geostatistics in a peri-urban area of Delhi, India, Arabian Journal of Geosciences, 5(6), 1423-1434.

[36] M. Sela-Adler, Z. Ronen, B. Herut, G. Antler, H. Vigderovich, W. Eckert, and O. Sivan, 2017. Co-existence of methanogenesis and sulfate reduction with common substrates in sulfate-rich estuarine sediments. Frontiers in microbiology, 8, 766.

[37] N. M. Sivaram, and D. Barik, 2019. Toxic waste from leather industries. In Energy from toxic organic waste for heat and power generation, 55-67. Woodhead Publishing.

[38] L. C. Backer, 2000. Assessing the acute gastrointestinal effects of ingesting naturally occurring, high levels of sulfate in drinking water. Critical reviews in clinical laboratory sciences, 37(4), 389-400.

[39] W. D. Heizer, R. S. Sandler, E. Seal, S. C. Murray, M. G. Busby, B. G. Schliebe, and S. N. Pusek,1997. Intestinal effects of sulfate in drinking water on normal human subjects. Digestive diseases and sciences, 42(5), 1055-1061.

[40] M. Kang, Y. Tian, S. Peng, and M. Wang, 2019. Effect of dissolved oxygen and nutrient levels on heavy metal contents and fractions in river surface sediments. Science of the total environment, 648, 861-870.

[41] J. Li, G. Luo, L. He, J. Xu, and J. Lyu, 2018. Analytical approaches for determining chemical oxygen demand in water bodies: a review. Critical reviews in analytical chemistry, 48(1), 47-65.

[42] G. K. Upadhyay, J. K. Rajput, T. K. Pathak, V. Kumar, and L. P. Purohit, 2019. Synthesis of ZnO: TiO2 nanocomposites for photocatalyst application in visible light. Vacuum, 160, 154-163.

[43] N. Gupta, P. Pandey, and J. Hussain, 2017. Effect of physicochemical and biological parameters on the quality of river water of Narmada, Madhya Pradesh, India. Water Science, 31(1), 11-23.