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Comparative Study of Physicochemical and Microbiological Parameter of Water from Rawal Dam and Its Silt Control Tank

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Abstract: Water plays a vital role on this planet it is a very important factor in the living of almost every species. Water resource has been depleted, exploit, and polluting day by day due to the exposure to different hazardous contaminants and misuse of water. Urbanization and increase in population increase the risk of deterioration of water quality of water resources. This study was conducted on physicochemical and microbiological analysis to determine the water quality of Rawal dam, its tributaries, and their comparison with the water quality of the silt control tank of Rawal dam which is the WASA filtration tank. The main objectives of this research water are to access the water quality parameters which are consumed by the public and to find out whether these parameters are complying with the standards given or not. Water samples were collected from the main Rawal dam, and from its tributaries that are entering the dam. All five water samples were analyzed separately to get the results and were compared with water quality standards prescribed by World Health Organization (WHO) and PAK-EPA. The samples were collected in sterilized plastic bottles during October and November 2019. Physicochemical and Biological parameters (pH, Temperature, Turbidity, ORP, EC, Salts, Total Hardness, Total alkalinity, Carbonates, Chlorides, Calcium, Magnesium, Total and Fecal coliform) were analyzed at the Chemistry Lab of Bahria University Islamabad campus. Despite, most of the parameters from upstream to the main dam exceeding the standards, most of the parameters of Dam samples and all parameters of WASA water samples were within the permissible limits given by WHO and PAK-EPA. Microbiological analysis showed that the water samples contain high microbial counts of different pathogens like Salmonella, Shigella, and Total Coliforms in the Dam and its tributaries as compared to the WASA filtration plant (silt control tank). It is recommended to the regulatory authorities to analyze, inspect and monitor the drinking water quality regularly and it needs immediate attention of governmental bodies and public participation.
Keywords: TDS, Water treatment, EC, pH, Rawal Dam

INTRODUCTION

Water Resources

"Water is not just for life, water is life." This quote by the United Nations Secretary-General illustrates the demanding importance of water as a need that connects all aspects of human life. The health of people and their economic development are deeply linked to the availability and usability of water. Too little water can mean food insecurity and drought at a time when it is most needed. Too much water in the form of storms and floods can raze an entire population. The water that is contaminated, either from anthropogenically or industrial sources, claims the lives of children and affects the health of communities all over the world, with far-reaching effects. The Global Water Cycle occupies about three-quarters of Earth's surface and is a vital element for life. Water molecules pass again and again through solid, liquid, and gaseous phases during their regular cycling between land, the oceans, and the atmosphere, but the total supply remains almost equal. There are different types of water resources found in Pakistan including surface water resources, groundwater resources, and rainfall. The degree of availability of these resources is based on location. A short description of the water resources of Pakistan is given in the following sections (Kahlown and Majeed, 2003).

Surface Water-Resources

The surface water resources of Pakistan are mainly based on the Indus River and its tributaries. The Indus River has a total length of 2900 km and the drainage area is approximately 966,000 km^2. Five

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major tributaries are joining its eastern side Chenab, Jhelum, Ravi, Sutlej, and Beas and besides these five there are also three minor tributaries Harrow, Soan, and Siran which drain into mountainous areas. Several small tributaries join the Indus on its western side. The biggest of such tributaries is River Kabul. The rivers in Pakistan have individual flow characteristics, but all of them begin to rise in the spring and early summer, with the monsoon rains and snow melting on the mountains, and have a combined peak discharge in July and August. Flows are minimal during winters e.g., during the period from November to February, mean monthly flows are only about one-tenth of those in summer Pakistan is limited to the three western rivers, namely Indus, Jhelum, and Chenab, while India is designated to divert flows of Ravi, Beas, and Sutlej. This treaty gave for the construction of several connecting canals, barrages, and dams on the Indus and its two tributaries, Jhelum and Chenab, transferring at least 20 MAF of water for the irrigation of areas that were cut off from irrigation systems of rivers Ravi, Sutlej and Beas rivers following the Indus Basin Treaty. It is worth mentioning that the Indus River alone accounts for 65 percent of total river flows, while the share of Jhelum and Chenab is 17 and 19 percent respectively (Kahlown and Majeed, 2003).

Groundwater Resources

Groundwater resources of Pakistan are mostly present in the Indus Plain, lengthening from Himalayan foothills to the Arabian Sea, and are stored inside an alluvial deposit. The Plain is about 1,600 km long and covers an area of 21 Mha and is blessed with an extensive unconfined aquifer, which is a supplemental source of water for irrigation. The aquifer has been built due to direct recharge from river flow, natural precipitation, and the continued seepage from the conveyance system of distributaries, canals, watercourses, and application losses in the irrigated lands during the last 90 years. This aquifer, with a potential of about 50 MAF, is overusing to an extent of about 38 MAF by over 562,000 private tube wells and about 10,000 public tube wells. In Baluchistan, groundwater, obtain from tube wells, dug wells, springs, and kareeze, is the dependable source of water for irrigation of orchards and other cash crops, because almost all the rivers and natural streams are ephemeral, with seasonal flows only. It is calculated that, out of a total available potential of about 0.9 MAF, 0.5 MAF is already being used, thereby leaving a balance of 0.4 MAF that can still be utilized. This, however, creates misunderstanding, as the aquifers are not continuous but are limited to basins due to geologic conditions. It is pointed out that, in two of the basins (Pishin-Lora and Nari) groundwater is being overexploited, beyond its development potential, creating mining conditions and causing a huge overdraft of groundwater that is threatening to dry up the aquifers in the long term (Kahlown and Majeed, 2003).

Rainfall

In Pakistan, about 70% of the rainfall occurs from June to September annually. This causes the loss of most of the run-off in the lower Indus plains to the sea. The mean annual rainfall distribution in Pakistan has abroad regional variation. It ranges from 125 mm in Baluchistan (South East) to 750 mm in the Northwest. Rainfall is neither adequate nor regular. The amount of rainfall and the volume of rainfall is much more than they can easily be used. Rainfall at huge amounts can cause either flood. In the riverine areas or villages, cities near the river can cause huge destructions and miseries, or flows into the sea without any economic benefit to the country. In the Sindh plains, high-intensity rainfall occurs during July and August and its intensity continues to decrease from coastal areas to central parts of Sindh. Southern Punjab and northern Sindh are a region of exceptionally low yearly precipitation less than 152 mm. The territories over the Salt Range, including the districts of Jhelum, Rawalpindi, Attock, and Mianwali, get high precipitation, above the average of 635 mm per year. The winter downpours are commonly far-reaching. The northern and northwestern areas of NWFP and the northern areas of Baluchistan receive a comparatively high order of rainfall during winter. The size of the yearly precipitation over nearly 21 million hectares (Mha) of Indus Plains and Peshawar valley averages about 26 MAF. The present contribution of rain to crops in the irrigated areas is estimated at 6 MAF (Kahlown and Majeed, 2003).

Access to safe drinking water

In Pakistan, access to safe drinking water falls beneath adequate levels with only 25% of the population having continuous access to quality drinking water. Like other countries that are under threat of safe and clean water, Pakistan is also under great threat regarding the availability of safe and clean drinking water. Contaminated water is the major cause of deteriorating health-related issues to the public. The quality of groundwater in the country is also no longer safe due to changes in external factors. The quantity of water available to the public sector for drinking is of low quality. The old and damaged pipelines carrying drinking water are becoming more dangerous to the natural composition of the water. Inadequate water treatment measures and no monitoring plan made this problem more severe (Mehmood et al. 2013).

Water demand and availability

The level of agricultural production is related directly to the availability and effective use of water as the main input. The water demand is increasing rapidly, while the opportunities for further development of water assets are decreasing. The expansion of irrigation activities to improve food and non-food production could be attributed to several reasons for increasing water strategies to meet the growing demand of the growing population. Salinity is another serious problem to be solved. Salinity mainly occurs in some irrigated land rocking water in the soil which absorbs mineral salts from the earth. Due to the evaporation of water, such salts dry out on the soil surface and deplete its fertility. It is estimated that about 25 percent of cultivated land has been affected by salinity. The reclaiming of salted land is too expensive. In Pakistan half of the run water is drawn about as much gain from the underground spin aquifer. By 2025 water demand would be 92 percent of the entire runoff. It is estimated that 25 percent has been destroyed due to salinity. For irrigation purposes, only one-third of the water is used (Kaleem, 2007).

Physical and chemical characteristics

Each freshwater body has an individual pattern of physical and chemical characteristics which are determined largely by the climatic, geomorphological, and geochemical conditions prevailing in the drainage basin and the underlying aquifer. Water characteristics, such as total dissolved solids, conductivity, and, provide a general classification of water bodies of a similar nature. Mineral content, determined by the total dissolved solids present, is an important feature of any water body quality resulting from the balance between precipitation and dissolution. The o aquatic environment's chemical quality varies according to local geology, the distance from the ocean, climate, the amount of soil cover, etc. If surface waters were not affected by human activities, up to 90-99 percent of global freshwaters, depending on the variable of interest, would have natural chemical concentrations suitable for aquatic life and most human uses (Nilsson et al. 2009).

Biological characteristics

The development of biota including flora and fauna in surface waters is governed by a variety of environmental conditions which determine the selection of species as well as the physiological performance of individual organisms. The primary production of organic matter is most intensive in lakes and reservoirs and usually more limited in rivers. The degradation of organic substances and the subsequent growth of bacteria can be a long-term process that may be essential in groundwater and deep lake waters that are not directly exposed to sunlight (Nilsson et al., 2009).

Anthropogenic impacts on water quality

With the emergence of industrialization and growing populations, the range of water requirements has expanded along with increased demands for higher quality water. The use of water, including water diversion and waste disposal, results in real, and usually very predictable, impacts on aquatic environment quality. Besides these deliberate uses of water, several human activities have indirect and harmful, if not catastrophic, effects on the aquatic environment. Topics involve unregulated land use for urbanization or deforestation, unintended (or unauthorized) emission of chemical substances, and leakage from solid waste dumps of untreated waste or leaching of noxious liquids. Similarly, the uncontrolled and excessive use of fertilizers and pesticides has long-term effects on ground and surface water resources (Nilsson et al. 2009).

Importance of construction of dams

The building of dams in Pakistan is essential, as after 1947 only two major dams were constructed, whereas, during the same time, India and Turkey built 24 and 65 dams respectively. Sedimentation in dams is drastically increasing not only halting irrigation resources but also lowering energy generation which also affects the expansion and efficiency of agriculture in the industrial sector. The government is working on prospective storage schemes to fulfill our country's future water and energy demand (Ahmed et al. 2007).

History of dams in Pakistan

Pakistan's historical Dams history is comparatively short. There were only three dams in Pakistan, at the time of independence. The Khushdil Khan Dam–1890 and Spin Karazi-1945 were located in Baluchistan's water-scarce area. In Punjab, there was only the Nomal Dam, built in the Mianwali district in 1913. In Pakistan, dam construction began in 1955, when the country faced acute power shortages and Warsak Dam was built near Peshawar on the Kabul River. India eventually stopped water supply for Pakistan which affected the channel system network. Development of the large storage of dams to recover water for the damaged canal system became very necessary. Two large dams have been built; one is Mangla with 5.88 MAF gross storage capacities and the other is Terbala with 11.62 MAF storage capacity as part of its Indus Basin Replacement Works. There are numerous dams for water supply and relatively small irrigation schemes have also been carried out (Ahmed et al., 2007).

Rawal dam

Rawal Lake Water Treatment Plant

Under the Rawalpindi Development Authority (RDA) Rawal Lake Water Treatment Plant is operated by the Water & Sanitation Agency (WASA). It collects water from the Rawal Dam / Lake located in Islamabad and provides water to Rawalpindi's Potohar district. It has a 275 Km^2 catchment which includes four major streams and 43 small streams which contribute to its storage. The total storage capacity of the lake is 58.5 MCM with live storage of 40 MCM (Pervaiz, 2016). Sludge generated from sedimentation tank and filtration backwash is disposed of in Korang River. The RLWTP has two different technologies for coagulation and flocculation as they were extended at different phases. The first phase consists of the Mechanical flash mixer, shaft paddle flocculator, and rectangular type sedimentation tank. The second phase consists of the clariflocculator. The effluent from these phases is then conveyed to the rapid sand filter for filtration (Pervaiz, 2016). Therefore, (Figure 1) shows the water treatment process.

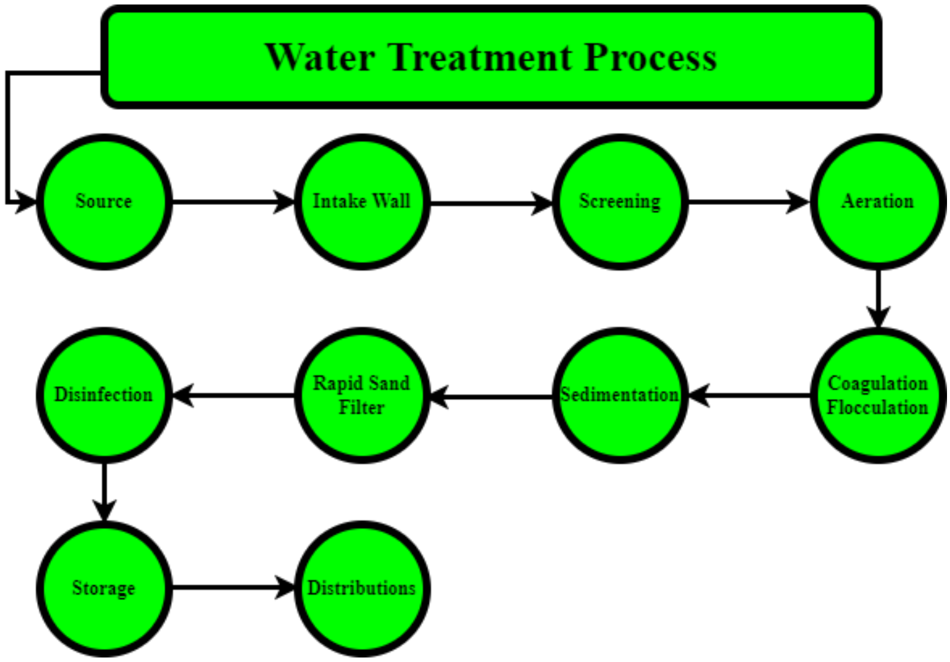

Figure 1. Flow chart diagram of the Water treatment process

Literature review

To examine the physicochemical parameters of water and sediments obtained from Rawal Dam Islamabad, the present analysis has been carried out by (Masood et al. 2015). Six samples at different locations were obtained at different periods. According to WHO and TWOR, the findings of the physiochemical parameters of water obtained from the Rawal dam were in the normal range, suggesting that water from the Rawal dam was convenient. (Chandio et al., 2019) investigated the physicochemical characteristics along the Rawal Dam Reservoir catchment area, Islamabad, Pakistan. Samples from key streams, drainage, community, and Dam mid were collected. Using standard methods the physicochemical parameters were evaluated. The results obtained showed that, despite a reasonable limit, the pH level was highest along Bani Gala at Pak-EPA. Mostly, conductivity was well above the allowable limit. The maximum level was shown. In the Bani Gala source, Total Suspended Solids were maximum, it has no permissible limit. Total Dissolved Solids in the nearby Bani Gala stream were a high of 1241 but some samples were within the acceptable limit. In Pre-and Post-monsoon chloride was maximum and there was no sample above the acceptable level. The hardness level in various stream locations was maximum but for most samples was above the permissible limit. Using a UV / absorption spectrophotometer, the sulfate and phosphate were also analyzed in the same sample. The sulfate and phosphate level concentration was highest at most stream positions and Rawal dam, both samples were above the permissible limit. DO range from 0.17 to 5.2. All analyses were below the permissible level. COD was, that not all of the samples were within the permissible limit. The values of various Rawal Dam water parameters suggested their levels are above permissible limits, mainly samples showed above permissible limits. It is concluded that the research area's drinking water poses an existential threat to living and drinking people. The study by (Daud et al., 2017) recorded the drinking water quality status and pollution studies conducted in Pakistan that accounted for sewerage water (fecal) mixing with drinking water as the dominant and main contaminant due to poor sanitation and sewerage network. The second source of waste is chemical emissions from industrial effluent toxic substances, clothing colors, pesticides, nitrogenous fertilizers, Arsenic, and other chemicals. Periodic monitoring of already existing treatment plants needs to be maintained and updated. Today, the Pakistani government is installing drinking water filters throughout Pakistan. The findings highlighted the need to consider sewerage interference with drinking water as a significant environmental and health problem. (Awais et al., 2015) has shown that the population has grown enormously in the Rawal Lake catchment area particularly in the last 11 years, i.e. 1998-2009. The population statistics showed an increase of 84 percent compared to 1998 at a growth rate of 5.75 percent per annum. The trend of land use has changed in the Rawal Lake catchment; from 1998 to 2009, the area under the category of built-up land increased from 14.7-23.12%, while the area under forest decreased from 58-48%. The average inflows from (1998-2009) were reduced as compared with the average inflows from previous years, the increase in urbanization in the catchment area is a factor in this decrease in inflows. There is no significant change in the catchment area's rainfall, but the inflows have declined which shows that the inflows are being decreased due to the increase in urbanization. The rise in urbanization has reduced Rawal Lake's water quality and its two major tributaries i.e., Main Noorpur Shahan, and river Korang. Biologically, the water is unfit for human consumption. Total coliform and fecal bacteria are more in count than the requirements of the WHO. There are also +ve E. coli bacteria found in Noorpur Shah Stream and Korang River. The main lake and Korang River water were also found more turbid than the WHO standards. The amount of calcium was observed more than WHO standards in the case of Noorpur Shah Stream. (Ali et al., 2014) concluded that due to several factors, the water quality of all the evaluated sites is declining in this research study; most notable are the human-induced activities such as irrigation, deforestation, soil erosion, poultry waste, solid waste disposal, and the domestic use of water and discharge to the sites without pretreatment. The sampling sites near populated areas such as the Angoori road and Rawal Lake were to derive to be more contaminated, and in June this load is greater than in April. In June, pollution intensity is due to increased anthropogenic activity, and summer heat and many tourists visit Murree Hills which is the catchment area of all the sampling sites. Recreational activities along the adjacent sampling site areas cause the surface water bodies to be heavily polluted. Some criteria are appropriate at all sites except for COD, DO, TA, and TSS and metals such as lead and cadmium according to USEPA, Pak-EPA, and WHO standards, except for WASA filtration plants, and therefore cannot be used for drinking; though other water activities can be carried out effortlessly. In addition, the WASA filtration system works effectively, eliminating the number of pollutants from all locations and making the water quality acceptable for drinking. Water samples have higher levels of lead and cadmium toxicity, so irrigation in agricultural fields should be strictly prohibited and the use of agrochemicals strictly controlled. The main line of defense should be the protection of water resources. National standards of environmental quality or the disposal of urban and industrial effluents should be enforced. A standard water quality inspection system should be formulated and implemented. There should be constant monitoring of all critical parameters. Thus, the main focus of our study and targeted objectives are to achieve the water quality of Rawal dam and its silt control tank (WASA) and to compare the quality of Rawal dam water with the WASA filtration plant.

MATERIALS AND METHODS

Study Area

The study area of this study was the Rawal Dam, its tributaries (Diplomatic enclave stream, Quaid e Azam university stream, Korang river), and silt control tank WASA (Table 1). Rawal Lake is the main water supply source for Rawalpindi town and cantonment district. Rawal dam is built on the Korang River and has a 106 square miles catchment area that generates 84,000 hectares of water in an average year of rainfall (Figure 2). Four major streams are contributing to its storage, and 43 are small streams. The total storage capacity is 12994 MG (47.500-acre feet). The open warehouse is 43,000 acre feet 11763 MG). The highest level for flooding is 1752 feet. Rawal Lake and its catchment area are important resources for Rawalpindi and the entire region. Proper management of this resource is vital for achieving and maintaining full benefits shortly. The most obvious benefit of the resources is for Rawalpindi to provide water supplies. The lake has been subject to contamination by several sources for the last few decades. These are Rawal Lake's human population, poultry waste, recreational activities, agricultural practices, deforestation, erosion and sedimentation, and eutrophication. Due to its effects on human health and aquatic ecosystems, surface water quality is of great importance. Running water is highly vulnerable to contamination due to its role in carrying off urban and industrial wastewater in its vast drainage basins and run-off from agriculture. As well as natural processes, anthropogenic activities deteriorate the surface water and hinder its use for drinking, commercial, farming, recreational or other purposes. In mid-June 2004, Rawal Lake, Islamabad took place (Tahir et al. 2016).

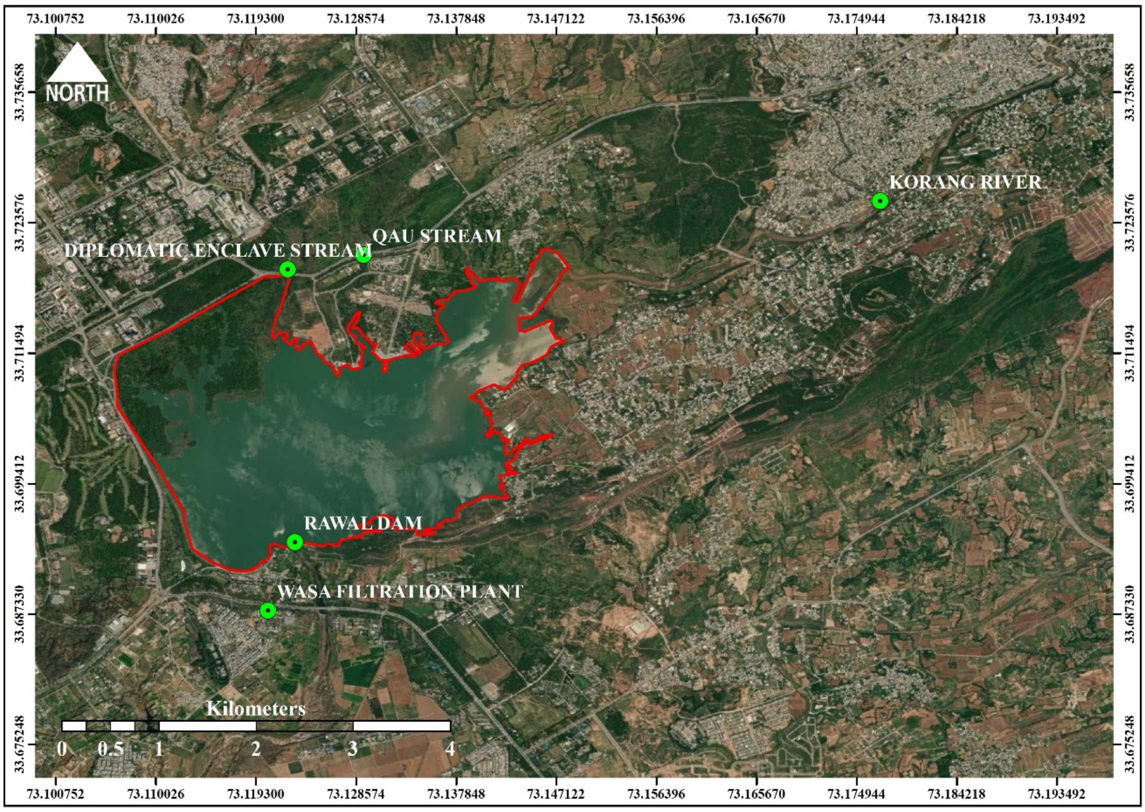

Figure 2. Layout map of study area showing water collection samples with green points

Sample collection

Water samples were collected from Rawal Dam, its tributaries, and the WASA filtration plant. The water samples were collected on a temporal basis in October (before rainfall) and November (after rainfall). The sampling places, names, and location GPS coordinates are given in (Table 1). Two different plastic bottles were used for water samples. Polyethene bottles of 500 ml were used for physical and chemical testing of collected water, and for the biological testing especial designed sterilized sealed bottles of 100 ml were used. Before collecting the samples from sample locations, we washed the polyethylene bottles thoroughly and filled them in such a way that no air bubbles were entrapped in the bottle. For biological testing, sealed bottles were completely dipped in water and its seal were opened inside the water so that no external contamination could enter the water sample. After sample collection, the sample bottles were closed properly, transferred to the laboratory, and stored at room temperature. We analyzed these samples within 24 hours of collection. (Figure 4) shows the pictorial view of sampling and laboratory analysis.

Table 1. GPS Coordinates the location of the study area

Sources	GPS Coordinates
Rawal Dam	33°41'38.2"N 73°07'22.5"E
Diplomatic Enclave Stream	33°43'09.2"N 73°07'20.1"E
Quaid E Azam University Stream	33°43'14.6"N 73°07'45.4"E
Korang River	33°43'32.0"N 73°10'37.8"E
WASA Filtration Plant	33°41'15.4"N 73°07'13.5"E

Analysis of Physical, Chemical, and Biological Parameters

(Figure 3) shows a flow chart for tests conducted for analysis of physical, chemical, and biological parameters. Standard procedure was employed for the analysis of physical and chemical parameters. Physical parameters including (pH, EC, Salt, Temperature, TDS, etc.) were analyzed by using Multi-parameter tester 34, and turbidity was measured by using an electronic turbidity meter, while ORP was measured by a conductivity meter. On the other side, Chemical parameters were analyzed by using the volumetric titration method. Likewise, Microbiological parameters were analyzed by spread plate count method and by biochemical test i.e., gram staining method**.**

Figure 3. Flow chart diagram for physical, chemical, and biological testing methods

Physical Parameters

pH

The pH is an important variable in water quality assessment as it influences many biological and chemical processes within a water body and all processes associated with water supply and treatment. The pH is a measure of a solution's acid balance and is defined as the logarithm negative of the concentration of hydrogen ions at base 10. The pH scale ranges between 0 and 14 (i.e. very acidic to very alkaline), with pH 7 indicating a neutral state. At a given temperature, pH (or behavior of hydrogen ions) indicates the strength of a solution's acidic or basic character and is controlled by the dissolved chemical compounds and biochemical processes in the solution. For uncontaminated waters, pH is regulated mainly by the equilibrium of carbon dioxide, carbonate, and bicarbonate ions. The pH of most natural waters is between 6.0 and 8.5, although lower values can occur for diluted waters rich in organic content and higher in eutrophic waters, groundwater brines, and salt lakes (Nilsson et al. 2009).

Total dissolved solids

Inorganic and organic matters present in water that can pass through the filter of 2 microns are known as total dissolved solids (TDS). It is the sum of Cations and anions present in water. TDS will only tell how much the total amount of these ions are present in it but will not tell the relationship between them and nature.

Electrical conductivity

Conductivity, or particular conductance, is a function of water's ability to conduct an electric current. Variations in dissolved solids, mostly mineral salts, are sensitive. The extent to which these dissociate into ions, the sum of electrical charge on each ion, the mobility of ions, and the solution temperature all affect the conductivity. Conductivity is expressed as micro Siemens per centimeter (µS cm-1) and, for a given water body, is related to the concentrations of total dissolved solids and major ions (Nilsson et al. 2009).

Temperature

In addition to normal climatic variability, the water bodies undergo temperature variations. Such changes occur seasonally and over 24-hour cycles in some water bodies. Surface water temperature is determined by latitude, altitude, seasons and time of day, air circulation, cloud cover, and water body movement and depth. The temperature in turn affects physical, chemical, and biological activities in water bodies and hence the concentration of many parameters in water bodies. As the temperature of the water increases, the rate of chemical reactions generally increases with the evaporation and volatilization of substances from the levels of water. Growth rate (this is most significant for bacteria and phytoplankton which double their populations in very short periods) leads to increased water turbidity, macrophyte growth, and algal blooms when nutrient conditions are suitable.

Turbidity

The unseen particles to the naked eyes cause the turbidity of water. The measure of turbidity by turbidity meter will tell the quality of water. Different size of particles is suspended in water. Different man-made activities like mining, urbanization, and construction are the reason for turbidity in water. So therefore it is one of the important parameters to analyze because many dangerous bacteria attach to particles and may cause serious health issues.

Oxidation-reduction potential

Oxidation-reduction potential also called ORP is a factor that determines the cleanliness of the water and the ability to remove or break down contaminants from water sources. The higher the level of ORP the more water can break contaminants such as microbes.

Salt

The salty nature of water and the presence of dissolved salts is called salt water or saline water. NaCl molecules get separated when salt molecules are dissolved in water and then they become free ions.

Chemical Parameters

Alkalinity

Natural water alkalinity is usually due to the presence of bicarbonates that are produced in reactions in the soils through which the water percolates. It is a measure of the water's ability to neutralize acids and represents its so-called buffer capacity (it is inherent pH shift resistance). Inadequately buffered water will have low or very low alkalinity, and will be vulnerable to pH reduction by, for example, "acid rain." Moreover, river alkalinity values of up to 400 mg / l CaCO3 can sometimes be found; they are irrelevant in terms of water quality. The most widely used indicators are phenolphthalein (color change around pH8.3) and methyl orange (color change around pH 4.5), resulting in additional terms alkalinity of phenolphthalein and alkalinity of methyl orange; the latter synonymous with total alkalinity. The following (Equation 1) is used for the Alkalinity.

$$\mathrm{TA}\frac{1\mathrm{mg}}{\mathrm{L}}\text{ for CaCO3} = \frac{\mathrm{A}\times\mathrm{B}\times1000}{\text{ml of sample}} \qquad (1)$$

Where, A = ml of H_2SO_4 used with only methyl orange, B = normality of H_2SO_4, TA = total alkalinity

Carbonates

The presence of carbonates ($CO_3{}^2$) and bicarbonates (HCO^3) influence the water hardness and alkalinity. The inorganic carbon component (CO^2) arises from the atmosphere and biological respiration. The rock weathering contributes production of carbonate and bicarbonate salts. In areas of noncarbonated rocks, the HCO^3 and $CO_3{}^2$ derive completely from the atmosphere and soil CO_2, whereas in areas of carbonate rocks, the rock itself contributes approximately 50% of the carbonate and bicarbonate present. The relative amounts of carbonates, bicarbonates, and carbonic acid in pure water are related to the pH. As a result of the weathering process, combined with the pH range of surface waters (~6-8.2), bicarbonate is the dominant anion in most surface waters. Carbonate is uncommon in natural surface waters because they rarely exceed pH 9, whereas groundwaters can be more alkaline and may have concentrations of carbonate up to 10 mg l-1. Bicarbonate concentrations in surface waters are usually < 500 mg l-1, and commonly < 25 mg l-1. The concentration of carbonates and bicarbonates can be calculated from the free and total alkalinity. However, the calculation is valid only for pure water since it assumes that the alkalinity derives only from carbonates and bicarbonates (Nilsson et al., 2009).

Chlorides

Most of the chlorine occurs in the solution as chloride (Cl-). This penetrates surface waters with the atmospheric accumulation of oceanic aerosols, weathering some sedimentary rocks (predominantly rock salt deposits) and industrial waste effluents, and run-off of agricultural and highways. Road salting during winter periods will significantly contribute to groundwater chloride increases. High chloride concentrations can make water objectionable, and hence unacceptable for drinking or watering livestock. Chloride concentrations are considerably lower than 10 mg l-1 in pure freshwater habitats and sometimes lower than 2 mg l-1. Higher concentrations can exist in the vicinity of sewage and other waste sources, irrigation drains, intrusions of salt water, arid areas, and west coasts. Chloride determination samples do not need preservation or special treatment and can be kept at room temperature. The analysis can be carried out using normal or potentiometric titration methods. Chloride-sensitive electrodes may make direct potentiometric determinations.

Principle:

Silver nitrate reacts with the chloride to form the AgCl white precipitate which is very slightly soluble. When all the chlorides become precipitated at the endpoint, free silver ions react with chromate to form reddish brown silver chromate. The following (Equations 2 & 3) were used.

$$Chloride\ (\frac{mg}{L}\ of\ CL- = \frac{(\mathrm{ml} \times \mathrm{N})\ \mathrm{of\ AgNO3} \times 1000 \times 35.5}{35.5\ Vol.of\ sample} \quad (2)$$

$$Chloride\ (\frac{mg}{L}\ of\ NaCl) = \frac{(\mathrm{ml} \times \mathrm{N})\ \mathrm{of\ AgNO3} \times 1000 \times 58.5}{35.5\ Vol.of\ sample} \quad (3)$$

Hardness

Hardness is a natural characteristic of water which can increase its nutritional quality and the acceptability of consumers for drinking purposes. In recent years, health studies in several countries have shown that mortality rates from heart disease are lower in hard water regions. Natural water hardness largely depends on the presence of soluble calcium and magnesium salts. The overall content of these salts is classified as general hardness, which can be further divided into carbonate hardness (determined by calcium and magnesium hydro carbonate concentrations) and non-carbonate hardness (determined by heavy acid calcium and magnesium salts). Hydro carbonates are transformed during the boiling of water into carbonates, which usually precipitate. During the boiling of water, hydro carbonates are converted into carbonates that generally precipitate. Hence carbonate hardness is also known as temporary or withdrawn, whereas it is called constant hardness remaining in the water after boiling. Calcium hardness is generally prevalent (up to 70%); while magnesium hardness can exceed 50-60% in some cases. Generally, general hardness is determined by complex metric titration with EDTA. You can assess either general hardness (using eriochrome black T) or calcium hardness (using murexide), depending on the indicator used. The durability of magnesium is determined by the difference between the two determinations. The durability of carbonate is determined by acid-base titration (Nilsson, 2009). Ca^{2+} is abundantly present in natural water due to the constant leaching from luck into water. The concentration of water can differ depending on the concentration of Ca in the water. It is an essential nutrient to the organism so even if it reaches 1500 ppm; it does not have a health hazard. Calcium can be intoxicating the toxicity of Pb, Zn, and KCl but the increased concentration of calcium in water can increase the hardness of water so not applicable for domestic or industrial purposes. Mg+ in natural water is less common than Ca +. The rocks, sewage, and industrial waste are important sources of Mg. If Mg+ concentration exceeds 500 ppm, it will impart an unpleasant taste and will also increase water hardness (Joshi and Shrestha, 2018).

Microbiological Parameters

This analysis was carried out by the spread plate count method. This method was done to check the total number of coliform bacteria present in water samples. Three different types of media were used including NA, EMB, and SS agars. For removal of contamination and microorganism sterilization of Petri dishes (Figure 4) were done in an autoclave for 2 hours. Also, the media solution required for samples was sterilized along it in the autoclave. After autoclaving, the media was poured into sterilized dry plates using an aseptic technique in a laminar airflow cabinet, after pouring let agar dry and solidified. A water sample was spread on each petri dish to check the presence or absence of total coliform bacteria, fecal coliforms, Salmonella, and Shigella Bacteria.

Figure 4. shows a pictorial view of the sampling water and laboratory analysis

Gram staining method

The gram staining technique is used to differentiate between Gram-positive and Gram-negative bacteria. For the method, four reagents were used: 1. Crystal violet, 2. Gram iodine, 3. Decolorizer, and 4. Safranine. (Figure 5) represents the Gram staining method below.

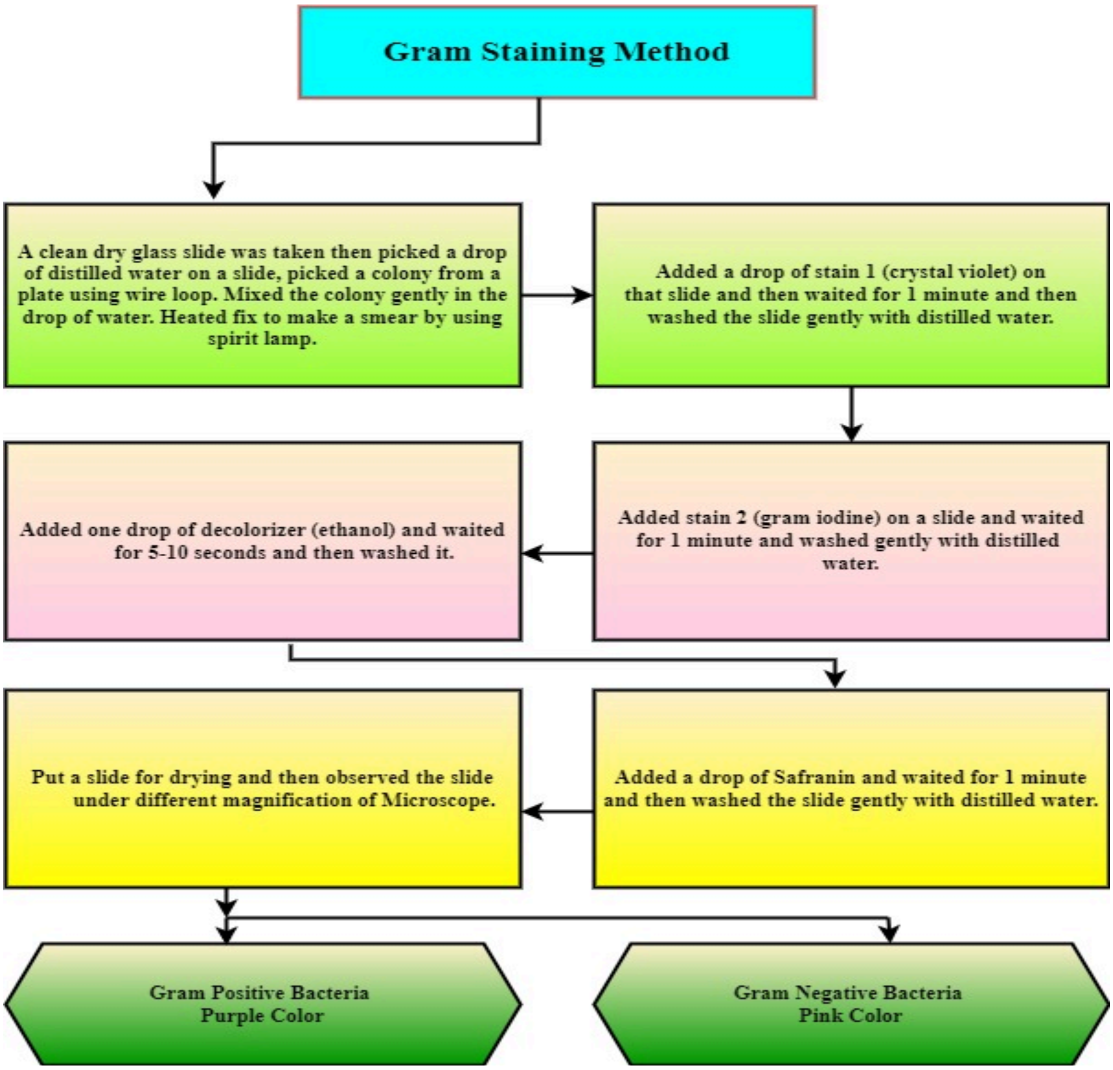

Figure 5. flow chart methodology for Gram Staining Method

RESULTS AND DİSCUSSİON

Physico-chemical analysis

In this study, water samples collected from the study area were analyzed, in which various parameters were tested. The physicochemical data of the study area were collected in October and November 2019 and then compared with the standards of WHO and Pak-EPA.

pH

pH is an important factor that determines the acidity and basicity of water. It also evaluates the acid-base balance of water. pH is determined by the amount of carbon dioxide dissolved in water, which forms carbonic acid. WHO and PAK-EPA have recommended a specific range of pH in which water is termed neutral (acid-base balance), the determined range is 6.5-8.5 (Figure 6).

Total Dissolved Solids (TDS)

The standard limit for total dissolved solids in PAK-EPA is 1000, while the standard for TDS in WHO is not specified/ defined. The TDS concentration in water samples of DAM, DE, QAU, KR, and WASA are 244, 322, 283, 337.5 and 305 ppm respectively lies within the range given for TDS in water samples (Figure 7).

Electrical Conductivity (EC)

Electrical conductivity determines the concentration of electrolytes in water containing mineral salts. The results showed that the electrical conductivity of water samples obtained from DAM, DE, QAU, KR, and WASA is within standard limits of WHO and PAK-EPA which is equal to 600 µs/cm (Figure 8).

Salt

The standard Concentration of salt content given by WHO and PAK-EPA is 250 mg/L. The concentration of salts in DAM is 175.5 mg/L which is within the permissible limits. Similarly, the salt content of DE, QAU, KR, and WASA are 238, 205.5, 246, and 250 mg/L respectively (Figure 9). The value of the KR sample is within the standards of WHO.

Oxidation Reduction Potential (ORP)

ORP stands for oxidation-reduction potential which is the ability of water to clean up all the contaminants by eliminating them by a redox reaction. WHO and PAK-EPA did not define any specific limit for ORP. DAM contains more able to clean the water while other samples such as DE, QAU, and KR are followed by each other in ORP. The ORP value of WASA is 17mV (Figure 10).

Turbidity

Turbidity should not exceed more than 5 NTU according to the standards of WHO and PAK-EPA. The value of turbidity in DAM is within the given limit which is 4.44 NTU, while values of DE and QAU are also within the limits. The value of turbidity in KR is extremely higher than the given limit which is due to its dirty and turbid water, while the value of WASA is 6.08 NTU which is slightly higher than the value of standards (Figure 11).

Magnesium

The results showed the magnesium concentration in the water sample collected from the study area and compared with the given standards of PAK-EPA, but there is not any standard set by WHO. As the graph shows only the water collected from the WASA filtration plant is within the permissible limit, while the other water sample collected from the DAM, QAU, DE, and KR are approximately equal to or above the given limits.

Calcium

The limits given by PAK-EPA for calcium concentration are less than 200 mg/L, but there is not any limit given by WHO. Calcium concentrations of all the water collected from the study location lie within the permissible limit given by PAK-EPA.

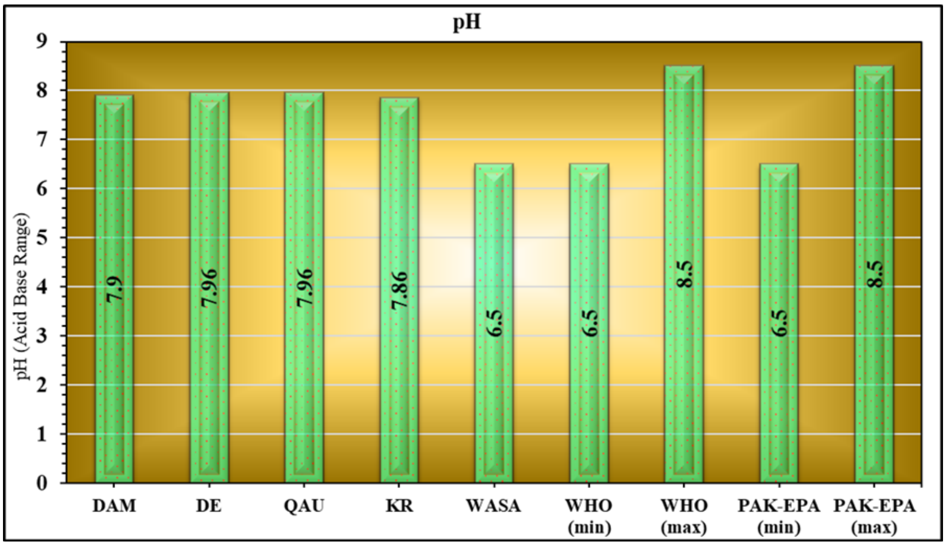

Figure 6. pH of water samples compared with standards

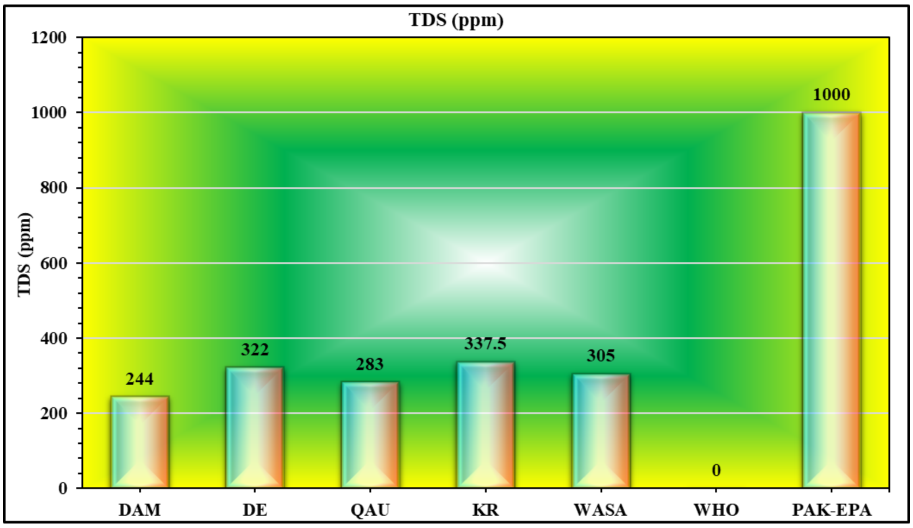

Figure 7. Total dissolved solids of water samples compared with standards

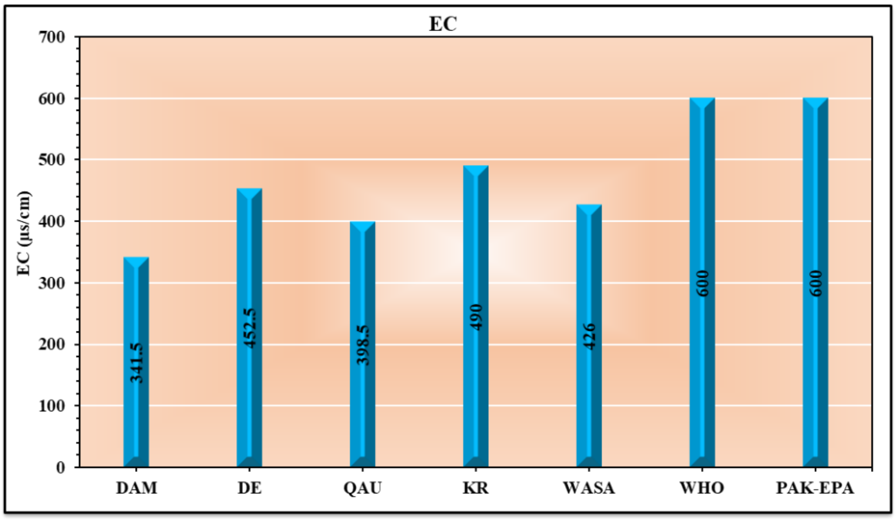

Figure 8. Electrical conductivity of water samples compared with standards

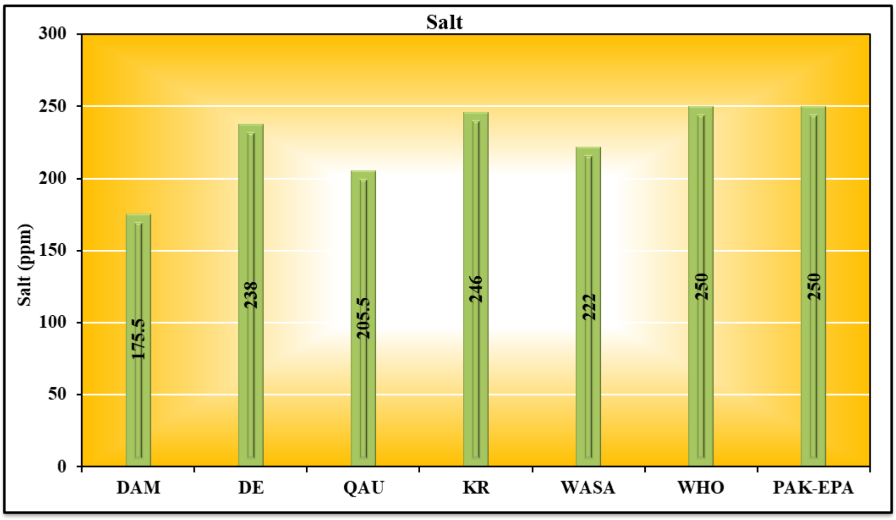

Figure 9. The salt content of water samples compared with standards

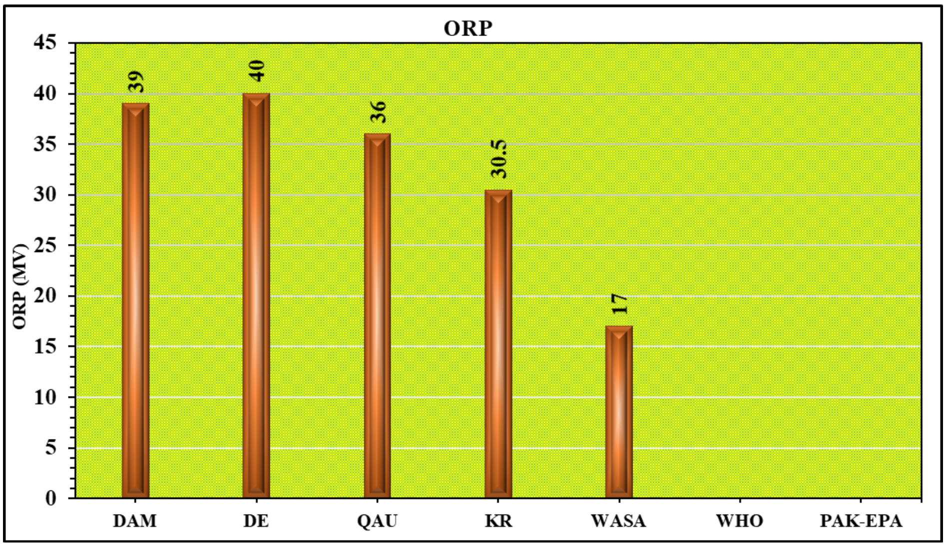

Figure 10. The oxidation-reduction potential of water samples compared with standards

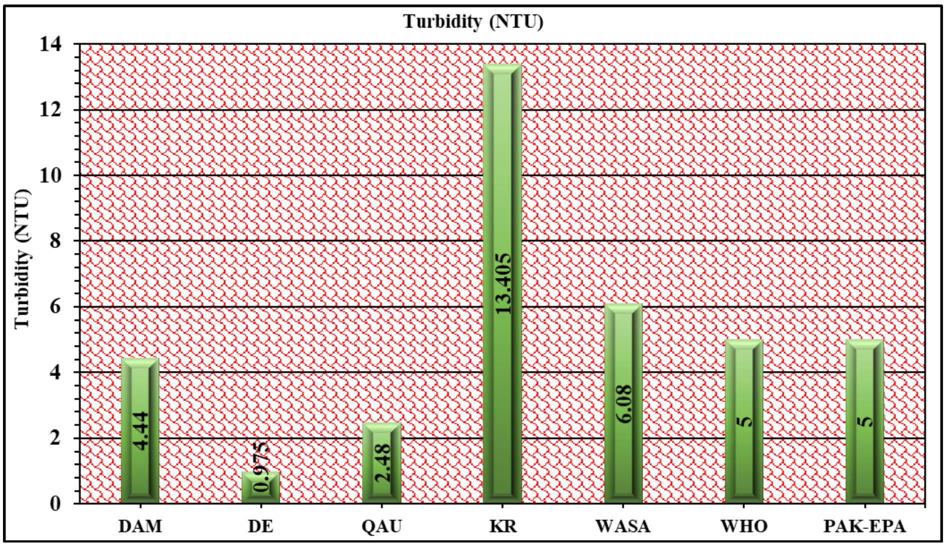

Figure 11. Turbidity of water samples compared with standards

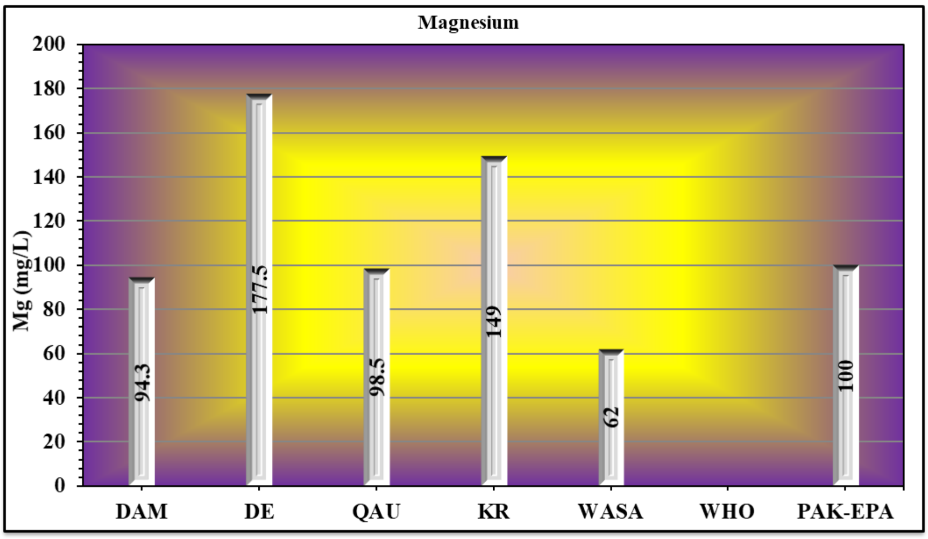

Figure 32. The magnesium content of water samples compared with standards

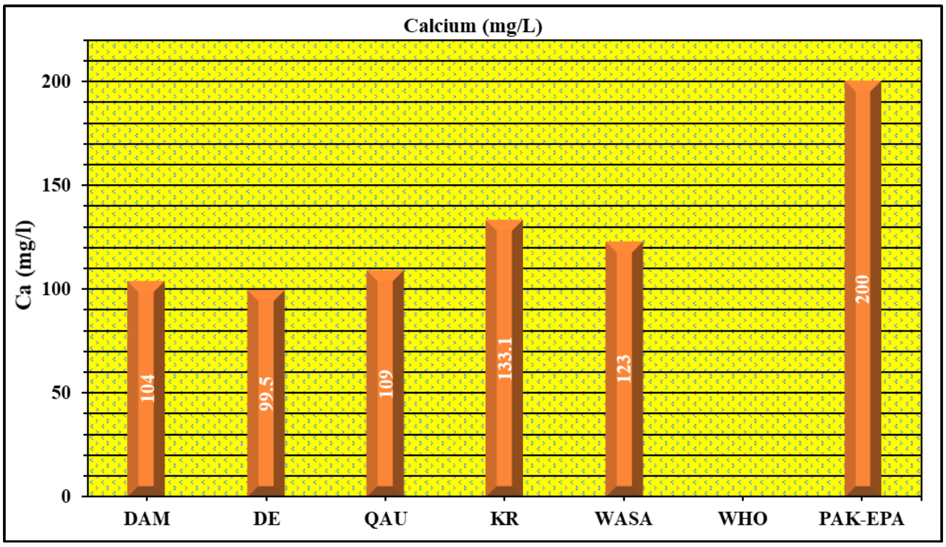

Figure 43. Calcium content of water samples compared with standards

Total Alkalinity

The limit of total alkalinity given by WHO does not exceed more than 200 mg/L, but PAK-EPA has not given any standard for alkalinity. The concentration of total alkalinity in water samples collected from all the study locations lies within the permissible limits given by WHO (Figure 23).

Sodium Chlorides

Sodium chlorides determine the measure of salts (NaCl) in water. PAK-EPA and WHO have given limits for salt in water, which should not exceed more than 250 mg/L. The chlorides concentration in all water samples collected from the study area is within the permissible limit given by PAK-EPA and WHO (Figure 24).

Total hardness

PAK-EPA has given the limit of total hardness in water which should not exceed more than 250 mg/L, WHO has not given any standard related to the total hardness. Only the total hardness of DAM water and water collected from WASA lies within the permissible limits and all the other samples have a total hardness more than the given limits of PAK-EPA expressed in (Figure 25).

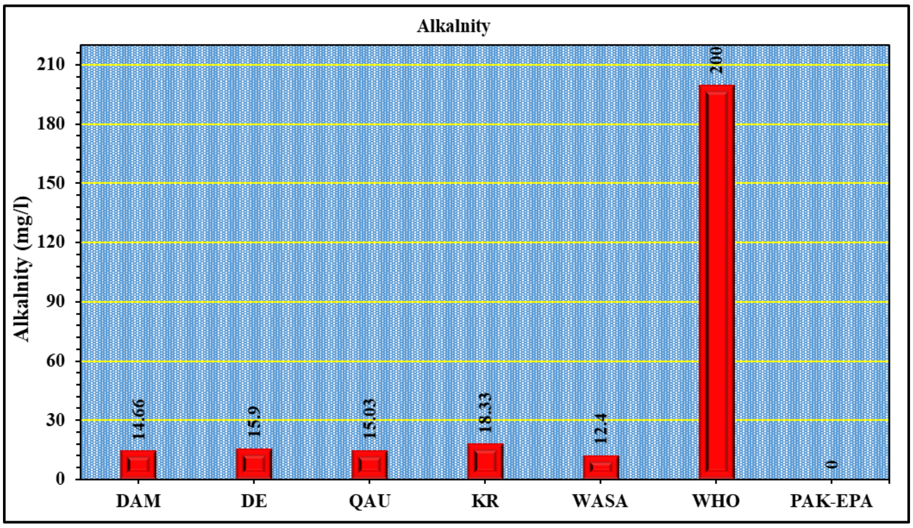

Figure 14. Total alkalinity of water samples compared with standards

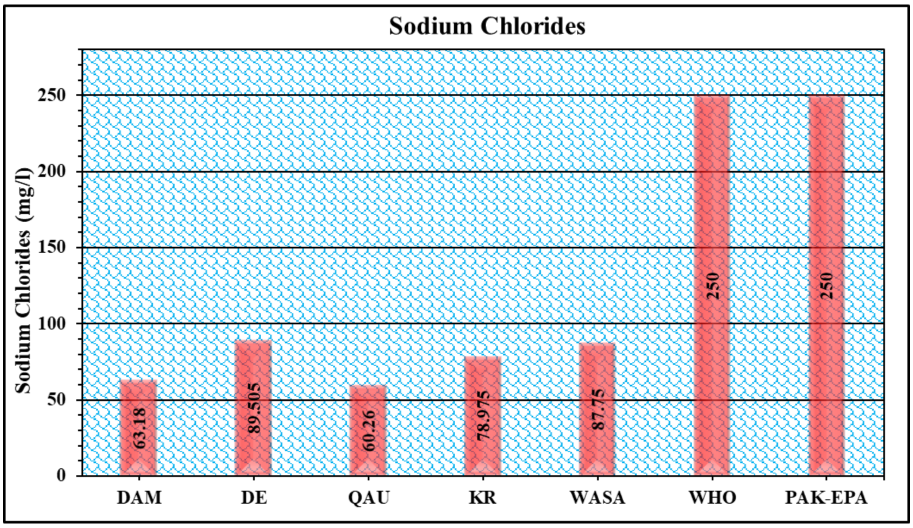

Figure 55. Chlorides content of water samples compared with standards

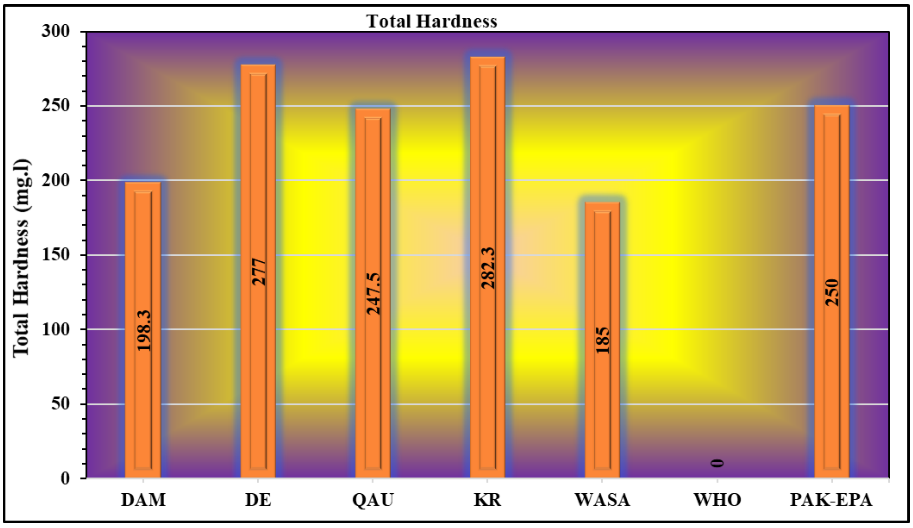

Figure 66. Total Hardness of water samples compared with standards

Table 2. Mean concentrations of physicochemical parameters in water samples

Parameters	DAM	DE	QAU	KR	WASA	WHO	PAK-EPA
Ph	7.9	7.96	7.96	7.86	6.5	6.5-8.5	6.5-8.5
TDS (ppm)	244	322	283	337.5	305	NSRD	1000
EC (µs)	341.5	452.5	398.5	490	426	600	600
Salt (ppm)	175.5	238	205.5	246	222	250	250
Temperature (°C)	17.05	17.2	17.45	17.3	14.4	NSRD	NSRD
Turbidity (NTU)	4.44	0.975	2.48	13.405	6.08	5	5
ORP (mV)	39	40	36	30.5	17	-	-
Total Alkalinity (mg/L)	14.66	15.9	15.03	18.33	12.4	200	-
Total Carbonates (mg/L)	19.185	18.485	19.415	24.715	26.12	-	-
Calcium (mg/L)	104	99.5	109	133.1	123	-	200
Magnesium (mg/L)	94.3	177.5	98.5	149	62	-	100
Sodium Chlorides (mg/L)	63.18	89.505	60.26	78.975	87.75	250	250
Total Hardness(mg/L)	198.3	277	247.5	282.3	185	-	250

Microbiological Analysis

The results of the microbiological analysis showed that the bacteria are present in all water samples except in the sample of the WASA filtration plant. According to the WHO and PAK-EPA standards, there should not found any bacteria in the drinking water. A water sample from WASA complied with the standards while other water samples (DAM, DE, QAU, and KR) contain bacteria that are gram-positive during October while some samples contain gram-negative bacteria in November. Gram staining results determined that diverse bacteria are present in samples collected from the study area because EMB and SS Agars showed the growth of gram-positive bacteria as well.

E-coli is an indicator microorganism for fecal contamination in water samples and the presence of E-coli is shown by gram-positive results of gram staining. A gram-positive result shows the presence of E-coli along with other pathogenic bacteria inhabiting the water reservoirs. These results are further supported by the presence of *salmonella* and *shigella* in the bacterial count at all locations except the WASA filtration plant. Only the water of WASA is acceptable for drinking purposes because there were not any pathogenic bacteria found. In (Table 5), Gram-positive bacteria include Bacillus, Listeria, Staphylococcus, Streptococcus, Enterococcus, and Clostridium. Gram-negative include cyanobacteria, spirochetes, green sulfur bacteria, and most Proteobacteria.

Table 3. Microbial counts of water samples compared with WHO standard

	DAM	DE	QAU	KR	WASA	WHO
NA	74	467	373	261	2	0 CFU/100mL
EMB	2	40	30	70	0	0 CFU/100mL
SS	2	27	57	118	0	0 CFU/100Ml

Table 5. Gram staining results of water samples

Sample locations	Gram Staining Result	
	Oct	Nov
DAM	Gram-positive	Gram-negative
DE	Gram-positive	Gram-negative
QAU	Gram-positive	Gram-negative
KR	Gram-positive	Gram-positive
WASA filtration plant	-	Gram-positive

DISCUSSION

The findings showed that all the physicochemical and biological parameters are within the prescribed limits of WHO and PAK-EPA standards of drinking water quality. The water quality of the korang river (KR) is not that good and concentrations of certain parameters exceeding from the given limits. This is due to the increase in urbanization/population around the river korang. All the sewage waste is being disposed of directly into the river without any treatment. Similarly, the Korang River contains high microbial counts due to the sewage waste which can pose serious health issues to humans or other species. Other than that, the investigation found that the maximum parameters were under the limits given by WHO and PAK-EPA. The comparison of results with the WASA filtration tank showed that the water coming from the DAM is being filtered and sediments are being settled down in the tank. In this way, filtered water is supplied to the population for drinking purposes. All deviations from the given limits are because of the high concentration of sediments and salts which increase the hardness of water and eventually impact the quality of water and the health of the consumer. The main reason for these deviations is unplanned urbanization and poor sewage system.

CONCLUSIONS

In this study, the collected water samples of Rawal dam, its tributaries (QAU, DE, and, KR), and the WASA filtration plant were analyzed for physical parameters (ph., temperature, EC, turbidity, ORP, salt), chemical parameters (chlorides, magnesium, calcium, total hardness, total alkalinity, and carbonates) and microbiological parameters (total coliforms bacteria, gram staining). All obtained results are within the permissible limits of WHO and Pak-EPA standards. The results show that the quality of water of the WASA filtration plant is very good as compared to the water of the Rawal Dam and its tributaries. All the obtained results of water quality of WASA filtration plants were lower than that of Rawal dam water. From the obtained results of physicochemical and biological parameters of collected water, it was shown that the water quality of Korang River is very bad. The tributary of the Korang River is the main source of the polluting water of Rawal Dam. The main reasons are the increase in urbanization and the damaged sewage system.

RECOMMENDATIONS

- ✓ Our study recommended that there is a need to place a proper check and balance on the spread of urbanization and discharge of effluents in the Rawal dam tributaries.
- ✓ The residential wastewater/ sewage water must be collected at a specific area where it is to be treated before being discarded directly into the stream.
- ✓ EPA and other authorized agencies should inspect and monitor all the parameters of the water of the WASA filtration plant regularly before supplying it to the consumer and should ensure the health of consumers.
- ✓ Further detailed and authentic studies and research should be carried out on microbial characteristics of water quality and the risks they pose to human health.

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