COMPARATIVE STUDY OF PHYSICOCHEMICAL AND MICROBIOLOGICAL PARAMETER OF WATER FROM RAWAL DAM AND ITS SILT CONTROL TANK

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ABSTRACT

Water plays vital role on this planet it is very important factor for living of almost every species. Water resource has been depleting, exploiting, and polluting day by day due to the exposure to different hazardous contaminants and misuse of water. Urbanisation and population growth increase the risk of water quality degradation of wate r 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 silt control tank of Rawal dam which is WASA filtration tank. The main objectives of this research work was to access the water quality consumed by the public and to find out whether the water quality parameters are complying with the standards or not. Water sample were collected from the main Rawal dam, and from its tributaries which are entering the dam .All the five water samples were analyzed separately to get the results and were compared with water quality standard prescribed by World Health Organization (WHO) and PAK-EPA. The samples were collected in sterilized plastic bottles during the months of 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. It was revealed from the results that most of the parameters from upstream to the main dam were exceeding the standards, while 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 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.

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ABBREVIATIONS

DE	Diplomatic Enclave
QAU	Quaid e Azam university
WASA	Water And Sanitation Agency
KR	Korang River
EMB	Eosin Methylene Blue
NA	Nutrient Agar
SS	Salmonella Shigella
TDS	Total Dissolve Solids
NTU	Nephelometric Turbidity Unit
PPM	Parts Per Million
EC	Electrical Conductivity
ORP	Oxidation Reduction Potential
Oct	October
Nov	November
EDTA	Ethylenediamine Tetra Acetic Acid
Mha	Million Hectare
MAF	Million Acre feet
NWFP	North West Frontier Province
RDA	Rawalpindi Development Authority
RWTP	Rawalpindi Water Treatment Plant
N	Normality
M	Molarity

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INTRODUCTION

1.1 Water

“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 much water in the form of storms and floods can raze an entire population. Too little water can mean food insecurity and drought at a time when it is most needed. The water that is contaminated, whether anthropogenically or industrial sources, claims lives of children and affects the health of communities all over the world, with far-reaching effects (Ahmed et al., 2019).

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 (Pedro and Valley, 2014).

1.1.1 Water resources

There are different types of water-resources found in Pakistan including surface water resources, ground water resources and rainfall. The degree of availability of these resources is based on location. A short description of water resources of Pakistan is given in the following sections (Kahlown and Majeed, 2003).

1.1.2 Surface Water-Resources

Surface water resources of Pakistan are mainly based on Indus River and its tributaries. The Indus River has a total length of about 2900 kilometers (km) and the drainage-area is approximately 966,000 square kilometers. There are five major tributaries joining its eastern side are Chenab, Jhelum, Ravi, Sutlej, Beas and besides these five there are also three minor tributaries are the Harow, Soan, and Siran which drain in mountainous areas. A number of 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 designate to divert flows of Ravi, Beas and Sutlej. This treaty also given for the construction of a number of connecting canals, barrages and dams on the Indus and its two tributaries, Jhelum and Chenab, transferring at least about 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 about 65 percent of total river flows, while the share of Jhelum and Chenab is approximately 17 and 19 percent respectively(Kahlown and Majeed, 2003).

1.1.3 Groundwater Resources

Groundwater resources of Pakistan are mostly present in the Indus Plain, lengthening from Himalayan foothills to Arabian Sea, and are stored inside an alluvial deposits. The Plain is about 1,600 km long and covers an area of about 21 Mha and is blessed with a wide unconfined aquifer, which is supplementary source of water for irrigation. The aquifer was developed over the past 90 years as a result of direct drainage from river flow, natural precipitation, and continuous flow from the conveyance network of distribut aries, canals, watercourses and application-losses in irrigated lands. This aquifer, with a potential of about 50 MAF, is being over use 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 karezes, 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).

1.1.4 Rainfall

In Pakistan about 70 percent of the rainfall occurs in the months of 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 between 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 are much more than they can easily be use. Rainfall at huge amount can cause either floods

In the riverine areas or villages, cities near the river and 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 towards central parts of the Sindh. The southern Punjab and northern Sindh are the 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. Northern and northwestern area of NWFP and the northern areas of Baluchistan receive 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 about 6 MAF (Kahlown and Majeed, 2003).

1.2 Access to safe drinking water

In Pakistan access to safe drinking water falls beneath adequate levels with only about 25% of the population has 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 availability of safe and clean drinking water. Contaminated water is the major cause in deteriorating the health related issues to the public. The quality of ground water in the country is also no longer safe due to changing of external factors. The quantity of water available to public sector for drinking is of low quality. The old and damage 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).

1.2.1 Water demand and availability

The level of agricultural production is related directly to the availability and effective use of water as a 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 in order to meet 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 evaporation of water, such salts dry out on the soil surface and deplete its fertility. It is estimated that about 25 per cent 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 entire runoff. It is estimated that 25 percent about has been destroyed due to salinity. For irrigation purpose, only one third of water is used (Kaleem et al., 2007).

1.3 Physical and chemical properties

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 chemical quality varies according to local geology, the distance from the ocean, climate, and the amount of soil cover, etc. If surface waters were not affected by human activities, up to 90-99 per cent 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).

1.3.1 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).

1.4 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. 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, there are several human activities that 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).

1.5 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 halted irrigation resources but also lower 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).

1.5.1 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 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 had an effect on 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 appproximately 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).

1.5.2 Rawal dam

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. There are four major streams contributing to its storage, and 43 small streams. The total storage capacity is about 12994 MG (47.500 acre feet). 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 in the near future. The most obvious benefit of the resources is for Rawalpindi to provide water supplies. The lake has been subject to contamination by a number of 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 the 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. At mid-June 2004, Rawal Lake, Islamabad took place (Tahir and Ali, 2016).

1.5.3 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 the live storage of about 40 MCM (Pervaiz,2016).

Water treatment process

The treatment process includes:

- Screening
- Aeration
- Coagulation and Flocculation
- Sedimentation
- Rapid Sand Filter
- Disinfection
- Storage
- Distribution

Sludge generated from sedimentation tank and filtration backwash is disposed of to 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 the 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 the filtration (Pervaiz, 2016).

1.6 Literature review

In order to examine the physiochemical parameters of water and sediments obtained from Rawal Dam Islamabad, present analysis has been carried out by Masood et al., 2015. Six samples at different locations were obtained at different time 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 (Masood et al., 2015).

The word "Coliform" refers to rod-shaped bacteria, with no spore forming, Gram negative. They help in food digestion. A unique subgroup of this bacteria family is the fecal coliform bacteria, the most common member being Escherichia coli which passes through human, livestock, and wildlife fecal excrement. Such species may be distinguished from the total coliform community by their ability to g row at elevated temperatures and are only associated with the warm blooded animals' fecal material. During the rainy season, fecal coliform bacteria can enter the water reservoir by discharging waste directly from mammals and birds, from farm and storm runoff, from untreated human sewage, or through individual home septic tanks, causing untreated human waste to spill into drainage ditches and surrounding waterways. The study shows the Coliform bacterial population for water samples obtained from source of input water (feeding streams) and three representative locations covering the lake's cross-section of inflow and outflow. Analysis of water samples obtained from sources of input water (streams that feed Rawal Lake) reveals that total coliform levels range from 55 to 102 per 100 mL of water. Total Coliform higher values are recorded for the Minor Stream (located at a milestone of 22 km). Fecal Coliform levels range from 25 to 37 Fecal Coliforms/100 mL for input water sources. The higher Fecal Coliform values for the Korang River water are observed (Mashiatullah et al., 2010).

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 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. Hardness level in various stream locations was maximum but for the most samples were above the permissible limit. Using 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 position and Rawal dam, both samples were above the permissible limit. DO ranged in from 0.17 to 5.2. All analyses were below the permissible level. COD was, 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 the living and drinking people (Chandio et al., 2019).

The study of 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 and nitrogenous fertilizers, Arsenic and other chemicals. Periodic monitoring of already existing treatment plants needs to be maintained and updated. Today, 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 (Daud et al., 2017).

In this paper Ahmad et al., 2007 studied the different aspects of Pakistan's water resources and proposed a plan for water conservation. It cannot be left aside the value of water when thinking about Pakistan's economic growth and development as it serves as the economy's life blood. Despite rapid population growth and increased water usage, its supply fails to meet the requirement over time. In addition to the challenges of water scarcity and energy crisis, global warming is yet another significant challenge that is overwhelming the country's policymakers. The country's water-use policies are not in line with water efficiency and safety standards. Almost all of the water is contaminated and unhygienic for both human and animal drinking purposes. Study of existing water supplies and development of a holistic conservation and management policy with a view to fulfilling planning criteria for the future (Ahmad et al., 2007).

Memood et al., 2013 conducted this study for drinking activities some samples collected from Rawalpindi and Islamabad were not suitable. Chemical parameters such as hardness, total dissolved solids, and calcium were greater than the drinking water quality standards set by WHO and PSQCA. Total viable count testing conducted to examine the microbial quality of water samples reported that all of the samples were heavily loaded with microbial contaminants such as coliforms, fecal coliforms and E.coli and the water was unfit for drinking. It is therefore concluded that pollution in drinking water from certain regions of Rawalpindi and Islamabad needs efficient treatment of water for chemical and microbial quality before it reaches the user (Mehmood et al., 2013).

In this research Awais et al., 2015 has shown that 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; throughout the duration of 1998-2009 the area under the category of built up land has increased from 14.7-23.12%, while area under forest has decreased from 58-48%. The average inflows from (1998-2009) 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 is 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 was also found more turbid than the WHO standards. The amount of calcium was observed more than WHO standards in case of Noorpur Shah Stream (Awais et al., 2015).

In this research Ali et al., 2015 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, 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 quantity 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 defence 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 (Ali et al., 2015).

1.7 Study Area

The study area of current research work was Rawal dam, its tributaries (Diplomatic enclave stream, Quaid e Azam university stream, Korang river) and silt control tank WASA filtration plant.

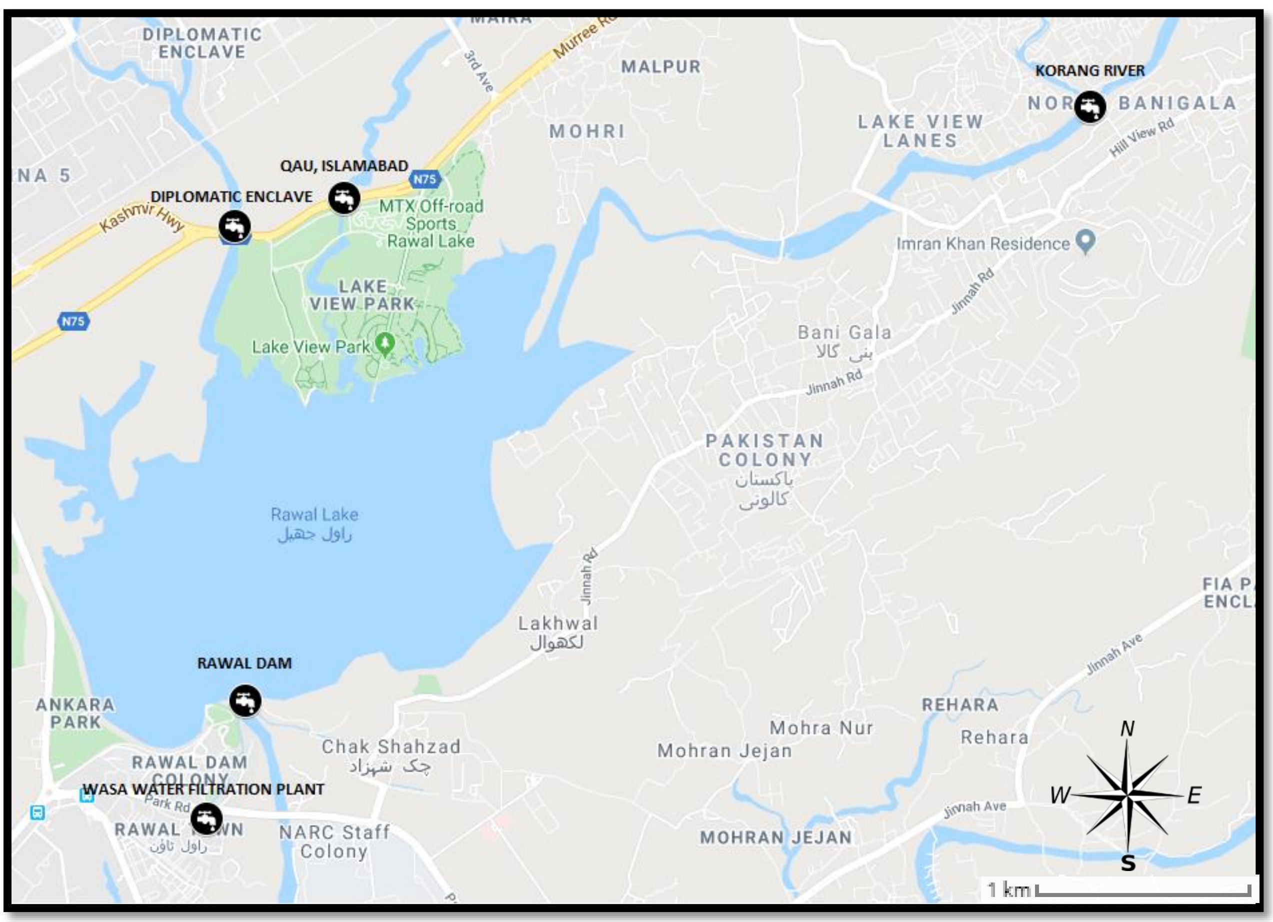

Figure 1.1 Map Showing Water Collection Points

1.8 Research objectives

- To analyze the water quality of Rawal dam and its silt control tank (WASA)
- To compare the quality of Rawal Dam water and WASA filtration plant.

Chapter 2

MATERIALS AND METHODS

2.1 Sample collection

Water samples were collected from Rawal Dam, its tributaries and WASA filtration plant. Water samples were collected on temporal basis in the months of October (before rainfall) and November (after rainfall). Water samples were collected in two different plastic bottles. For physiochemical testing water samples were collected in polyethylene bottles of 500 ml, for biological testing water samples were collected in specially designed sterilized sealed bottles of 100 ml. Before collecting the samples from sample locations, polyethylene bottles were washed thoroughly with water and filled in such a way that no air bubbles 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 in the water sample. After sample collection, the sample bottles were closed properly as per recommended, transferred to the laboratory and stored at a room temperature. We analyzed these samples in the lab within 24 hours of collection.

Table 2.1 GPS Coordinates of the location of 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

Tests conducted for physical, chemical and biological analysis.

2.1.1 Physical analysis

- pH
- TDS
- EC
- Salt

- Temperature
- Turbidity
- Oxidation reduction potential

2.1.2 Chemical analysis

- Chlorides
- Total Hardness
- Total Alkalinity
- Carbonates
- Magnesium

2.1.3 Biological parameter

- Total coliform bacteria
- Gram staining technique

2.2 Physicochemical Analysis

Physical and chemical parameters mentioned above were analyzed using standard procedures and compared them with WHO and Pak-EPA standards.

2.2.1 Instruments used and analysis method

Physical parameters (pH, EC, salt, temp, TDS) were analyzed by using Multi parameter tester 34 and turbidity was measured by using electronic turbidity meter, while ORP were being measured by conductivity meter. Chemical parameters were analyzed by using volumetric titration method. Microbiological parameters were analyzed by spread plate count method and by biochemical test i.e. gram staining method**.**

2.2.2 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).

2.2.3 Total dissolved solids

Inorganic and organic matters present in water that can pass through filter of 2 microns is 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 present in it but will not tell their relationship among them and nature.

2.2.4 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 at 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).

2.2.5 Salt

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

2.2.6 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. 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 time periods) leading to increased water turbidity, macrophyte growth and algal blooms, when nutrient conditions are suitable.

2.2.7 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, construction they are the reason for turbidity in water. So therefore it is one of important parameter to analyze because many dangerous bacteria attach to particles and may cause serious health issues.

2.2.8 Oxidation reduction potential

Oxidation reduction potential also called as ORP it is a factor which determine the cleanliness of water and ability to remove or breakdown contaminant from water sources. The higher the level of ORP the more water has ability to break contaminants such as microbes.

2.2.9 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.

Procedure

- 10ml water sample was taken in a titration flask and measured its initial pH with a pH meter
- If pH of water sample is basic then used phenolphthalein(2-3 drops) as an indicator in titration flask and swirled to mix
- If pH of water sample is neutral then used methyl orange(2-3 drops) as an indicator in titration flask and swirled to mix
- Filled a 50 ml burette with 0.02 N H_2SO_4 standard solution
- Titrated the sample while swirling the flask until the solution changed from orange to pink
- Noted the volume of acid used
- Continued the titration until end point was reached and repeated this process for three time for accurate results

Calculations

Formula

$$TA \frac{1mg}{L} \text{ for CaCO3} = \frac{A \times B \times 1000}{\text{ml of sample}}$$

A = ml of H_2SO_4 used with only methyl orange

B = normality of H_2SO_4

TA = total alkalinity

2.2.10 Carbonates

The presence of carbonates (CO_3^2) and bicarbonates (HCO^3) has influence on 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 or 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 groundwater's 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).

2.2.11 Chlorides

Most of the chlorine occurs in 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, in arid areas and wet 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 chloride to form the AgCl white precipitate which is very slightly soluble. When all the chlorides become precipitated at the end point, free silver ions react with chromate to form reddish brown silver chromate.

Requirements:

1. Silver nitrate 0.02N: (Dissolve 3.400gm of dried $AgNO_3$ (A.R) in distilled water to make 1 liter of solution and keep in a dark bottle).
2. Potassium chromate, 5%

Methods:

1. 50ml of sample was taken in a conical flask and added 2ml of K_2CrO_4 solution.
2. Titrated the contents against 0.02N AgNo3 until a persistent red tinge appeared.

Calculation:

$$\boldsymbol{Chloride}\ (\boldsymbol{mg/L}\text{ of Cl-}) = \frac{(\text{ml} \times \text{N}) \text{ of AgNO3} \times 1000 \times 35.5}{35.5\ Vol.of\ sample}$$

$$\boldsymbol{Chloride}\ (\boldsymbol{mg/L}\text{ of NaCl}) = \frac{(\text{ml} \times \text{N}) \text{ of AgNO3} \times 1000 \times 58.5}{35.5\ Vol.of\ sample}$$

2.2.12 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 a number of 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. Durability of magnesium is determined from the difference between the two determinations. 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 in 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 for Mg. If Mg^+ concentration exceeds 500 ppm, it will import on unpleasant taste and will also increase water hardness (Joshi and Shrestha, 2018).

Methods:

- First of all, 50 ml of sample was taken in conical flask. If the sample is having higher calcium, a small volume was taken and diluted to 50 ml.
- 1 ml of buffer solution was taken.
- 100-200 mg of Eriochrome Black T indicator was added due to which the solution turned into wine red.
- The content was titrated against EDTA solution till color changed from wine red to blue.
- Process was continued until concurrent reading was obtained.

2.3 Microbiological analysis

This analysis was carried out by 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, SS agars. Glassware and media used was sterilized in autoclave at 120°C for 2 hours prior to the experiment. After autoclaving the media was poured into sterilized dry plates using aseptic technique in a laminar air flow cabinet, after pouring let agar dry and solidified. Water sample was spread on each petri dish to check the presence or absence of total coliform bacteria, fecal coliforms and Salmonella and Shigella Bacteria.

2.3.1 Gram staining

Principle

It is used to differentiate between Gram positive and Gram negative bacteria

Reagents:

1. Crystal violet
2. Gram iodine

3. Decolorizer
4. Safranine

Procedure

- A clean dry glass slide was taken then picked a drop of distilled water on a slide, picked a colony from a plate using wire loop. Mixed the colony gently in the drop of water. Heated fix to make a smear (by using spirit lamp)
- Added a drop of stain 1 (crystal violet) on that slide and then waited for 1 minute and then washed slide gently by distilled water.
- Then added stain 2 (gram iodine) on a slide and then again waited for 1 minute and washed gently with distilled water.
- After that added one a drop of decolorizer (ethanol) and waited for 5-10 seconds and then washed it.
- In the end added a drop of Safranin and waited for 1 minute and then washed the slide gently with distilled water.
- Then put aside a slide for drying and then observed the slide under different magnification of Microscope.
- Gram negative bacteria will give pink color, and gram positive bacteria will give purple color.

Chapter 3

RESULTS AND DISCUSSION

3.1 Physicochemical analysis

In this study, water samples collected from study area were analyzed, in which various parameters were tested. The mean concentrations of physicochemical parameters in water collected in the month of October and November 2019 and their comparison with the standard values prescribed by WHO and Pak-EPA are depicted in table 3.1.

Table 3.1 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	NSRD	NSRD
TEMP (℃)	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	NSRD	NSRD
Total.Alkanity (mg/L)	14.66	15.9	15.03	18.33	12.4	200	NSRD
Total.Carbonates (mg/L)	19.185	18.485	19.415	24.715	26.12	NSRD	NSRD
Calcium (mg/L)	104	99.5	109	133.1	123	NSRD	200
Magnesium (mg/L)	94.3	177.5	98.5	149	62	NSRD	100
Chlorides Cl^{-}(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	NSRD	250

* Not specific range defined

3.1.1 pH

pH is an important factor which 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 has recommended a specific range of pH in which water is termed as neutral (acid-base balance), the determined range is 6.5-8.5.

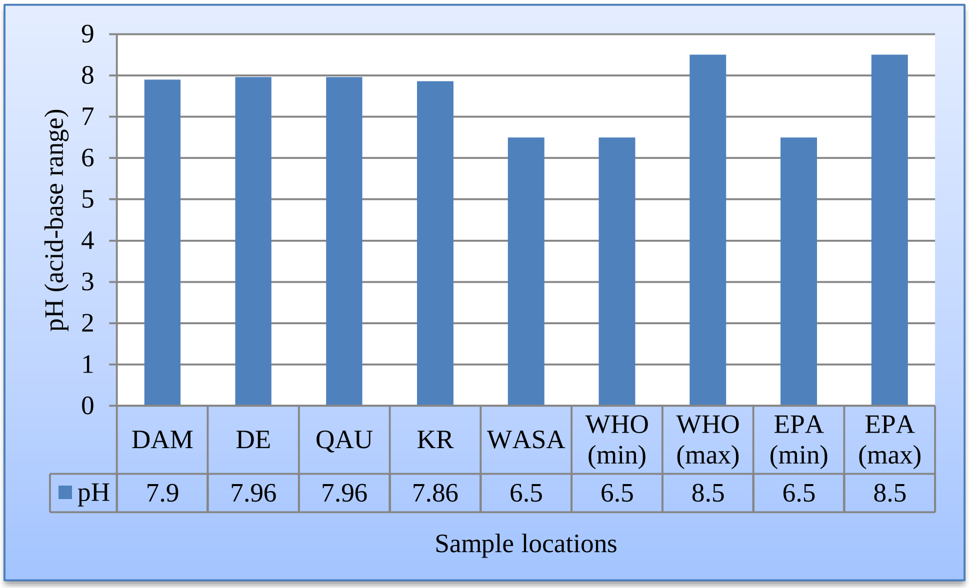

Figure 3.1 pH of water samples compared with standards

3.1.2 Total Dissolved Solids (TDS)

The standard limit for total dissolve solid in PAK-EPA is 1000, while standard for TDS in WHO is not specified/ defined. The TDS concentration in water samples of DAM,

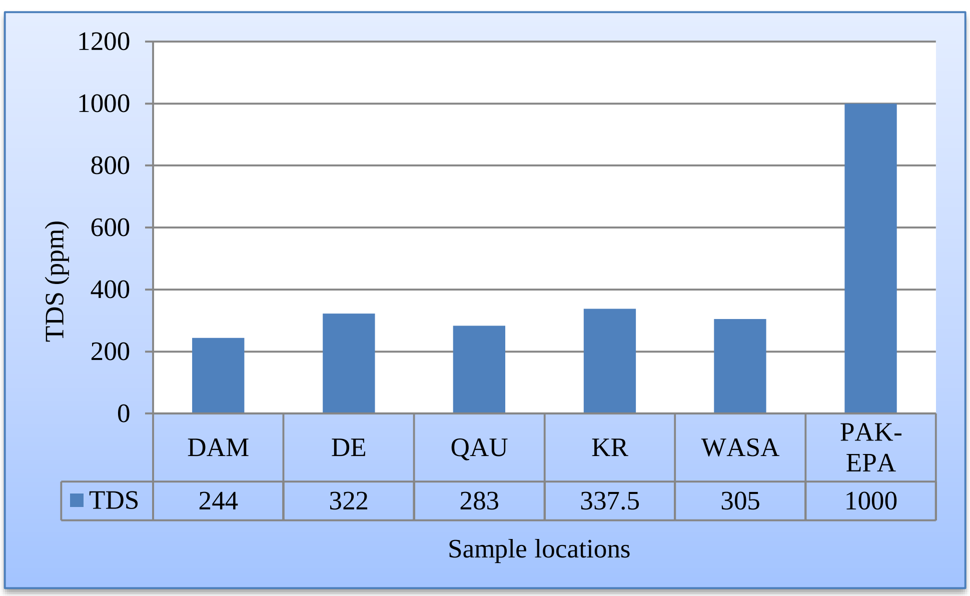

Figure 3.2 Total dissolved solids of water samples compared with standards

DE,QAU, KR, and WASA are 244, 322, 283, 337.5 and 305 ppm respectively lies within the range given for TDS in water sample.

3.1.3 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.

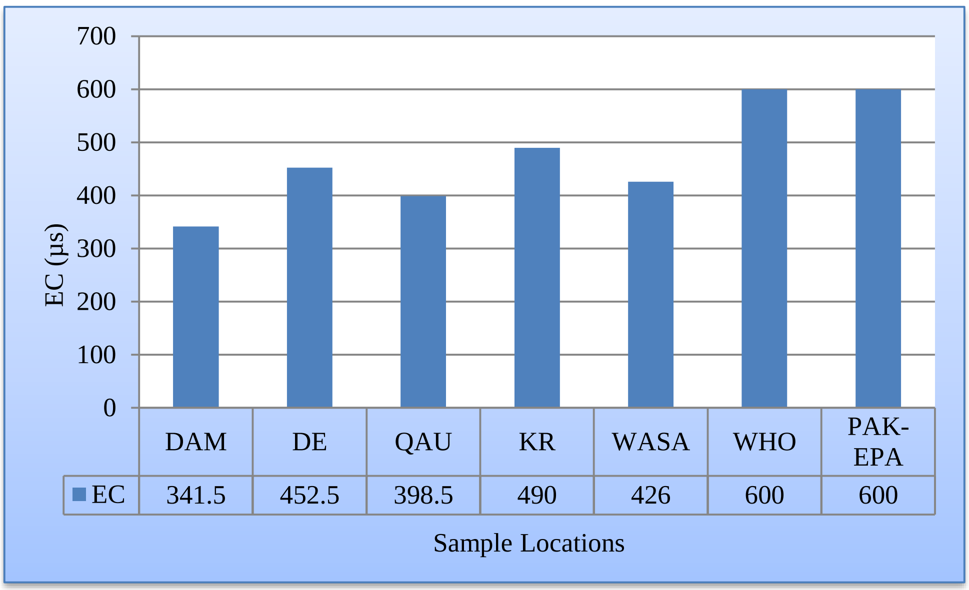

Figure 3.3 Electrical conductivity of water samples compared with standards

3.1.4 Salt

Salts means total salt in water sample. There is no standard of salt content given by WHO and PAK-EPA.

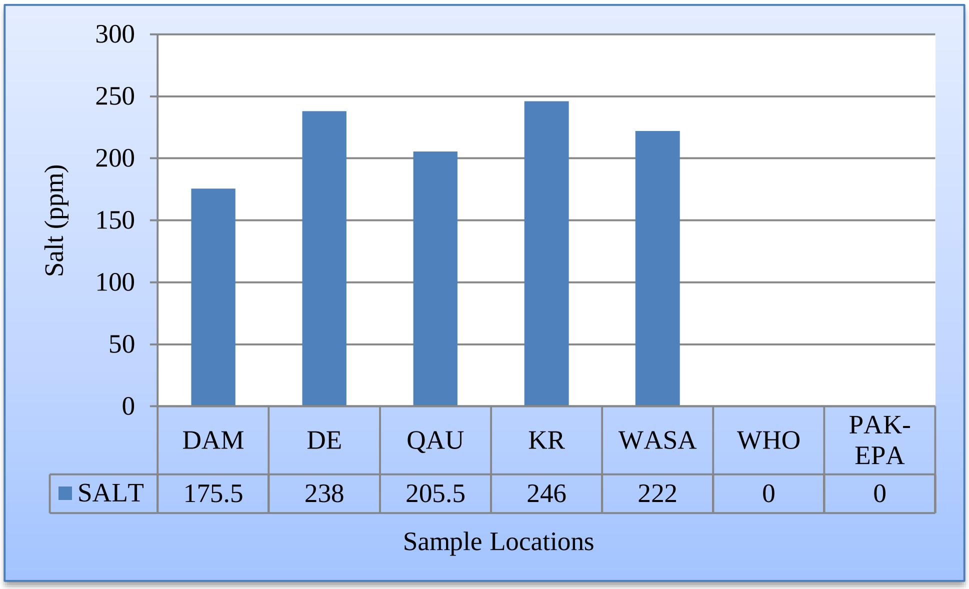

Figure 3.4 Salt content of water samples compared with standards

3.1.5 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 redox reaction. WHO and PAK-EPA did not define any specific limit for ORP. DAM contains the more ability to clean the water while other samples such as DE, QAU, and KR followed by each other in ORP. The ORP value of WASA is 17mV.

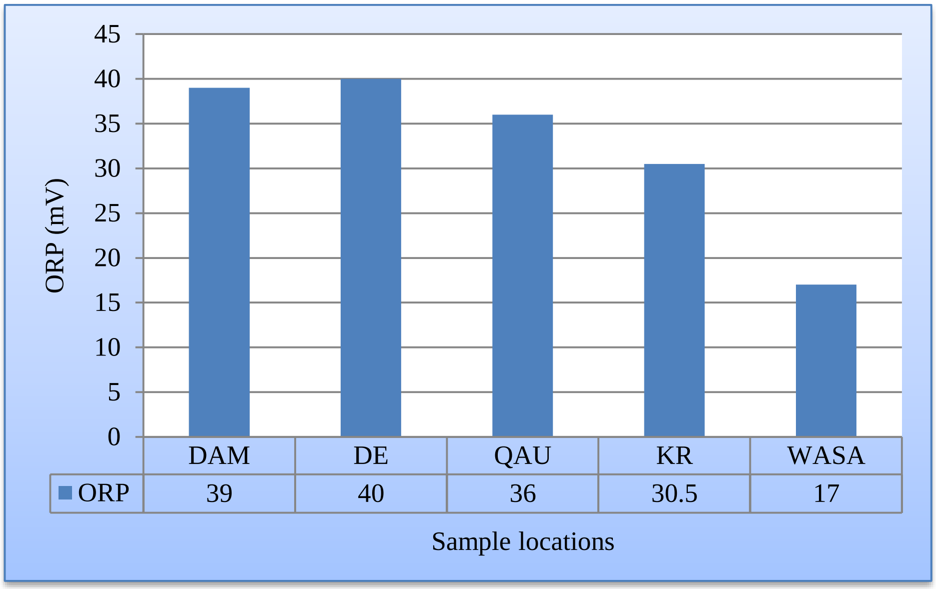

Figure 3.5 Oxidation reduction potential of water samples compared with standards

3.1.6 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 value 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.

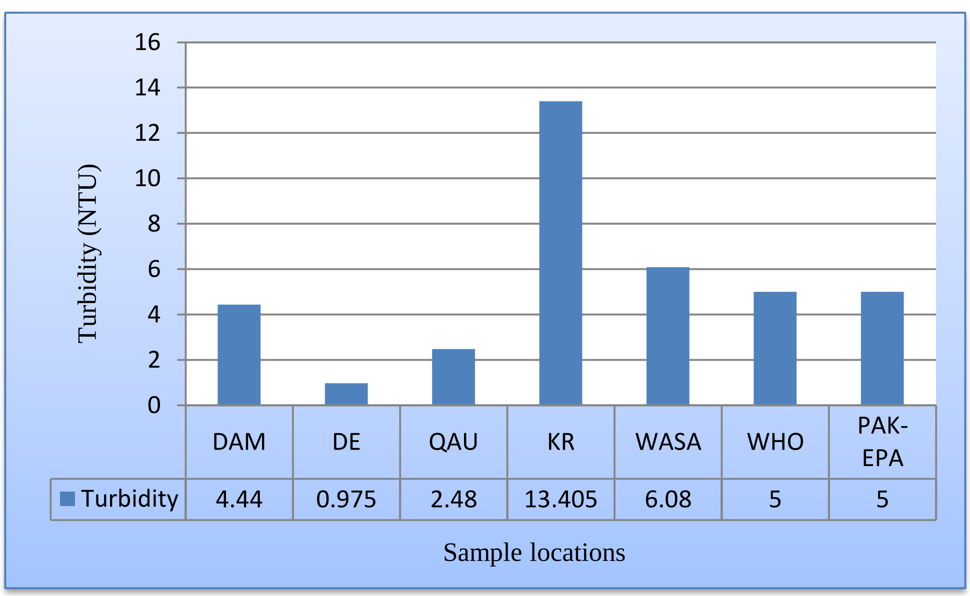

Figure 3.6 Turbidity of water samples compared with standards

3.1.7 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 WASA filtration plant is within the permissible limit, while the other water sample collected from the DAM, QAU, DE, and KR are approximately equal or above the given limits.

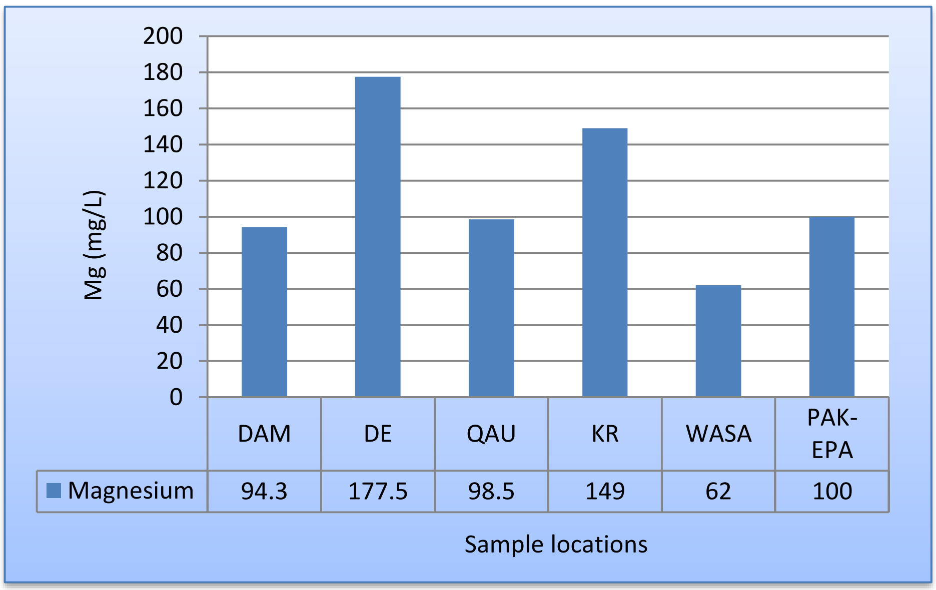

Figure 3.7 Magnesium content of water samples compared with standards

3.1.8 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 lies within the permissible limit given by PAK-EPA.

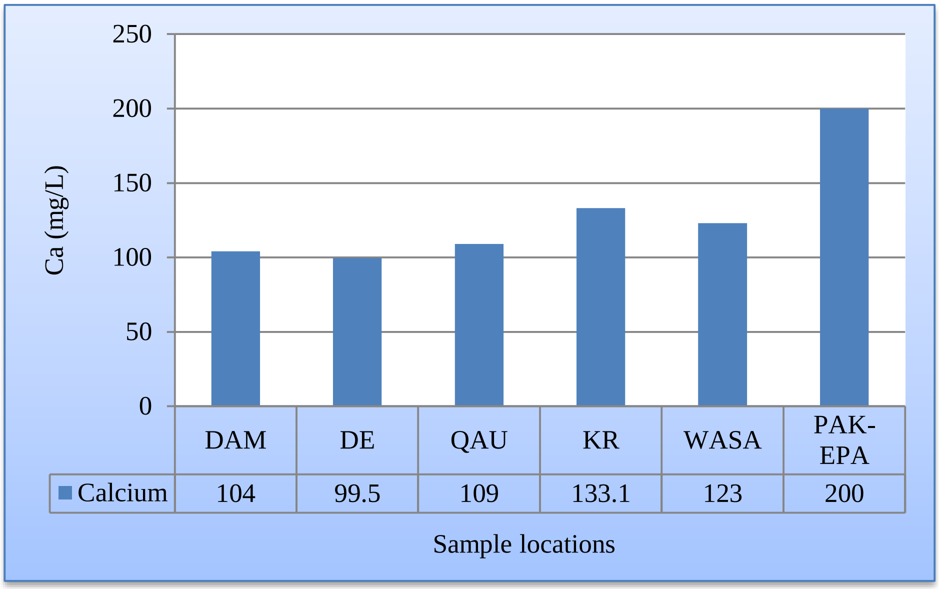

Figure 3.8 Calcium content of water samples compared with standards

3.1.9 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 location lies within the permissible limits given by WHO.

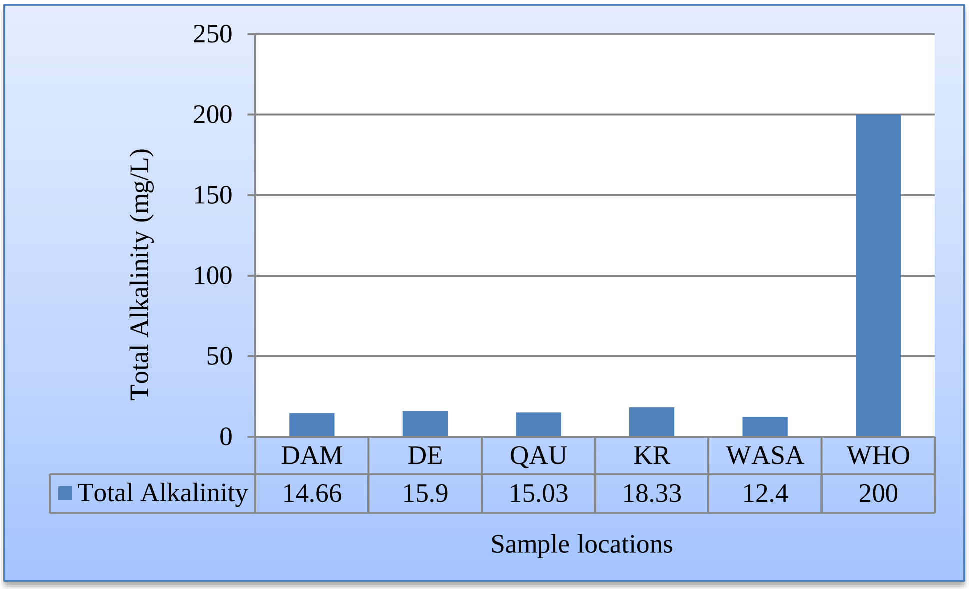

Figure 3.9 Total alkalinity of water samples compared with standards

3.1.10 Chlorides Cl^-

Chlorides determine the measure of salts (cl^-) in water. PAK-EPA and WHO has given the 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 are within the permissible limit given by PAK-EPA and WHO.

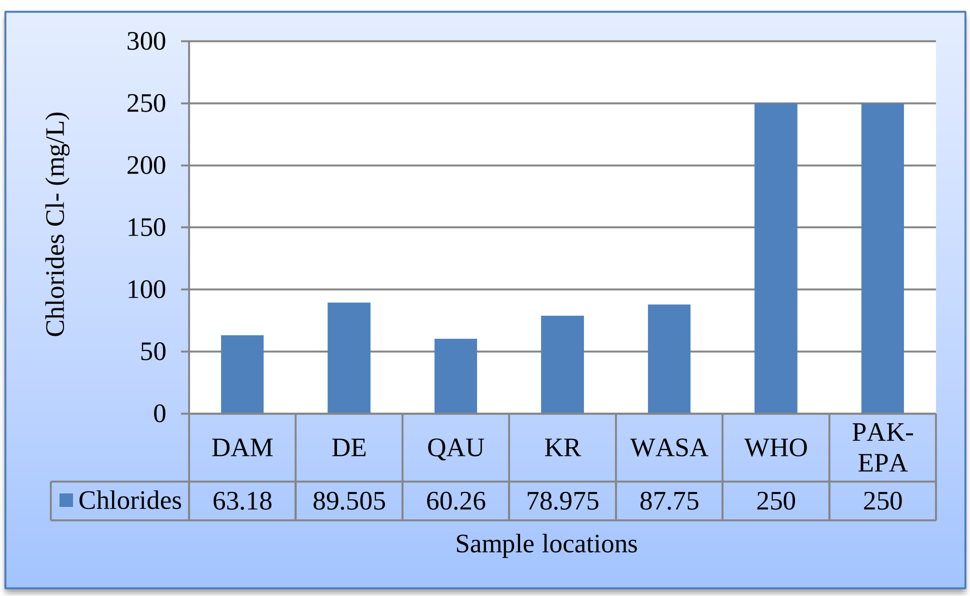

Figure 3.10 Chlorides content of water samples compared with standards

3.1.11 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 total hardness more than the given limits of PAK-EPA.

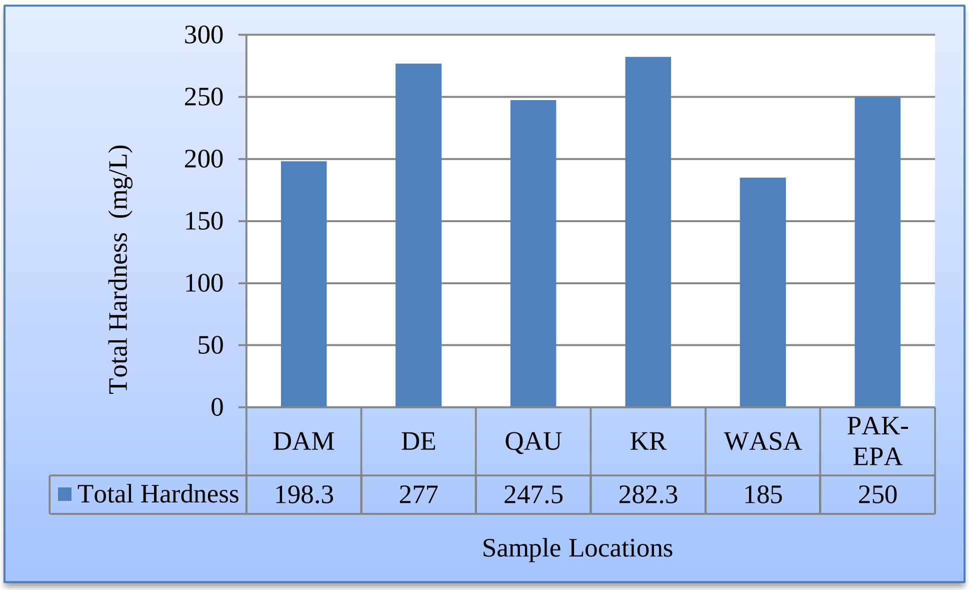

Figure 3.11 Total Hardness of water samples compared with standards

3.2 Microbiological Analysis

The results of microbiological analysis showed that the bacteria are present in all water samples except in the sample of WASA filtration plant. According to the WHO and PAK-EPA standards there should be absolutely zero microbial count in the drinking water. Water sample from WASA complied with the standards while other water samples (DAM, DE, QAU, and KR) contain bacteria which are gram positive in nature during the month of October while some samples contain gram negative bacteria in the month of 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.

Table 3.2 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

E-coli are an indicator microorganism for fecal contamination in water samples and presence of E-coli shows by gram positive results of gram staining. A gram negetive result shows the presence of E-coli along with other pathogenic bacteria inhabiting in the water reservoirs. These results are further supported by the presence of *salmonella* and *shigella* in the bacterial count at all locations except WASA filtration plant. Only the water of WASA is acceptable for drinking purposes because there were not any pathogenic bacteria found.

Table 3.3 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

Gram positive bacteria include *Bacillus, Listeria, Staphylococcus, Streptococcus, Enterococcus,* and *Clostridium.* Gram negative include *cyanobacteria, spirochetes,* and *green sulfur bacteria,* and *most Proteobacteria.*

Discussion

The findings showed that some of the physicochemical parameters were within the standards of WHO and Pak – EPA and parameters including total hardness, magnesium content and turbidity of some water samples were exceeding the standards, and microbiological results depicts not all side were microbiologically safe. The water quality of 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, Korang River contain high microbial counts due to the sewage waste which can pose serious health issues to human 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 impacts the quality of water and health of consumer. The main reason of these deviations is unplanned urbanization and poor sewage system.

CHAPTER 4

CONCLUSIONS

In this study, the collected water samples of Rawal dam, its tributaries (QAU, DE, and, KR) and 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).

The results showing that the quality of water of WASA filtration plant is very good as compared to the water of 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 physiochemical and biological parameters of collected water, it was shown that the water quality of Korang River is very bad. Tributary of Korang River is the main source of polluting water of Rawal Dam. The main reasons are increase in urbanization and damaged sewage system.

RECOMMENDATIONS

- Our study recommended that there is 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 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 water of WASA filtration plant regularly before supplying to the consumer and should ensure the health of consumers.

- Further detailed and authentic studies and researches should be carried out on microbial characteristics of water quality and the risks they poses on human health.

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APPENDIX

Figure 4.1 Multi Parameter Testr35

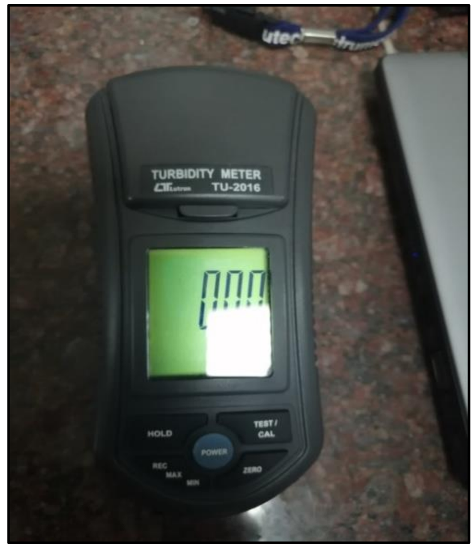

Figure 4.2 Turbidity Meter

Figure 4.3 Autoclave machine

Figure 4.4 Digital Scale Cell Precision Balance

Figure 4.5 Conductivity Meter

Figure 4.6 Sterilized Container

Figure 4.7 NA , EMB, SS Agars

Figure 4.8 Sterilized Petri dishes and Media

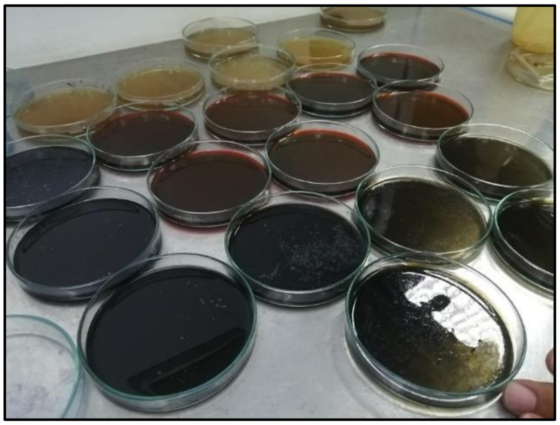

Figure 4.9 Petri Dishes filled with Media Solution

Figure 4.10 Water sample collection for biological testing

Figure 4.11 Water sample collection of physicochemical testing

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