DETERMINATION OF WATER QUALITY INDEX OF SIMLY DAM, ISLAMABAD USING PHYSICO-CHEMICAL PARAMETERS

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A thesis submitted to Bahria University, Islamabad in partial fulfillment of the requirement for the degree of B.S in Environmental Sciences

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CHAPTER 1

INTRODUCTION

1.1 Background

The Simly Dam is a high earthen levee dam in Rawalpindi District of Pakistan. The Simly Dam is able to hold up to 1,977,000 m^3 of water. The weather is overall pleasant thus it provides a good spot for fishing. Simly Dam is the chief source for providing drinking water to people residing in Islamabad and Rawalpindi. The dam is replenished by the melting snow and the natural springs coming from the Murree hills. Its construction began in 1963 by the Capital Development Authority and officially finished in 1982. However after years due to the lack of engineering expertise the maintaince of the Simly Dam was outsourced to the Water and Power Development Authority but after the establishment of the Metropolitan Corporate Islamabad in 2015, the water sector comes under MCI. The Simly Dam is mostly known for its scenic and picturesque beauty and also for the Simly Lake. Tourists and fishing enthusiasts enjoy whatever Simly dam has to offer, since the main activity is fishing. However a fishing license has to be acquired by the Capital Development Authority, ever since the strictness regarding the fishing has increased. If the fishes are provided with a favorable climate and environment their productivity rate is increased however if the water quality diminishes it leads to lower number in fish population. As it is a prime area for tourism and proves to be a source of income for many locals it is highly important to study and investigate the water quality which further relates to the health of the fish inhabiting the waters.

Water quality isofgreat importance due to its impact onhuman healthand aquatic systems. Running water in streams if highly susceptible pollution considering to its role in carrying of municipal and industrial waste water. Anthropogenic influences and activities lead to detrimental effects on water. The amount of discharge of domestic and industrial effluents are so vast that the rivers cannot provide the necessary dilution capabilities. Human development and growthexert a great amount ofpressure onthe water quality, itsresources and access to them and as the demand for fresh water is increasing day by day it is highly obvious that we check for its suitability. We conduct the water assessment techniques to determine its quality.   Water quality refers to the chemical, biological and physical characteristic of water. It is a measure of the state of water in relation to the requirements of one or more biotic organisms and to any human need or intent (Aydin, 2016). The water quality is based on certain physico-chemical parameters which show whether it is fit for use or not. Actually when we consider the quality of water we really mean the purpose it is used for. For instance, water used for irrigation must absolutely free from any dissolved minerals to avoid salinization; potable water must safe for drinking and cleaning (Aydin, 2016). Water quality monitoring and analysis form the base for water quality management.

Water is an integral part of our lives. Water makes up 60 % of the human bodies, while the brain and heart are composed of 73% of water and the lungs to about 83%. This further clarifies the importance of water, without water the survival and sustenance of any living being not only humans would be impossible. Although it has no organic nutrients or calories it is vital for all forms of life. Water circulates through the land the similar as it does through the human body. It transports, dissolves the organic matter and replenishes and recharges the essential nutrient and subsequently washing away the waste material. Moreover in the human body it plays a role in regulating the functions and activities of fluids, cells, tissues, blood and various secretions. Hence it is our ultimate source of life. Water is an indispensable and crucial resource, in the absence of water there would a state of worldwide hunger since shortage of food due to less crop being grown. It also plays a key and vital role in the world economy, most of it goes to the agricultural sector that is about 70%. Fishing in salt and freshwater is a major source of food in many parts of the world. Much long-range trade is carried by boats through waterways, rivers, lakes and canals, with merchandises and products manufactured. For cooling and heating, manufacturing and houses, large quantities of water is used. Water is an excellent solvent for a wide range of natural and organic materials and is therefore commonly used in manufacturing, cooking and washing processes.

The globaldistribution ofwater is vastly variable; 97% is the saline water which is majorly the ocean and 3% is the fresh water and from the fresh water 68.7% is in the glaciers and ice caps, 30.1% resides in the underground and less than 1% in lakes, rivers and swamps. In our project we majorly focus on the fresh water more specifically the potable water or drinking water.

The origin ofwater dates back to millions of years ago, in the early historyofthe formation of the earth, around the time of the beginning of the earth's crown, severe volcanic activity emanated from an underlying mantle many volatile gasses including water. The early atmosphere were these explosive gases. Almost all the waters in the seas, rivers, streams, air, and the subsurface today have now been gassed out. Throughout these centuries this water mass has been cycling and recycling.

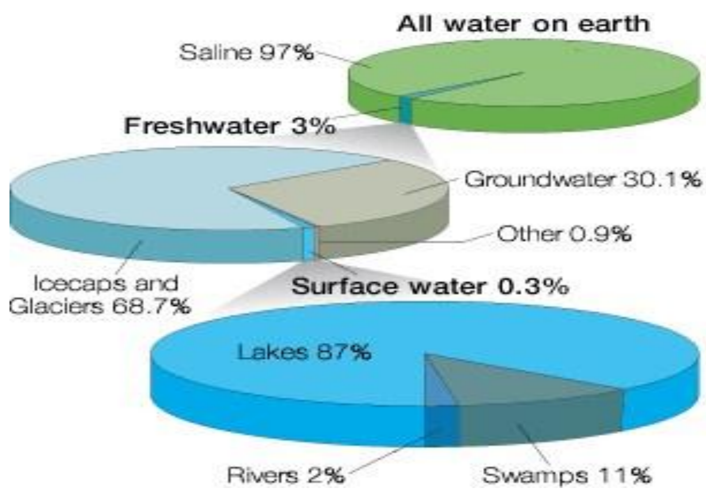

Figure 1.1 Global Distribution of Water (US Geological Survey Department of the Interior)

1.2 Inherent Characteristics of water

Water has a great number of intriguing characteristics. These properties make it an ideal medium to support life on Earth. It is called a universal solvent because of its ability to dissolve a large number of naturally or man-made substances. The boiling and freezing of water make it possible for all three phases; solid, liquid and gas, to exist on Earth. Water is also lighter when it freezes, so that it floats. If water sank, then the bottom of our oceans would be solid. Under such circumstances, we would only have a thin layer on the surface that would be only liquid. There would be far less global ocean currents, and many of our nutrients would be locked up inside (Balasubramanian, 2015).

Water floats when it becomes ice because of the fact that it become lighter, this is the anomalous characteristic of water. The bottom of our oceans would be solid if the water sank. We would have only a thin layer on the surface, which would be liquid under these circumstances. There would be significantly less global ocean currents, which would contain many of our nutrients. Survival of the life forms would be difficult if these properties were not possessed by water. Water also has the ability to transform into vapor from a liquid, this is due to evaporation. Another inherent property of water is that it converts into a solid from liquid, this is called freezing. Its ability to flow downwards due to the action of gravity, able to flow overland on any slope and its ability to move under the action of wind, these are some the major inherent properties.

The capillary action of water which is the rising up through capillary tubes is another feature of water. This attribute helps the plants to get water from the soil medium along with the nutrients. The dissolving ability of water is a major factor for several environmental, geological, hydrological and other processes.

Water can dissolve mineral components present in hard rocks and also the waste food materials that are consumed by people and animals. Water can also exert hydrostatic pressure. Hydrostatic pressure can be exerted by water when it is in an equilibrium state at any given point under the influence of gravity. The density of water is an important property. Due to the dissolution of salts and minerals, the density increases. This, in turn, increases the hydrostatic pressure of water.

1.3 Physical Properties of Drinking Water

Drinking water is also called potable water, which is the water that is safe to consume and it is accessed from fresh water bodies. The important properties of water are dipole moment; defined as the unequal sharing ofelectrons, dielectric constant, heat capacity, and its ability to both donate and accept protons. This imparts on water the ability to hydrogen bond with itself, to hydrogen bond with both proton donors and proton acceptors, to dissociate, to coordinate with ions and other dipoles, and to store and transport heat.

Water is also tasteless, odorless liquid at standard temperate and pressure. It is a small solvent occupying about 55.5 moles/ liter at liquid stage in the room temperature, however it still possess strong intermolecular bonds which are hydrogen bonds (H-bonds), between the oxygen and hydrogen atoms. And it is because of the H-bonds the boiling point, vaporization and surface tension are quite high. However the bond can be destabilized by replacing the hydrogen atoms which ultimately reduces the boiling point, vaporization point and surface tension. Due the immense strength of the unified interactions specific heat capacity of water is also steep. Given below is a table depicting some fundamental physical properties of water.

Table 1.1: Physical properties of drinking water

PROPERTY	**VALUES**
Molecular Weight	18.0 g mol^{-1}
Molar Volume	55.5 moles/ litre
Boiling Point	100 ^{o}C
Freezing Point	0^{o}C
Triple Point	0.01^{o}C
Vapor Pressure	0.0212 atm at 20°C
Surface Tension	73 dynes at 20°C
Heat of Vaporization	40.63 KJ/mol 6.013
Heat of Fusion	KJ/mol 4.186 J/g
Heat Capacity	°C
Viscosity	1.002 centipoise at 20°C
Density	997 kg/m^3
Dipole Moment	1.8546 d
Dielectric Constant	78.54 at 25°C

Source: (http://www.geo.utexas.edu/)

1.4 Chemical Properties of Drinking Water

1.4.1 Dissolution Properties

As we know water is termed as the universal solvent because it dissolves many of the substances. Water molecules have a polar arrangement of the oxygen and hydrogen atoms one side has a positive electrical charge and the other side has a negative charge. This allows the water molecule to become attracted to many other different types of molecules. Water can become so heavily attracted to a different molecule, like salt that it can disrupt the attractive forces that hold the sodium and chloride in the salt molecule together and, thus, dissolve it. It also able to dissolve solutes because of the arrangement of the atoms in its structure. The atoms are in a V- like formation. Since the bonds between the oxygen and hydrogen are covalent, which means that the electron are shared between the oxygen and hydrogen atoms. A reaction called hydration occurs when salts come in contact with water. Water dissolves great amount of salts which proves to be useful factor in transporting nutrients. Water is an excellent solvent due it high dielectic constant. The solutes which interact with water can either be hydrophobic or hydrophilic. Hydrophilic as the name indicate are water loving the easily dissolve in a water whereas hydrophobic are the solutes which do not mix or dissolve with water. Substances like salt are hydrophilic and organic substances like oil are hydrophobic. The dissolving ability of water also depends on the fact that whether that other compound s can overcome the bonds in the water molecules.

1.4.2 pH Properties

Water in nature is rarely pure in the distilled water because it contains dissolved salts, buffers, nutrients, etc., with exact concentrations dependent on local conditions. pH measures the acidity and basicity of a substance, more intently it refers to the amount of free hydrogen and hydroxyl ions in the water . Water is known to be at a neutral pH of 7, which means it neither acidic nor basic. It is highly critical that the water remains at a neutral pH because only at this state it is safe to consume. Water also depicts the buffering capacity which is the ability of water to keep the pH stable as the bases or acids are added into it.

. The parameters we selected are mentioned below in the text. In order to keep the well-being of any aquatic system at an optimal level, certain water quality indicators or parameters must be monitored and controlled. The physicochemical parameters give an in depth perspective on the function and structure of the water body.

1.5 Drinking Water Quality in Pakistan

In recent years water quality in Pakistan has gotten a lot awareness amongst in people, as poor water quality is the major concern in the respect of health and environment. With ample land and groundwater wealth, Pakistanhas beentruly blessed, but unfortunatelyover the years, industrialization, over population and rapid growth has hindered the water resources (Daud et al., 2017). In both urban and rural Pakistan, drinking water quality is not properly managed. Different studies show that the majority of the supplies of potable water are contaminated. In sites, the quality of groundwater is declining because of the natural contamination from sub-soils and anthropogenic behaviors (Aziz, 2005). The quality of water is not managed adequately, in terms of drinking water, Pakistan ranks 80 out of122 nations, both ground and surface drinking water sources are polluted throughout the country with microbes, toxic metals and pesticides (Häder, 2014). Even now-a days some rural areas in Pakistan have no access to fresh, clean water for their use in daily life.

The country's water capitals have been stressed enormously by rapid population growth and continuous industrial development. The prolonged droughts and population growth have further exacerbated water shortages and contamination. While Pakistan does have both ground and surface water resources, the availabilityofwater per capita has fallen from 5,600 m3 to 1,000 m3 per year (Shahid et al., 2015). Drinking water quality in Pakistan is depleting day by day due to the effluent and pollutant released by t industries. Piped water also gets contaminated because the network ofthe pipeline is not planned properly and laid poorly. This leads to the leachate being seeped into the water sources and cause diseases which are ware borne. According to a monitoring report published by Pakistan Council of Research in Water Resources, they monitored 369 drinking water sourcesout ofwhich 116 water sources (31%), were supplying safe drinking water and 253 (69%) were determined as unsafe.

1.6 Water Reservoirs in Pakistan

Numerous number of river have benefitted Pakistan over the years, Jhelum, Chenab, Ravi, Beas and Sutlej are the five major rivers that link Indus from the North, and Haro, Soan and Siran are next to three minor rivers (Ahmed et al., 2007).

Diamer-Bhasha Dam is designed for the northern area of the River Indus, It sits approximately 314 km upstream of Tarbela Dam and approximately 165 km upstream of Gilgit, it is planned that this dam will build a large reservoir up to 7.3 million acres in the Diamer district. The Gomal Zam Dam is located in Khyber Pakhtun Khwa, near the Damaan area, it is one of the most important tributaries of the River Indus, standing at a height of 437 ft it is be able to irrigate an enormous amount of land. Hub Dam is a located within the reservoir of Hub River, located near Karachi it is the paramount supply of drinking water to the metropolitan city of Karachi. Kalabagh Dam is a hydroelectric power dam on the River Indus in Kalabagh in Mianwali, Punjab. This dam has been discussed overtime due to its controversies involving debated in other provinces however if this dam is constructed it would generate electricityof3,600 MW and pose a solution to long-lasting flooding problems. Mangla Dam built in 1967 by the funding of the World Bank is the world's twelfth largest dam, located in River Jhelum it consist of 4 storage reservoirs, 2 spillways, 5 irrigationaltunnels and a power station. Primarily it was built to store the large amount of water for irrigation purposes, it is also used for electricity generation.

Famously known as the National Dam, the Tarbela Dam is an embankment dam constructed along the River Indus in Khyber Pakhtun Khwa. Precisely it is located in the Swabi District of the province. This dam was finished in 1976 and was predetermined to store water for irrigation, flood control and hydropower generation from the River Indus. In 2001, the Water and Power Development Authority (WAPDA) commissioned Mirani Dam to supply water to the city of Gwadar, it is situated at the Dasht River in the Makran District of Balochistan, about 48 km west of Turbat and 610 south west of Quetta. Warsak Dam which was built with the collaboration of the Canadian Government, under the Colombo Plan. It has the capacity to generate power up to 243 MW. The Warsak Dam is located in the Kabul River, however recently Warsak Damhas now been completely silted, and there is practically no space available. Between October to March, the lean flow cycle at Warsak is observed with a power drop of around 100 MW.

1.7 Water Quality Index (WQI)

A water quality index is a method which is used for systematically summarizing water quality for the public coverage, this resembles the UV or air quality index. It provides us a simple way to determine that what the quality of drinking water is from a drinking water supply. Water quality index gives us a single number (like a grade) that expresses overall water quality of a certain location and time based on several water quality parameters. The basic objective of an index is to turn huge, complex water quality related data into simpler information that can be easily understood and used by the public. Mainly the WQI data is calculated by comparing the water quality data to certain standard value of drinking water of the required area. The WQI tests the surpassing of water quality, frequency and amplitude and then combines all these measurements into one common assessments value. The WQI consists of grades, respective values and the water quality status. For each value a grade is integrated to depict the status of water quality. It is used to represent a large number of parameters in a single value. Thus, the index reflects the composite influence of different water quality parameters on the overall quality of water of a water body.

The WQI concept was first developed by Horton in 1965 to measure water quality by using 10 most regularly used water parameters. The method was subsequently modified by different experts. These indices used water quality parameters which vary by number and types. The weights ineachparameter are based on itsrespective standards, and the assigned weight indicates the parameter’s significance and impacts on the index (Tahera Akhtar, 2016). Later, Brown in 1970 established a new WQI and selected it uses physicochemical parameters. It is based on the professionalopinion ofa panelof142 experts and established five classes for dividing water quality: red (very poor), orange (poor), yellow (average), green (good) and blue (excellent). (Brown et al., 1972). The index proposed by Brown et al. took the arithmetic form and became weighted arithmetic method. This gathering of the physical and chemical parameters should be important not only for indices but also for water resources monitoring. Generally, water quality indices are divided into four main groups:

i. **Public indices**:
These indices ignore the kind of water consumption in the evaluation process, such as NSFWQI (National Sanitation Foundation Water Quality Index).

ii. **Specific consumption indices**:
In this the classification of water is on the basis of the kind of consumption and application (drinking, industrial, ecosystem preservation, etc.). The most significant and valid of these indices are the Oregon and British Columbia indices.

iii. **Statistical indices:**
In these indices statistical methods are used and personal opinions are not considered.

iv. **Designing indices:**
This category is an instrument, aiding decision making and planning in water quality management projects (Bharti, 2011).

This analysis has been described as identifying policies that can promote sustainable development in order to reduce environmental problems. A water quality index introduced in the sense of monitoring often enables the reuse of information for administrators and individuals who use water directly.

The method used in this study to estimate the WQI is the “Weighted arithmetic method”. In this method, different physicochemical water quality parameters are selected and multiplied by a weighting factor and are then are aggregated using simple arithmetic mean as the name indicates. To achieve a correct accurate value for water quality a selection of definite parameters is required. We selected 12 physicochemical parameters that are considered important in drinking water. The parameters are: pH, Biological Oxygen Demand, Dissolved Oxygen, Nitrates, Total Dissolved Solids, Electrical Conductivity, Total Alkalinity, Total Hardness, Calcium, Potassium, Sodium and lastly Total Chlorides. (Chandra et al., 2017)

The reason for choosing the WAWQI method in this study is because it has edge over other methods such as in this method multiple water quality parameters are incorporated in to a mathematical equation that rates health of the water body through a number called water quality index as well as it describes the suitability of surface and ground water sources for human consumption. (Khwakaram et al., 2012)

Various researchers have attempted to develop water quality index based on five types of WQI aggregation functions: arithmetic aggregation function, multiplicative aggregation function, geometric mean, harmonic mean, and minimum operator (Shah et al., 2015).

1.8 Literature Review

As we know that the water supply comes from four major sources such as stream water, springs, groundwater and impounding reservoirs. The water supply in Islamabad is primarily from Khanpur Dam and Simli Dam and a few tube wells, since the water tank is sparse and shallow in the federal capital.

The inhabitants of Islamabad rely on their domestic water supplies on both surface and groundwater. The available resources were planned to be roughly 107 million gallons per day. To Islamabad, Simly reservoir is the biggest source of surface water. Ground water fromtubes installed in the National Park area is obtained. Water fromthe rivers in Saidpur, Nurpur and Shahdrahills are drained from the wells (Ahmad, 2000).

The method of calculating WQI we used the weighted arithmetic (WAWQI). The advantages for this method are that it incorporates data from multiple water quality parameters into a mathematical equation that rates the health of water body with number. It requires less number of parameters in comparison to all water quality parameters for particular use. It is useful for communication of overall water quality information to the concerned citizens and policy makers. This reveals the combined influence of different parameters i.e., important for the assessment and management ofwater quality (Shah et al., 2015).

The Water Quality Index model developed in the present study consists of certain steps: Selection of parameters for measurement of water quality, development of a rating scale to obtain the rating, estimating the unit weight of each indicator parameter by considering the weightage of each parameter, aggregating the sub-indices to obtain the overall WQI.

There are several studies related to Water Quality Index which were conducted by certain individual. Out of these only a study conducted by Rajbongshi et al. (2016), Aydin et al. (2016), Ramakrishnaiah et al. (2009). The data reported in these studies are briefly explained in the proceeding paragraphs. Some of them are summarized below.

The main goal of estimating the water quality index is to determine that whether it is fit for use or not and that it is viable for human consumption. Basically the water quality index provides an overall value which helps us to determine the water quality at a particular time and location based on the selected physico-chemical parameters. The result obtained are simple to understand and even a layman can comprehend it. In the mathematical data from various physico-chemical parameters are incorporated into the water quality indices that value the water's caliber with one single number. The important parameters selected to assess the water quality are: pH, Turbidity, Temperature of the water, Biological Oxygen Demand, Dissolved Oxygen, Total hardness, Total alkalinity, Electrical Conductivity, Magnesium, Chlorides, Total Dissolved Solids, Calcium, Potassium, Sodium, Color, and Odor. In this temperature, color and odor are physical parameters whereas the rest are chemical parameters.

A study named the 'Water quality assessment of capture and culture fishery' conducted in Assam, India. This paper deals with the comparison of various physical and chemical parameters such the total alkalinity, total hardness, electrical conductivity, pH, etc. in this the samples were collected in 5 litres bottles, they were analyzed through conducting various tests mainly titration, on examination the results revealed that the WQI is 68.8 and 62.4 in capture and culture fisheries respectively. This indicates poor water quality. This suggests for a proper management of the fisheries to yield better growth dynamics (Rajbongshi et al., 2016).

Another study was carried regarding WQI. This occurred in Kastamonu City in Turkey, named 'water qualityindex for main for main source ofdrinking water in Karacomuk Dam. The study used the Water Quality Index which, for the period between September 2015 and July2016, provides a single express value ofoverallquality based on 13 variables. The

WQI reveals that for locations 35.5 and 32.4. On the other hand, the water quality index showed significant temporal fluctuations between poor and high quality, while January 2016 safely experienced an elevated site deterioration, which may be due to the beginning ofwinter 2016, where the downstreamwaterfall contributes greatly to the increase in water dam deterioration (Aydin, 2016).

The results depicted that the WQI method has been useful in determining the water quality and it has been on a deciding stage that the in the near future the WQI will be assessed using biological parameters as well (Aydin, 2016).

As safe, pure drinking water is a right to all living beings it is vitalthat weassess its quality. Additionally the WQI method is also used in evaluating groundwater. A group ofassessors inspected the water quality of groundwater in Tumkur Taluk in the Karnataka State in India. It was a very comprehensive analysis as it involve taking sample in over 250 locations. For calculating the sample there were 12 parameters taken into consideration such as pH, total hardness, calcium, magnesium, bicarbonate, chloride, nitrate, sulphate, total dissolved solids, iron, manganese and fluorides.

The result ranged from 89.21 to greater than 100, the greater value were though t0 be from the higher quantity of iron, nitrate, total dissolved solids, hardness, fluoride, bicarbonates and manganese in the groundwater. The outcome suggests that the water requires a greater degree of treatment before consumption and need to be conserved and protected from contamination (Ramakrishnaia et al., 2009).

1.9 Scope and Objectives

This study evaluates the various physical and chemical parameters of drinking water in Simly Dam. The parameters were determined and perused on the basis of an arithmetic based formula named the Water Quality Index. The water quality index is one of the most effective means of communicating water quality data to the people concerned and understanding the temporal and spatial quality variability. A water quality index summarizes large amounts of water quality data into simple terms such as, excellent, good, poor, very poor and unfit for drinking.

1.9.1 Objectives

The objectives of this study were:

1) To carry out physicochemical analysis of water samples collected from Simly Dam at various locations.
2) To compare and examine the samples before and after having gone through filtration at Simly Dam.
3) To calculate the Water Quality Index for Simly Dam.

CHAPTER 2

MATERIALS AND METHODS

2.1. Methodology:

In order to determine the water quality of Simly dam, Islamabad; quantitative research methods are used. Quantitative research methods are those methods that rely on measuring variables using a numerical system, analysing these measurements using any of a variety of statistical models, and reporting relationships and associations among the studied variables. The water quality was analyzed using Water Quality index (WQI). WQI was calculated for both raw dam water and the filtered water that is supplied to the residents of Islamabad.

The methodology adapted for the research work is shown in the flow chart below:

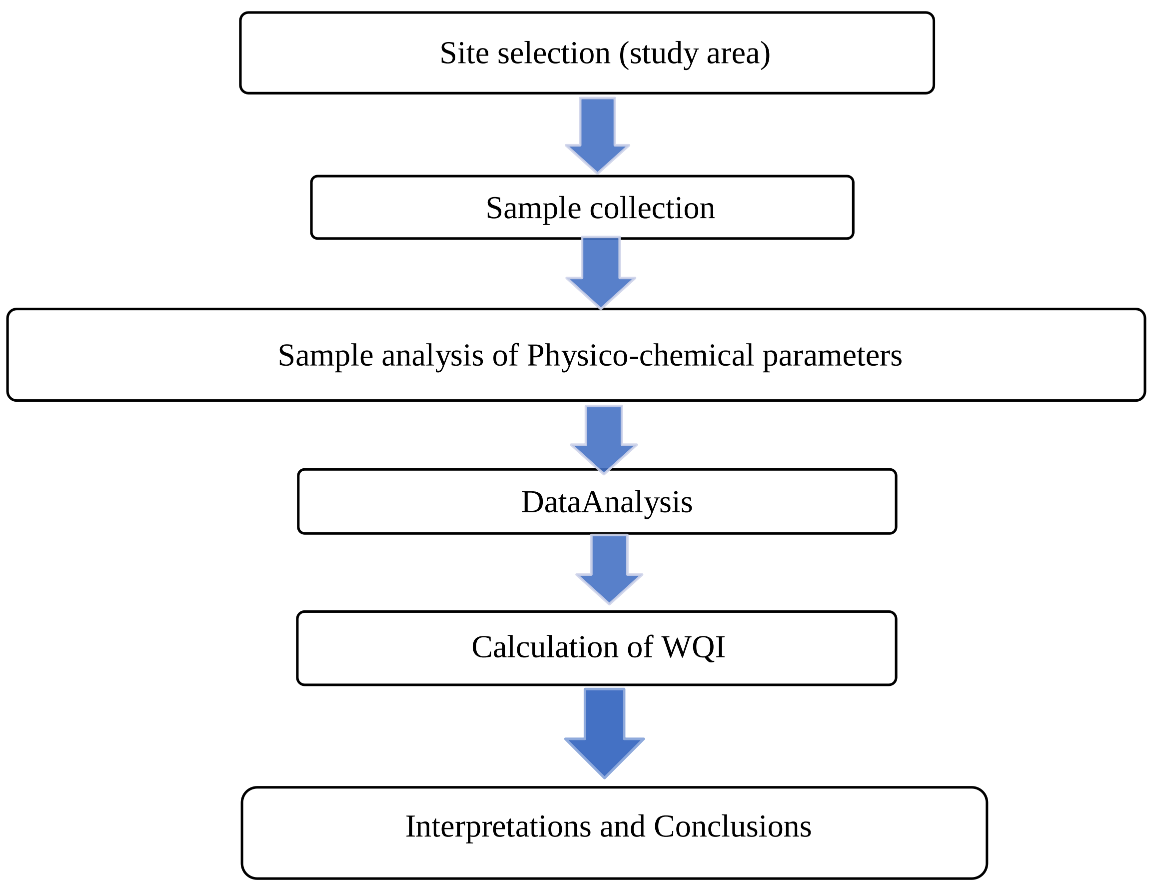

Figure 2.1: Flow chart showing research work methodology

2.2. Study Area:

The study area selected for the study was Simly dam which is located 30 kilometres east of Islamabad and Rawalpindi in Rawalpindi District, Punjab, Pakistan. (Ghoraba et al., 2015) It is the largest reservoir of drinking water to people living in Islamabad, the capital ofPakistan. It is situated between 33°43′08″ N and 73°20′25″E. The map ofthe studyarea is shown in figure 2.2 and 2.3 below.

Figure 2.2: Satellite image of the study area along with sampling points

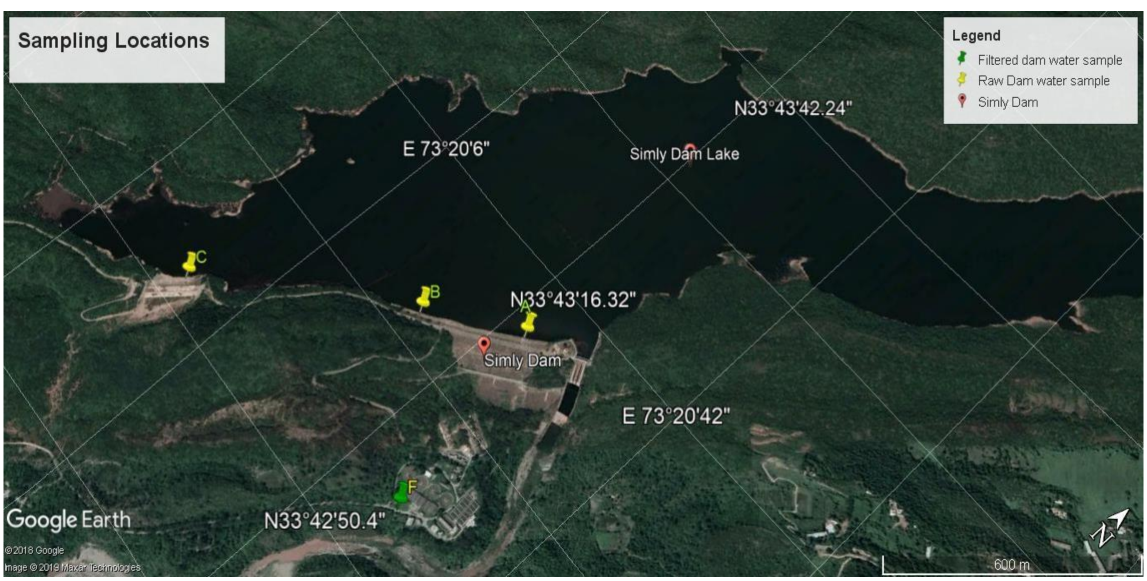

Figure 2.3: Satellite image of Simly dam with coordinates

2.3. Description of study area

Simly dam is high earthen embankment dam on the Soan River, constructed in 1983. The water in dam come from natural springs of Murree hills and melting snow and developed by Capital Development Authority (CDA). The catchment area of dam receives heavy precipitation in the form of rainfall and snow, which occurs in December to January and July to September.

Figure 2.4: Sample collection from various locations

The study area is the main source and largest reservoir of drinking water to the people of Islamabad, the capital of Pakistan and nearby areas where Simly dam is located. Water released fromthe reservoir is the cheapest source ofdrinking water for the city. Along with the dam has a huge filtration plant which filters the dam water before turning it to the supply lines. Geographically Simly dam is located at elevation of 80 meters (260ft) above sea level. The dam has following characteristics (Shahid, et al., 2014)

Table 2: Characteristics of Simly Dam

Height	80 m (262 ft)
Length	313 m (1,027 ft)
Dam volume	1,977,000 m3
Spillway capacity	34,405 m3/s
Total capacity	35,463,000 m3
Active capacity	24,669,000 m3

Inactive capacity	10,793,000 m3
Catchment area	153 km2
Surface area	1.7 km2
Maximum length	11.2 km

2.4. Sample collection

Sampling was done on September to October 2019. The water samples were collected in 500ml plastic bottles. Initially the prewashed bottles were rinsed with sample water and then dipped in the lake at 20cm depth, filled the sample water in bottles and then closed its cap tightly. Samples were collected at two different locations in Simly dam i.e. directly from Simly dam (before filtration) and from filtration plant (after filtration) of simly dam.

For raw dam water: Samples were collected from three different locations around the dam. From each site five water samples were collected from various locations. The three samples were:

i. **A** (samples coded as A_1, A_2, A_3, A_4, andA_5)
ii. **B** (samples coded as B_1, B_2, B_3, B_4, and B_5)
iii. **C** (samples coded as C_1, C_2, C_3, C_4, and C_5).

For the filtered water: Five water samples were collected from filtration plant directly.

As the Simly Dam authorities did not allow us to go inside the filtration plant , therefore the filtration processes were not known to us.

All the tests were carried out in the laboratory of Bahria University Islamabad Campus except BOD, DO, Nitrate and potassium which were sent to the Pakistan Council of Research in Water Resources (PCRWR) for analysis

Figure 2.5 Sample collection

2.5. Analysis of water quality parameters:

A total of 12 water quality parameters were selected to calculate the water quality index (WQI). Water samples were collected from two locations i.e. Dam and filtration plant and transported to laboratory for analysis. Temperature was recorded on site, while for the rest of the parameters water samples were sent to the laboratory for analysis using American Public Health Association standard methods 22^{nd} and 23^{rd} edition (APHA, 2012) which were followed for the determination of various physical and chemical parameters in water samples. All measurements were carried out in triplicate, and the results were expressed as averages.

Table 2.1: Methods used for sample analysis

Sr No	Parameters	Equipment & Methods Used
1	pH	Digital pH meter.
2	Electrical Conductivity	Digital Conductometer
3	Total Hardness	Titration using E.D.T.A.
4	Total Alkalinity	Using Acidimetric titration
5	Total Dissolved Solids	Digital TDS meter
6	Biological Oxygen Demand	Winkler's method with azide modification
7	Dissolved Oxygen	Winkler's method with azide modification

8	Total Chlorides	Standard Silver Nitrate titration method
9	Sodium	Standard Silver Nitrate titration method
10	Potassium	Flame photometric method
11	Nitrate	Using UV- Visible Spectrophotometer
12	Calcium	Titration using E.D.T.A.

For the analysis of the water quality parameters the water samples were transported to Bahria University laboratory where pH, EC, TDS, Total Alkalinity, Total Hardness, Calcium, Sodium and Total Chlorides were analyzed. Estimation for Nitrate, Potassium, BOD and Dissolved oxygen contents were outsourced to PCRWR labs due to unavailability of equipment. They used Standard methods (APHA, 2012) for Nitrate and Potassium estimation whereas for BOD and Do Winkler's method were used.

Temperature: Water temperature was measured using a centigrade thermometer at the sampling station itself. Readings were noted by dipping a thermometer into the water and results were recorded in degree centigrade.

pH, EC, TDS: These three parameters were measured using a digital pH, EC and TDS meter. The digital meter was Hanna Instrument Model-HI 8424 which was standardized according to the manufacturer's instruction, it consists of four modes for measuring pH, EC, TDS and Salts. Before measurement of each sample the electrode was first washed thoroughly with distilled water and then with the sample water. The electrode was then dipped into the sample and was allowed to stabilize for about 1-2 minutes before taking the final reading.

Total Hardness: Water Hardness is defined as the sum of calcium and magnesium concentrations. TotalHardness wasestimated byEDTATitrationStandard Method (2012). The reagents used were:

i. 0.01M EDTA solution
ii. NH_4Cl Buffer solution
iii. Eriochrome Black-T (EBT) indicator

A 50 ml water sample was taken in conical flask. To this flask 2 ml of buffer solution (NH_4Cl), the pH of buffered solution should be around 10. Then added 2 to 3 drops of Eriochrome Black-T (EBT) indicator. It was then slowly titrated against 0.01 M EDTA with continuous stirring until the last reddish tinge color changed to bluish purple. The formula used was:

Total hardness (mg/L) = A x B x 1000/ mL of sample

A= mL of EDTA used for sample – mL of EDTA used for blank

B= mg of $CaCO_3$ equivalent to 1mL of EDTA titrant (which is equal to 1 mg $CaCO_3$)

Calcium: Calcium which is a major contributor to the total hardness of water was also analyzed. The method used for this analysis was the EDTA Titration Standard Method (2017). Reagents used were:

i. 0.01M EDTA solution
ii. 1N NaOH
iii. Eriochrome Black-T (EBT) indicator

A 50 ml of water sample was taken in a clean conical flask; to this 2 ml of NaOH solution and 2-3 drops of EBT indicator were added. This was titrated against standard EDTA solution until color changed from reddish purple to blue. The formula used was:

Calcium (mg/L) = A x B x 400.8 / ml of sample

A= mL of EDTA used for sample

B= mg of $CaCO_3$ equivalent to 1mL of EDTA titrant (which is equal to 1 mg $CaCO_3$)

Total Chlorides: Chloride ions is one ofthe major inorganic anions present in water. Total Chlorides were analyzed using Standard Silver nitrate titration method (2012). Reagents used were:

i. Standard silver nitrate solution
ii. Potassium chromate indicator (K_2CrO_4)

10 ml of water sample was taken in a conical flask to which 2 to 4 drops of potassium chromate as indicator were added and titratedagainst 0.01N AgNO3 solutionuntilthe color

changed to a pinkish yellow. Amount of chloride present was calculated from the amount of silver nitrate used as a titrant using the formula:

$$Cl\ (mg/L) = V \times N \text{ of } AgNO_3 \times 1000 \times 35.5\ mg/L\ /ml \text{ of sample}$$

Where, V= volume of $AgNO_3$ consumed for sample.

Sodium: To calculate the amount of sodium ion concentration, first Sodium Chloride (NaCl) concentration in water was calculated using the same titration method which was used as for total chloride. Reagents used were:

i. Standard silver nitrate solution
ii. Potassium chromate indicator (K_2CrO_4)

10 ml of water sample was taken in a conical flask to which 2 to 4 drops of potassium chromate as indicator were added and titratedagainst 0.01N AgNO3 solutionuntilthe color changed to a pinkish yellow. Amount of Sodium Chloride present was calculated from the amount of silver nitrate used as a titrant using the formula:

$$NaCl\ (mg/l) = V \text{ x } N \text{ of } AgNO_3 \text{ x } 1000 \text{ x } 58.44\ mg/l\ /\ ml \text{ of water sample}$$

Where, V= volume of $AgNO_3$ consumed for sample.

This gave the amount of Sodium Chloride , from which total chlorides were subtracted giving the concentration of Sodium remaining in the sample.

$$Na^{+}\ (mg/L) = NaCl\ (mg/L\ ) - Cl^{-}\ (mg/L)$$

Total Alkalinity: Alkalinity of water is its acid neutralizing capacity. Alkalinity is primarily a function ofcarbonate, bicarbonate and hydroxide contents. Totalalkalinity was determined by acid titration using methyl-orange as indicator. The reagents used were:

i. Standardized Acid (H_2SO_4)
ii. Methyl Orange indicator

50 ml of water sample was taken in a flask, 2 drops of methyl orange were added, and it was slowly titrated against 0.02M H_2SO_4 until the color changed from yellow to colorless. The volume of acid used was noted. The procedure was repeated three times for each sample. All samples were tested in the same way,

Total Alkaliniy (mg/L) = Volume of acid used x 0.02M x 50000 / ml of sample

2.6. Water Quality Index Calculation:

Water Quality Index (WQI) is defined as a technique used for rating that provides the composite influence of individual water quality parameters on the overall quality of water (Kuttimani, 2017). This technique reduces the large volumes of water quality data to a single numerical figure. Since it is calculated from the point of view of human consumption, Therefore, WQI is a very useful and most efficient tools to communicate information on the quality of any water body. It serves the understanding of water quality issues by integrating complex data and generating a score that describes the water quality status.

There are several types of WQI proposed using different formulas. The one used in this study is the ‘weighted arithmetic method”. The Index has been calculated from the 12 selected physiochemical parameters with respect to WHO and PSQCA standards. . In present study, WQI wascalculated by methodsproposed byHortonand modified byTiwari and Mishra. In this method, different water quality parameters are multiplied by a weighting factor and are then combined using simple arithmetic mean. According to the role ofvariousparameters based on importance and incidence onoverallqualityofdrinking water, rating scales were fixed in terms of ideal values of different physicochemical parameters. Even if, they are present, they might not be ruling factor. Hence, they were assigned zero values except for PH and dissolved oxygen.

For doing the calculation of WQI in this study required following steps:

First step after parameter selection is the qualityrating scale (Qi) for each parameter, which is calculated by using the following equation:

$$Qn = \{ [(Vn - V io) / (Sn - Vio)] * 100 \}$$

Where,

Qn = Quality rating of the nth parameter

Vn = Actual value of nth water quality parameter that is obtained after the laboratory analysis

Vio= Ideal value of that water quality parameter can be obtained from the standard tables

That is 0 for all the parameters except for pH and DO the ideal values are 7 and 14.6 respectively

Sn = Standard value of that nth water quality parameter.

Then, after calculating the quality rating scale (Qn), the Relative unit weight for each parameter was computed by a value inversely proportional to the standard value for that corresponding parameter using the following expression+

$$Wn = 1/ Sn$$

Where,

Wn = unit weight for nth parameter

Sn= Standard value for nth parameter

Finally, the overall WQI was calculated by combining the quality rating with the unit weight by using the following equation:

$$\mathbf{WQI = \Sigma QnWn / \Sigma Wn}$$

Where,

WQI = water quality index

Qn = Quality rating

Wn = Relative weight

The water quality index rating level and status of water quality as suggested by Brown and Chatterji and Raziuddin has been presented in Table 2.2. Which shows the range of WQI value along with its rating and grading which can be used to display result in single word. (Kuttimani, 2017)

Table 2.2: WQI rating levels and status

WQI Value	Rating of Water Quality	Grading
0-25	Excellent Water Quality	A
26-50	Good Water Quality	B
51-75	Poor Water Quality	C
76-100	Very Poor Water Quality	D
Above 100	Unsuitable for Drinking Purpose	E

Source: (Brown, 1972) (Chaterjee, 2002)

The drinking water standards as recommended by recommending agencies and unit weight have been presented in table 2.3 below.

Table 2.3: Drinking water standards along with recommending agencies and unit weight

Sr no.	**Parameters**	**Standard value**	**Unit**	**Recommending Agency**	**Unit weight (Wn)**
1	pH	6.5-8.5	-	WHO/ PSQCA,2010	0.1176
2	TDS	1000	mg/l	PSQCA, 2010	0.001
3	Electrical conductivity	300	µS cm-1	US EPA	0.003
4	Total Alkalinity	200	mg/l	US EPA	0.005
5	Total Hardness	<500	mg/l	PSQCA/NSDWQ,2010	0.002

6	Calcium	200	mg/l	PSQCA 2010	0.005
7	Sodium	200	mg/l	WHO	0.005
8	Total Chlorides	<250	mg/l	PSQCA/NSDWQ,2010	0.004
9	BOD	<5	mg/l	US EPA	0.200
10	Dissolved oxygen	>4	mg/l	US EPA	0.250
11	Potassium	12	mg/l	WHO	0.083
12	Nitrate	10	mg/l	PSQCA/NSDWQ,2010	0.100

CHAPTER 3

RESULTS AND DISCUSSION

3.1. Physico-chemical parameters:

In order to determine the Water Quality Index of Simly Dam, water sample were taken directly from raw dam water and from the filtration plant located within the Simly Dam area. Samples were collected directly from the dam and from the filtration plan of the dam. The twelve physico-chemical parameters were analyzed using the samples collected from the two different locationswithinthe SimlyDam. The sampleswere subjected to laboratory analysis using standard (APHA, 2012) for the calculation of Water Quality Index (WQI). From the laboratory analysis of the physico-chemical parameters of water the results obtained were tabulated.

The results of the physico-chemical parameters of the fifteen samples of raw dam water have been presented in the table 3.1 and the results of five samples of filtered dam water have been presented in the table 3.2 below.

Table 3.1: Results from the sample analysis raw dam water

Sr No	Samples	pH	EC	TDS	T.A	T.H	BOD	DO	Ca+	Na+	K+	NO_3^-	Cl^-
		-	µS/cm	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
1	A1	7.79	264	187	101.2	134	3.28	5.6	127	35.95	3.2	2.5	55.2
2	A2	7.71	259	184	94	126	4.0	5.2	117	36.91	3.5	2.8	56.6
3	A3	7.73	254	181	115	136	3.5	4.9	125	57.6	3.1	2.6	88.5
4	A4	7.79	261	186	123.2	136	3.3	5.1	128	34.56	3.3	2.2	53.1
5	A5	7.77	260	185	98	152	4.5	4.8	134	52.98	3.2	2.4	81.4
6	B1	7.82	263	187	120	146	2.1	4.46	130	55.98	3.5	2.9	86.0
7	B2	7.73	255	182	98	138	2.2	4.5	124	35.25	4.1	3.0	54.1
8	B3	7.81	262	186	111.2	132	3.3	4.8	124	38.24	3.4	2.8	58.7
9	B4	7.83	259	184	124	144	3.1	4.4	122	39.12	4.2	3.1	60.1
10	B5	7.75	254	181	128	144	2.9	4.7	126	36.86	3.9	2.5	56.6
11	C1	7.65	263	187	116	134	3.9	5.6	122	33.62	3.5	2.9	51.6
12	C2	7.68	261	186	118	139	4.1	5.5	128	37.5	3.8	2.6	57.7
13	C3	7.72	257	185	114	134	3.8	5.1	127	46.8	3.9	2.3	71.8
14	C4	7.70	260	185	118	138	4.0	4.9	124	43.74	4.0	2.8	67.2
15	C5	7.79	261	186	120	134	3.7	5.2	127	39.2	4.1	2.6	60.1
Mean Value (Vn)		**7.75**	**259.5**	**184.8**	**113.24**	**137.8**	**3.45**	**4.98**	**125.6**	**41.62**	**3.64**	**2.67**	**63.94**

Table 3.2: Results from the analysis of filtered water sample

Sr No	Samples	pH	EC	TDS	T.A	T.H	BOD	DO	Ca+	Na+	K+	NO_3^-	Cl^-
			μS/cm	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
1	F1	7.61	258	180	112.2	80	3.0	6.5	54.6	23.0	2.9	0.76	35.4
2	F2	7.3	255	178	108	88	2.9	6.6	41.2	23.6	3.0	0.70	36.4
3	F3	7.55	257	182	108.5	96	3.0	6.5	42.6	207	2.9	0.80	31.8
4	F4	7.6	258	180	112	83.2	3.0	6.6	48.0	19.1	2.8	0.81	29.3
5	F5	7.4	253	180	111	89.2	2.8	6.6	39.2	23.0	2.9	0.75	35.4
Mean Value (Vn)		**7.5**	**256**	**180**	**110.2**	**87.28**	**2.94**	**6.5**	**45.12**	**21.8**	**2.9**	**0.76**	**33.7**

The mean values of the physico-chemical parameters ofthe raw and filtered dam water are presented in the figure 3.1. The figure shows the comparison between physico-chemical parameters in raw dam water and filtered dam water.

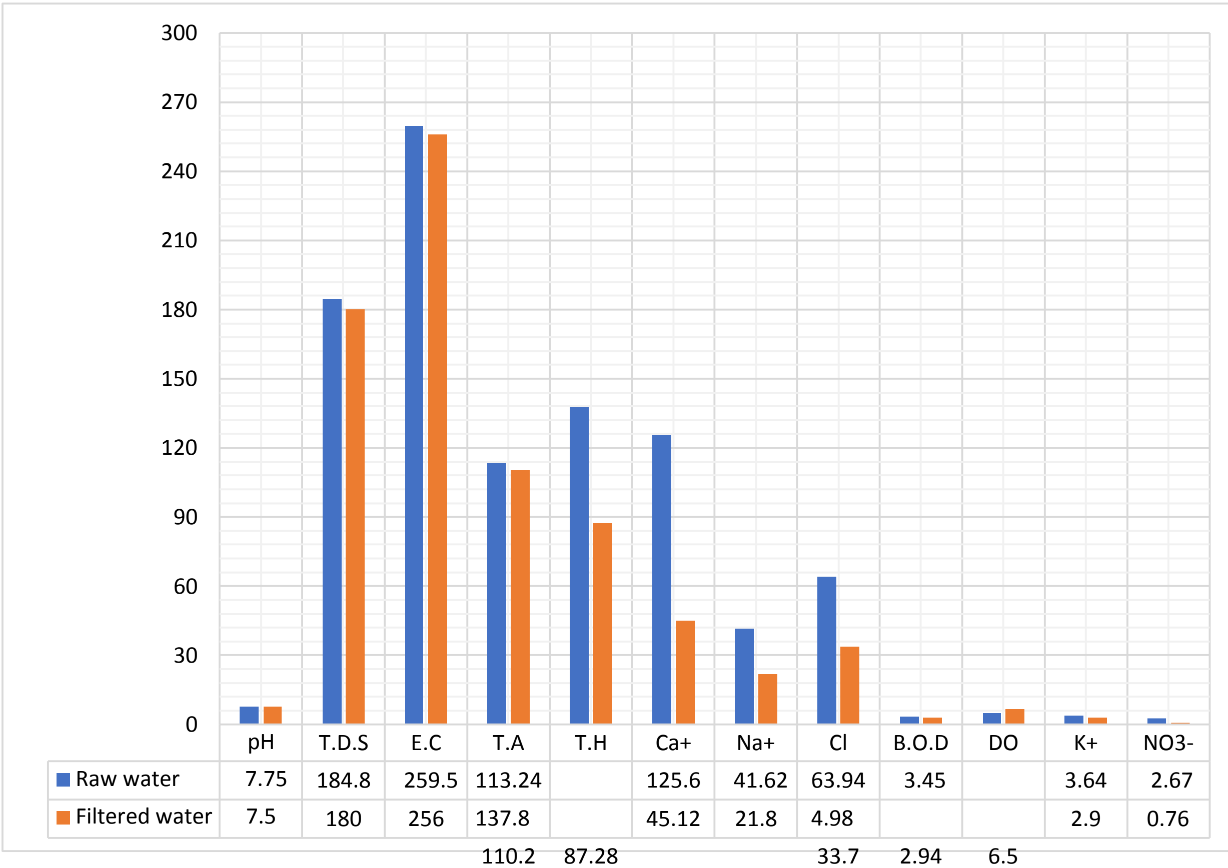

Figure 3.1: Comparative physicochemical parameters in raw and filtered dam water

The water samples taken for the study were pale yellow in color and odorless in both stations. Temperature of water is basically important because it effects bio-chemical reactions in aquatic organisms. A rise in temperature of water leads to the speeding up of chemical reactions in water, reduces the solubility of gases and amplifies the tastes. The average water temperature was 23 ºC in the both stations and was checked on the spot.

pH:

pH is the negative logarithm of hydrogen ion concentration. This value is an indication of the level ofacidity or alkalinity ofa solution. The permissible limit ofpH in drinking water according to WHO is within 6.5– 8.5. The value of pH in raw dam water ranged from 7.65 to 7.83 (highest and lowest) with average value of 7.75 and in filterd dam water it ranged between 7.3 to 7.61 with average of 7.5 .The pH of both locations is between the desirable range. The average pH values have been computed in figure 3.2, while figure (3.2.1) and (3.4.2) shows the pH values obtained in raw and filter dam water respectively.

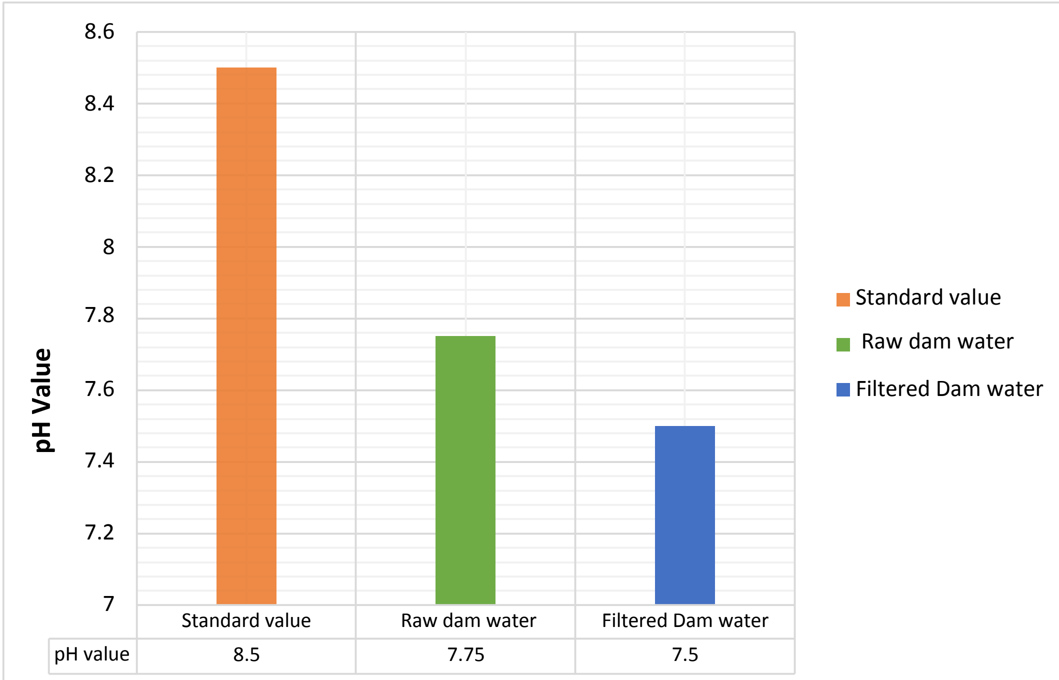

Figure 3.2: Average pH values in study area

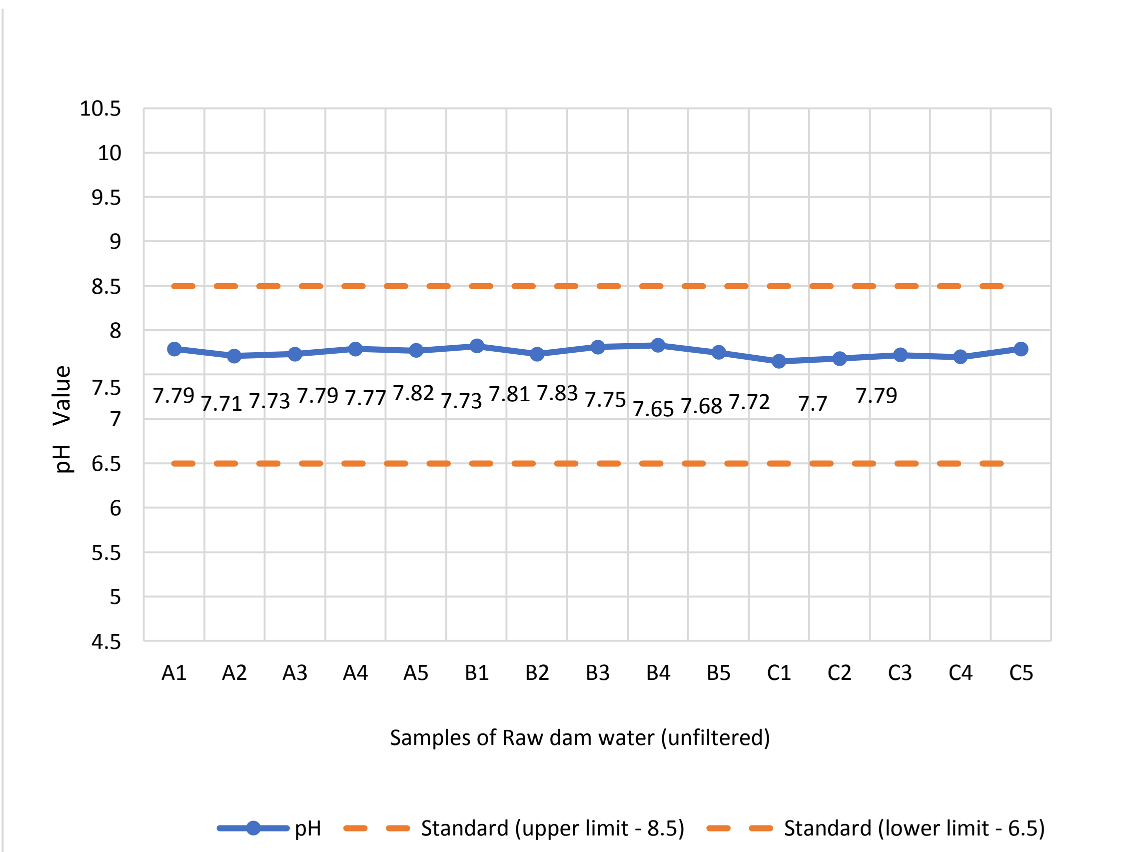

Figure 3.3: pH of raw dam water samples

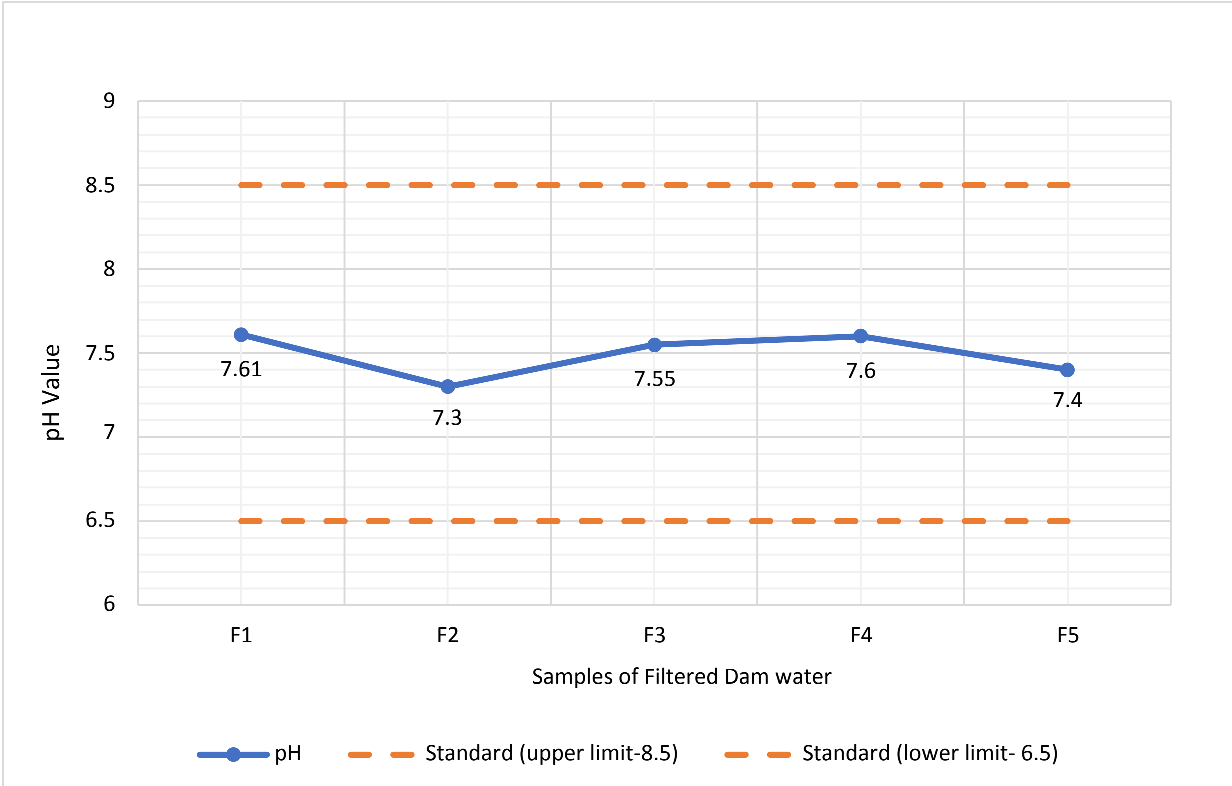

Figure 3.4: pH of filtered dam water samples

Electrical Conductivity:

Electrical conductivity is basically a measure of water's ability to transmit electric current through it and also it is a usefultoolto assess the purityofwater. EC depends in the amount of salts present in a water. High EC values are an indication of pollution, thus electrical conductivity measures the concentration of ions in water. The concentration of ions in turn depends on the environment, movement and sources water.

Standard limit for EC is 300µS/cm according to US EPA. Electric Conductivity in the raw dam water 254 to 264 µS/cm, with an average value of 259.5 µS/cm. while the EC in filtered wart was found to be ranged between 253 to 258 µS/cm, with an average value of 256 µS/cm.

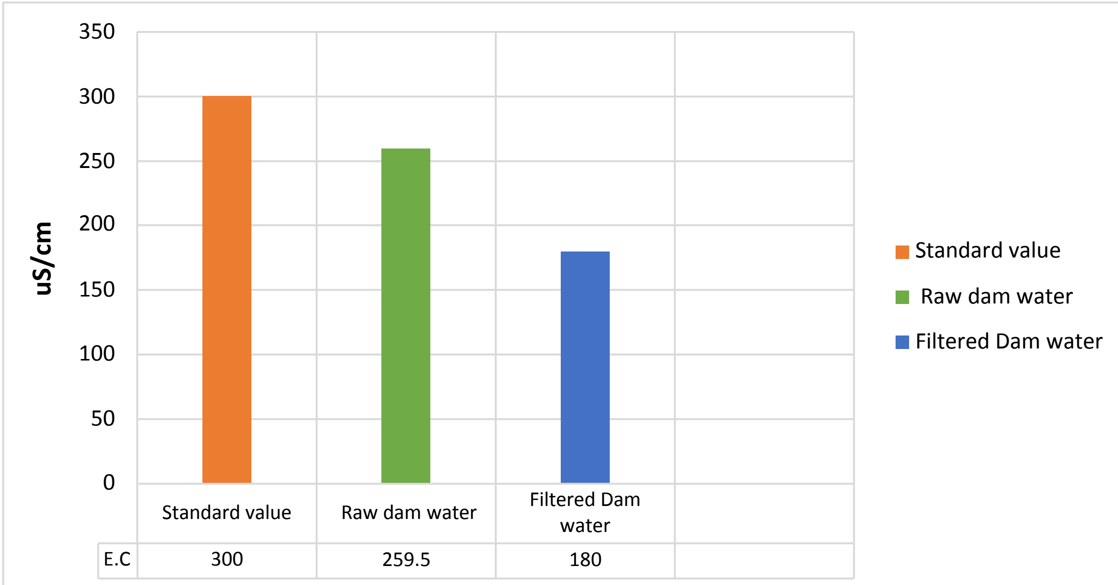

Figure 3.5: Average Electrical Conductivity values in study area

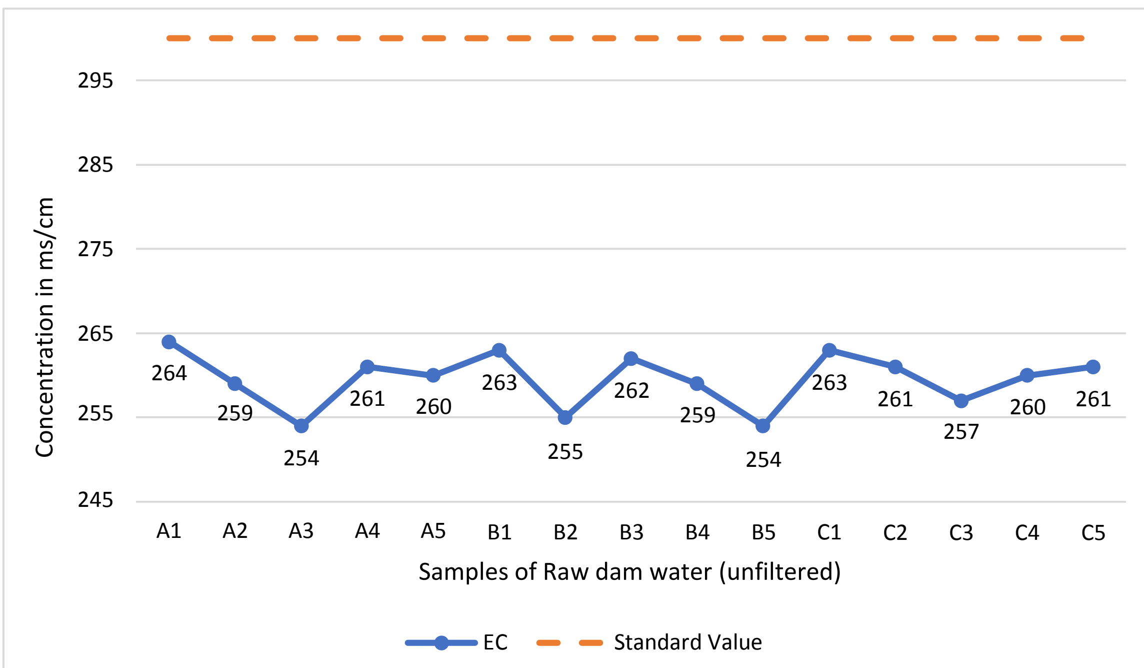

Figure 3.6: Electrical Conductivity of raw dam water samples

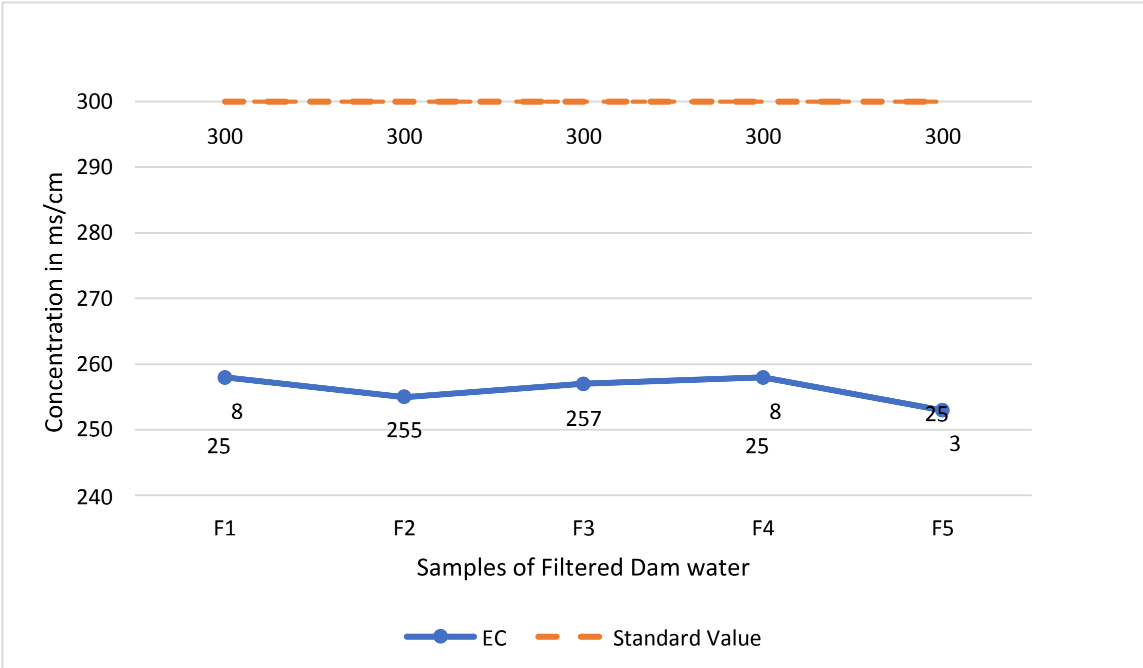

Figure 3.7: Electrical Conductivity of filtered dam water samples

Total Alkalinity:

Alkalinity is basically a measure of water's capacity to neutralize acids. It is a measure of buffering capacity of the water. The permissible limit for total alkalinity for drinking water specified by WHO is 300 mg/l. The obtained alkalinity in raw dam water ranged from 94 to 128 mg/l, with an average value of 113.24 mg/l. while the alkalinity of filtered water ranged between 108 to 112.2 mg/l, with an average value of 110.2 mg/l. Both the locations have alkalinity under the permissible limits and there is not much difference in value of alkalinity of filtered water from raw water.

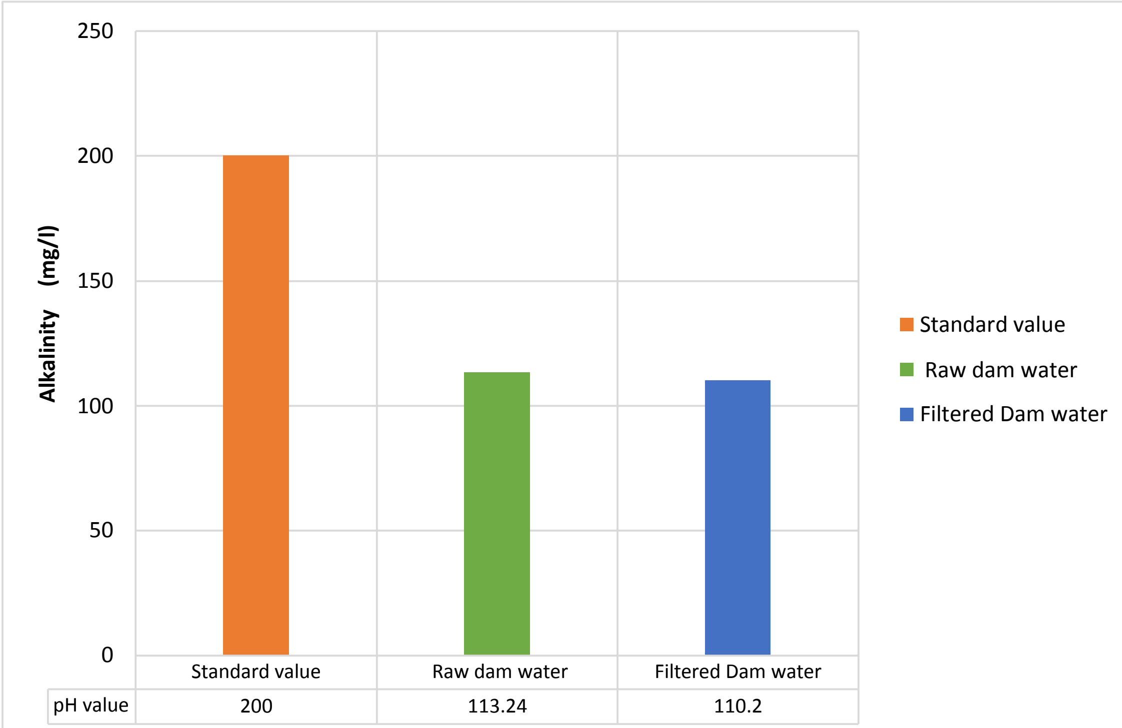

Figure 3.8: Average alkalinity levels in study area

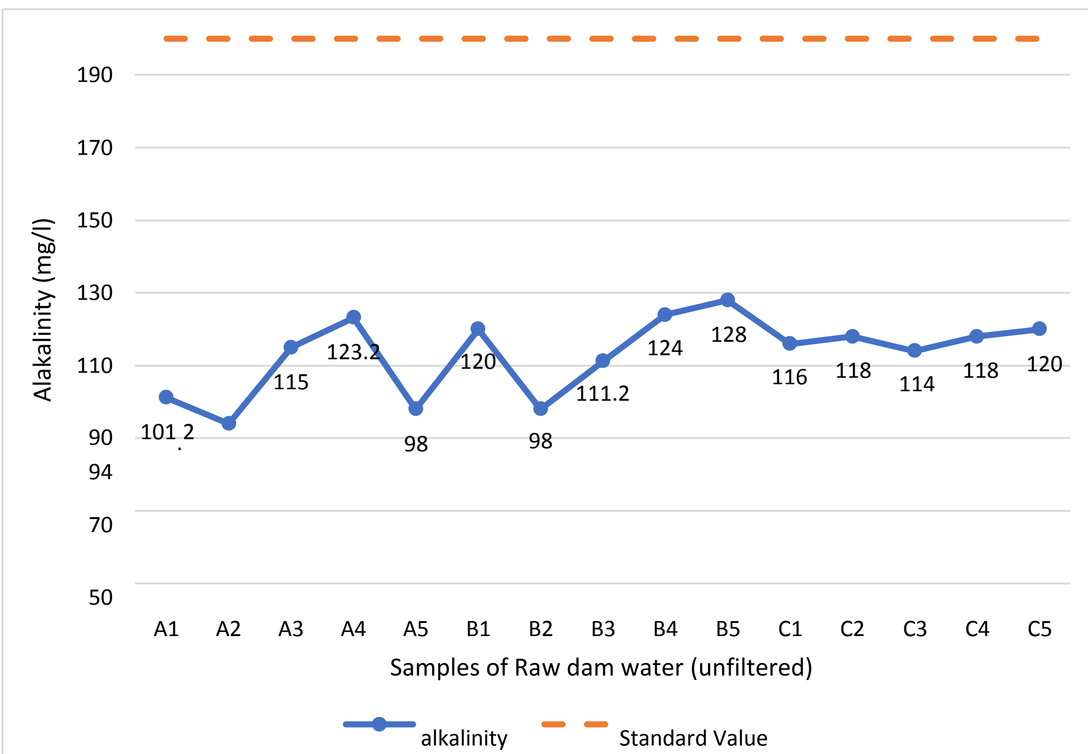

Figure 3.9: Alkalinity values in raw water samples

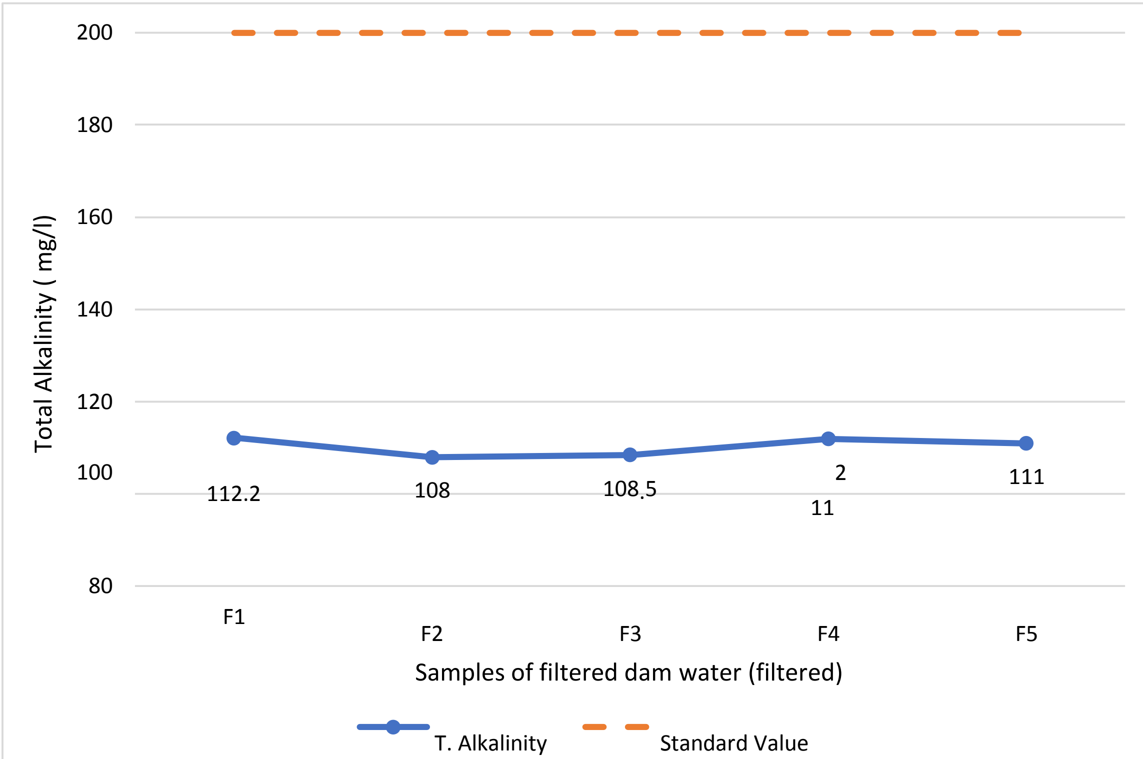

Figure 4: Total Alkalinity values in filtered water samples

Total Hardness:

Total Hardness is the parameter which is used to describe the effect of dissolved minerals particularly Calcium and Magnesium in water. Combined these two minerals contribute to the total hardness of water. The permissible limit of hardness for drinking water is 500 mg/l. The samples of raw dam water consisted of hardness ranging from 126 to 152 mg/l, with an average of137.8 mg/l. While the filtered dam water showed hardness ranging from 80 to 96 mg/l, with an average of 87.28 mg/l. The values of total hardness if within the standard limits.

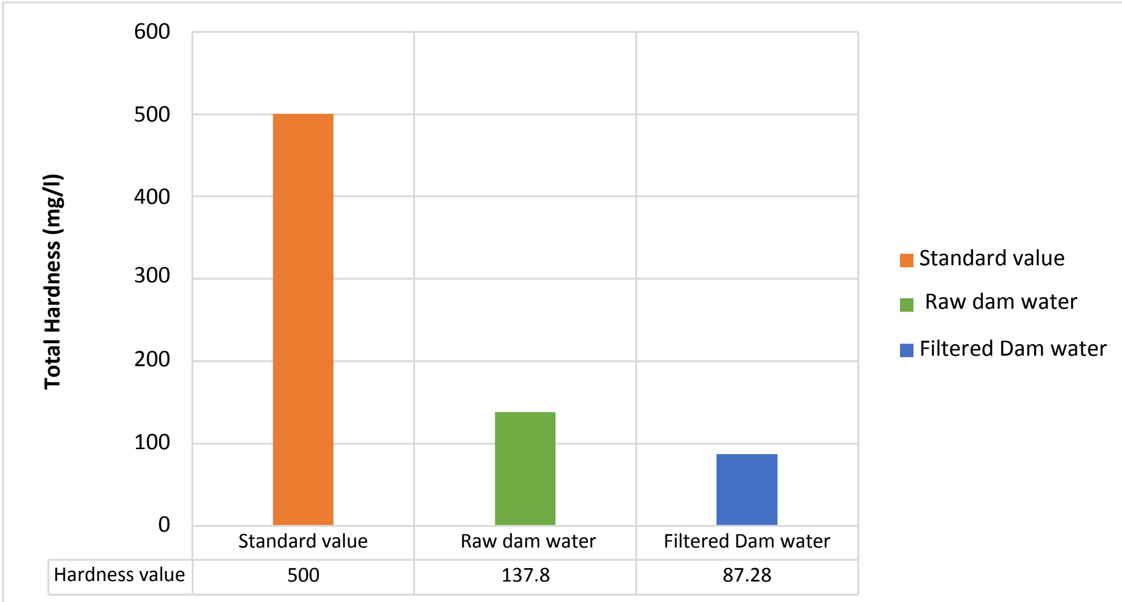

Figure 4.1: Average Total Hardness value in study area

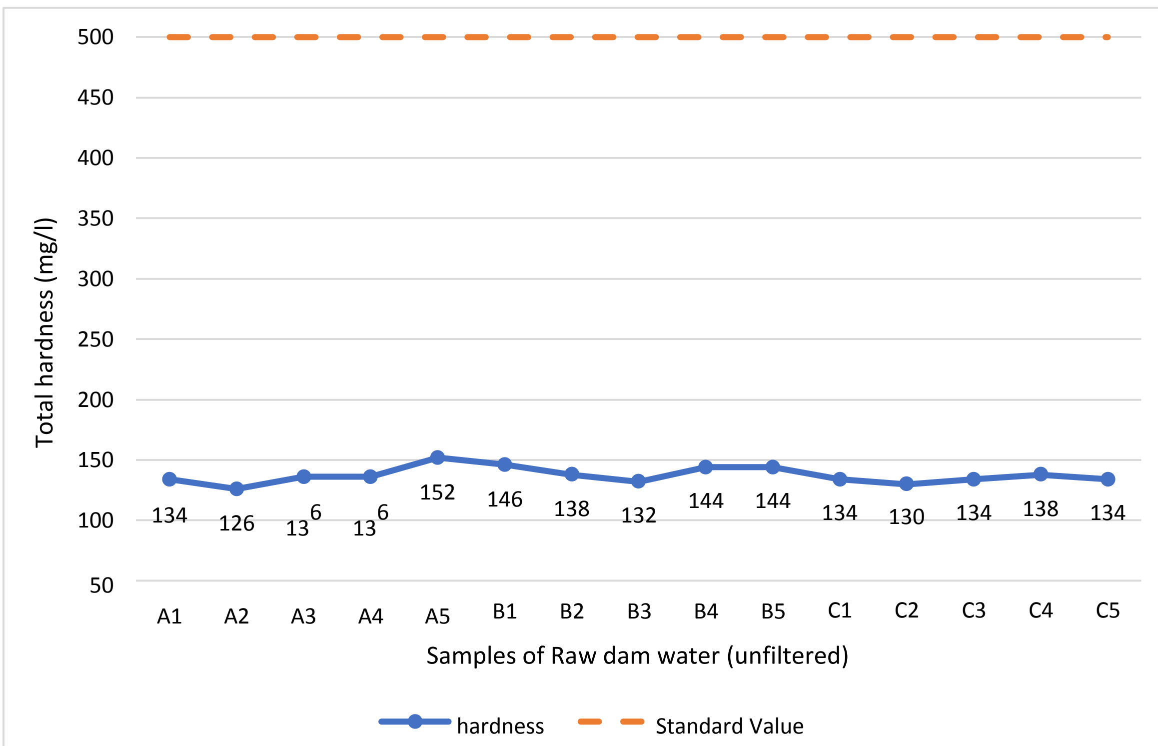

Figure 4.2: Total Hardness values in raw water samples

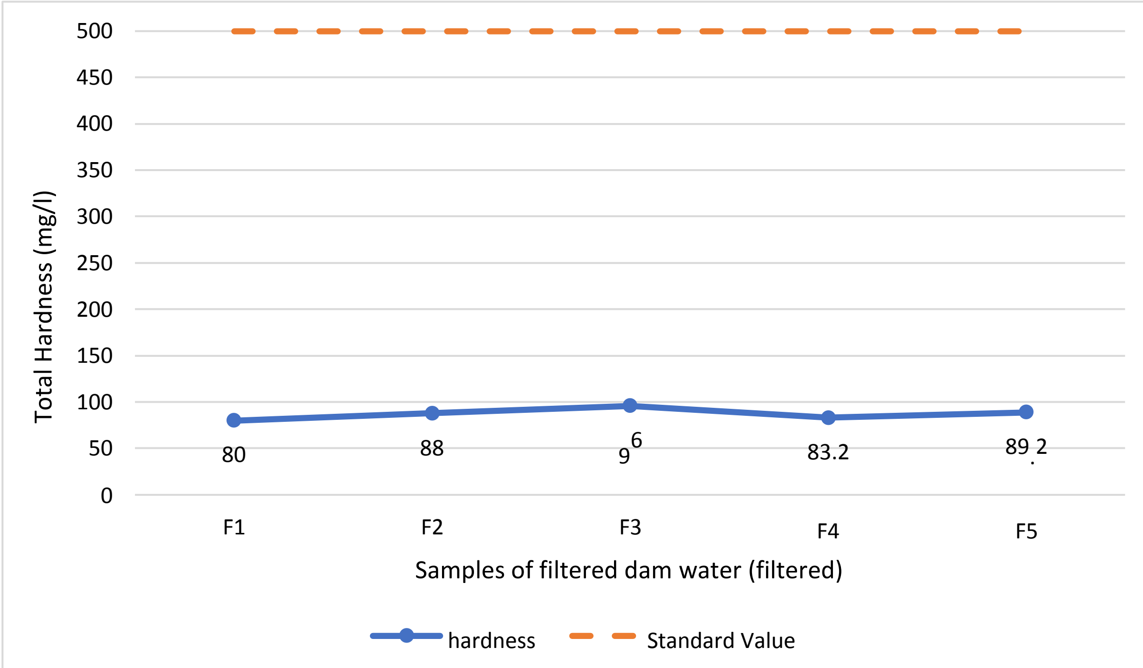

Figure 4.3: Total Hardness values in filtered water samples

Total Dissolved Solids:

Total Dissolved Solids mainly denote the presence of various kinds of minerals in the water. It is a measure of amounts of solids present in water. The permissible limit of TDS for drinking water is 1000 mg/l. The samples of raw dam water consisted of total solids ranging from 181 to 187 mg/l, with an average of 184.8 mg/l. While the filtered dam water showed solids ranging from 178 to 182 mg/l, with an average of 180 mg/l. both locations have TDS well under the permissible limits.

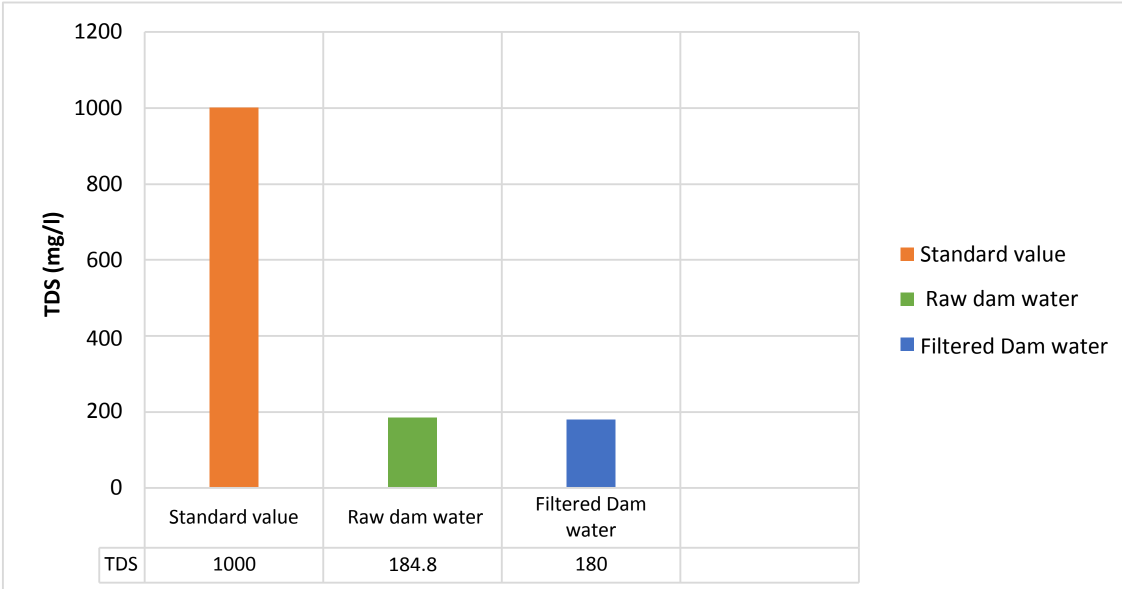

Figure 4.4: Average value of TDS in study area

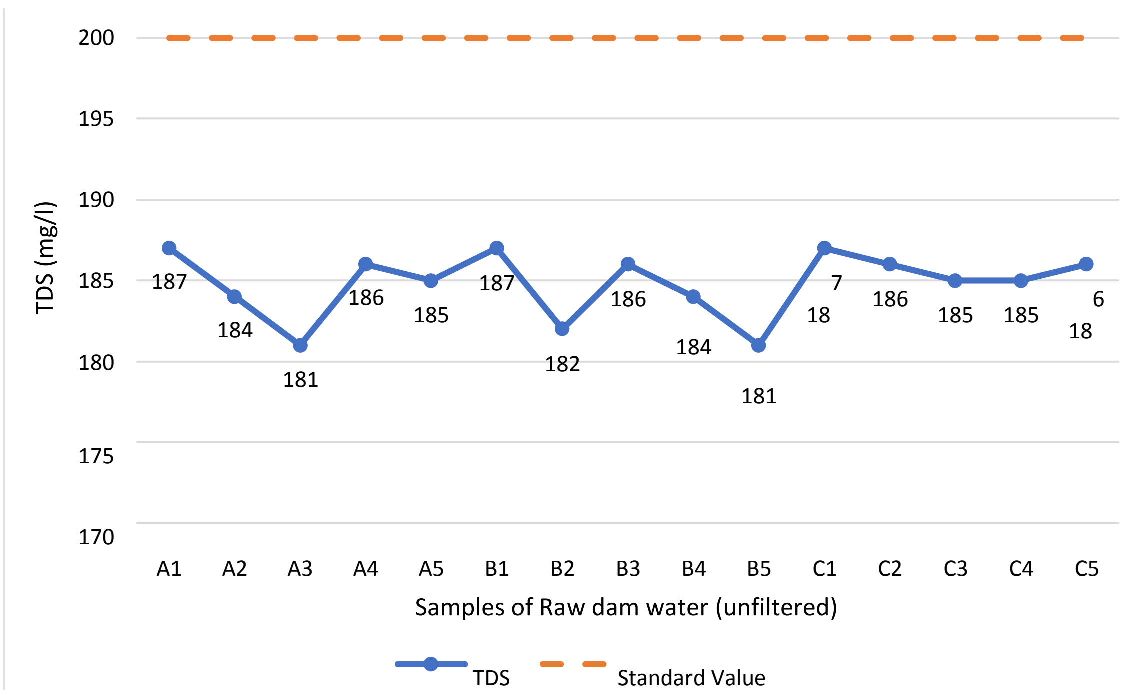

Figure 4.5: TDS values in raw dam water samples

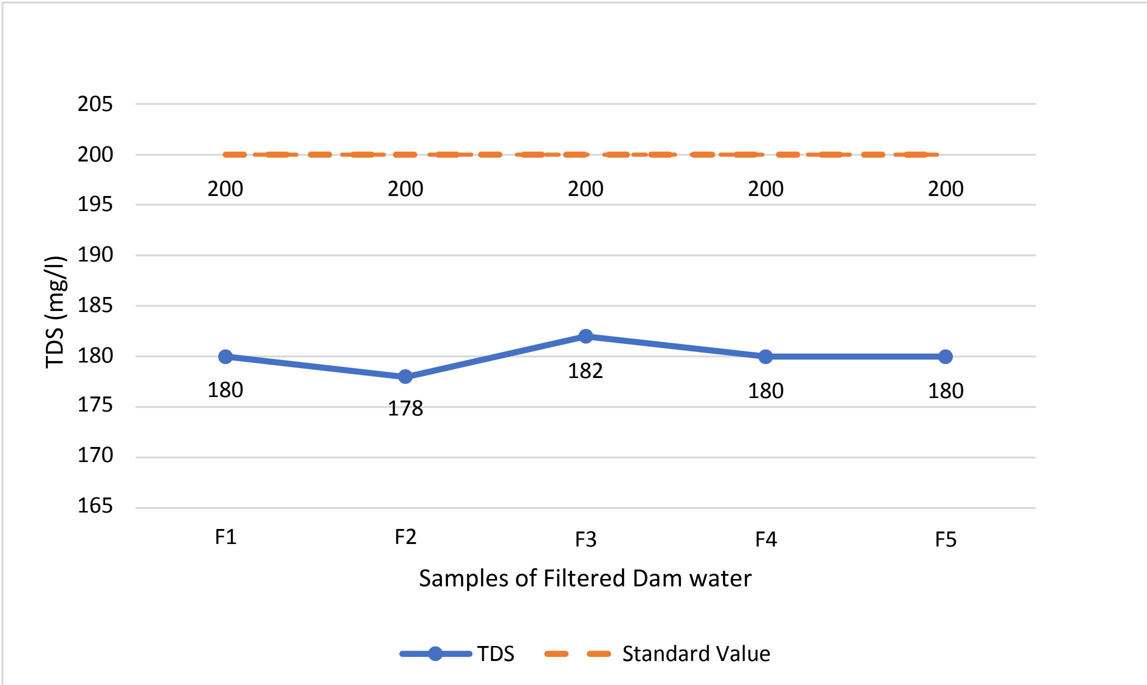

Figure 4.6: TDS values in filtered dam water samples

Dissolved Oxygen:

Dissolved Oxygen is defined as the measure of the amount of gaseous oxygen that is dissolved inwater. Dissolved oxygen isan important parameter inwater qualityassessment as it reflects the physical and biological processes of aquatic life. Free oxygen or DO is needed for respiration by aquatic organisms and microorganism. The DO levels below 1 ppm will not support fish; levels of 5 to 6 ppm are usually required for most of the fish population. The average standard value of DO levels is greater than 4 mg/l. The samples of raw dam water consisted of DO ranging from 4.4 to 5.6 mg/l, with an average of 4.98 mg/l. While the filtered dam water showed DO ranging from 6.5 to 6.6 mg/l, with an average of6.5 mg/l. The values ofDO were within the standard limits in both locations but were better in filtered water with increased amount of dissolved oxygen.

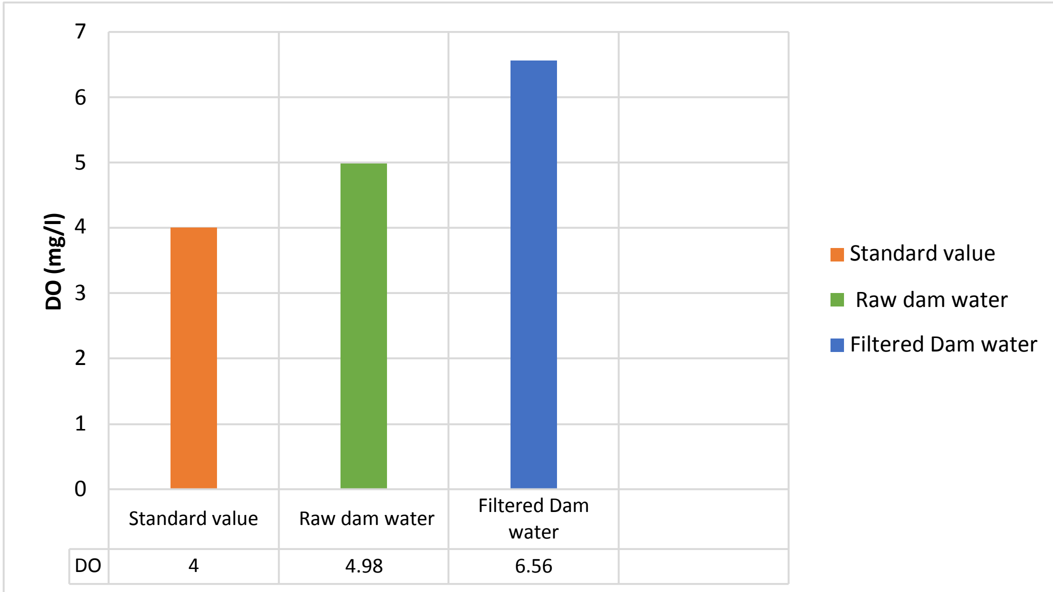

Figure 4.7: Average DO levels in study area

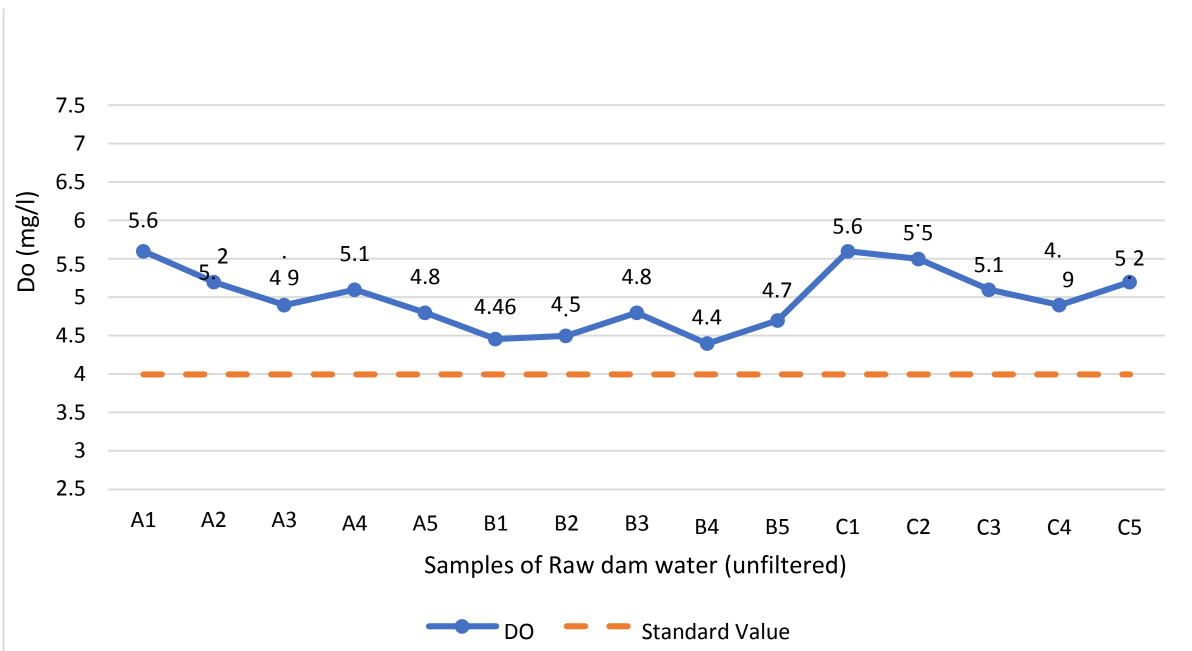

Figure 4.8: DO levels in raw dam water samples

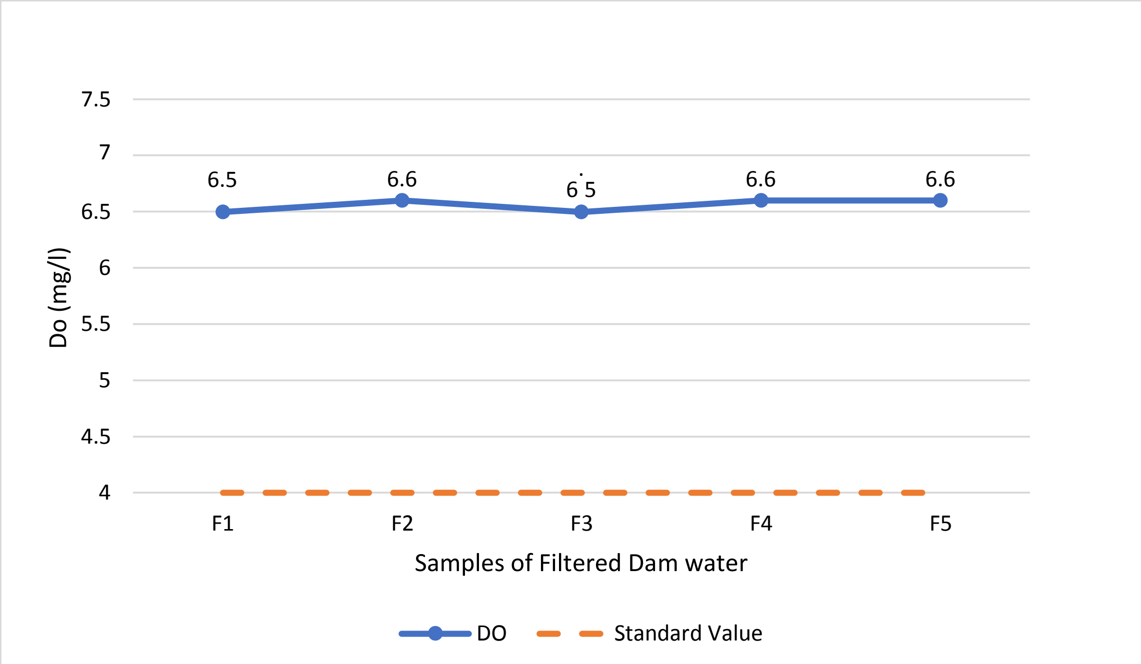

Figure 4.9: DO levels in filtered water samples

BOD:

The Biochemical Oxygen Demand can be defined as the oxygen required by the microorganism to perform the decomposition of dissolved solids or organic matter in the water under aerobic conditions. BOD directly affects the amount of dissolved oxygen in rivers and streams. The greater the BOD, the more rapidlyoxygen is depleted in the stream. This means less oxygen is available to higher forms of aquatic life. The consequences of high BOD are the same as those for low dissolved oxygen: aquatic organisms become stressed, suffocate, and die. Unpolluted, natural waters should have a BOD of 5 mg/l or less. The samples of raw dam water consisted of BOD ranging from 2.1 to 4.5 mg/l, with an average of 3.45 mg/l. While the filtered dam water showed hardness ranging from 2.8 to 3 mg/l, with an average of 2.94 mg/l. The values of BOD are within the standard limits in both locations with better conditions in filtered water due to reduced BOD levels.

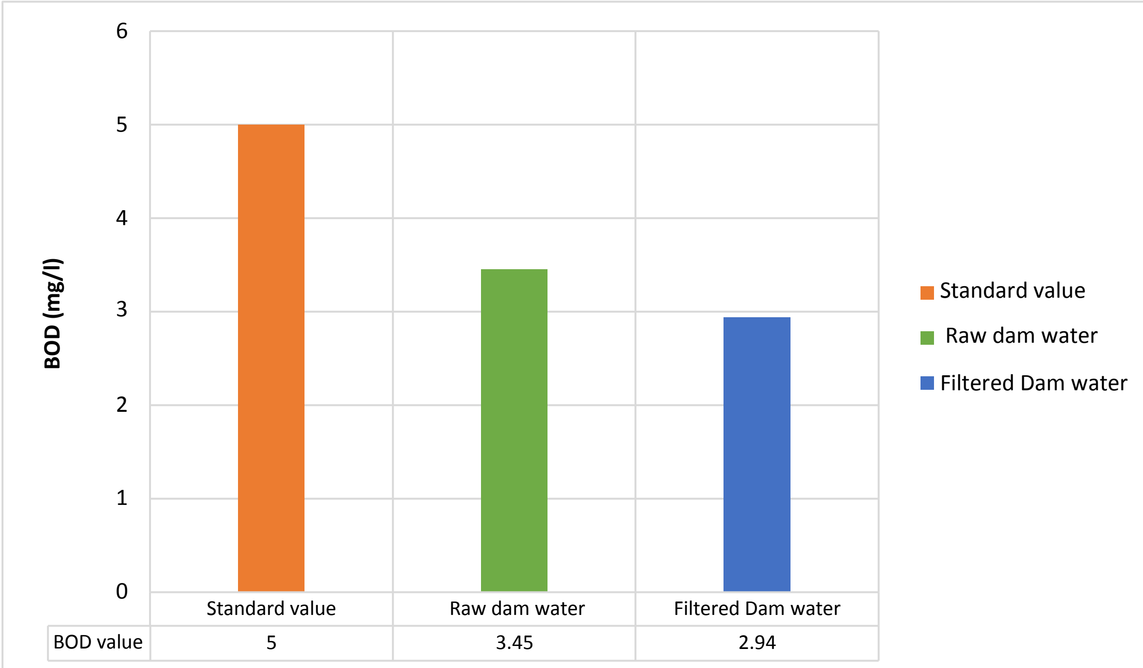

Figure 5: Average BOD levels in study area

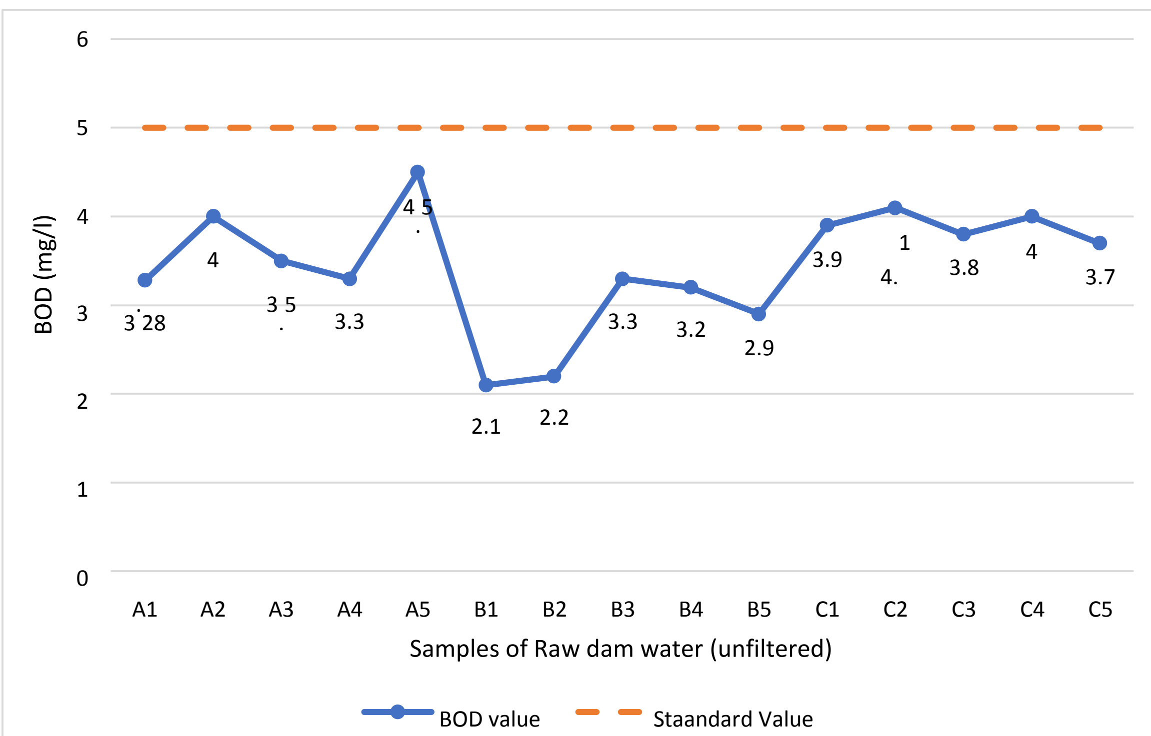

Figure 5.1: BOD values in raw water samples

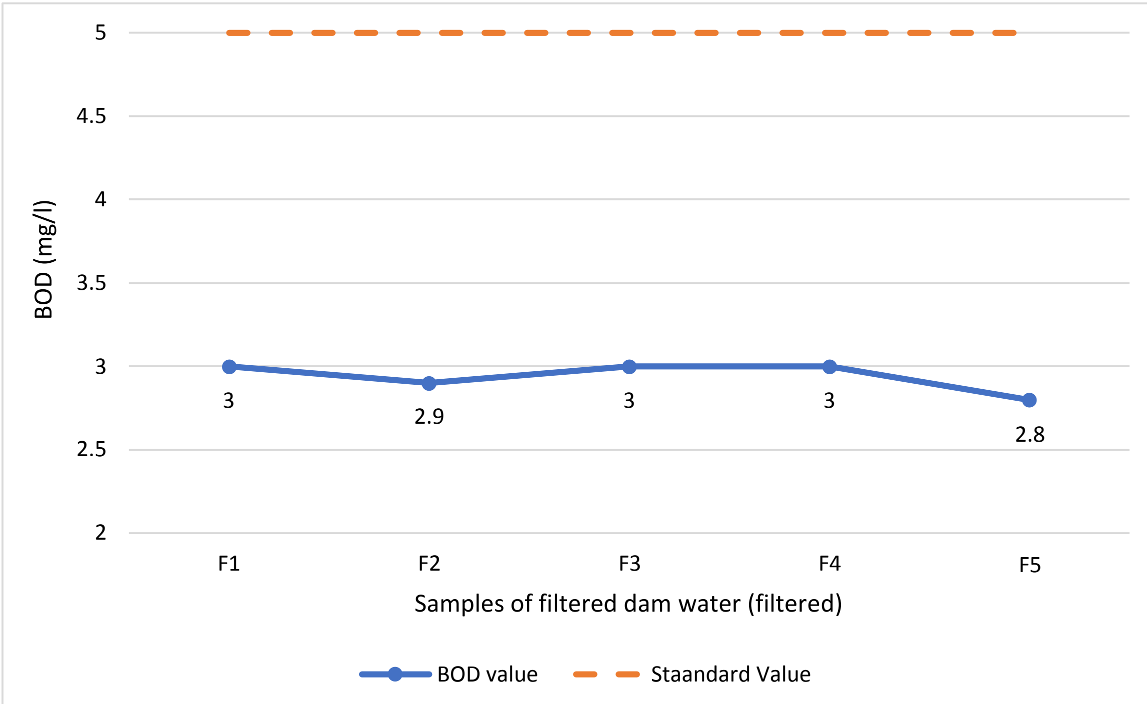

Figure 5.2: BOD values in filtered water samples

Nitrate:

The permissible limit of nitrates for drinking water is 10 mg/l. The samples of raw dam water consisted of nitrates ranging from 2.2 to 4.1 mg/l, with an average of 2.67 mg/l. While the filtered dam water showed nitrate concentration ranging from 0.7 to 0.8 mg/l, with an average of 0.76 mg/l. The values of nitrates are well within the standard limits. With an increased reduction in filtered water.

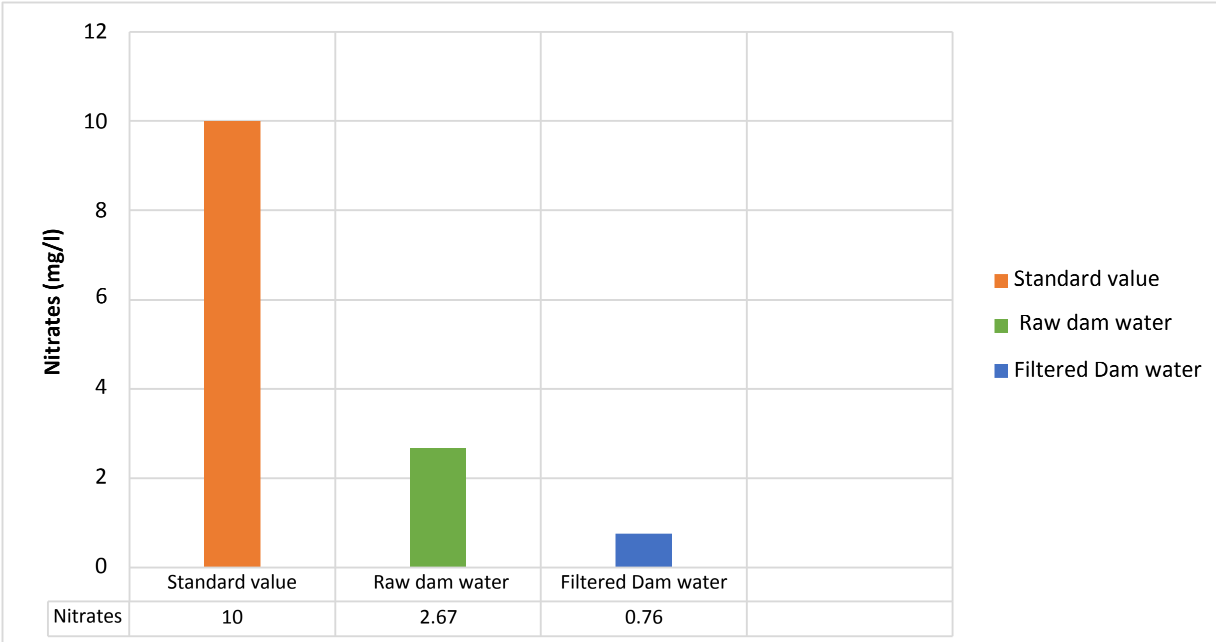

Figure 5.3: Average nitrate value in study area

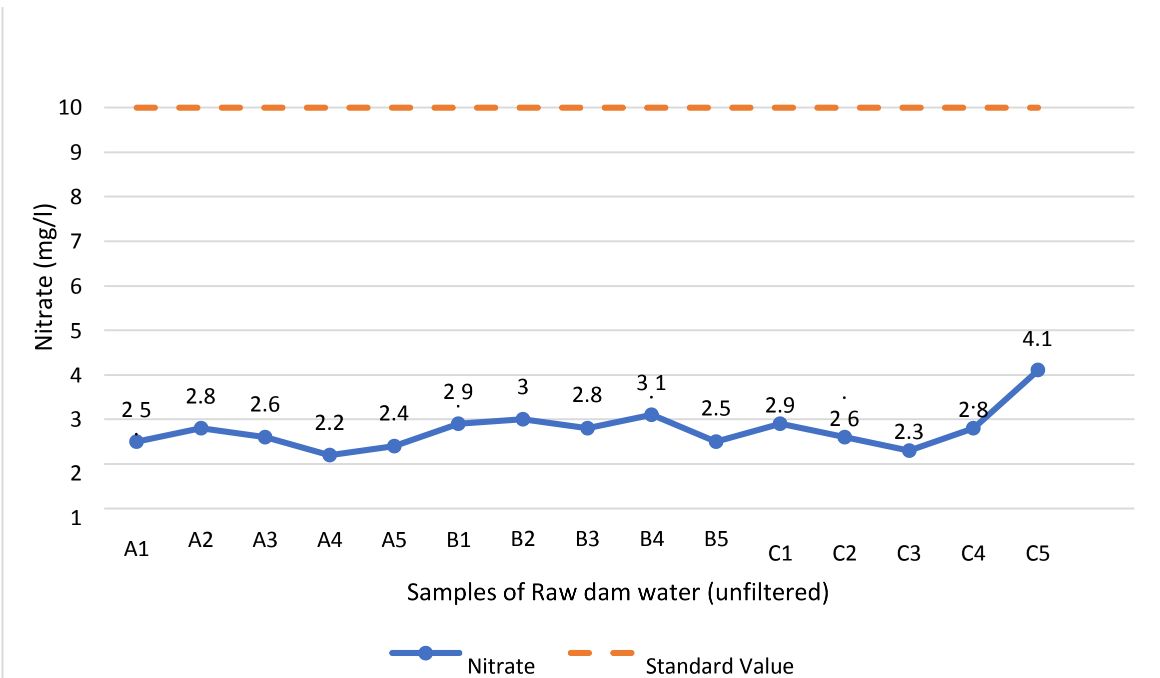

Figure 5.4: Nitrate values in raw dam water samples

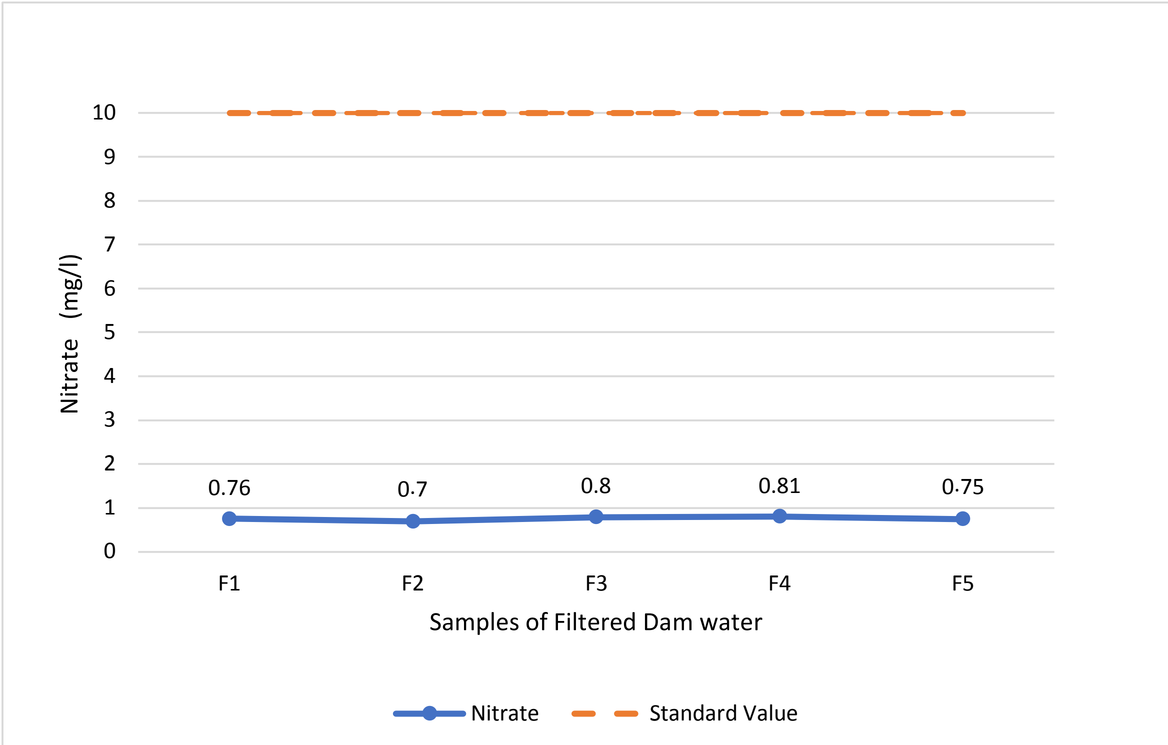

Figure 5.5: Nitrate values in filtered water samples

Total Chlorides:

Chloride is an indicatorofsalinity in water. The permissible limits for chlorides in drinking water are 250 mg/l. The samples of raw dam water consisted of chloride concentration ranging from 51.68 to 88.5 mg/l, with an average of 63.94 mg/l. While the filtered dam water showed chloride concentration ranging from 29.3 to 35.4 mg/l, with an average of 33.7 mg/l. The values of total chlorides are within the standard limits with an increased reduction in filtered water.

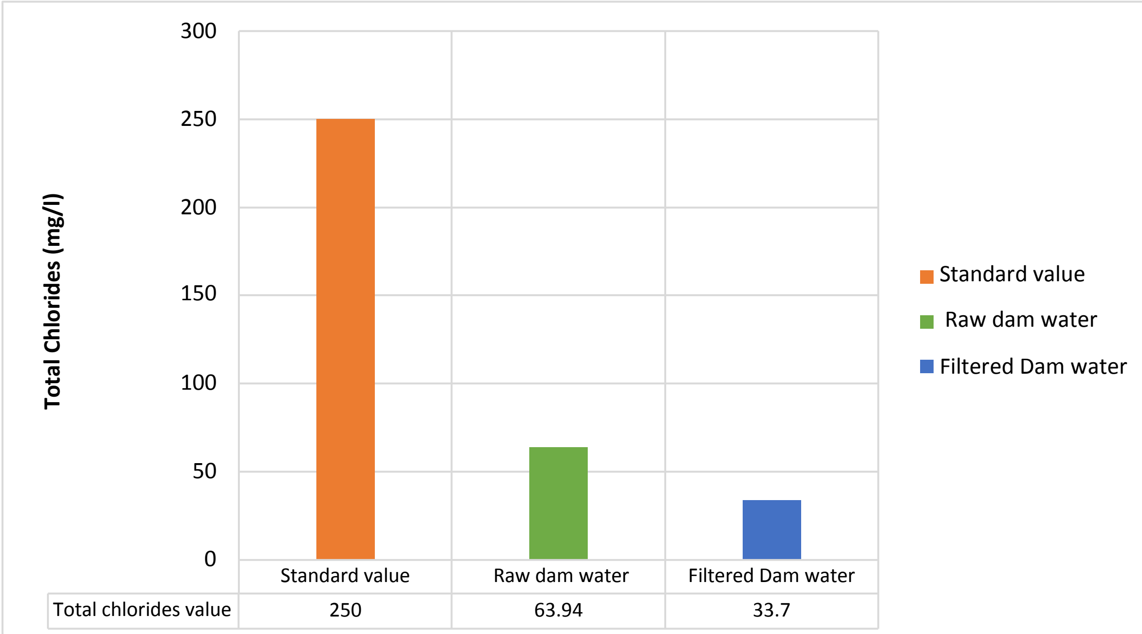

Figure 5.6: Average chloride value in study area

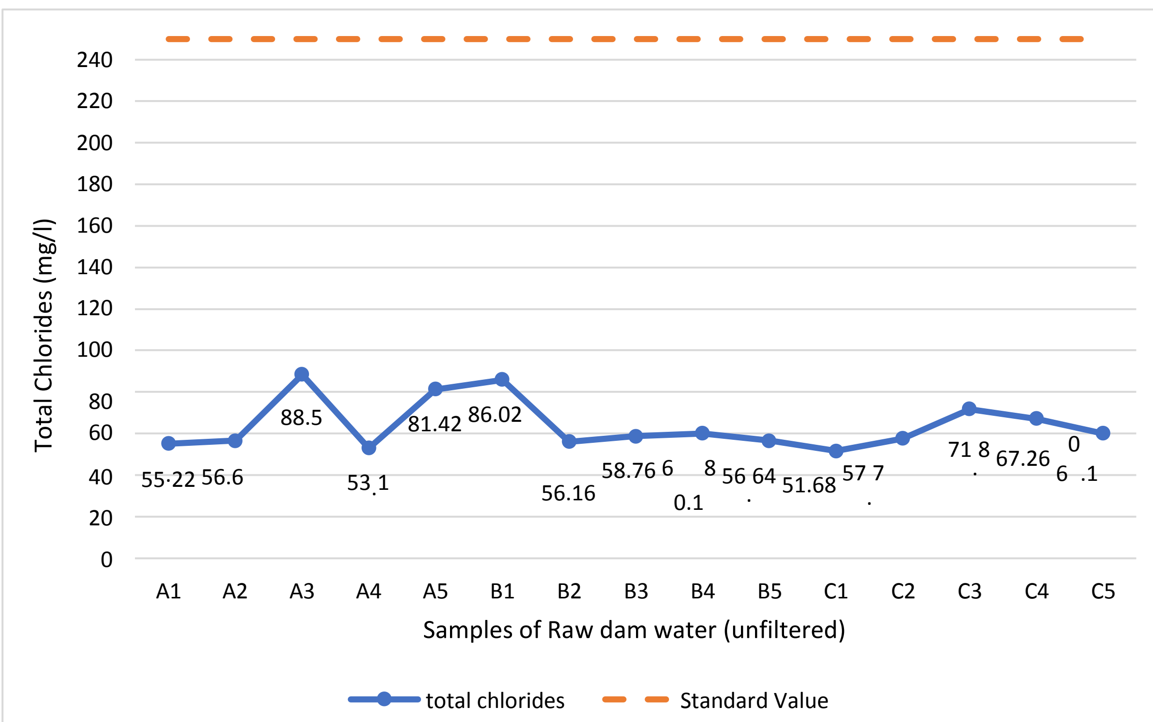

Figure 5.7: Chloride values in raw water samples

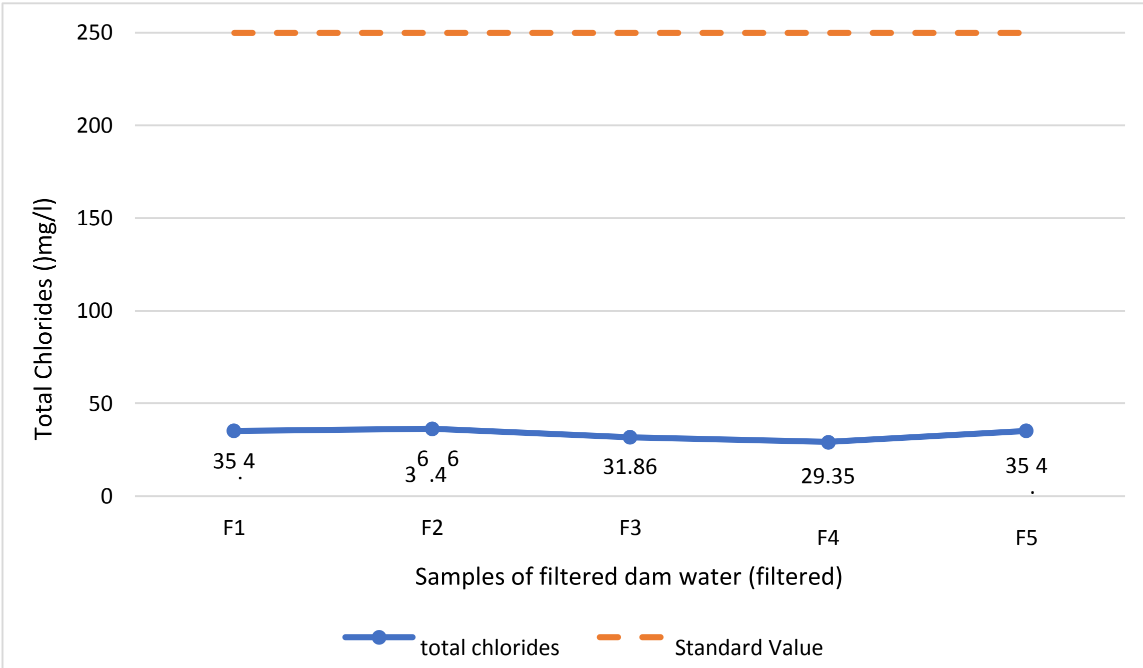

Figure 5.8: Chloride values in filtered water samples

Calcium:

The permissible limits for calcium in drinking water are 200 mg/l. The calcium concentrations samples of raw dam water ranged between 117 to 134 mg/l. While the filtered dam water showed calcium concentration ranging from 39.2 to 48 mg/l, with an average of 45.12 mg/l. The values of calcium are within the standard limits.

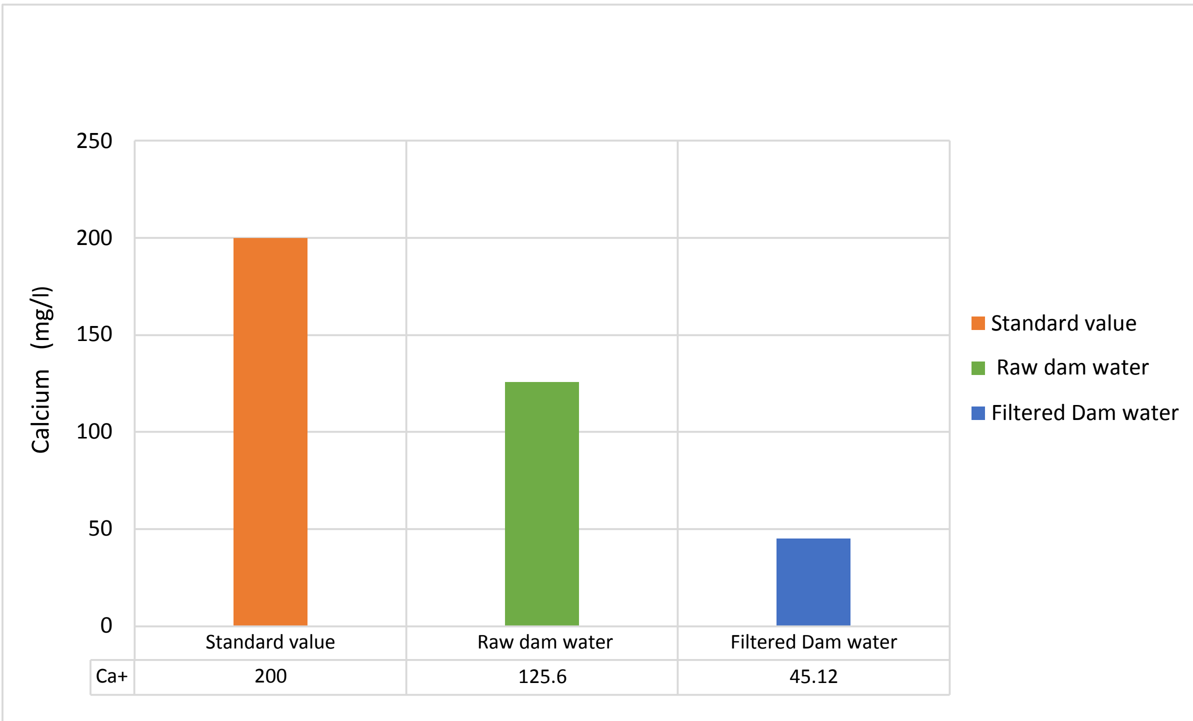

Figure 5.9: Average values of Calcium in study area

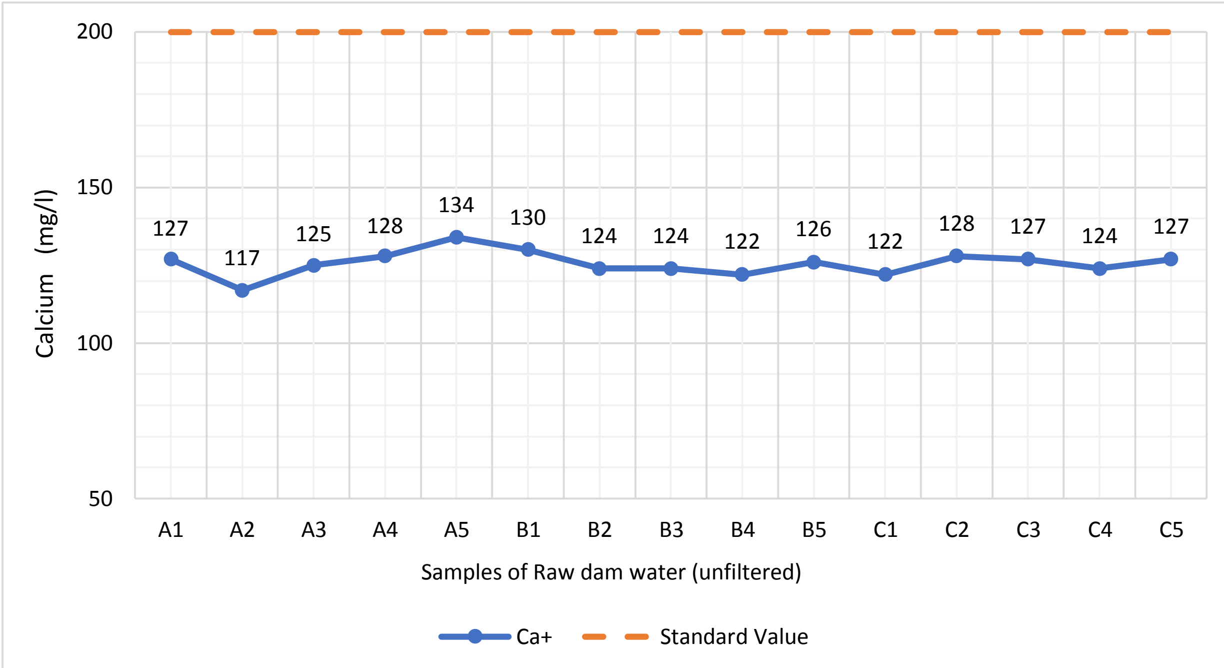

Figure 6: Calcium values in raw dam water samples

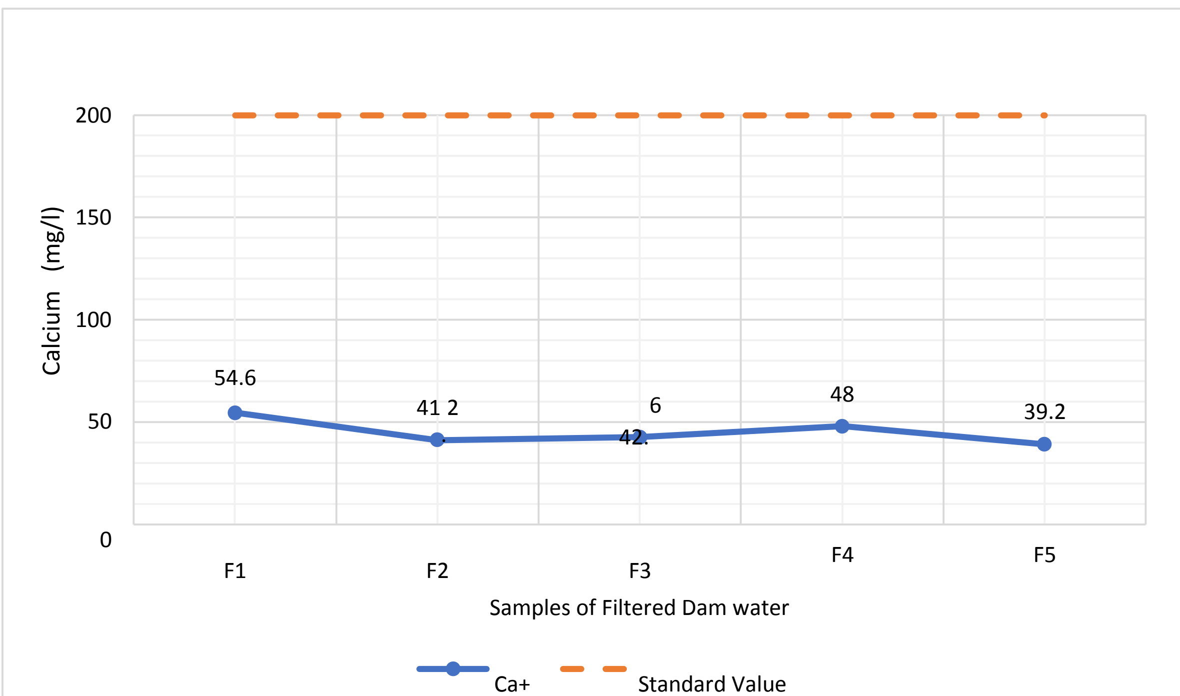

Figure 6.1: Ca+ values in filtered water samples

Potassium:

Potassium is the most important mineral occurring naturally. The primary natural source of this comes from the weathering of rocks. The permissible limits for potassium in drinking water are 12 mg/l. The samples of raw dam water consisted of potassium concentration ranging from3.1 to 4.2 mg/l, with an average of 3.64 mg/l. While the filtered dam water showed concentration ranging from 2.8 to 3 mg/l, with an average of 2.9 mg/l. The values of potassium are within the standard limits in both waters.

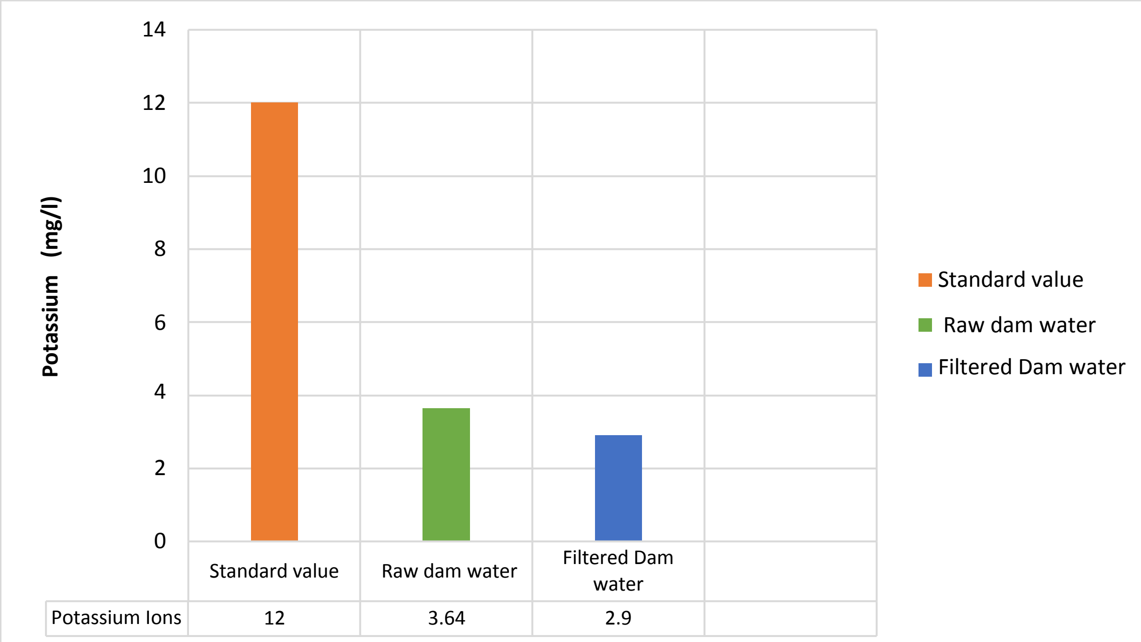

Figure 6.2: Average Potassium values in study area

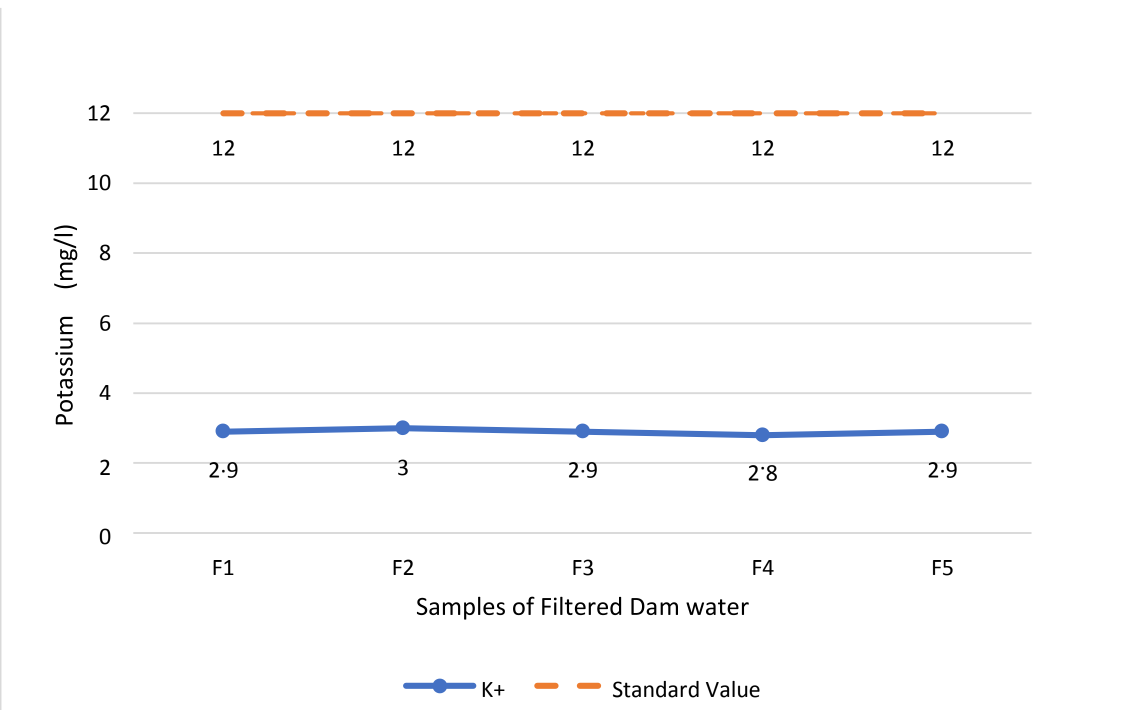

Figure 6.3: Potassium values in raw dam water samples

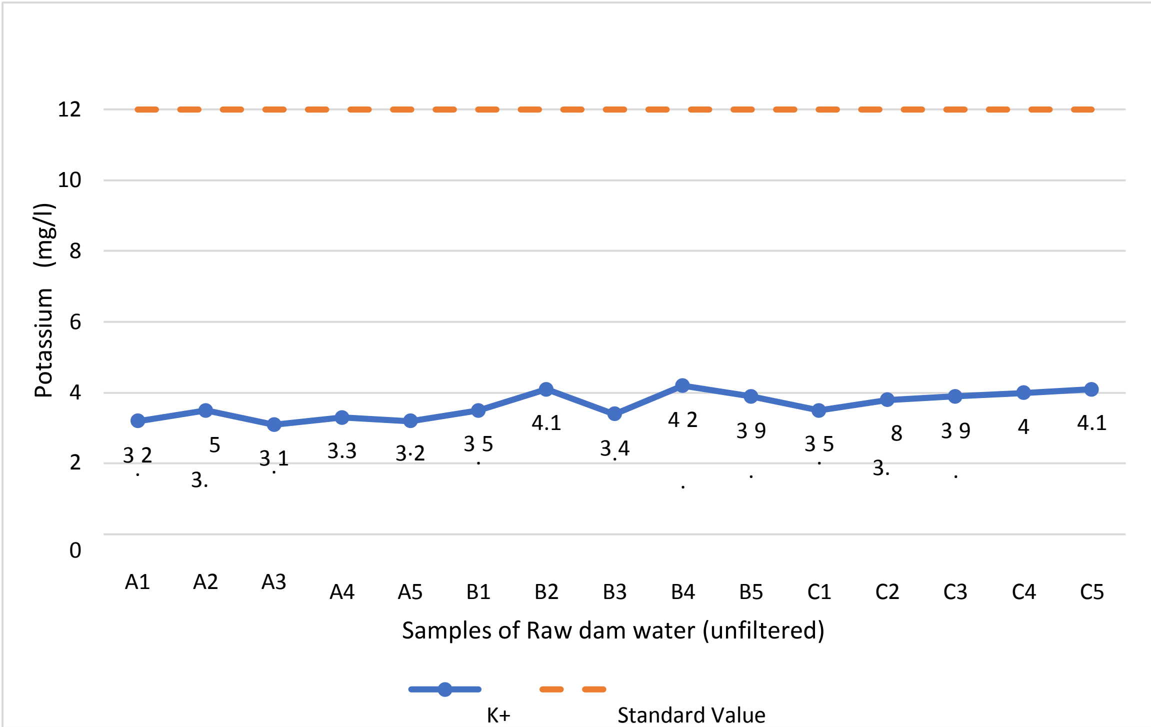

Figure 6.4: Potassium values in filtered water samples

Sodium:

The sodium and chloride are the two important parameters salts concentrations. The permissible limits for sodium in drinking water are 200 mg/l. The samples of raw dam water consisted of sodium ranging from 33.62 to 57.6 mg/l, with an average of 42.62 mg/l. While the filtered dam water showed sodium levels ranging from 19.1 to 23.6 mg/l, with an average of 21.8 mg/l. The values of sodium are within the standard limits.

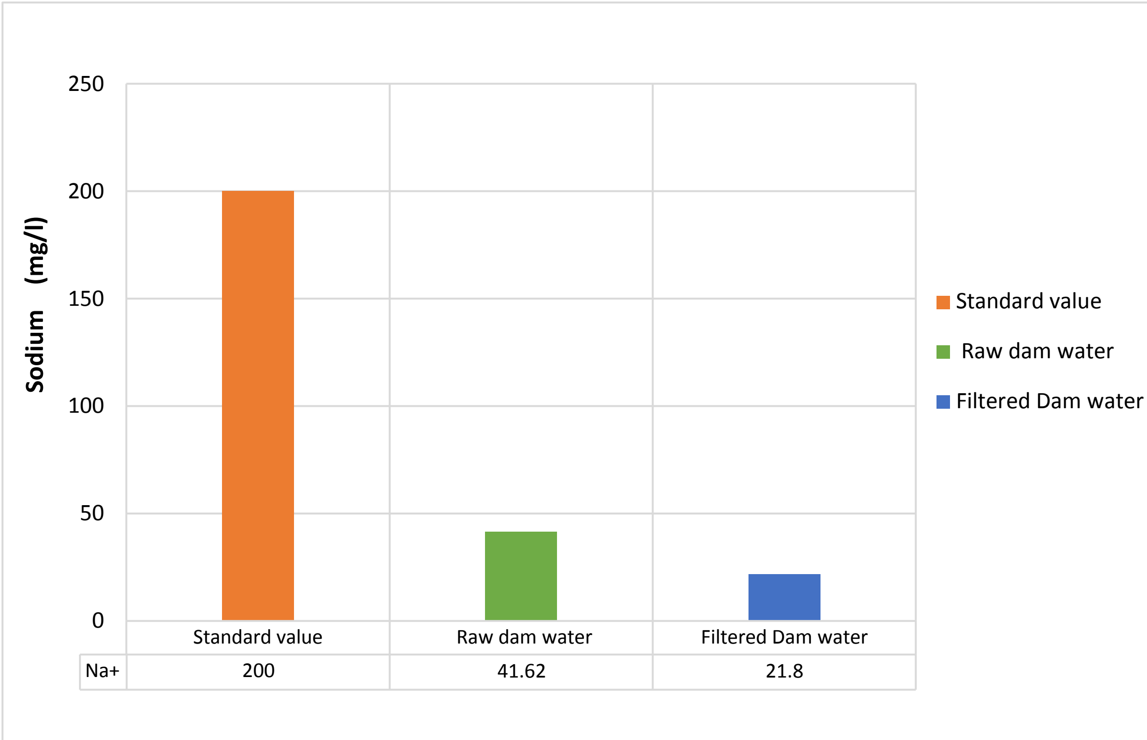

Figure 6.5: Average Sodium values in study area

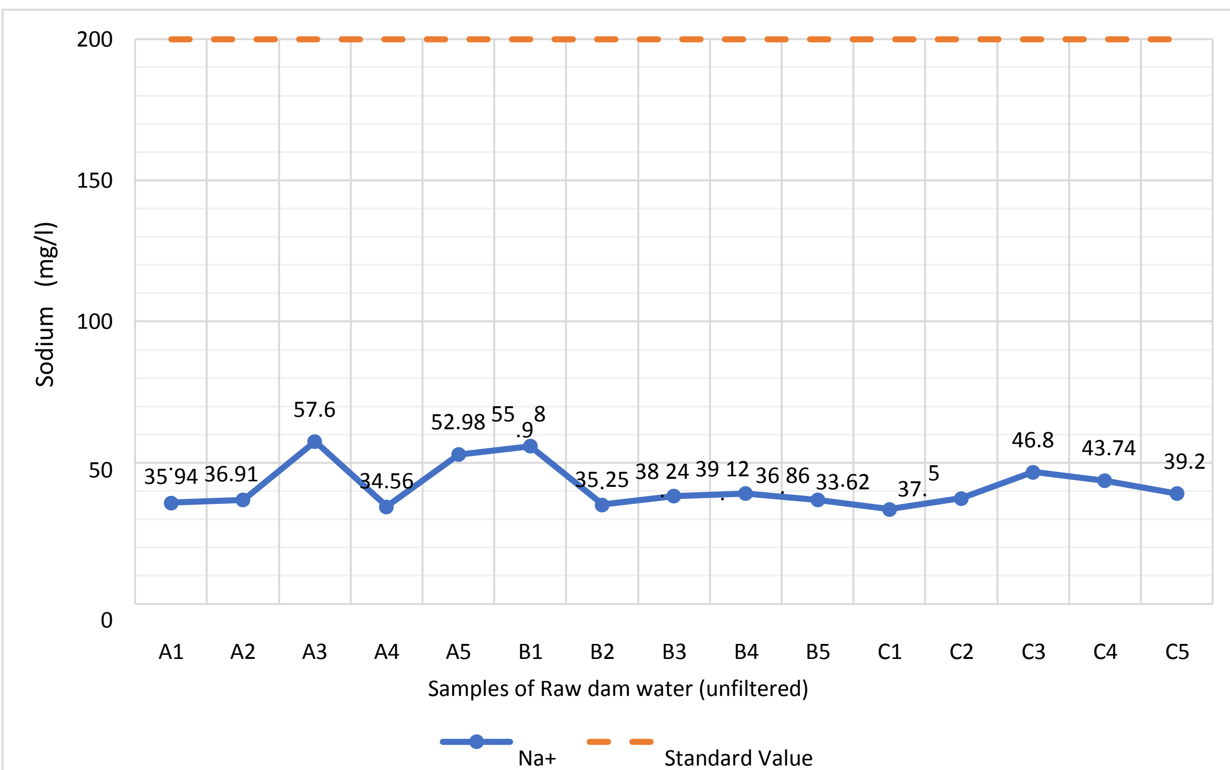

Figure 6.6: Sodium values in raw dam water samples

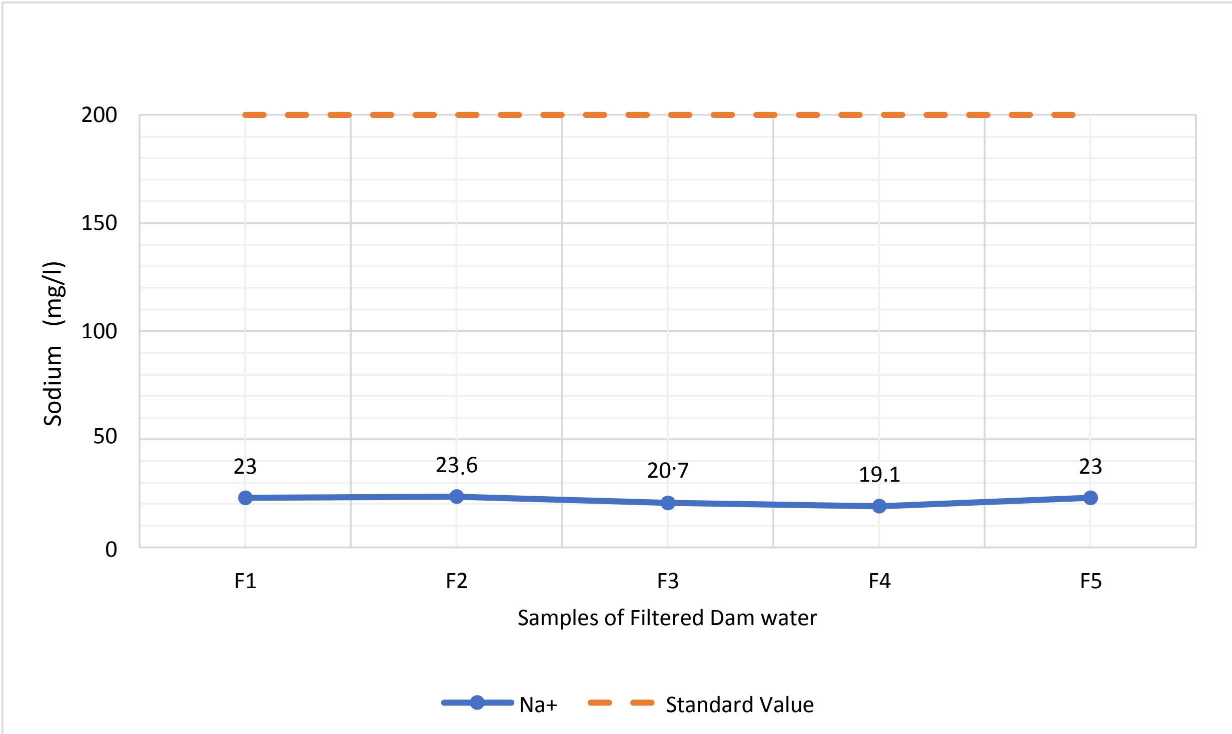

Figure 6.7: Sodium value in filtered water samples

3.2. Water quality index:

The WQI of the both raw and filtered water is established from important various physicochemical parameters namely; pH (Hydrogen ion concentration), EC (Electrical conductivity), TDS (total dissolved solids), DO (Dissolved oxygen), BOD (Biological oxygen demand), TH (Total hardness), TA (Total alkalinity), ions of Ca^{+} (Calcium), Na+ (sodium), K+ (potassium), Total Cl- (chloride) and NO3- (Nitrate).

The observed value (Vn) was achieved for each parameter by the laboratory analysis. In order to calculate the Quality rating (Qn) for each parameter the following equation was used:

Qn = { [(Vn– V io) / (Sn – Vio)] * 100 }

Here, Vio represents the Ideal value that is ideally recommended for drinking water. Ideal value of the water quality parameter can be obtained from the standard tables. That is 0 for all the parameters except for pH and DO the ideal values are 7 and 14.6 respectively. Let there be "n" water quality parameters and the quality rating (Qn) corresponding to nth parameter isa number reflecting the relative ofthis parameter in polluted waterwithrespect to its standard permissible value.

The values of twelve physicochemical parameters of both the raw and filtered dam water for calculation of Water Quality Index (WQI) for the year 2019 are presented in Tables (3.3, 3.4) respectively.

Table 3.3: WQI calculation of raw dam water

Sr no.	Parameter	Observed value (Vn)	Standard value (Sn)	Ideal value (Vio)	Vn-Vio	Sn-Vio	Quality rating (Qn)	Unit weight (Wn)	QnWn
1	pH	7.75	6.5-8.5	7	0.75	1.5	50	0.1176	5.88
2	TDS	184.8 3	1000	0	184.8	1000	18.48	0.001	0.018
	EC	259.5 4	300	0	259.5	300 0	86.50	0.003	0.259
	T.A	113.24	200		113.24	200 0	56.62	0.005	0.283
5	T.H	137.8 6	500		137.8	500 0	27.56	0.002	0.055
	Ca	125.6 7	200		125.6	200 0	62.80	0.005	0.314
	Na	41.62 8	200		41.62	200 0	20.81	0.005	0.104
	Cl	62.94 9	250 5		62.94	250 0	25.57	0.004	0.102
	BOD	3.45 10	4		3.45	5	69	0.200	13.8
	DO	4.498	12	14.6	-9.62	-10.6	90.75	0.250	22.68
11	K	3.64	10	0	3.64	12	30.33	0.083	2.517
12	NO_3^-	2.67		0	2.67	10	26.70	0.100	2.67
								ΣWn = 0.7756	
									ΣQnWn = 48.7

WQI = ΣQnWn/ ΣWn

WQI = 62.79

Table 3.4: WQI calculation of filtered dam water

Sr no.	**Parameter**	**Observed value (Vn)**	**Standard value (Sn)**	**Ideal value (Vio)**	**Vn-Vio**	**Sn-Vio**	**Quality rating (Qn)**	**Unit weight (Wn)**	**QnWn**
1	pH	7.5	6.5-8.5	7	0.5 0	1.5	33.33	0.1176	3.92
2	TDS	180	1000	180 0		1000	18	0.001	0.018
3	EC	256	300	256 0		300	85.33	0.003	0.255
4	T.A	110.2	200	110.2 0		200	55.1	0.005	0.275
5	T.H	87.28	500	87.28 0		500	17.45	0.002	0.035
6	Ca 7	54.12	200	54.12 0		200	22.56	0.005	0.113
	Na	21.8	200	21.8 0		200	10.9	0.005	0.054
8	Cl	33.7	250 5 4	33.7 0		250	13.48	0.004	0.053
9	BOD	2.94	12	2.94		5	58.8	0.200	11.76
10	DO	6.5	10	14.6	-8.1	-10.6	76.41	0.250	19.10
11	K	2.9		0	2.9	12	24.1	0.083	2
12	NO_3^{-1}	0.75		0	0.75	10	7.6	0.100	0.76
								ΣWn= 0.7756	
									ΣQnWn=38.34

WQI = ΣQnWn/ ΣWn

WQI = 49.43

The results from the WQI calculations shows that the raw water from Simly dam that is unfiltered has a WQI of 62.79 that falls in the "poor" category in the class C of the WQI rating. While the filtered water has a WQI of 49.43 that falls in the "good" category in the class B of WQI ratings. Although all parameters were within the permissible limits, but the unfiltered water was falling in the poor category due to comparatively high calcium, chlorides and other minerals as compared to filtered dam water that shows very low levels of chlorides, calcium and other minerals along with high oxygen levels which makes thef filtered dam water good for drinking purposes. The figure 44 shows the WQIs of the Simly dam

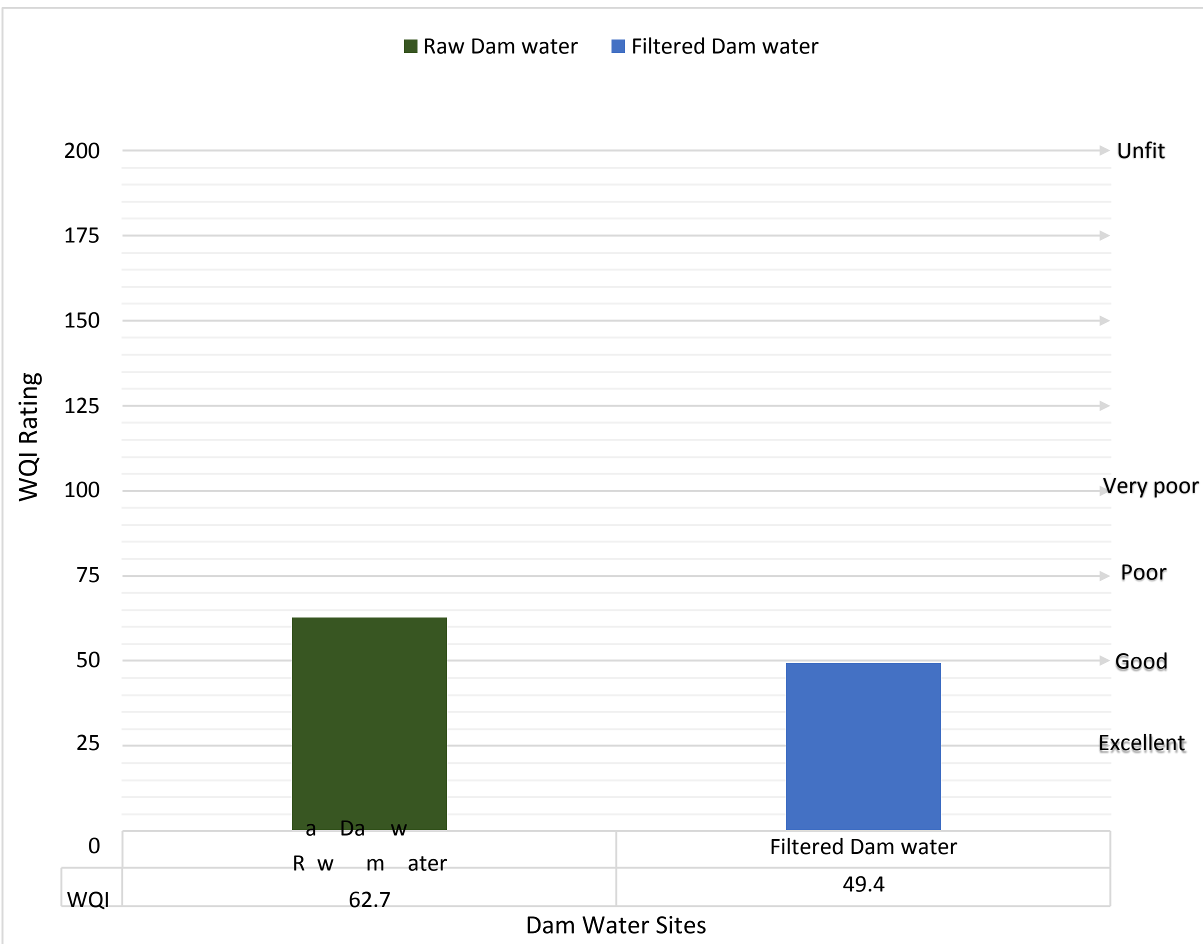

Figure 6.8: WQI rating of study area

3.3.Evaluation of Simly dam water for drinking purposes

The statistical analysis ofSimlydamwater was done to determine the chemical parameters ofdam water and filtration plant water in order to check the water quality. The calculations of physicochemical parameter of dam water shows the poor water quality of dam water because of the presence of high quantity of minerals in water. The water is still drinkable as all parameters all within permissible limits but not desirable for drinking purposes according to the WQI rating. The filtered water evaluation shows good water quality of filtered damwater because ofthe treatment ofthe water in plant which lowered the mineral contents of water far below permissible limits which makes the filtered water suitable for drinking purposes. This study also shows that the filtration plant installed in Simly dam is also working efficiently due to reduced amounts of the salts content after filtration. Since this index involved calculations only with physicochemical parameters and no biological parameters were taken for analysis thus is also important to keep microbiological parameters under limits to make the water optimal for drinking purposes.

CONCLUSIONS

In the present study, the collected water samples of Simly dam water and filtration plant water of Simly dam were utilized for obtaining water quality information ofthe study area. The physiochemical analysis result of the dam water and filtered water of dam samples were compared with the WHO and National Environmental Quality Standards (2010) drinking water specification. Water quality index offers a useful representation of overall quality of water for public or for any intended use as well as in water quality management. Water quality index of the study area was calculated on the basis of various physical chemical parameters like pH, electrical conductivity, and total dissolved solids, Nitrate, Calcium, Total Hardness, Sodium, Chloride, Dissolved Oxygen, Total Alkalinity, Potassium and Biological Oxygen Demand. 15 samples were taken from 3 different locations of raw dam water while 5 samples were taken from filtration plant of Simly dam for filtered dam water. Average values of before and after were taken into account for calculation.

The laboratory results showed difference in the physico-chemical parameters for the filtered and unfiltered Dam water. The filtered dam water consisted of a decreased value of Hardness and salts content as compared to raw dam water. The pH in raw dam water was 7.75 while in filtered water was 7.5. Electrical conductivity was 259.5 μS/cm and 256 μS/cm in raw and filtered dam water respectively. Total Dissolved Solids was 184.8 mg/l and 180 mg/l in raw and filtered dam water respectively. Total Alkalinity was 113.24 mg/l and 110.2 mg/l in raw and filtered dam water respectively. Total Hardness was 137.8 mg/l and 87.28 mg/l in raw and filtered dam water respectively. BOD was 3.45 mg/l and 2.94 mg/l in raw and filtered dam water respectively. DO was 4.98 mg/l and 6.5 mg/l in raw and filtered damwater respectively. Calciumwas 124.6 mg/l and 45.12 mg/l in raw and filtered dam water respectively. Sodium was 41.62 mg/l and 21.8 mg/l in raw and filtered dam water respectively. Potassium was 3.64 mg/l and 2.9 mg/l in raw and filtered dam water respectively. Nitrate was 2.67 mg/l and 0.76 mg/l in raw and filtered dam water respectively. Total Chlorides was 63.94 mg/l and 33.7 mg/l in raw and filtered dam water respectively. The Water Quality Index of raw dam water was 62.79 which falls in poor categoryofthe WQI ratings, while that of filtered damwater was 49.43 which falls in good category of the WQI ratings.

From the results of analysis of the water quality of the simly dam: raw dam water comes in class C which is graded as poor water quality. All the parameters were not exceeding the permissible limits of given standards because of the natural sources of water which makes the dam water less contaminated but were in comparatively higher amounts making the water poor for drinking purposes. The water quality of dam water was also compared with filtration plant water ofSimly dam. The analysis of filtered water showsthat the water quality comes in class B grading which refers to good water quality. It means that the filtered water based on the physico-chemical parameters is suitable for drinking purpose. The results shows that the concentration of all the parameters were far below the permissible limits after filtration given by above mentioned standards. These result are based on the physico-chemical parameters of drinking parameters

RECOMMENDATIONS

The recommendations are as following:

1. In future, evaluation of water quality in Simly dam should be given main priority by using the microbiological parameters along with physio-chemical parameters in WQI calculations and to water quality monitoring.
2. Although all the parameters were within the standard limits, but if the filtration process is enhanced the water quality of the dam will be improved.
3. The filtered water after passing through pipelines can be contaminated and may cause deterioration of water quality, so proper monitoring of pipelines from which the filtered water pass, must be carried out which otherwise can contaminate the filtered water.

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