WATER QUALITY ASSESSMENT OF FILTRATION PLANTS ISLAMABAD, PAKISTAN

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ABSTRACT

This study was conducted to assess the water quality of Islamabad filtration plants installed in the city. The total of 96 samples were analyzed for physicochemical, heavy metals and the micro biological contamination (coliform/ E coli). The results showed that pH ranged from before treatment (6.85-7.92)mg/L and after treatment (6.91-7.93)mg/L, TDS ranged before treatment (379-750)mg/L, after treatment (305-521)mg/L, hardness ranged before treatment (265-315)mg/L, after treatment (175-533)mg/L, Electrical conductivity ranged before treatment (615-639)mg/L, after treatment (510-409)us/cm, Chloride ranged before treatment (31-39)mg/L, after treatment (30-32)mg/L. All the results were compared with NEQS guidelines, it was found that pH, TDS, hardness and Chlorides were within the permissible limits, while EC were above the permissible limits in few samples. The heavy metals such as iron, cadmium and manganese were also tested in the same samples and results show that iron were above the permissible limits in many samples while cadmium and manganese were within the permissible limits. The microbial analysis showed that out of 32 samples, water samples collected before filtration from I-10 Markaz, I-10/2, I-9 Mangal Bazar, I-8/2, G-10/2, F-10/1, Pak secretariat, Parliament house, G-7/1, G-7/2 Sitara Market and I-8/3 showed the presence of E.coli. Samples collected after filtration from I-10 Markaz, I-10/2 Chanmbali road, G-8/1, G-10/2 and F-10/1 showed presence of E.coli. The biological analysis of water determines the portability of water. The reason for higher number of bacterial colonies might be due to inadequate maintenance of water, these results suggest that the regular monitoring and maintaining of filtration plants should be monitored.

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ABBREVATIONS

PCRWR	Pakistan Council of Research in Water Resources
CLEAN	Central Laboratory for Environmental Analysis
WHO	World Health Organization
NEQS	National Environmental Quality Standards
PAK-EPA	Pakistan Environmental Protection Agency
PSQCA	Pakistan Standard Quality Control Authority
IARC	International Agency on Research on Cancer
CDA	Capital Development Authority
TMA	Tehsil Municipal Administration
MCI	Metropolitan Corporation Islamabad
PVC	Polyvinyl Chloride
TDS	Total Dissolves Solids
EPA	Environmental Protection Agency
EDTA	Ethylene Diamine Tetra Acetic Acid
EC	Electrical Conductivity
TH	Total Hardness
E.coli	Escherichia coli
TCB	Total Coliform Bacteria
Fe	Iron
Mn	Manganese
Cd	Cadmium

CHAPTER 1
INTRODUCTION

CHAPTER 2
MATERIAL AND METHODS

Table of Figures

Table of table Page

CHAPTER 1

INTRODUCTION

Water is the basic necessity of life. Without water life on Earth is not possible. Water is not only need for quenching thirst, but also control body temperature, transmit nutrients and oxygen to the cells, helps in digestion of food and excretion of waste from the body. Pakistan has been naturally blasted with ample water resources. Being an Agrarian country, large amount of water is used for irrigation. In the last 50 years, the rapid increase in population, continual industrial and urban development has placed huge stress on water resources (Soomro et al., 2011). Country who once considers water surplus is now becomes waster scarce country. When the Pakistan came into being in 1947 its per capita water was 5,600 cubic meters which has been decreased to 1,038 cubic meters in the last 6 decades. If the trend continues, then, by 2020, the water accessibility will plunge to 877 cubic meters per annum (Daud et al., 2017). Three fourth of country population are appeasing their water need by drinking polluted water while rest of the population are blessed with clean water (Saleem et al., 2018). People dependent on surface and groundwater for drinking and other requirement. Around 70% of surface and ground water sources are unfit for consumption because of organic, inorganic and microbial contamination (Hisam et al., 2014).

1.1 Sources of water contamination

Direct dumping of municipal waste and untreated sewerage in lakes and rivers are foremost causes of water pollution. In Pakistan, drinking water system and drainage lines run in parallel; and as these lines are damaged and rusted, they cause leakages and intermixing result in deterioration of water quality. Discarding of toxic chemicals and heavy metals from industrial discharge and fertilizers from cultivation activities are indirect reason for water bodies' contamination. Heavy metals from industrial activities and automobiles can deposit on the soil from where they can leachate in the ground and can contaminate the shallow aquifers (Daud et al., 2017; Ali et al., 2012).

1.2 Dependency on groundwater

Pakistan receive significant amount of water from monsoon spell that, if stored can eradicate water shortage problem and could provide sustainable irrigation system. From the past 40 years, country has failed to build any major dam except Tarbela and Mangala dam. According to a research study on water resources of Pakistan, approximately water having economic values of $70 billion is being thrown into sea every year due to lack of dams and reservoirs. Thus dependency on groundwater is significantly increases and water table is decreasing rapidly in many areas of the country (Saleem et al., 2018).

1.3 Groundwater contamination in provinces

Over pumping of groundwater in the coastal areas of Sindh and Baluchistan result in sea water intrusion, which leads to the contamination in groundwater of those regions. According to some reports and experts, over 70 per cent of underground water in the Thar Desert is brackish. While less than 30 per cent of ground water is fit for human consumption and wells are a major source of water for a majority of people. The desert has recently been identified as one of the most fluoride affected areas, where residents have been consuming groundwater with Fluoride concentrations as high as 7–32mg/L; exceeding WHO permissible limit of 1.5mg/L (Rafique et al., 2008).

Fluoride bearing granite rocks are the main source of dissolved fluoride in groundwater resources. Manmade sources ascending from activities such as the quarrying of phosphate rocks and various manufacturing activities. Fluorosis is the diseases that occur due to high intake fluoride are serious problem facing by many countries in the world; with china and India being the worst affected. In Pakistan it has becoming the endemic disease in the Tharparkar at the regional level. Although fluoride is beneficial to human health at 0.5-1.0mg/L limit prescribed by WHO but too much consumption of fluoride leads to dental and skeletal Fluorosis. Skeletal Fluorosis is most vulnerable in children as the high intake of Fluorosis leads to bone deformities in children (Rafique et al., 2008).

1.4 Arsenic contamination in Punjab and Sindh

In Punjab and Sindh Arsenic contamination is a major issue as it is most industrialized and agriculture region of the country. In Punjab arsenic in ambient air is much higher than any other country in the world. It is estimated that 50 million people are at a risk of arsenic poisoning in Punjab. Arsenic is present naturally in the water especially in deep aquifers. WHO limit of arsenic is 10ug/L, while in Punjab the maximum limit of arsenic is 50mg/L, five times greater than the safe limit (Podogoroski et al., 2017). As Punjab is the agriculture hub of the country the farmers use both surface water and groundwater for irrigation purposes. As the groundwater is used for irrigation for crops the arsenic contamination is also found in the vegetables and then can enter into the food chain. Arsenic in low concentration is found in onion, carrot and potato (Sanjrani et al., 2017). Arsenic contamination can leads to diabetes, elevated risk for cancer development most notably skin cancer and liver cancer, lung, bladder and kidney (Nafeez et al., 2011).

1.5 Health impacts of drinking contaminated water

Microbes, nitrates, arsenic, lead, cadmium and saline contamination (fluoride) are major contaminates found all over the country. Microbiological contamination is consider as a major threatcausing number of health problems in public.Chlorea, Typhoid, Hepatitis A and Diarrhea are the most common diseases found in people. Diarrhea being the prominent cause of demise in toddlers and youngsters claim 361,000 lives each year (Saleem et al., 2018). Water born disease generally arises due to contamination of water with fecal matter, and thus coliform test is conducted to check the potability of water. E.coil is the indicator of water contamination with fecal matter as they are present in gut and feces of animals and humans (Nabeela et al., 2014).

Heavy metals also poses serious health risk and are lethal. Consumption of heavy metal contaminated water causes cardiovascular disesases, neurological disorders, kidney damage and increase cancer risk. Inorganic Cadmium and Arsenic areclassified by IARC (International Agency for Resaerch on Cancer) as known human carcinogen (Malik and Khan, 2016). Intake of fluoride rich water causes skeletal and dental fluorisis. Children are more suscepitble as they are in their growing age. About

80% of patiences in hospitals and 33% of total fatality occurred in a year is due to consumption of unsafe drinking water (Saleem et al., 2018). Consumption of contaminated water accounts for 20-40% of all diseases in the country (Farooq et al., 2007).

1.6 Bottle water dilemma

In recent years, the popularity of bottle water among the consumer has become prominent with more than 5000 brands of water bottled throughout the world. The consumption of bottled water regardless of its high cost has been increasing every year at the rate of 12%. In Pakistan the trend of bottled water has also increasing, majority of public consider bottled water as a safe drinking water option. However there raise some concerns on the quality of bottled water worldwide that they are not precisely safer than other water options. According to PCRWR quarterly report on bottled water for April-June 2018, 85 brands of mineral water bottles were analyzed for physicochemical and microbiological characteristics. 80 brands were found to be safe while 5 brands Gourmet, Aqua super life, Shiraz, Aqua Splash and Marina were found to have chemical and biological contamination (PCRWR, 2018).

1.7 Water concerns in country's capital

Islamabad, the capital of the country with population of almost 2 million is also fronting water quality problem due to contamination from raw manure and industrial waste. Diarrhea and typhoid fever are endemic in residents. With increase in population growth and mass migration of people, the city water resources are becoming insufficient. In Islamabad the water is supplied mainly from three dams, Rawal, Khainpur and Simly dam to different sectors of Islamabad. In 1962, Rawal dam was built; it is an artificial reservoir build to overcome the need of water shortage. It is constructed on Korang River and has a depth of 102ft and storage capacity of 47,500 acre feet. Khainpur dam was built in 1983 on Haro River and has depth of 167ft of storage capacity of 1077076 acre feet. Water from Khainpur dam is supplied to Islamabad through Sang-Jani water treatment plant which was constructed in 2000 by CDA (Capital Development Authority), and provides safe drinking water to general public (Pervez, 2016).

Simly dam was built in 1954 on Soan River. It has depth of 2300ft and storage capacity of 7,400 million gallons. Water is supply to different sectors of Islamabad from Simly dam filtration plant which was established in 1969, which supply 24 million gallon filtered water per day for safe drinking water purpose (Ahmad et al., 2004). CDA installed 37 filtration plants were in different zones of the city to deliver safe drinking water to the occupants. The sources of water to these filtration plants are either groundwater or surface water sources or in some filtration plants both (Hisam et al., 2014).

1.8 Literature Review

Ali et al. (2011) conducted a study to determine microbial contamination in different water reservoirs at schools of Peshawar. 32 drinking water samples were analyzed for Escherichia coli, fecal coliform and total coliform bacteria (TCB) from 19 selected schools. Almost half of the samples (15) were found to be safe for drinking according to WHO standards.

Ali et al. (2012) evaluated the treatability performance of Sang Jani and Simly dam water treatment plant for a year. The effluent water qualities of both plants were found to be within WHO permissible limits. The turbidity removal efficiency was observed 91% and 81% at Sang Jani and Simly water treatment plant respectively. While microbial removal efficiency was found 100% for both plants.

Mehmood et al. (2013) appraised the quality of potable water in Islamabad and Rawalpindi by analyzing physio- chemical and microbial parameters. The study reveal that drinking water was unsafe for human consumption as all samples were highly polluted with microbial contamination while chemical parameters like Total dissolve solids (TDS), hardness and Calcium (Ca) were also above the permissible limit of WHO and PSQCA.

Hisam et al. (2014) analyzed 32 water filtration plants in Islamabad for microbiological contamination. Results showed that 23 samples were adulterated with E.coli and Total coliform while only 9 samples were found to be free of contamination.

Similarly, a study conducted by Shoaib et al (2016) on 130 drinking water samples of Islamabad and Rawalpindi revealed that 56% of the samples had fecal contamination.

Shakoor et al. (2015) conducted assessment of health risk for arsenic and its specification in 62 samples of groundwater from selected regions in rural Punjab. Arsenic was found above permissible limit in 53% of the samples and 62% of the samples were unsafe for human consumption. The hazard quotient and cancer risk of arsenic were also found to be extremely higher. The study urged the importance of remedial measure in the region to safeguard human health.

A case study conducted by Riaz et al. (2016) on the assessment of ground water quality in Sargodha city of Pakistan. The result reveal that groundwater is not suitable for drinking purposes as all physical and chemical parameters concentration were above the permissible limit given by WHO apart from Ca and pH value.

A case study conducted by Pak-EPA to examine the condition of water supply by filtration plants of Rawalpindi and Islamabad. For bacterial and chemical contamination, 26 filtration units were evaluated. Two plants were chemically contaminated, 14 were microbial contaminated and 16 plants were inefficient and providing unfit water to the people (Ghalib et al., 2015).

Ghazanfar et al. (2017) conducted cross sectional study in Peri urban community of Islamabad by filling questionnaire to assess the source of drinking water, its method of disinfection and sanitary situation. The study comprised of 2,078 household. 76.4% household use water from CDA, 20% from ground water and 3.6% from other sources. 77% residents respond that they did not disinfect drinking water while only 23% did. 18.2% use boiling for disinfection and 1.9% use solar disinfection and 3.6% and 1.9% use aqua tabs.

Khan et al. (2018) evaluated the groundwater quality of Gulistan-e-johar town Karachi for drinking. 18 samples were analyzed and high concentration of TDS, Sodium (Na), Manganese (Mn), Chlorides (Cl) and Fluoride ions were found in groundwater. The result indicate that groundwater of the town is unfit for humanoid and may lead to adversarial health impact.

Panezai et al. (2018) assessed the fluoride concentration in drinking water of Quetta, Pakistan. 20 samples taken from tube wells were analyzed and high concentration of fluoride were found varies from 0.32ppm to 3ppm. Fluoride concentration was found above the permissible limit of WHO in 65% water samples while only 35% were found safe for drinking purpose. Result also shows that solubility of fluoride depends on pH level and salts of potassium (K), Na, Ca and Cl ions play important role in achieving favorable pH for dissolving of fluoride containing compounds.

Baig et al. (2019) evaluated Spatial-Temporal variation for selected heavy metals in drinking water of community tapes, open water channels, water storage tanks and traditional wells of central Hunza, Pakistan. The study reveal that majority of water samples were highly contaminated with heavy metals exceeding WHO permissible limits. Source wise Mean heavy metals concentration and turbidity in water resources were found greater during summer than winter season attributing to glacier melting which eroded glacier silt, geological texture and high agriculture activities.

Therefore in the light of prevalence drinking water quality issues in Islamabad, the present study is conducted to analyze physicochemical characteristics of drinking water filtrations plants installed by CDA in different sectors of Islamabad.

1.9 Objective

The objective of the study are;

1. To analyze the physicochemical parameters (pH, temperature, TDS, hardness, chloride, EC and nitrates), heavy metals (iron, cadmium, manganese,) concentration and Qualitative analyses of Microbial contamination.
2. To assess the quality of water before and after treatment of filtration plants.

CHAPTER 2

MATERIAL AND METHODS

2.1 Study area

Islamabad, the Federal of Pakistan is sat between 72° 48′ and 73° 22′ E longitude and 33° 28′ and 33° 48′ N latitude. It is positioned at northwest part of the country on Potohar plateau. With increase in population growth and mass migration of people, estimated population of city reached 2 million according to 2017 census. Increased in population has not only put great pressure on natural resources but also deteriorate the environment (Daud et al., 2017).

Water is supplied mainly from three dams, Rawal, Khainpur and Simly dams to different sectors of Islamabad. CDA installed 37 filtration plants in different sectors of the city to provide safe drinking water to the residents. The sources of water to these filtration plants are either groundwater or surface water sources or in some filtration plants both (Hisam et al., 2014). These filtrations plants are installed in F-10 Markaz, F-10/1, F-6/1, G-6 Abpara, G-6 Abpara Bazar, G-6/1, G-6/2,G-7/2 Sitara market, G-7/4, G-8/1, G-8/2, G-9/2, G-9/3, G-10 Markaz, G10/2, G-11/2, G-11/3, F-6/1, I-8/1, I-8/2, I-9 Mangal Bazar, I-9/4, I-10 Markaz, I-10/1, I-10/2, I-10/2 Chanmbali Road, I-10/4, Minister Colony, Pak Sectraiet, Block P, Parliament House, Awan-e-Sadar Colony, Parliament Lodges, Masjid Noor Qadimi and Margalla Town (Ali et al., 2012).

2.2 Filtration plant selected

Table 2.1 is shows the sources of water for the selected filtration plants. I-10 and I-8 sector filtration plants are supply with groundwater from the tube well located in Margalla town. In most of the G-sector the source of water in filtration plants is also groundwater from tube wells located beside the filtration plants while G-7 sector, Pak Secretariat and Parliament house are supply with surface water from Simly and Khainpur dam.

Table 2.1 List of selected filtration plants and their sources

SOURCES	FILTRATION PLANTS	LATITUDE	LONGITUDE
Margalla tube well	I-10 Markaz	33.64742	73.03894
Margalla tube well	I-10/4	33.64572	73.04359
Margalla tube well	I-10/2	33.65195	73.03075
Margalla tube well	I-10/2 Chanmbali Road	33.65263	73.03268
Tube well	I-9 Mangal Bazar	33.65203	73.05377
Tube well	I-8/2	33.66386	73.06391
Simly dam	I-8/3	33.67093	73.07508
Abpara tube well	G-7/4	33.70542	73.07422
Simly dam	G-7/1	33.69989	73.06946
Simly dam	G-7/2 Sitara Market	33.70463	73.06785
Tube well	G-8/1	33.69053	73.04827
Tube well	G-10/2	33.68273	73.00722
Tube well	F-10/1	33.68404	72.99939
Tube well	Parliament Lodges	33.72550	73.09393
Simly dam	Pak-Secretariat P-Block	33.73455	73.09420
Simly dam	Parliament House	33.73023	73.09693

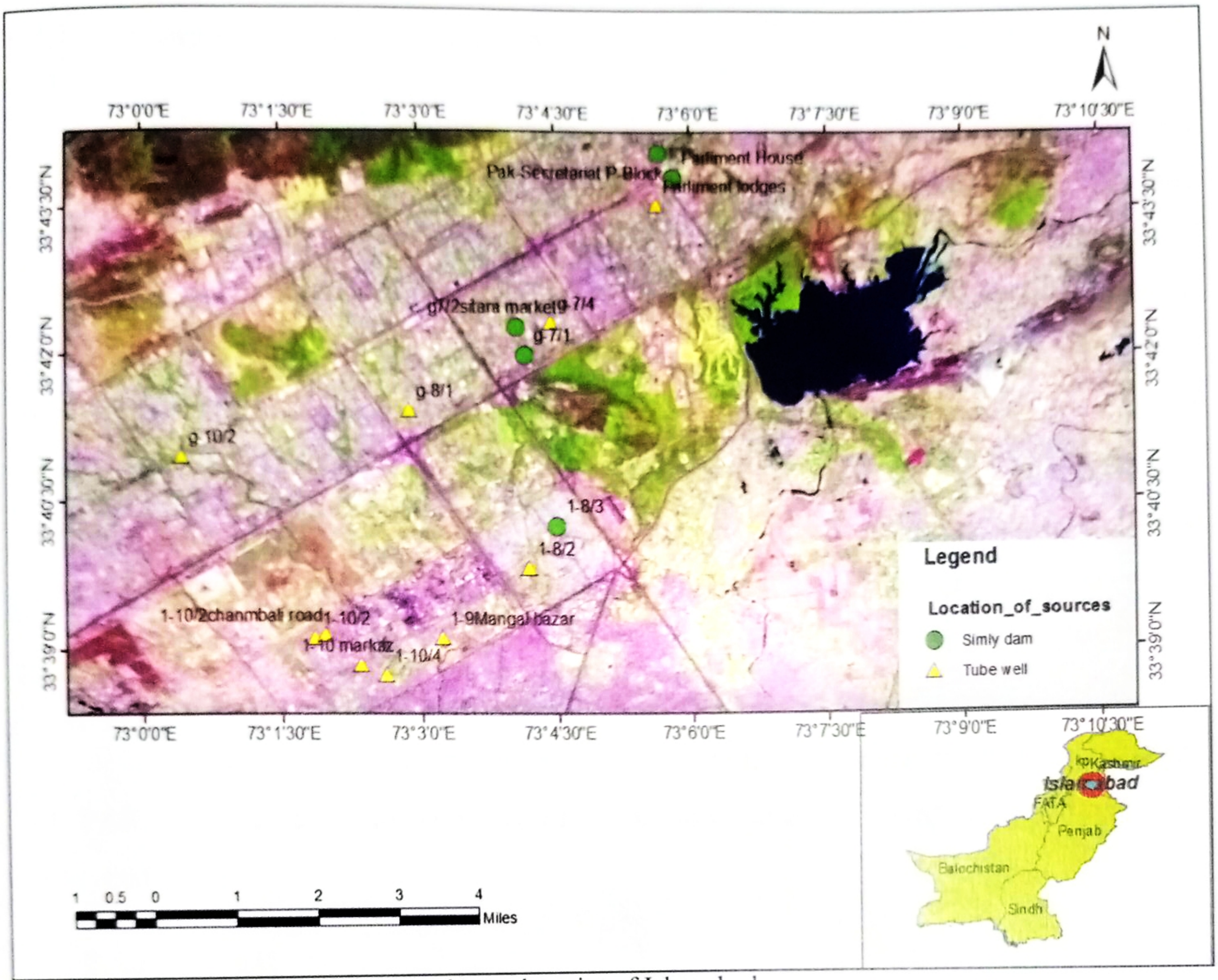

Figure 2.1. Study area map of selected sample point of Islamabad

Our study area map of Islamabad, 36 points were selected as shown in figure 2.1.

2.3 Sample collection and storage

At each point, 3 samples were collected. One for heavy metals, one for physicochemical and one for microbial testing. Samples were collected in polyethylene bottles designed for water sampling. Samples were collected from filtration plants of Islamabad along with its water sources. The bottles were first washed with distilled water. Later on, the bottles were rinsed thoroughly from source water before the final sampling. After water collection, the bottles were sealed securely, placed in a sample storage container and bought back to EPA lab for further analysis. Temperature, pH and TDS were analyzed on the spot. For heavy metals preservation, 2-3 drops of Nitric acid is added. Samples were placed in a refrigerator at 4°C for storage.

2.4 Laboratory analysis

The analysis was carried out in Central laboratory for Environmental analysis of PAK EPA located in H-8 sector, Islamabad and following parameters were analyzed.

2.4.1 pH

The pH of the sample was immediately determined after sample collection through a pH meter. The meter was first calibrated before analysis. The sample was poured into 250ml of glass beaker. The reading was recorded by dipping the probe of the meter into the sample. The pH meter by WTW Wissenschaftlich-Germany, Model 3301/SET was used. The procedure was repeated to collect the readings of all the water samples (Ghalib et al., 2015).

2.4.2 Temperature

The temperature of each sample was recorded by thermometer. The thermometer was calibrated prior to the usage. The sample was poured into 250ml of glass beaker, after that the thermometer is dipped inside the sample for 2 minutes. The procedure was repeated for all the samples to collect the readings (Ghalib et al., 2015).

2.4.3 Total dissolved solids

The amount of total dissolved solids in the sample was determined through meter. Senso Direct 150 by LOVIBOND was used in the study. The meter was first calibrated to remove error. The sample was poured into 250ml of glass beaker, after that the probe of the meter was dipped in the sample and the readings were recorded. The procedure was repeated for all the samples and readings were collected (Ghalib et al., 2015).

2.4.4 Hardness

The hardness of water was checked by using titration method. In this method the indicator used was EBT (Eriochrome Black T) and buffer hardness with a pH of 10 and EDTA (Ethylene diamine tetraacetic acid) reagent. 10ml of water sample and 40 ml of distilled water were taken in 250ml of glass beaker, in which to 2ml of buffer hardness was added and 2-3 drops of EBT indicator was added by using glass pipette and the color of water was turned to purplish. 50ml of glass burette was used which is filled with EDTA solution. Noted the reading of EDTA solution in glass burette, after the color of water change to bluish. The procedure was repeated two more times and the mean value was taken to ensure the efficiency of the result (Panezai et al., 2018).

$$\text{Hardness} = \frac{\text{value of titrant} \times 1000}{\text{volume of sample}}$$

2.4.5 Chloride test

Chlorination is a process done in all filtrations plant to kill unwanted bacteria. Chloride test was done by titration process in which $AgNO_3$ (Silver Nitrate) was used as reagent, $K_2Cr_2O_7$ (Potassium Chromate) was indicator which is yellowish in color. 50ml of water sample was pour into 250ml of glass beaker and 2-3 drops of potassium chromate indicator is dropped by using glass pipette. In 50ml of glass burette, Silver Nitrate is filled. Note the reading of silver nitrate in glass burette when the color of water turned to reddish. Repeat the procedure two more time and take the mean value to ensure the efficiency of the result (Panezai et al., 2018).

$$\text{Chlorides} = \frac{\text{value of titrant} \times 1000 \times 0.0141 \times 35.5}{\textit{volume} \text{ of sample}}$$

2.4.6 Electrical conductivity

Electrical Conductivity is the ability of water to conduct electricity. It depends on the free ions of salt and other chemical dissolve in the water. EC is measured by using Senso Direct 150 by LOVIBOND meter. The electrode of the meter was first washed by distilled water and then is dipped into the 200ml of water sample in 250ml of glass beaker and the reading was noted. The procedure is repeated for all the samples one by one (Panezai et al., 2018).

2.4.7 Heavy metals

Heavy metals such as lead, cadmium, Arsenic, Mercury and manganese are very dangerous metals when found in drinking water in excess. They can cause damage to nervous system and even cancer. Atomic Absorption Spectroscopy is the most effective and widely used method to determine the presence of heavy metals. The Atomic absorption Model AAS-700 by Perkin Elmer was used to determine the presence of lead, cadmium and manganese in water sample (Baig et al., 2019).

2.4.8 Microbial testing

Qualitative analysis of microbial contamination of Coliform and E.coli bacteria was done by Merck "Water Check" kit. Coliform and E.coli is normal flora of human intestine and are excreted along with stool. This is an indicator group of bacteria which if present in water mean that water is contaminated with human feces. This kit has developed to check fecal/sewerage contamination in drinking water. The kit consists of sterile container and a Blister pack. Firstly the cap of the container is opened and 50ml of water sample is poured up to the given red line mark. Then take out blister pack and tap it to ensure the granules at the bottom. Break it at the neck with hands and add the contents of blister pack into the container having water close the mouth of the container with the cap and shake it to completely dissolve the granules. Make sure not to touch the inner part of the cap or container with fingers or anything. Put the container at room temperature for 48 hours and check the color of the water. If color change to any shade of green or blue it means water is contaminated with sewerage and is not fit for drinking. If no change in color or color changes to yellow, off-white, brownish shade occurs it means water is not contaminated with fecal or sewerage contamination and can be used for drinking (Hisam at al., 2014).

CHAPTER 3

RESULTS AND DISCUSSIONS

3.1 pH

Water samples collected from water supply to filtration plants of I-10, I-9, I-8, G-7, G-8, G-10, F-10, parliament lodges showed a range of 6.8-8.3 pH with the mean value of 7.7 as shown in table 3.1 and 3.2. All the water samples collected from filtration plants before and after treatment showed pH with in standard limit of NEQS and WHO as shown in figure 3.1.Water with low pH is tend to be toxic and with high pH is bitter in taste. Acidic water can lead to corrosion of metal pipes and plumbing system. Meanwhile alkaline water shows disinfection in water (Mohsin et al., 2013).

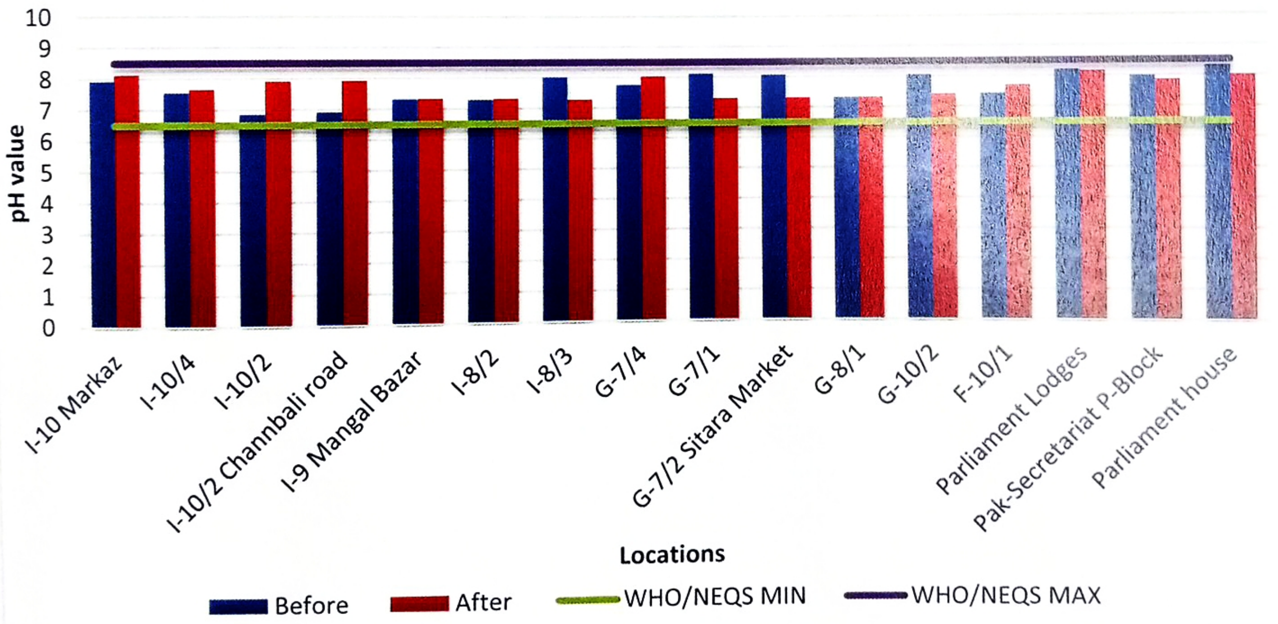

Figure 3.1. The pH value of water samples of study area

3.2 Temperature

Water samples from filtration plants of various sectors were also analyzed for temperature and electrical conductivity as shown in table 3.1 and 3.2. Temperature of all the samples collected before the filtration ranged from 17.9-20°C with the mean value of 19.0°C. Similarly water samples collected from filtration plants after filtration showed temperature in range of 18-20°C with the mean value of 19.1°C as shown in figure 3.2.

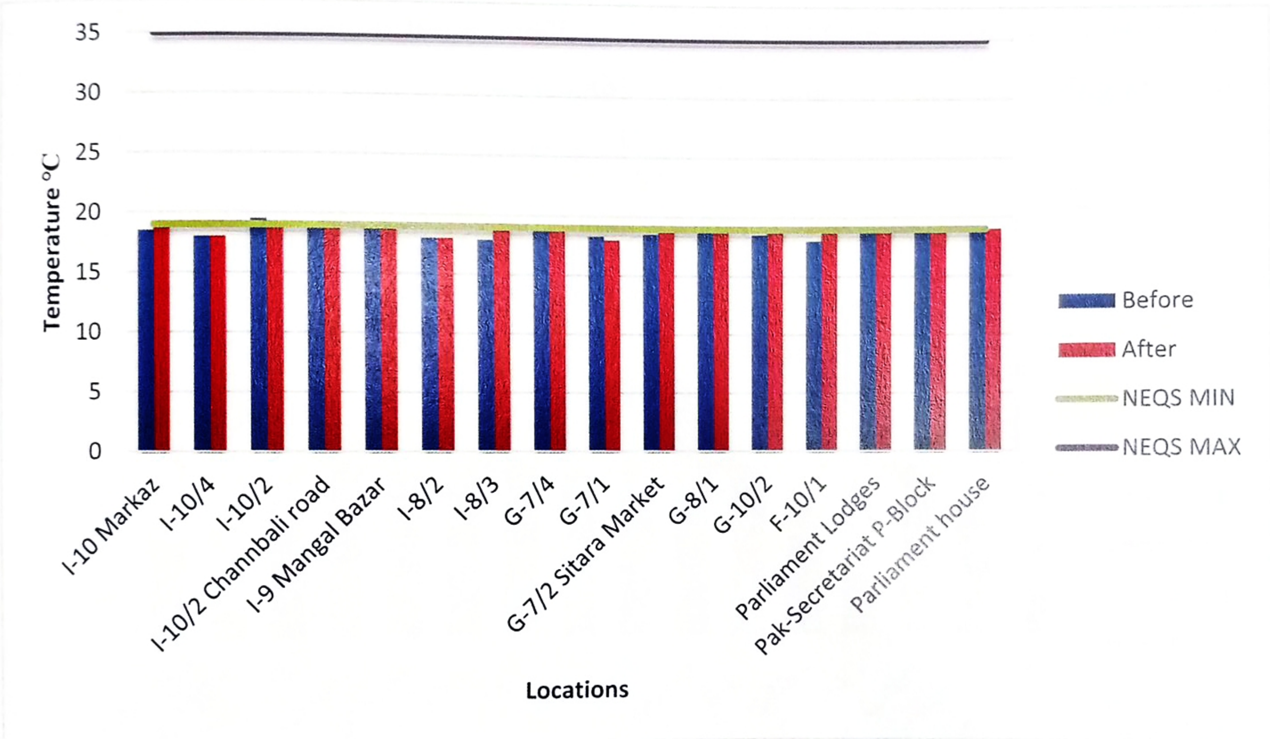

Figure 3.2. The temperature value of water samples of study area

3.3 Electrical conductivity

The presence of dissolved solids such as calcium, chlorides, and magnesium in water samples carries the electric current through water. Electrical conductivity of all the water samples before treatment ranged in 789-410μS/cm with the mean value of 672.6μS/cm. While samples collected after filtration showed the electrical conductivity in range of 325-788μS/cm with mean value of 562.3μS/cm as shown in figure 3.3. Conductivity does not have direct impact on human health. It is determined for several purposes such as determination of mineralization rate (existence of minerals such as K, Ca and Na) and estimating the amount of chemical reagents used to treat this water. High conductivity may lead to lowering the esthetic value of water by giving mineral taste to the water (Panezai et al., 2018).

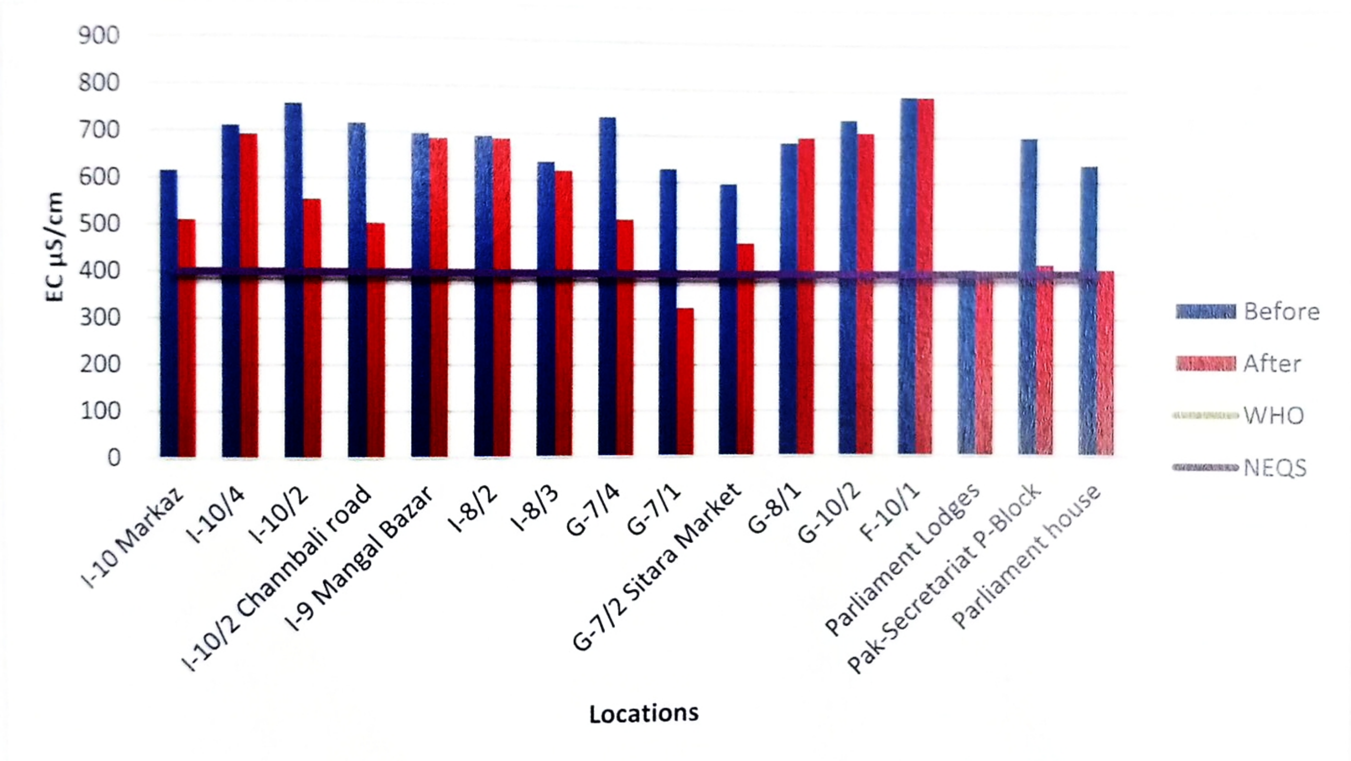

Figure 3.3. The EC value of water samples of study area

The Table 3.1 and 3.2 are showing the analysis results of pH, Temperature and TDS parameters of the water samples collected from the sources and Filtration plants respectively.

Table 3.1 Physicochemical parameters of drinking water samples (before)

Sectors	Before	pH	Temp °C	Conductivity µS/cm
I-10 Markaz	Margalla tube well	7.92	18.5	615
I-10/4	Margalla tube well	7.55	18	711
I-10/2	Margalla tube well	6.85	19.5	758
I-10/2 Channmbali Road	Margalla tube well	6.91	20	718
I-9 Mangal Bazar	Tube well	7.32	19	697
I-8/2	Tube well	7.29	18	694
I-8/3	Simly dam	8.01	17.9	641
G-7/4	Abpara tube well	7.76	19	739
G-7/1	Simly dam	8.11	18.3	629
G-7/2 Sitara Market	Simly dam	8.07	18.5	597
G-8/1	Tube well	7.32	20	688
G-10/2	Tube well	8.05	18.5	738
F-10/1	Tube well	7.43	18	789
Parliament Lodges	Tube well	8.2	20	410
Pak-Secretariat P-Block	Simly dam	7.99	18.9	699.1
Parliament House	Simly dam	8.31	19	639
WHO		6.5-8.5	-	400
NEQS		6.5-8.5	19-35	400

Table 3.2 Physicochemical parameters of drinking water samples (AFTER)

Sectors	After	pH	Temp °C	Conductivity µS/cm
I-10 Markaz	Filtration plant	8.12	19	510
I-10/4	Filtration plant	7.65	18	692
I-10/2	Filtration plant	7.91	20	555
I-10/2 Chanmbali Road	Filtration plant	7.93	20	505
I-9 Mangal Bazar	Filtration plant	7.33	19	688
I-8/2	Filtration plant	7.32	18	689
I-8/3	Filtration plant	7.27	19	622
G-7/4	Filtration plant	8.03	20	518
G-7/1	Filtration plant	7.3	18	325
G-7/2 Sitara Market	Filtration plant	7.31	19	468
G-8/1	Filtration plant	7.32	20	699
G-10/2	Filtration plant	7.41	19	710
F-10/1	Filtration plant	7.70	19	788
Parliament Lodges	Filtration plant	8.15	20	398
Pak-Secretariat P-Block	Filtration plant	7.86	19	421
Parliament House	Filtration plant	8	19	409
WHO		6.5-8.5	-	400
NEQS		6.5-8.5	19-35	400

3.4 Total dissolved solids

Total dissolved solids of water samples collected from filtration plants of various sectors were analyzed as shown in table 3.3 and 3.4. Concentrations of TDS were compared with standard limit of NEQS and WHO which are <1000 and 1000 mg/L respectively. Results of TDS analysis of samples collected from water supply to filtration plant showed concentration in range of 270 to 650mg/L with the mean value of 526.1mg/L, whereas water samples collected from filtration plants after the filtration showed TDS concentration in range of 195 to 650mg/L with the mean value of 415.2mg/L. All the samples of water collected before and after the filtration showed TDS concentration within the standard limit of NEQS as well as WHO as shown in figure 3.4. Water ability to dissolve organics and inorganics minerals produces undesirable taste and color in appearance of the water (Mohsin et al., 2013).

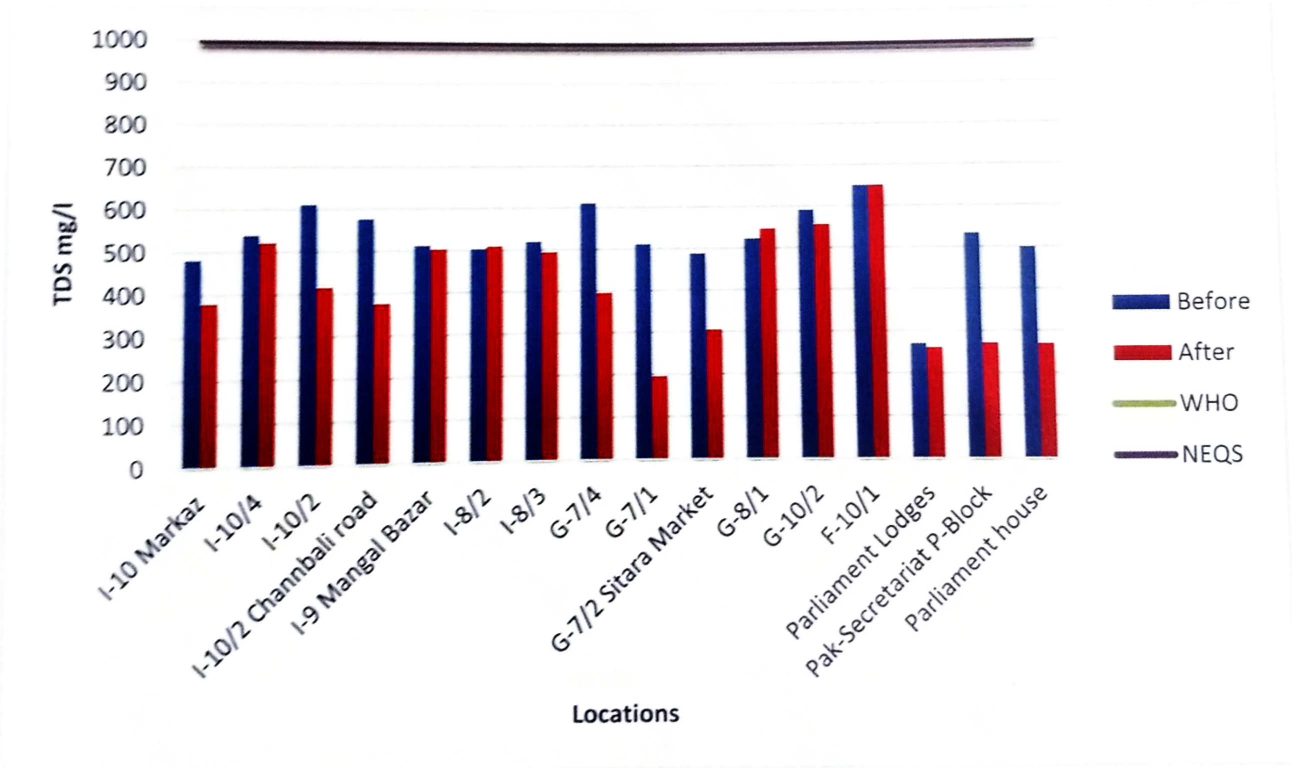

Figure 3.4. TDS concentration of water samples of study area

3.5 Chloride

Water samples collected from filtration plants of various sectors of Islamabad were analyzed for chlorine as shown in table 3.3 and 3.4. Samples from water supply to filtration plant showed Cl concentration in range of 25-68mg/L with the mean value of 37.3mg/L. Similarly water samples collected after filtration showed Cl concentration in range of 21-62.3mg/L with the mean value of 35mg/L. Cl concentrations were compared with the standard limits of NEQS and WHO which are <250 and 250mg/L respectively. Cl concentrations from all the samples collected before and after filtration falls within the standard limit by NEQS as well as WHO as shown in figure 3.5. The high concentration is due to dissolution of salts, soil erosion, and discharge effluents into water sources (Panezai et al., 2018).

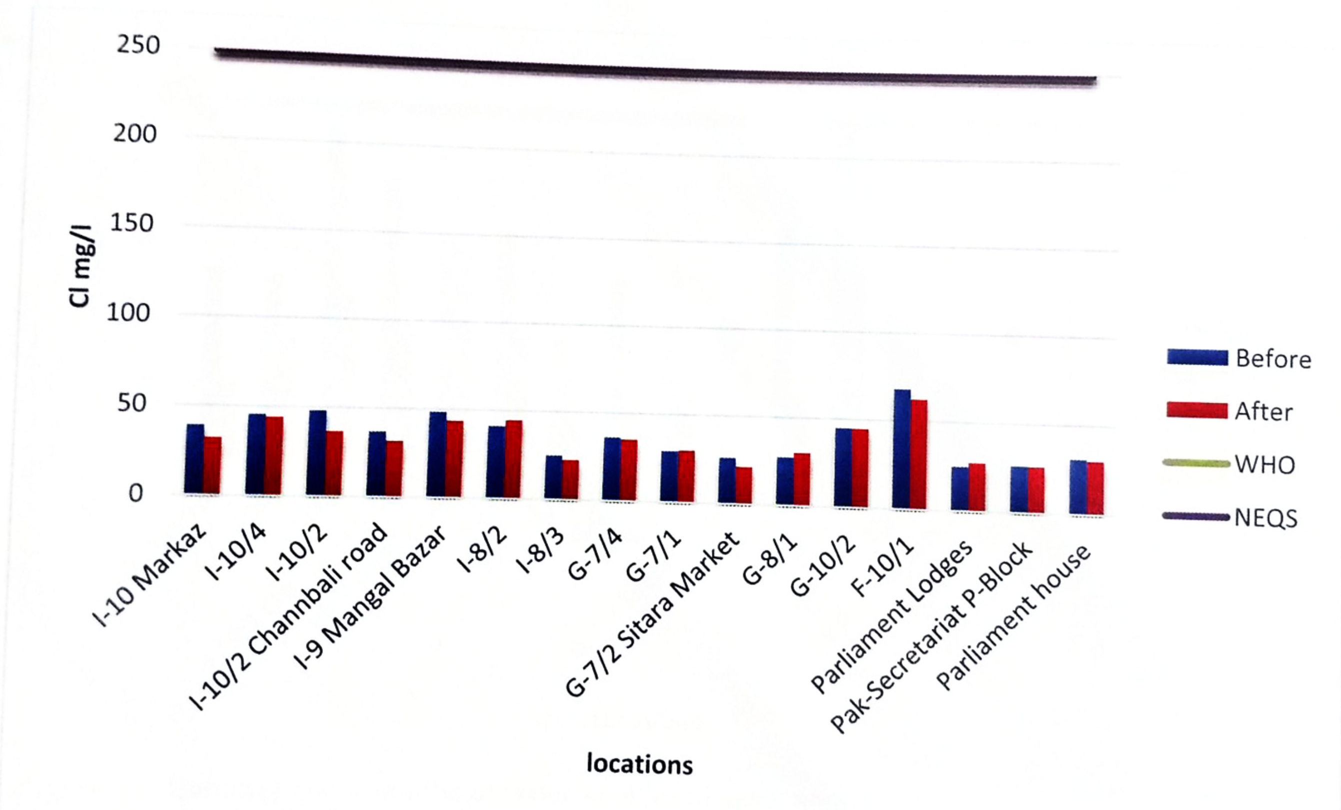

Figure 3.5. Chloride concentration of water samples of study area

3.6 Total hardness

Total hardness of water samples collected from filtration plants of various sectors were analyzed as shown in table 3.3 and 3.4. Concentrations of total hardness were compared with standard limit of NEQS and WHO which are <500 and 500mg/L respectively. Results of total hardness analysis of samples collected from water supply to filtration plant showed concentration in range of 188.5-533.0mg/L with the mean value of 299.7mg/L, whereas water samples collected from filtration plants after the filtration showed total hardness concentration in range of 88.15-310mg/L with the mean value of 175.0mg/L. All the samples of water collected before and after the filtration showed total hardness concentration within the standard limit of NEQS as well as WHO as shown in Figure 3.6. Total hardness represent the concentration of calcium and magnesium in water (Panezai et al., 2018).

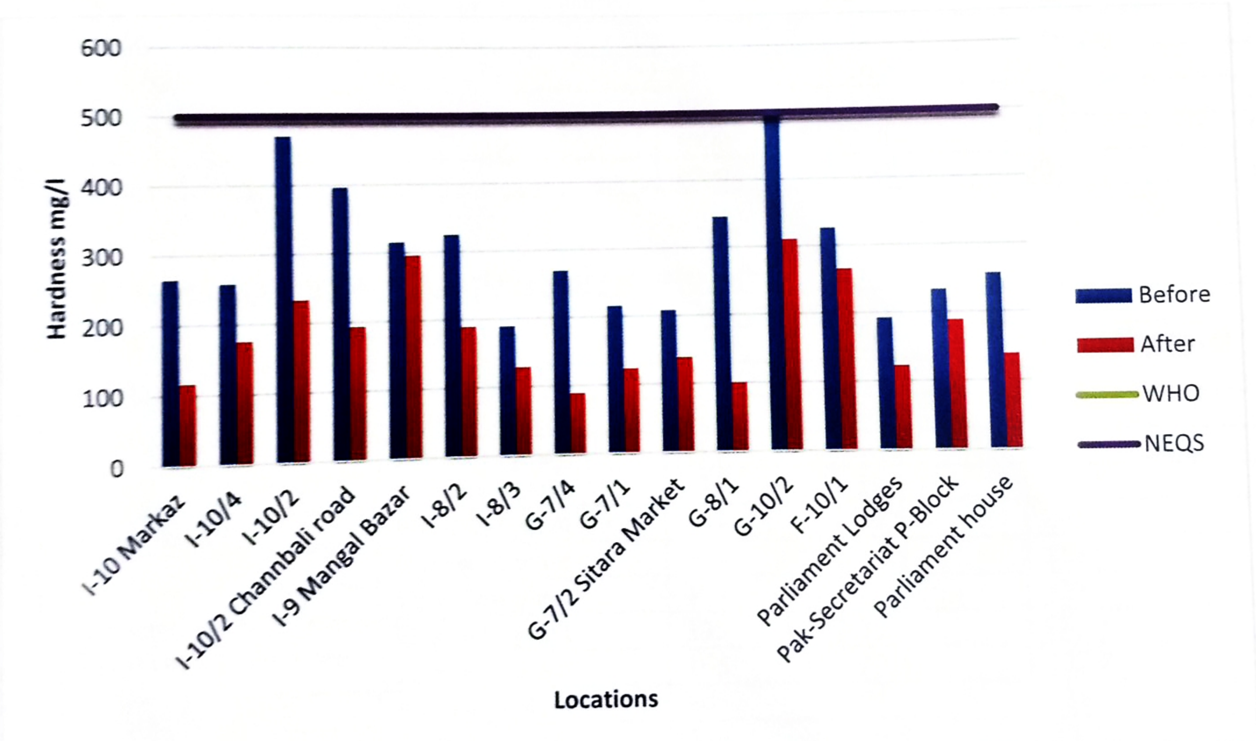

Figure 3.6. Hardness concentration of water samples of study area

The table 3.3 and 3.4 are showing the overall results of the chemical parameters like TDS, Cl, Ca, Mg and Total hardness of the water samples collected from the sources and Filtration plants respectively.

Table 3.3 Chemical parameters of drinking water samples (before)

SECTORS	Before	Concentration (mg/L)		
		TDS	Cl	Total Hardness
I-10 Markaz	Margalla tube well	481	39	265
I-10/4	Margalla tube well	539	45.5	2.58
I-10/2	Margalla tube well	611	48	471
I-10/2 Chanmbali Road	Margalla tube well	576	36.8	396
I-9 Mangal Bazar	Tube well	512	48.5	315
I-8/2	Tube well	503	41	325
I-8/3	Simly dam	519	25	188.5
G-7/4	Abpara tube well	611	36	268.9
G-7/1	Simly dam	511	28.9	215.5
G-7/2 Sitara Market	Simly dam	488	26.1	208
G-8/1	Tube well	523	27.2	345
G-10/2	Tube well	591	44.8	501
F-10/1	Tube well	650	68	326
Parliament Lodges	Tube well	270	25	192
Pak-Secretariat P-Block	Simly dam	533	26.3	233
Parliament House	Simly dam	499	31	256
WHO		1000	250	500
NEQS		1000	250	500

Table 3.4 Chemical parameters of drinking water samples (after)

SECTORS	After	Concentration (mg/L)		
		TDS	Cl	Total Hardness
I-10 Markaz	Filtration plant	379	32	115.9
I-10/4	Filtration plant	521	44	175
I-10/2	Filtration plant	415	36.5	233
I-10/2 Chanmbali Road	Filtration plant	375	31.5	192.8
I-9 Mangal Bazar	Filtration plant	503	43.5	295
I-8/2	Filtration plant	509	44.5	188.9
I-8/3	Filtration plant	494	22.5	128
G-7/4	Filtration plant	395	35	88.15
G-7/1	Filtration plant	195	29.5	122.8
G-7/2 Sitara Market	Filtration plant	305	21	138
G-8/1	Filtration plant	546	29.9	99.7
G-10/2	Filtration plant	556	44.6	310
F-10/1	Filtration plant	650	62.3	265
Parliament Lodges	Filtration plant	260	27.2	122
Pak-Secretariat P-Block	Filtration plant	271	26	188
Parliament House	Filtration plant	269	30	138
WHO		1000	250	500
NEQS		1000	250	500

3.7 Iron

Iron of water samples collected from filtration plants of various sectors were analyzed as shown in table 3.5 and 3.6. Concentrations of Fe were compared with standard limit of NEQS and WHO which are <0.1 and 0.3mg/L respectively. Results of Fe analysis of samples collected from water supply to filtration plant showed concentration in range of 0.09-0.6mg/L with the mean value of 0.24mg/L. whereas water samples collected from filtration plants after the filtration showed Fe concentration in range of 0.01-2.1mg/L with the mean value of 0.35mg/L. All the samples of water collected before and after the filtration showed Fe concentration above the standard limit of NEQS as well as WHO as shown in figure 3.7. The reason behind the higher concentration of iron in filtration water was that after the water has been filtered from filtration plants they are kept stored in iron containers which are rusted and contaminated thus are adding contamination in the water (Ali et al., 2012).

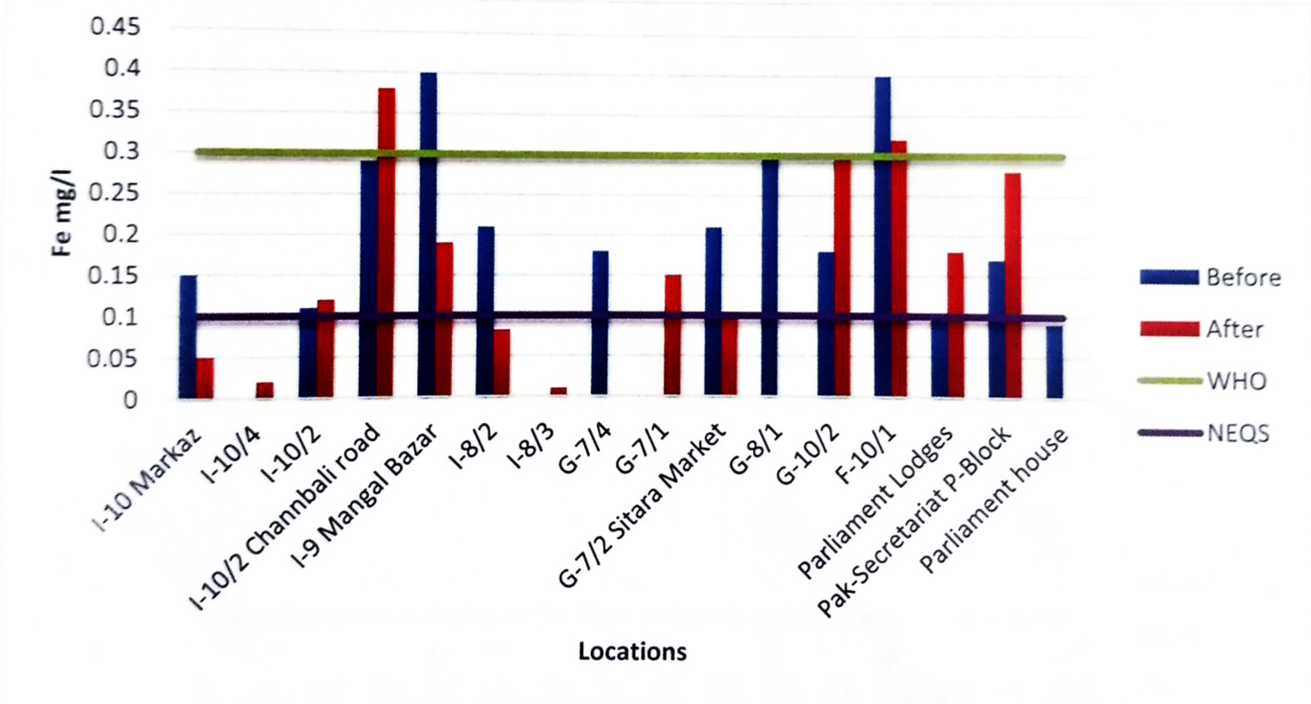

Figure 3.7. Fe concentration of water samples of study area

3.8 Cadmium

Water samples collected from filtration plants of various sectors of Islamabad were analyzed for cadmium. Samples from water supply to filtration plant showed Cd concentration in range of 0.001-0.1mg/L with the mean value of 0.003mg/L. Similarly water samples collected after filtration showed Cd concentration in range of 0.001-0.001mg/L with the mean value of 0.001mg/L. Cd concentrations were compared with the standard limits of NEQS and WHO which are 0.01 and 0.003mg/L respectively, and all the samples collected before and after filtration falls within the standard limit as shown in figure 3.8. Cd concentration was within the limit of 0.001mg/L in samples collected from water supply from Margalla town tube well to I-10 Markaz, I-10/2, Abpara tube well supply to G-7/4, tube well supply to G-10/2, F-10/1, Parliament lodges, Simly dam supply to Pak secretariat, Parliament house, G-7/1, G-7/2, I-8/3. Similarly water samples collected after filtration of I-10 Markaz and I-10/4 showed the absence of Cd. The concentration of cadmium before and after is shown in table 3.5 and 3.6. Cd occurs naturally in rocks and soils and enters water when there is contact with sift ground water or surface water. Increased concentration of Cd might be due to corrosion of galvanized steel pipe that is used for pipping of water distribution over the area (Baig et al., 2019).

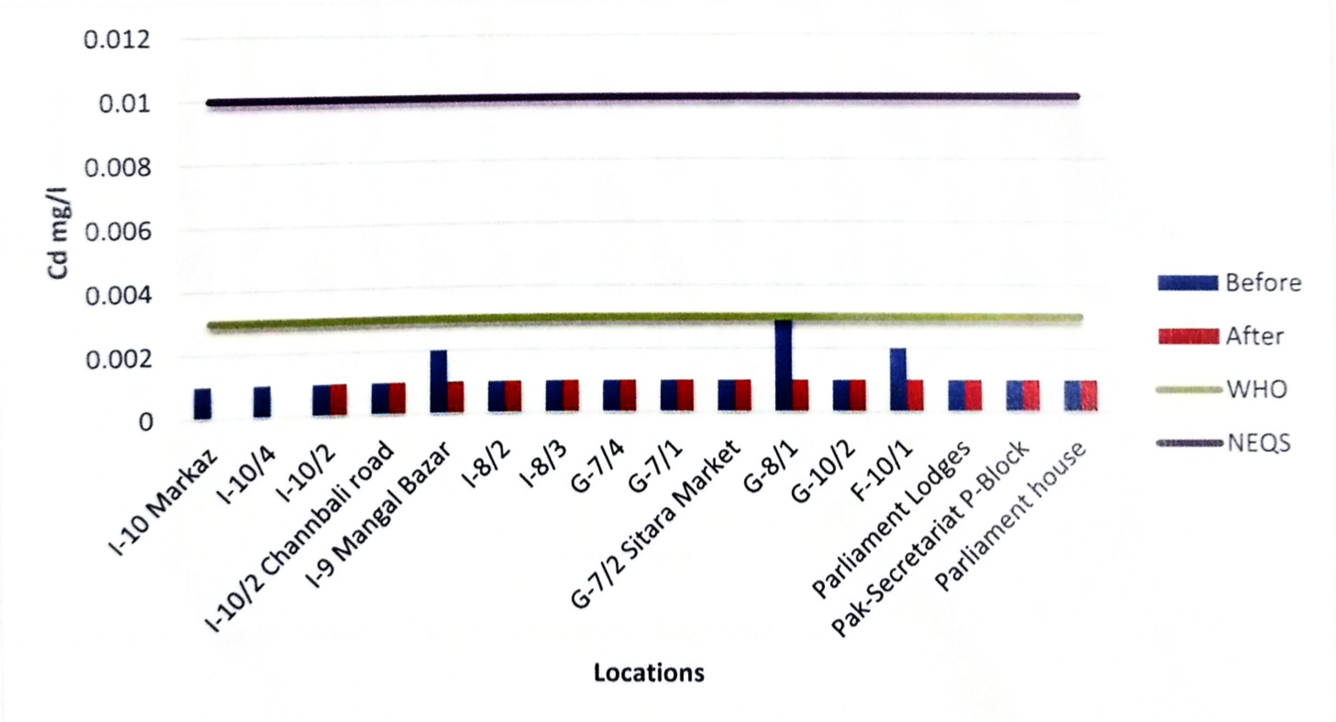

Figure 3.8. Cd concentration of water samples of study area

3.9 Manganese

Manganese of water samples collected from filtration plants of various sectors was analyzed as shown in table 3.5 and 3.6. Concentrations of Mn were compared with standard limit of NEQS and WHO which are <0.5 and 0.5mg/L respectively. Results of Mn analysis of samples collected from water supply to filtration plant showed concentration in range of 0.17-0.59mg/L with the mean value of 0.37mg/L. whereas water samples collected from filtration plants after the filtration showed Mn concentration in range of 0.1-0.3mg/L with the mean value of 0.2mg/L. Most of the samples of water collected before and after the filtration showed Mn concentration within the standard limit of NEQS as well as WHO as shown in figure 3.9. Samples of water from I-8/3 and Parliament house showed the lowest Cd concentration limit. Drinking water manganese is a potential threat to children's health due to its association with a wide range of outcomes including cognitive, behavioral and neuropsychological effects. Although adverse effects of manganese on cognitive function of children indicate possible impact on their academic achievement (Baig et al., 2019).

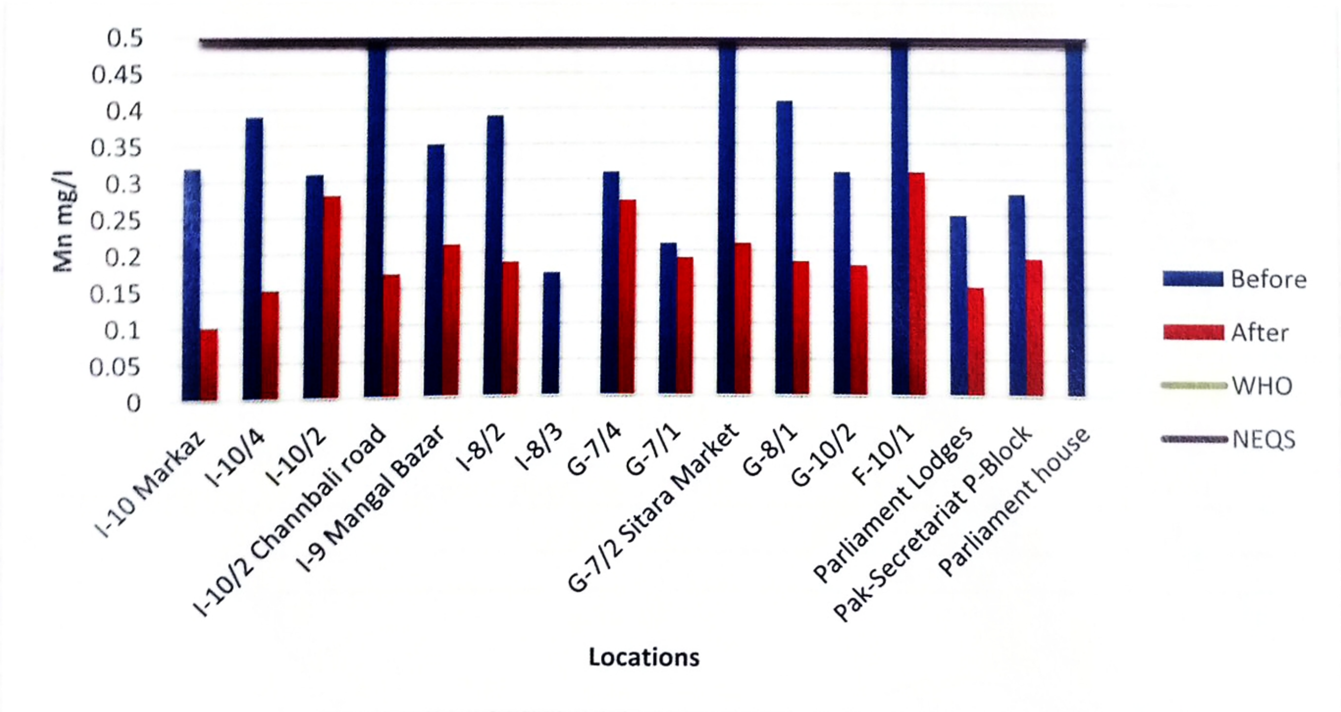

Figure 3.9. Mn concentration of water samples of study area

Table 3.5 Heavy metal concentration in water samples (Before)

SECTORS	Before	Concentration (mg/L)		
		Fe	Cd	Mn
I-10 Markaz	Margalla tube well	0.15	0.001	0.32
I-10/4	Margalla tube well	0.001	0.001	0.39
I-10/2	Margalla tube well	0.11	0.001	0.31
I-10/2 Chanmbali Road	Margalla tube well	0.29	0.001	0.57
I-9 Mangal Bazar	Tube well	0.40	0.002	0.35
I-8/2	Tube well	0.21	0.01	0.39
I-8/3	Simly dam	0.001	0.001	0.17
G-7/4	Abpara tube well	0.18	0.001	0.31
G-7/1	Simly dam	0.001	0.001	0.21
G-7/2 Sitara Market	Simly dam	0.21	0.001	0.59
G-8/1	Tube well	0.30	0.003	0.41
G-10/2	Tube well	0.18	0.001	0.31
F-10/1	Tube well	0.40	0.002	0.52
Parliament Lodges	Tube well	0.10	0.001	0.25
Pak-Secretariat P-Block	Simly dam	0.17	0.001	0.28
Parliament House	Simly dam	0.09	0.001	0.57
WHO		0.3	0.003	0.5
NEQS		0.1	0.01	0.5

Table 3.6 Heavy metal concentration in water samples (After)

SECTORS	After	Concentration (mg/L)		
		Fe	Cd	Mn
I-10 Markaz	Filtration plant	0.05	*nil	0.10
I-10/4	Filtration plant	0.02	nil	0.25
I-10/2	Filtration plant	0.12	0.001	0.28
I-10/2 Chanmbali Road	Filtration plant	0.38	0.001	0.17
I-9 Mangal Bazar	Filtration plant	0.19	0.001	0.21
I-8/2	Filtration plant	0.082	0.001	0.185
I-8/3	Filtration plant	0.01	0.001	0.001
G-7/4	Filtration plant	0.001	0.001	0.27
G-7/1	Filtration plant	0.15	0.001	0.19
G-7/2	Filtration plant	0.10	0.001	0.21
G-8/1	Filtration plant	0.001	0.001	0.185
G-10/2	Filtration plant	0.30	0.001	0.18
F-10/1	Filtration plant	0.32	0.001	0.31
Parliament Lodges	Filtration plant	0.18	0.001	0.15
Pak-Secretariat P-Block	Filtration plant	0.28	0.001	0.19
Parliament House	Filtration plant	0.001	0.001	0.001
WHO		0.3	0.003	0.5
NEQS		0.1	0.01	0.5

*nil = 0

3.10 E.coli

E.coli bacteria analysis was also carried out for samples collected from filtration plants of various sectors. Water samples collected before filtration from I-10 Markaz, I-10/2, I-9 Mangal Bazar, I-8/2, G-10/2, F-10/1, Pak secretariat, Parliament house, G-7/2 Sitara Market and I-8/3 showed the presence of E.coli. Samples collected after filtration from I-10 Markaz, I-10/2 Chanmbali road, G-8/1, G-10/2 and F-10/1 showed presence of E.coli as shown in table 3.7. I-10/2 Chanmbali road, G-8/1 and F-10/1 filtration plants shows microbial contamination because their filter paper replaces after 6 months and thus are incapable of filtering E.coli. The higher number of bacterial colonies might be due to percolation of sewage into well water and the presence of fecal material from warm blooded animals and poor condition of pipeline which favor the growth of microorganisms (Hisam et al., 2014).

Table 3.7 Microbial contamination in both before and after water samples

SECTORS	BEFORE	E.coli	AFTER	E.coli
I-10 Markaz	Margalla tube well	Positive	Filtration plant	Positive
I-10/4	Margalla tube well	Negative	Filtration plant	Negative
I-10/2	Margalla tube well	Positive	Filtration plant	Negative
I-10/2 Chanmbali	Margalla tube well	Negative	Filtration plant	Positive
I-9 Mangal Bazar	Tube well	Positive	Filtration plant	Negative
I-8/2	Tube well	Positive	Filtration plant	Negative
I-8/3	Simly dam	Positive	Filtration plant	Negative
G-7/4	Abpara tube well	Negative	Filtration plant	Negative
G-7/1	Simly dam	Positive	Filtration plant	Negative
G-7/2 Sitara Market	Simly dam	Positive	Filtration plant	Negative
G-8/1	Tube well	Negative	Filtration plant	Positive
G-10/2	Tube well	Positive	Filtration plant	Positive
F-10/1	Tube Well	Positive	Filtration plant	Positive
Parliament Lodges	Tube well	Negative	Filtration plant	Negative
Pak-Secretariat P Block	Simly dam	Positive	Filtration plant	Negative
Parliament House	Simly dam	Positive	Filtration plant	Negative

3.11 Comparison of filtration plants and their sources

The table below is showing the results of parameters in before and after samples. In all Filtration plants and their sources, EC and Iron is found above the permissible limit, except in I-10/4 and I-10 Markaz Filtration plants where Fe is found below the permissible limit. I-10/2 was found effectively removing E.coli from source water while astonishingly result is found in I-10/2 Chanmbali road that before filtration E.coli is not present, but found after treatment from Filtration Plant.

Table 3.8. Filtration plants that are supplied with Margalla tube well water

Parameters	**I-10 Markaz**		**I-10/4**		**I-10/2**		**Chanmbali road**	
	before	after	before	after	Before	after	before	after
pH	7.9	8.1	7.5	7.6	6.85	7.9	6.9	7.9
Temp (°C)	18.5	19	18	18	19.5	20	20	20
EC (μS/cm)	615	510	711	692	758	555	718	505
TDS (mg/l)	481	379	539	521	611	415	576	375
Cl (mg/l)	39	32	45.5	44	48	36.5	36.8	31.5
Hardness (mg/l)	265	115	258	175	471	233	396	192.8
Fe (mg/l)	0.15	0.05	0.001	0.02	0.11	0.12	0.29	0.38
Cd (mg/l)	0.001	0	0.001	0	0.001	0.001	0.001	0.001
Mn (mg/l)	0.32	0.10	0.39	0.25	0.31	0.28	0.57	0.17
E.coli	+ve	+ve	-ve	-ve	+ve	-ve	-ve	+ve

Table 3.9 is showing the results of analyzed parameters of Filtrations plants that are supplied with Simly dam (source). Only in G-7/1 Filtration Plant, EC is found within the limit while in rest of the samples it is found above the limit. Iron concentration was found within the permissible limit in I-8/3 and Parliament house Filtration Plants and sources. E.coli is found in Simly dam (source) while all Filtration Plants were found effectively removing E.coli.

Table 3.9. Filtration plants that are supplied with Simly dam water

Parameters	I-8/3		G-7/1		G-7/2		Pak Secretariat		Parliament house	
	before	after	before	after	before	after	before	after	before	after
pH	8.0	7.2	8.1	7.3	8.0	7.3	7.9	7.8	8.3	8.0
Temp (°C)	17.9	19	18.3	18	18.5	19	18.9	19	19	19
EC (µS/cm)	641	622	629	324	597	468	699	421	639	409
TDS (mg/l)	519	494	511	195	488	305	533	271	499	269
Cl (mg/l)	25	22.5	28.9	29.5	26.1	21	26.3	26	31	30
Hardness(mg/l)	188.5	128	215.5	122.8	208	138	233	188	256	138
Fe (mg/l)	0.001	0.01	0.001	0.15	0.21	0.10	0.17	0.28	0.09	0.001
Cd (mg/l)	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Mn (mg/l)	0.17	0.001	0.21	0.19	0.59	0.21	0.28	0.19	0.57	0.001
E.coli	+ve	-ve	+ve	-ve	+ve	-ve	+ve	-ve	+ve	-ve

Table 3.10 is showing the analyses results of those Filtration Plants that have their own tube well to supply water to them. EC and Fe is found above the permissible limits in all before and after samples while rest of physicochemical parameters and heavy metals were found within the given limits in all samples. I-9 and I-8/2 Filtration Plants were found effectively removing E.coli in water while G-10/2 Filtration Plant was found ineffective. Astonishing result is found in G-8/1 Filtration Plant where E.coli is not found in source sample, but found after treatment from Filtration Plant.

Table 3.10. Filtration plants that are supplied with their own tube well water

Parameters	I-9		I-8/2		G-8/1		G-10/2	
	before	after	before	after	before	after	before	after
pH	7.3	7.3	7.2	7.3	7.3	7.3	8.0	7.4
Temp (°C)	19	19	18	18	20	20	18.5	19
EC (µS/cm)	697	688	694	689	688	699	738	710
TDS (mg/l)	512	503	503	509	523	546	591	556
Cl (mg/l)	48.5	43.5	41	44.5	37.2	29.9	44.8	44.6
Hardness (mg/l)	315	295	325	188.9	345	99.7	501	310
Fe (mg/l)	0.40	0.19	0.21	0.08	0.30	0.001	0.18	0.30
Cd (mg/l)	0.002	0.001	0.01	0.001	0.003	0.001	0.001	0.001
Mn (mg/l)	0.35	0.21	0.39	0.18	0.41	0.185	0.31	0.18
E.coli	+ve	-ve	+ve	-ve	-ve	+ve	+ve	+ve

Table 3.11 showing before and after results of selected parameters. In G-7/4 Filtration Plant, EC and Fe concentration was found within the limit while rest of parameters were found above the permissible limit. Bacterial analyses found that F-10/1 filtration plant water contain E.coli and thus are not suitable for drinking.

Table 3.11. Filtration plants that are supplied with their own tube well water

Parameters	G-7/4		F-10/1		Parliament lodges	
	before	after	before	after	before	after
pH	7.7	8.0	7.4	7.7	8.2	8.1
Temp (°C)	19	20	18	19	20	20
EC (µS/cm)	739	518	789	788	410	398
TDS (mg/l)	611	395	650	650	270	260
Cl (mg/l)	36	35	68	62.3	25	27.2
Hardness (mg/l)	268.9	88.1	326	265	192	122
Fe (mg/l)	0.18	0.001	0.40	0.32	0.10	0.18
Cd (mg/l)	0.001	0.001	0.002	0.001	0.001	0.001
Mn (mg/l)	0.31	0.27	0.52	0.31	0.25	0.15
E.coli	-ve	-ve	+ve	+ve	-ve	-ve

3.12 General characteristics of filtration plants

The general characteristics of filtration plants that we visit are given in table 3.12. Most of the filtration plants were in good working condition, their filter paper and were satisfactory. I-10/2 and G-7/1 filtration plants were dirty and not in good condition. Their taps were broken and were surrounded by garbage. Filtration plants located in Parliament house, Pak Secretariat P block and Parliament lodges were found to be cleanest as their all taps are working and no garbage was present in their surroundings.

Table 3.12 General characteristics of filtration plants of the study area

S.no	location	Functional/non-functional	Condition of filtration plant	Replacement of filter paper	No. of taps	UV lamp	Source of water	Depth	Running time
1	I-10 Markaz	Functional	clean	3 month	7	off	Ground	300 ft.	24 hrs.
2	I-10/4	Functional	clean	2 month	3	on	Ground	> 300 ft.	6am-10pm
3	I-10/2	Functional	dirty	3 month	5	on	Ground	300 ft.	24 hrs.
4	I-10/2 Chanmbali road	Functional	clean	6 month	4	off	Ground	> 300 ft.	24 hrs.
5	I-9 Mangal Bazar	Functional	clean	2-3 month	7	on	Ground	250-300 ft.	7am-1pm, 3pm-12am
6	I-8/2	Functional	clean	3 month	7	on	Ground	250-300 ft.	24 hrs.
7	I-8/3	Functional	clean	3 month	6	on	surface	Dam	24 hrs.
8	G-7/4	Functional	dirty	3 month	5	on	Ground	300 ft.	5:30am-1pm, 3pm-10pm
9	G-7/1	Functional	clean	3 month	2	on	surface	Dam	8am-10pm
10	G-7/2 Sitara Market	Functional	clean	3 month	5	on	surface	Dam	8am-1pm, 3pm-10am
11	G-8/1	Functional	clean	5-6 month	2	off	Ground	> 300 ft.	11am-2pm,5pm-6pm
12	G-10/2	Functional	clean	4 month	4	off	Ground	300 ft.	24 hrs.
13	F-10/1	Functional	clean	6 month	3	off	Ground	250 ft.	6am-10pm
14	Parliament Lodges	Functional	clean	3 month	7	on	Ground	250 ft.	24 hrs.
15	Pak-Secretariat P-Block	Functional	clean	3 month	4	on	surface	Dam	24 hrs.
16	Parliament house	Functional	clean	3 month	3	on	surface	Dam	24 hrs.

CONCLUSIONS

1. The values of water quality parameters such as pH, temperature, conductivity, total dissolved solids, chlorine, magnesium , calcium and nitrates from all samples collected from filtration plants of various sectors of Islamabad were found within the recommended limits of WHO and NEQS.
2. The concentrations of heavy metals such as manganese and cadmium were also measured and found within standard limit of WHO and NEQS, while iron concentration in few samples were found above the standard limit of WHO and NEQS.
3. Biological analysis shows the presence of E.coli in samples collected from I-10/2, I-9 Mangal Bazar, I-8/2, I-8/3, G-7/2 Sitara Market, G-10/2, F-10/1, Pak Secretariat and Parliament house. This results showed that the Filtration plants which sources were Simly dam are contaminated with microbial growth and is therefore unfit for drinking purposes.
4. One of the surprising conclusion is that E.coli was not present in Channbali road and G-8/1 filtration plants before treatment but were found after treatment, clearly indicates that contamination of water during treatment.

RECOMMENDATION

On the basis of following recommendations were drawn:

1. The filtration plant should be properly maintained and monitored by the authorities.
2. The filtration plants should be cleaned on daily basis and the hygienic conditions should be ensured by the regulatory authorities like (CDA and TMA).
3. To prevent rusting, the metallic supply pipes should be replaced by the PVC pipes.
4. The filter paper used in the filtration plant should be of good quality and should be changed according the manufacturer's recommendation.
5. Further studies should be conduct with focus on the treatment of water quality of filtration plants.

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ANNEXURE

Figure 4.1. Filtration plant of Parliament house

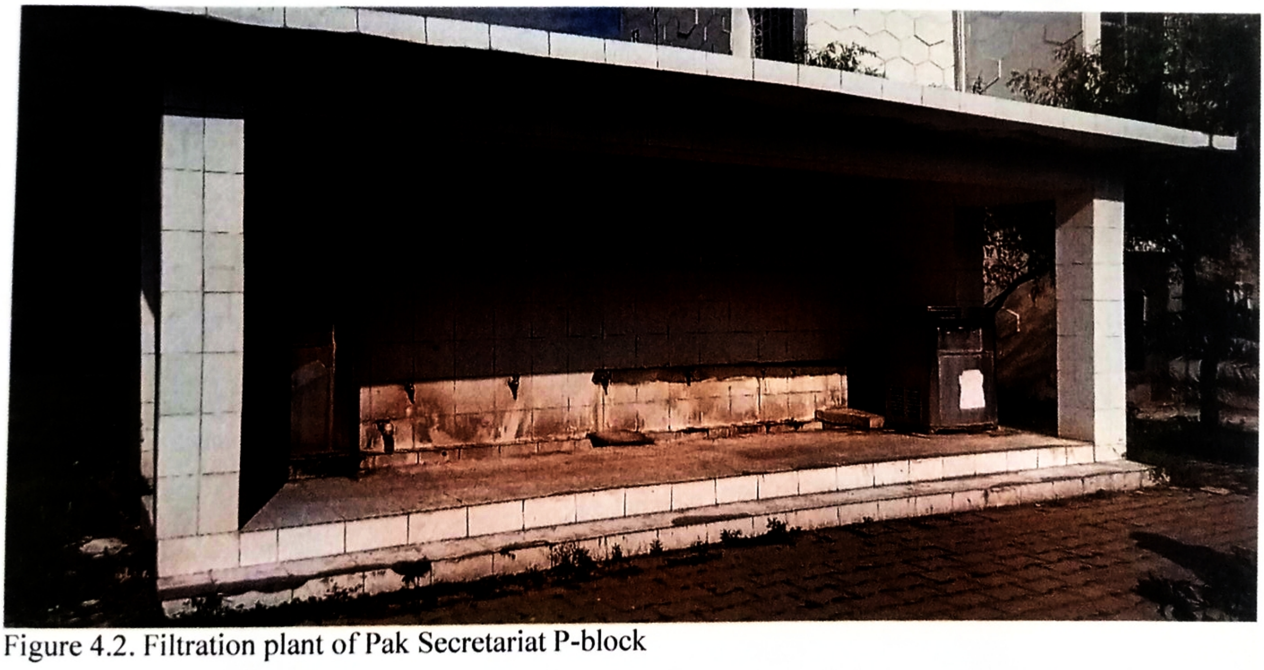
Figure 4.2. Filtration plant of Pak Secretariat P-block

Figure 4.3. Filtration plant of I-10/2

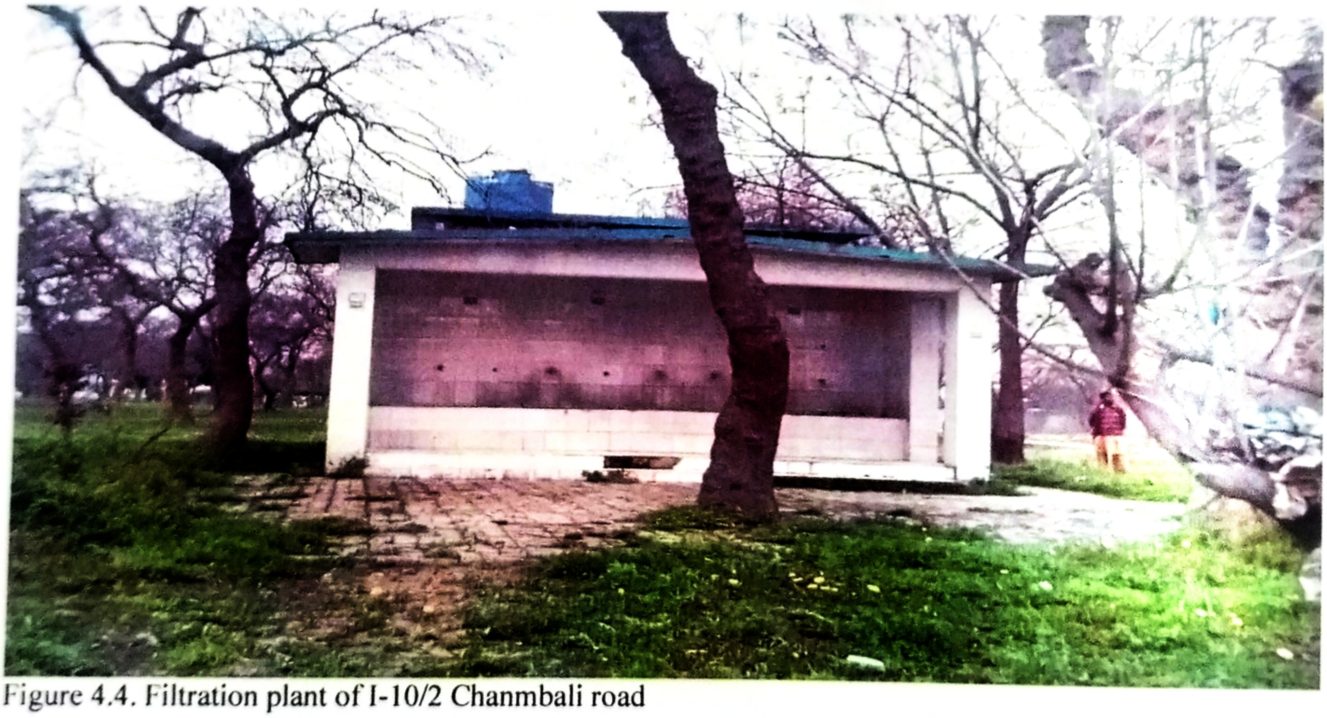

Figure 4.4. Filtration plant of I-10/2 Chanmbali road

WATER QUALITY ASSESSMENT OF FILTRATION PLANTS ISLAMABAD, PAKISTAN

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