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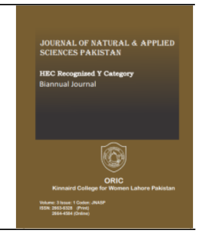

DETERMINATION OF DRINKING WATER QUALITY OF SAMANABAD TOWN, LAHORE

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Abstract
In Pakistan, only 20% of the country's population has access to safe drinking water, the rest of 80% is forced to rely on unsafe water. Safe and clean water is a necessity of every human being. The water consumed by human beings needs to be free from any kind of physical, chemical or biological pollution. But it so happens that the surface water and groundwater can be contaminated due to natural or anthropogenic reasons. Aim of this research was to assess the quality of water, drinking water quality analysis was carried out in Samanabad, Lahore Pakistan. 300 samples from low income, middle income and high income areas were collected, 100 samples from each area. Physico-chemical parameters (pH, turbidity, total hardness, fluorides, chlorides, TDS and Fecal Coliform) were analyzed in the laboratory against the standards of WHO and the National Standards for Drinking Water Quality, Pakistan. The results were not under the standard limits for the low and middle income areas. The pH for low, middle and high income areas were within 6.5-8.5 for the majority of the samples. The highest value of pH measured in low income area samples was 9.8 whereas 8.78 in high income area samples. The turbidity values were not in the range of 2NTU for the low income area samples. The TSS and TDS values for the low income area were also higher than the standard limit. Only the middle and low income area remained in the range of 200-450 ppm. The highest value recorded for total hardness in the middle income area was 453 mg/l. Chlorides were not under the limits for some samples exceeded the limits of 250-288 mg/l. Most Fluoride values remained under the limits but some values were calculated to be in the range of 1.5-2 mg/l. Fecal coliform was detected in low and middle income areas. The presence of fecal coliform in drinking water indicates that a sewage pipe might be leaking underground causing the dirty water to contaminate the drinking water as well. Since not all the drinking water parameters were within the standard range, it was declared that the drinking water requires further treatment.

Keywords
Water, Water Quality, Water Pollution, Drinking Water Quality Analysis, Lahore, Samanabad.

1.Introduction

In Pakistan, only 20% of the country's population has access to safe drinking water, the rest of 80% is forced to rely on unsafe water. Due to contaminated water consumption 40% of the deaths in Pakistan occur due to polluted water (Daud *et al*.,). According to WHO reports, 10% of the global population does not have access to treated drinking water (WHO, 2021). Surface water and groundwater are the two main sources for community drinking water around the world (Water Sources, 2021). Out of the 71% water on this planet, only 3% is considered drinking water whereas the rest of 96% is saline water which cannot be consumed due to its high salt content. The 3% of the water that can be consumed for human needs is present in the form of rivers, lakes, ice caps and glaciers and groundwater (Water Science,2021). The water consumed by humans needs to be free from any kind of physical, chemical or biological pollution (Ilyas *et al*., 2017). But it so happens that the surface water and groundwater can be contaminated due to natural or anthropogenic reasons. Any type of impurity in drinking water makes it unsafe for human consumption. The World Health Organization and the European Union innovated some standards for drinking water to ensure clean and safe supply of water (WHO,2008). These standards include a list of parameters and their permissible amounts in drinking water. Through these standards, countries can make better assessments if the water is fit for human consumption or not. Since consumption of unsafe drinking water can lead to waterborne diseases, it is important to follow these standards to prevent the spread of disease. In Pakistan alone, 2.5 million deaths occur due to endemic diarrheal disease because of consuming contaminated ground water (Kosek,2000). Waterborne diseases are caused due to the use of contaminated water. This consumption of contaminated water can be in any form. Food cooked in the contaminated water can also lead to waterborne diseases. Diarrhea is the most common manifestation of waterborne disease. It can further lead to dehydration and in severe cases, death. Death does not occur in areas where the risk factor is low, even if the residents are consuming contaminated water for quite some time. However, in many African regions the risk factor is high and water is scarce, so people have no other option but to consume contaminated water. Therefore, people including young, old and people with immunodeficiency diseases are prone to infections. [8] Another contamination source is fecal contamination. Fecal contamination of drinking water can occur due to two reasons. In rural areas it occurs due to run off from bushes and forests which many rural dwellers use as a site for defecation (Forstinus *et al*., 2016). In urban areas, it occurs due to leakage from water pipes. Drinking water can become contaminated after it enters the building's plumbing (Khoso *et al*.,2015). Since pipeline systems have been installed for both drinking water distribution and wastewater discharge, sometimes leaks occur in these pipelines.

Especially in older residential areas where the pipeline systems are quite old, these problems are quite common. Water scarcity is an issue that billions of people around the world are facing. When water is scarce, people are forced to rely on contaminated water sources as any form of water is better than no water. This leads to further outspread of disease. Pakistan is a developing country and on top of that an agricultural county with a rapidly increasing population. In Pakistan 69% of the water is used for the agricultural sector, 23% in the industrial sector and only 8% is utilized by the domestic sector. The Indus River system, glaciers and rainfall are the main sources of water in Pakistan.

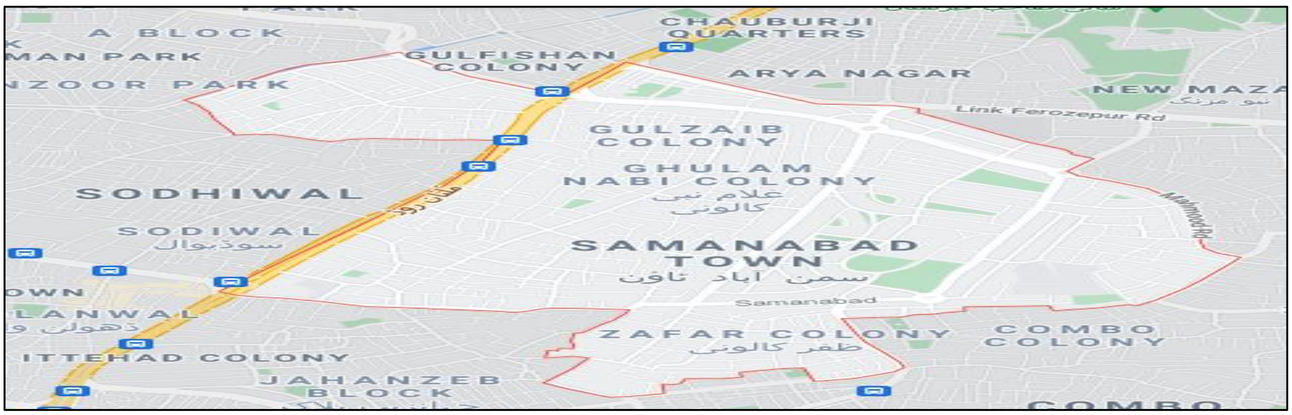

Figure 1: Map of Samanabad Area

But the Indus River is drying up, the water reservoirs are facing silting problems and the rainfall is reducing because of the increase in deforestation which is a cause of water scarcity in Pakistan (WHO). pH is one of the physical parameters of water that is very important for drinking water. The permissible limit for pH in drinking water is 6.5-8.5 (WHO, 2008). There have been no reported health effects due to lower or higher pH of drinking water. But in the case of pH less than 6.5, the water becomes acidic. Acidic water is capable of causing leaching of metals from the pipes that bring the water. These metals are extremely harmful for human health. On the other hand, pH higher than 8.5 makes the drinking water alkaline. Alkaline water has a slightly bitter taste. Taste is another physical parameter that should not be present in water. Alkaline water can also sometimes cause skin irritation and itching (UCLA Health,2021). In this way, pH may not have any direct impacts on human health but it can definitely lead to indirect health issues both in children and adults. Moreover, water from natural sources contains minerals like magnesium and calcium. Presence of these minerals can often make water hard. Water can range from soft, moderately hard, hard to very hard water depending on the amount of calcium carbonate it contains. Calcium and magnesium may be important minerals for our body and some part of the body's needs might be filled by water but above a certain limit, these minerals in water can cause harm too. Hardness of water can sometimes aggravate eczema. Studies have also shown that there is a close link between cardiovascular diseases and hard water but more research is still required in this area (WHO,2021). Another drinking water quality parameter is Total Dissolved Solids (TDS). TDS are to be less than 1000 in drinking water. [6] But too low concentration of TDS is also not acceptable in water as it gives a flat, insipid taste. All the inorganic salts and organic matter present in drinking water are termed TDS and they give a slight taste to the water that is undetectable. Direct health risks associated with TDS have not been reported (WHO). Turbidity of drinking water plays a significant role in the disinfection of water. The particles present in the drinking water end up providing protection to the organisms that need to be removed from the water. Hence high values of turbidity lead to reduced disinfection results. Turbidity does not have direct impacts on the health but it reduces the clarity of water and cloudy, murky water points towards contamination. Turbidity owing to microbial contamination has shown results of gastro vascular diseases in many cases. Due to these reasons, it is important to keep the turbidity of drinking water in check (WHO). In Pakistan contamination due to sewage water is one of the main reasons for polluted drinking water. Due to the presence of biological contaminants like bacteria, protozoa, etc. the rate of waterborne diseases is ever increasing in the county. 5 million children are estimated to die every year due to contaminated water in developing countries (Daud *et al*.,2017) In Pakistan alone, 45% of the infants die because of diarrhea. Among 31 Asian countries, Pakistan has the second highest rate of diarrhea. As the problem of contaminated water goes untreated, the waterborne disease problem continues to worsen in the country (Jabeen *et al*.,2015). Lastly, chlorine in drinking water generally comes from disinfection of water to control odor and bacteria. According to WHO, chlorine in drinking water should be less than 250 mg/L. Various studies have shown that chlorinated water can aggravate asthma. Dermatitis has also been associated with chlorine and hypochlorite. The risk of bladder cancer has also been shown to increase in individuals consuming chlorinated tap water (WHO). Another major cause of contaminated water is the presence of heavy metals. With increase in industrialization, the industrial waste water output has also increased. Many companies do not pay attention to the safe disposal of the contaminated water and end up dumping them in clean water sources like rivers and lakes. In other cases, improper disposal causes the contaminants to seep down and contaminate the groundwater sources. Many studies have been conducted on heavy metals in drinking water and results show presence of Arsenic in multiple samples from Sheikhupura, Lahore, Gujranwala, Multan, Kasur, and Bahawalpur (Daud *et al*.,2017) Iron and Lead presence was found in samples collected from Lakki Marwat District, KPK (Bibi *et al*) and samples from Swat Valley, KPK showed presence of Cadmium, Chromium, Nickel and Lead (Khan, 2013). Water quality can be tested and monitored by biological, physical and chemical methods. Biological methods include the use of bacteria, viruses, enzymes and antidotes for the assessment of water pollution. In physical tests color, turbidity, odor, taste, dissolved solids, and suspended solids are analyzed. Chemical tests are performed to monitor the pH, hardness, biological oxygen demand (B.O.D) and presence of toxic chemicals. Bacteriological tests are the indicator of disease-causing agents, mainly E. coli and fecal coliform matter. Mineral tests indicate if minerals in water are high enough to cause the water hard. Chemical tests determine whether a specific contaminant is added into the water stream from different sources such as industries or pesticides. Lahore is the capital city of the province Punjab, Pakistan. It is the second largest city after Karachi. In 2018, the population of Lahore was calculated to be 11,738,000 (Metro population Pakistan). The main source of water supply to Lahore is groundwater. 300 large capacity tube wells are installed in different locations of municipal areas of Lahore (Ahmad, 2002). Due to increase in the industrial and commercial activities, the usage of groundwater has increased to a great extent. Old infrastructure of water supply to Lahore causes leakage of pipes, mixing of sewage with the groundwater. The treatment of groundwater is not done properly. This is progressively worsening the drinking water quality. Samanabad is an administrative area of Lahore which covers many colonies and streets. According to 2016 population statistics, around 1,000,000 people live in Samanabad (Metro population Pakistan). Some areas of Samanabad are using tap water for drinking purposes. According to WHO, tap water in some countries is unfit for drinking purposes. The quality of water has been improved overall but, in some areas, bad quality of water has imposed threats to human health. This research will be helpful in identifying those areas of Samanabad where water quality is deteriorating**.** Water consumption has increased due to an increase in the population of the world.–Water quality is a major issue in developing countries like Pakistan. In Pakistan, water quality is continuously deteriorating because of increase in urbanization, deforestation etc (Daud *et al*., 2017). A study in Bahawalpur City provides an overview of the quality of drinking water in different areas of Bahawalpur and the impacts of health on the residents. Results indicated deteriorating quality of water in each town, especially Islamic colony where EC, TDS, hardness, pH etc. were above the permissible limits set by WHO. The study also indicated serious percentages of diseases in 3 towns (36%, 22% and 18%) due to deterioration in the drinking water quality (Mohsin, 2017). A study on the assessment of drinking water quality in southern Sindh was conducted. Drinking water samples were collected from the areas which touched the Arabian Sea. Sodium was found to be exceeding the limits of WHO. Sodium when entering the human body, forces calcium ions to move out hence kidney problems and hypertension were reported where Na content was high. Moreover, Iron was identified to be a major problem in water. Health issues such as gastroenteritis, diarrhea, and skin problems were observed. Different samples collected from the dug wells indicated very high hardness. Diseases like gallbladder stones, urinary stones, arthritis etc. in such areas where hardness was more than 500mg/l CaCO3, were reported (Memon, 2011) In Lower Dir, Pakistan, a study was conducted to explore the physicochemical characteristics and metal concentrations in the drinking water as no study had been conducted there previously. Their results showed that except hardness, magnesium, calcium, chromium and lead, all other parameters were within the permissible limits set by WHO for drinking water. The heavy metals present in the drinking water showed no effect on human health (Ilyas, 2017). In 2013, the drinking quality of Charsadda district, Pakistan was evaluated. According to their results, nitrate was above the permissible limits in 13 sites, sulphate was above limits in 9 sites, whereas Pb, Cd, Ni and Fe were also found to be well above the permissible limits in many of the sites. Coliform bacterial contamination was also confirmed in some of the sites. According to the survey conducted, waterborne diseases like gastroenteritis, dysentery, diarrhea and viral hepatitis were found to be prevailing among the residents (Khan, 2013). Three tehsils from the district Vehari, Punjab were selected to conduct a drinking water quality test and to assess the public perception on drinking water quality and safety. Electrical conductivity, total dissolved solids, Sodium, Calcium, Potassium, Chloride and Nitrate exceeded the WHO standards in many parts of the district. The researcher further questioned the residents about their perception and 48.6% of the respondent residents agreed that the water in their area was not good. Furthermore, residents who were of the perception that the water quality was not good reported more disease development than the respondents who did not perceive the water as bad quality (Khalid, 2018). Similar study was carried out in Sindh, Bahawalpur to assess whether the people are aware of the importance of drinking water quality and related waterborne diseases. Nearly half of the residents were aware of waterborne diseases and 65.2% of the respondents reported to have suffered from waterborne disease and diarrhea was the most commonly reported (Baig *et al*.,2017). Durmishi et. al 2012 conducted a drinking water quality test in different sites of the Tetova region, including both the city and the surrounding villages. They found that the water quality was better in the city sites as compared to the rural site due the better sanitary conditions and hygiene (Durmishi, 2012). Water quality in Mexico was found to be in compliance with WHO standards. 10 wells were selected from an urban area in Zamora, Mexico to assess its drinking water quality. Physicochemical and all other major components tested were found to be within limits in the majority of the samples. Water from 7 of the wells was declared to be in excellent quality whereas the other 3 were categorized as good (Reyes-Toscano,2020). Since poor drinking water quality is an issue faced all over the world, China introduced a program in the 1980s to supply improved drinking water to the consumers by building purification plants and pipeline systems. Zhang conducted a study to assess how this has improved the health of children and adults. Results imply that there has been an 11% decline in disease incidence, 0.835 kg/m increase in the weight-to-height of the adults. On the other hand, in children, weight-for-height rose by 0.446 kg/m and the height itself by 0.962 cm (Zhang, 2012). Recently in 2020, researchers carried out a research in China in order to assess the variation in the drinking water quality due to the seasonal changes. 80% of the water samples were found to be of good quality. The health assessment revealed that the carcinogenic risk faced by the people is higher in the wet season in terms of terminal tap water consumption; on the other hand they face higher carcinogenic risk in terms of the chlorinated water in the dry season. Children face almost twice as many carcinogenic risks than adults (Ji *et al*., 2020). In Nigeria, the drinking water quality and the public health assessment was done for a few selected towns. Their water quality tests revealed that total aerobic plate, total coliform bacteria, and Escherichia coli were present in the water. TDS and TSS were also above the permissible limits. Out of 6 metals tested, Pb, Ni, Cr, and Cd were found to be about the permissible limit. The study concluded that the drinking water from the bore-holes was safer than the drinking water from wells and hand pumps (Dahunsi *et al*.,2014). Coliform bacteria were also found in drinking water collected from student hostels in Punjab, Pakistan. Drinking water quality of the student hostels for the University of Punjab was assessed by a few researchers. Along with coliform bacteria, Arsenic was also found to be above the permissible limits (Shahid,2015). Researchers in Iran developed an innovative drinking water quality index (DWQI) based on the Canadian DWQI and used it to assess the groundwater used for drinking purposes. Their results showed that the over groundwater of the country used for drinking was in good condition. Other countries can also use a modified drinking water quality index for determining the water quality in their cities (Ghaderpoori,2018). Absorption spectrometer was used to analyze the metal concentrations in the drinking water of Swat, KPK. Cd, Cr, Ni and Pb were found to be higher than the permissible amounts. No health risks were found among the local people 17 (Khan *et al*.,2013). Heavy metals were also found in the drinking water of Lakki. In 2016, in Lakki Marwat District, KPK, heavy metals in drinking water were analyzed. Iron was a commonly occurring heavy metal in the drinking water of Lakki Marwat District whereas the rest of the heavy metals were present in varying amounts in different areas (Bibi *et al*.,2016). Clean water should be provided by the government to prevent the health risk associated with the contaminated water. Farmers should be educated on the safe number of fertilizers and pesticides that can be used. Men and women should be educated and awareness should be created regarding safe drinking water (Memon *et al*.,2011).

2. Materials and Methods

2.1. Site Selection

Situated Northeast from the center of the city, Samanabad is one of the oldest residential towns of Lahore. According to a study carried out in Lahore in 2016, the population of Samanabad was 1,086,000 (Jabeen *et al*., 2015). Samanabad forms one of the ten zones of Lahore and it is the administrative zone. The area of Samanabad is mainly residential and commercial. For the analysis, Samanabad town was divided into 3 categories i.e., low-income areas, middle income areas and high-income areas on the basis of the number of families living in each house. 3 Union Councils (UCs) were selected from each category for correct identification of the areas.

2.2. Sampling

The drinking water samples were collected in the months of August and September 2021 through random cluster sampling. Samples were collected in 1.5-liter plastic bottles. All samples were collected from households. 300 drinking water samples were collected in total, 100 from each area i.e, low income, middle income and high income. The drinking water samples collected were analyzed in the laboratory. Physico-chemical analysis was done. Physical parameters such as pH (9040C USEPA), turbidity (APHA 2130) and chemical parameters such as TDS (APHA 2540 C), TSS (APHA 2540), hardness (0130.2 USEPA), Chloride (APHA 4500-CL D), Fluoride (APHA 4500-F), Fecal coliforms (APHA 9222) were tested and monitored. The results were analyzed and compared with the standards of WHO and NEQs.

2.3. Turbidity Procedure

The sample was taken in the turbidity meter cuvette. The lid of the cuvette was carefully closed to prevent any interference of light. The cuvette was placed in the turbidity meter. We waited for the steady reading and the displayed reading was recorded. [APHA 2130]

2.4. TSS Procedure

A piece of filter paper was taken and weighed. The weighed filter paper was then stuck to the inside of a funnel. 50ml of water sample was taken and allowed to filter through the filter paper and into a china dish. After the filtration process was complete, the filter paper was placed inside an oven at 105C to dry the paper. The filter paper was then removed and weighed again. Calculations were performed to calculate the TSS. [APHA 2540]

2.5. pH Procedure

First, the pH meter was calibrated. Drinking water samples were taken in a clean beaker. The probe of the pH meter was rinsed properly before use, to prevent any carry over. Then the probe was immersed in the sample. The probe was stirred to establish equilibrium until the reading of the pH meter became stable. The reading of the pH meter was recorded. [9040C USEPA]

2.6. TDS procedure

A china dish was taken and it was weighed using an electric analyzer. Then a 50ml filtered sample was pipetted out into the china dish after mixing. The china dish was placed over a Bunsen burner and the water mixture was allowed to evaporate. When all of the water evaporated, the dish was removed from the flame. The dish was allowed to cool. After cooling the dish was weighed again and the weight was noted. Calculations were done to find out the weight of the dissolved solids. [APHA 2540 C]

2.7. Total Hardness Procedure

The tap water sample of volume 50 ml was taken in a beaker. 1 ml buffer solution was pipetted out in the water sample. A pinch of Eriochrome Black T was added to the water solution which turned the color of solution into purple. We titrated it against the standard solution of 0.02M EDTA until the color of the solution changed to color blue. Then the total hardness was calculated. [0130.2 USEPA]

2.8. Chloride Procedure

50 mL of tap water sample was pipetted out to a beaker in which 1-2 drops of potassium chromate (K2CrO4) were added, which acted as an indicator. We titrated it against the standard solution of silver nitrate (0.1 M), which was freshly prepared. A drop-wise solution of AgNo3 was added into the beaker. Titration continued until the color changed to brick red. Three readings were noted after performing the procedure three times. Then we calculated the chloride concentration. [APHA 4500-CL D]

2.9. Fluoride Procedure

A 100 ppm to 200ppm standard solution was made by dissolving salt solutions such as fluoride in water to calibrate the instrument. Buffer was added to the water sample and stirred gently. The Ion selective electrode probe was lowered into the beaker gently and stirred continuously. The displayed value was noted. Procedure was repeated for all samples. [APHA 4500-F]

2.10 Fecal Coliform Procedure

First agar was prepared in by mixing 50g in 250ml water, heating the mixture till the boiling point was reached and it was then placed in the Autoclave for 2 hours. The agar was then poured into petri dishes. Water samples were added to the agar with the help of droppers. The petri dishes were then covered and placed in the incubater for 24 hours. The samples were examined after 24 hours for signs of colonies. [APHA 9222]

3. Analysis of Results

All results were entered in Excel and calculation of results was done through plotting graphs and tables. Analysis of results was done according to the areas divided i.e. low income, middle income and high income. The parameters were then analyzed.

3.1 Results

The samples were tested in batches of 100. The first 100 samples were taken from low income areas and the values of the parameters were as shown in table 1.

Table 1: Drinking water quality analysis of samples from low income area

Sr. No.	pH 6.5-8.5	Turbidity (NTU) 5NTU	TSS (mg/l) 25mg/l	TDS (ppm) 100ppm	Chlorides (mg/l) 250mg/l	Fluorides (mg/l) 1-1.5mg/l	Hardness (mg/l) 500mg/l	Fecal Coliform None
1	7.87	2.77	11.1	602.4	142	1.497	113	No
2	7.94	2.36	8.3	443.7	88.75	1.562	57.87	No
3	7.46	2.06	10.2	584.2	124.23	0.528	109.31	No
4	7.8	1.31	21.6	230.3	88.75	1.064	73.945	No
5	7.52	2.93	19.2	536.8	88.75	0.03	356.865	No
6	7.81	2.71	18.32	634.6	106.5	1.487	45.28	No
7	7.68	5.34	28.13	1051.3	142	1.039	244.34	No
8	8	3.66	16.3	331.1	88.75	0.497	80.375	No
9	7.94	2.69	16.54	236	88.75	1.9	337.575	No
10	8.02	3.48	12.7	559.2	71	1.301	67.515	No
11	7.94	2.46	19.1	621.4	88.75	0.264	83.59	No
12	8.02	3.12	21.76	550.1	71	0.616	70.73	No
13	7.83	2.44	17.8	453.7	88.75	0.083	96.45	No
14	7.92	4.04	21.56	300	106.5	1.702	83.59	No
15	7.39	2.54	20.73	458.3	106.5	1.264	73.945	No
16	7.72	2.54	18.01	363	88.75	1.4	109.31	No
17	7.87	2.41	11.06	228	71	1.574	173.61	No
18	7.88	3.332	12.5	556.3	71	1.99	96.45	No
19	7.52	4.57	26.2	840.1	88.75	0.263	80.375	No
20	4.4	6.67	24.3	1237.8	88.75	1.22	360.08	No
21	7.26	4.41	12.2	360.3	88.75	1.116	109.31	No
22	6.95	4.6	25.12	649	53.25	0.662	80.375	No
23	6.66	5.14	20.9	993.7	88.75	1.764	96.45	No
24	7.57	6.46	28.3	1063.1	71	0.842	70.73	No
25	7.65	3.67	6.54	500.5	88.75	0.2	128.6	No

26	7.53	4.91	10.9	771.4	71	1.085	122.17	No
27	7.83	3.71	14.4	657	71	1.326	96.45	No
28	7.06	5.36	17.2	1244	88.75	1.598	113	No
29	7.61	4.33	10.33	761.2	106.5	1.039	45.28	No
30	7.89	1.65	8.76	357	5.325	1.131	64.3	No
31	8.15	4.73	15.4	868.2	5.325	1.264	90.02	No
32	7.1	6.49	19.77	1187	5.325	1.598	90.02	No
33	7.57	3.44	10.42	993	124.25	0.186	96.45	No
34	7.09	4.755	16.32	834.3	124.25	1.864	90.02	No
35	8.06	4.645	17.6	849	124.25	0.771	96.45	No
36	8.02	4.94	12.54	912.6	106.5	0.592	90.02	No
37	7.73	5.17	18.43	995	88.75	0.604	96.45	No
38	7.41	6.9	28.5	1242	106.5	0.99	90.02	No
39	8.09	4.13	27.3	939.7	106.5	0.902	109.31	No
40	8.36	5.48	13.53	112.3	106.5	1.008	109.31	No
41	7.65	4.38	11.5	553.1	106.5	1.182	430.81	No
42	7.9	3.66	20.2	547	106.5	1.913	231.48	No
43	7.72	2.54	9.98	382.1	88.75	1.003	337.575	No
44	7.3	3.405	10.88	347.4	177.5	1.666	115.74	No
45	7.295	3.65	13.79	453.3	71	0.72	83.59	No
46	7.695	4.62	26.63	947	124.25	1.551	96.45	No
47	7.9	2.91	11.6	541	106.5	0.716	90.02	No
48	7.455	1.09	10.53	444.5	88.75	0.777	90.02	No
49	7.495	2.605	23.63	643	195.25	0.583	45.28	No
50	7.835	4.395	22.7	935.1	195.25	0.712	80.375	No
51	7.45	5.9	26.2	1241.8	124.25	0.705	96.45	No
52	7.55	5.79	23.6	1041.3	177.5	0.685	80.375	No
53	7.585	2.59	16.12	639.5	159.75	0.639	96.45	No
54	7.975	4.645	19.2	729.4	159.75	0.562	83.59	No
55	7.385	2.935	15.81	368.1	159.75	0.654	83.59	No

56	7.585	1.9	20.22	743	124.25	0.431	109.31	No
57	7.56	1.82	11.65	321.33	124.25	0.526	128.6	No
58	7.53	3.073	18.9	875.4	159.75	0.598	45.28	No
59	7.5	5.115	21.43	545.2	177.5	1.392	90.02	No
60	7.2	6.505	29.62	993.6	124.25	0.102	96.45	No
61	7.2	6.1	27.2	1169.5	124.25	0.9	83.59	No
62	7.2	2.04	8.12	448.3	124.25	0.609	109.31	No
63	7.4	4.745	21.3	1031.2	124.25	0.519	96.45	No
64	7.37	5.445	27.4	1155.7	106.5	0.609	45.28	No
65	6.95	2.13	7.5	395.1	124.25	1.72	96.45	No
66	7.27	2.915	12.4	401	124.25	0.31	83.59	No
67	7.45	4.925	25.6	1307.5	213	1.418	45.28	No
68	7.605	2.76	6.5	658.5	124.25	0.697	90.02	No
69	8.05	3.15	19.64	846.4	142	0.685	115.74	No
70	7.61	2.5	10.43	671.5	159.75	0.717	115.74	No
71	7.665	2.435	17.3	707.5	284	0.963	128.6	No
72	7.595	2.7	15.5	819.4	195.25	0.513	80.375	No
73	7.98	3.04	9.31	529.5	142	0.772	83.59	No
74	7.6	2.325	6.4	211	124.25	1	64.3	No
75	7.57	2.275	18.52	398.5	195.25	1.513	96.45	No
76	7.94	4.285	20.1	906	142	1.2	90.02	No
77	7.7	5.22	27.1	1018.5	159.75	1.22	160.75	No
78	7.695	4.98	24.5	839	142	0.621	128.6	No
79	7.12	1.255	4.3	355.5	88.75	1.204	45.28	No
80	7.925	1.095	2.5	397.4	88.75	1.473	122.17	No
81	7.985	2.15	2.68	413.34	88.75	1.175	45.28	No
82	7.82	2.04	3.74	598.1	142	0.392	90.02	No
83	7.65	2.5	1.88	343.5	88.75	0.73	45.28	No
84	8	3.16	4.78	689.8	106.5	0.79	83.59	No
85	9.915	3.07	6.24	427	88.75	1.933	70.73	No

86	7.835	2.31	4.16	401.3	159.75	1.342	45.28	No
87	8.07	1.105	7.3	377.2	124.25	0.672	109.31	No
88	7.68	1.535	3.44	416.7	106.5	0.578	90.02	No
89	7.5	4.1	9.03	804.1	159.75	1.109	90.02	No
90	7.69	4.09	12.52	1171.3	106.5	1.185	96.45	No
91	7.7	4.18	16.58	918.2	159.75	0.888	80.375	No
92	7.3	2.3	8.02	509.2	195.25	0.1	135.03	No
93	7.11	1.08	10.1	313.7	284	1.578	128.6	No
94	7.74	2.47	2.12	448.3	142	0.949	122.17	No
95	7.69	1.91	4.08	269.1	124.25	1.09	141.46	No
96	7.48	3.66	15.02	452.9	177.5	1.263	128.6	No
97	7.41	3.56	18.04	528.4	124.25	0.94	180.04	No
98	7.59	1.44	6.02	204.7	159.75	0.698	192.9	No
99	7.51	2.05	7.16	378.4	124.25	1.109	128.6	No
100	7.42	2.43	12.4	457.5	142	0.449	128.6	No

Samples from 101 till 200 were taken from different neighborhoods of middle income area and their results are shown in table 4.2

Table 2: Drinking water quality analysis of samples from middle income area

Sr. No.	**pH**	**Turbidity (NTU)**	**TSS (mg/l)**	**TDS (ppm)**	**Chlorides (mg/l)**	**Fluorides (mg/l)**	**Hardness (mg/l)**	**Fecal Coliform**
	6.5-9.5	**5NTU**	**25mg/l**	**100ppm**	**250mg/l**	**1-1.5mg/l**	**500mg/l**	**None**
101	7.85	1.16	1.2	220	142	0.416	228.3	No
102	7.98	1.75	2.1	192	124.25	0.515	243	No
103	7.96	0.64	0.1	183	142	0.443	124	No
104	7.78	0.95	0.3	430	230.75	1.105	53.3	No
105	7.8	0.76	3.8	440	248.5	0.466	176.2	No
106	7.91	0.76	0.6	140	88.75	0.526	287.243	Yes
107	7.82	0.84	1.2	333	159.75	0.265	213.23	Yes

108	7.84	1.09	1.32	178	106.5	1.139	209.1	Yes
109	7.94	1.88	2.13	182	106.5	0.642	150.463	No
110	7.96	0.42	1.3	98.5	284	0.459	87.33	Yes
111	7.62	1.01	1.54	485	266.25	0.463	237.7	No
112	7.88	1.02	2.7	241	159.25	0.224	342.5	No
113	7.77	15	3.1	350	195.25	0.408	67.33	No
114	8.1	0	0.76	172	88.75	0.674	232.53	No
115	8.1	0.33	0.8	187	195.25	0.304	77.23	No
116	7.89	0.47	0.56	260	159.75	1.434	211	No
117	7.98	0.29	0.73	179	88.75	0.314	76.32	No
118	7.99	0.25	0.01	172	106.5	0.344	163.3	No
119	7.92	0.25	0.006	173	159.75	1.098	45.354	No
120	7.96	0.18	2.5	171	213	0.287	101.22	No
121	7.95	0.48	3.2	209	88.75	0.348	40.556	No
122	7.63	0.82	4.3	480	288	0.367	360	No
123	7.99	0.31	2.2	209	195.75	0.837	165.3	No
124	7.94	1.01	3.12	217	124.25	0.694	322.1	No
125	7.89	0.49	1.4	244	159.75	0.473	75.99	No
126	7.46	2.05	1.34	189	125.25	1.375	45.67	No
127	7.11	1.26	1.54	187	142	1.827	312	No
128	7.77	0	7.9	195	159.75	1.53	22.43	No
129	8.19	0.03	6.4	420	124.25	1.208	243.12	No
130	8.25	0.67	7.2	210	88.75	1.7	231.44	No
131	8.42	1.7	3.33	164	88.75	1.62	453	No
132	8.43	1.66	0.76	178	88.75	1.042	210	No
133	8.41	1.24	0.4	178	88.75	0.162	331.44	No
134	8.4	0.11	0.77	172	71	1.687	124.65	No
135	8.4	0.68	0.42	186	88.75	0.429	65.43	No
136	8.24	0.74	0.32	161	71	1.2	50.38	No
137	8.5	0	0.6	331	88.75	0.277	76.687	No

138	8.38	0.68	2.54	316	88.75	0.18	96.54	No
139	8.38	0.3	0.43	171	71	1.281	64.28	No
140	8.45	0.82	2.5	188	124.25	1.393	102.37	No
141	8.49	0.72	7.3	168	88.75	0.844	220.2	No
142	8.4	1.5	3.53	494	71	1.971	214.2	No
143	8.35	1.38	1.5	177	88.25	1.557	78.32	No
144	8.4	1.16	4.2	162	88.25	0.067	283.1	No
145	8.42	0	1.98	180	71	1.404	213	No
146	8.45	0	0.88	164	106.5	0.6632	255.2	No
147	8.37	0.4	0.79	172	106.5	0.456	209.2	No
148	8.43	0	0.63	181	71	0.603	233.1	No
149	8.32	0.33	0.6	178	88.75	0.305	311.28	No
150	8.39	0.1	0.53	227	106.5	1	222.43	Yes
151	8.43	1.5	1.63	186	88.75	1.429	389.3	No
152	8.37	1.01	1.7	217	71	0.791	321.9	No
153	8.33	0.67	1.2	381	88.75	1.091	254.3	Yes
154	8.34	0.75	1.6	207	88.75	0.622	223.34	No
155	8.35	0.66	0.5	218	106.5	1.134	311.1	No
156	8.47	0.64	3.1	179	53.25	1.059	90.543	No
157	8.27	0.34	2.1	203	106.5	1.04	76.886	No
158	8.44	0	3.22	187	106.5	1	99.21	Yes
159	8.36	1.11	1.65	180	71	1.06	70.2	Yes
160	8.4	1	1.9	168	88.75	1.22	96.4	No
161	8.5	0.8	1.43	280	88.75	0.87	165.33	Yes
162	7.18	2.41	1.2	208	53.25	1.01	175.6	Yes
163	8	3.03	4.2	193	71	1.18	154.3	No
164	8.06	2.79	3.2	194	106.5	1.78	57.4	No
165	7.87	3.28	3.3	170	88.75	0.35	86.4	No
166	7.81	2.03	2.4	192	106.5	0.65	187	No
167	7.78	2.81	1.5	175	71	1.38	154.74	No

168	7.8	2.23	2.4	171	88.75	1.16	66.34	No
169	7.83	1.83	3.6	165	35.5	0.31	94.498	Yes
170	7.86	2.71	2.5	169	266.5	0.47	337.2	Yes
171	7.96	1.75	1.64	103	88.75	1.49	122.98	No
172	7.99	0.95	1.43	190	71	1.17	73.34	Yes
173	7.93	1.38	1.3	191	124.25	1	99.754	No
174	8.09	1.32	1.5	121	71	1.21	374	No
175	7.98	0	1.31	255	88.75	1.23	211.32	Yes
176	8.03	1.3	1.4	208	88.75	1.6	109.84	No
177	7.81	1	1.52	248	53.25	1.32	322	Yes
178	8.01	1.13	2.1	194	71	0.64	165.3	No
179	8.11	0.22	2.4	290	53.25	1.48	321	No
180	7.98	0.23	1.54	193	284	1.37	232.343	No
181	8.15	0.99	1.3	212	71	1.91	112.1	No
182	8.11	0	0.2	220	71	0.61	274	No
183	8.1	1	0.33	192	17.75	1.14	62.55	No
184	8	0	0.65	288	88.75	1.01	176.96	No
185	7.78	0.64	0.3	296	53.25	1.3	221.1	No
186	7.5	0.42	0.12	265	71	0.37	165	No
187	7.77	0.72	0.009	284	124.25	0.42	143.22	No
188	7.32	0.32	0.25	265	88.75	1.39	121.76	No
189	8	0.62	0.03	234	142	1.89	106.3	No
190	8.1	1	0.23	264	106.5	1.27	270.2	No
191	7.8	1.63	0.1	186	88.75	1	233	No
192	7.44	1.32	2.1	199	88.75	1.11	187.2	No
193	7	0.95	0.54	200	71	1.23	221.3	No
194	8.03	0.53	0.3	274	71	0.43	76.5	No
195	8.02	1.2	0.1	295	106.5	0.82	88.45	No
196	7.87	0	0.54	187	53.25	0.988	99.31	No
197	7.66	2	0.32	288	88.75	1	154.33	No

198	7.43	0.42	0.12	277	88.75	1.3	287	No
199	7.11	0.73	0.31	277	35.5	1.2	211.1	No
200	8.5	0.7	0.6	204	71	0.856	111.54	No

Samples from 201 till 300 were taken from high income area neighborhoods and their results are shown in table 4.3.

Table 3: Drinking water quality analysis of samples from high income areas

Sr. No.	**pH**	**Turbidity (NTU)**	**TSS (mg/l)**	**TDS (ppm)**	**Chlorides (mg/l)**	**Fluorides (mg/l)**	**Hardness (mg/l)**	**Fecal Coliform**
	6.5-8.5	**5NTU**	**25mg/l**	**1000ppm**	**250mg/l**	**1-1.5mg/l**	**500mg/l**	**None**
201	8.22	1.97	1.45	184	71	0.766	89.33	No
202	8.12	2.5	3.1	157	106.5	0.947	121.76	No
203	8	2.33	1.63	153	71	0.928	114.2	No
204	7.98	2.03	2.01	165	53.25	0.887	91.343	No
205	8.1	1.62	4.6	184	88.75	1.303	142.98	No
206	8.42	1.64	3.2	158	106.5	0.836	131.75	No
207	8.5	1.56	5.32	184	88.75	0.839	78.43	No
208	8.41	1.2	2.13	174	53.25	1.497	101.22	No
209	8.12	1.81	3.8	148	159.75	1.21	213.44	No
210	8.3	1.74	2.54	158	71	1.201	263.1	No
211	8.1	0.98	2.7	159	88.75	1.264	211.54	No
212	7.93	1.39	3.71	152	71	1.616	143.2	No
213	8	1.62	1.69	174	71	1.083	127.21	No
214	8.11	1.99	3.8	195	142	0.786	221.2	No
215	8.5	1.62	2.56	185	106.5	0.782	96.254	No
216	8.7	1.46	4.73	183	71	0.984	78.23	No
217	8.51	1.9	3.01	153	88.75	0.974	154.2	No
218	8.47	1.98	0.6	150	53.25	0.699	113.212	No
219	8.67	1.61	2.5	177	71	1.263	165	No

220	8.39	1.27	3.2	185	71	0.922	215.32	No
221	8.35	0.73	4.3	173	106.5	0.837	226.94	No
222	8.52	0.92	2.2	153	71	0.574	311.23	No
223	8.72	0.6	3.12	175	71	0.964	153.32	No
224	8.19	0.61	1.4	173	35.5	1.242	234.4	No
225	8	1.43	1.34	133	71	1.26	212.23	No
226	7.98	1.8	1.54	125	106.5	0.835	126.2	No
227	8.57	1.62	3.9	192	106.5	0.634	153.2	No
228	8.7	1.64	1.74	153	35.5	0.935	111.65	No
229	8.5	1.73	2.2	177	71	0.933	154.32	No
230	8.15	1.85	3.33	175	88.75	0.931	99.75	No
231	8.46	1.97	0.76	176	88.75	0.614	234.3	No
232	8.65	1.47	0.4	153	88.75	1.281	143	No
233	8.52	1.31	2.77	150	71	1.186	98.13	No
234	8.38	1.32	2.42	150	53.25	0.862	89.65	No
235	8.31	1.28	2.32	149	88.75	0.281	132.8	No
236	8.46	1.28	3.6	153	106.5	1.592	84.38	No
237	8.39	1.2	2.54	153	124.25	0.804	97.45	No
238	7.75	1.91	2.43	159	106.5	1.69	121	No
239	8	1.63	2.5	152	53.25	1.623	128.32	No
240	8.45	1.59	3.3	153	88.75	0.864	221	No
241	8.38	1.06	3.53	151	71	0.776	238.22	No
242	8	1.48	3.5	415	159.75	0.513	176.3	No
243	8.21	2.04	1.2	174	88.75	0.903	158.488	No
244	7.41	1.84	1.98	434	177.5	0.493	186.32	No
245	8.47	1.56	2.88	169	124.25	1.19	166.44	No
246	8.41	1.48	2.79	183	88.75	0.688	187.38	No
247	8.44	1.71	2.63	163	106.5	1.282	198.31	No
248	8.17	1.63	2.6	194	142	0.875	177	No
249	7.4	1.66	4.53	400	213	0.767	153.76	No

250	8.53	1.69	3.63	202	106.5	1.444	163.44	No
251	8.37	1.03	4.7	184	71	1.325	183.3	No
252	8.55	0.36	2.22	155	106.5	1.121	221	No
253	8.37	0.38	3.62	155	88.75	0.834	176.37	No
254	8.33	0.29	4.65	152	88.75	0.639	163.54	No
255	8.28	0.76	3.1	151	88.75	1.04	185.3	No
256	8.34	0.54	2.1	150	88.75	0.768	139.4	No
257	8.3	0.76	3.22	151	124.25	0.706	177.3	No
258	8.28	0.33	2.65	152	71	1.16	121.98	No
259	8.25	0.31	2.9	150	71	1.45	176.4	No
260	8.24	1.07	3.43	152	106.5	0.901	99.46	No
261	8.02	0.7	5.2	154	71	0.878	111.02	No
262	8.29	0.66	4.2	151	88.75	1.01	299.8	No
263	8.22	0.86	3.2	156	71	0.965	215.32	No
264	8.4	0.53	4.39	151	106.5	0.395	180.5	No
265	8.23	1.12	2.84	156	71	0.838	197.45	No
266	8.3	1.23	3.5	151	124.25	1.22	133.2	No
267	8.4	1.3	2.4	175	71	1.31	163.5	No
268	8.5	1.3	3.6	158	71	1.47	327.2	No
269	8.22	0.71	2.5	153	106.5	0.779	112.3	No
270	8.5	0.81	3.64	160	53.25	0.917	128.73	No
271	8.3	0.64	2.43	157	124.25	0.574	128.7	No
272	8.4	1.38	4.63	155	124.25	0.281	176.36	No
273	8	0.97	4.5	154	106.6	0.873	56.34	No
274	8.4	1.43	5.31	160	71	0.659	84.38	No
275	8.2	1.38	9.4	153	71	0.878	58.479	No
276	8.4	1.34	1.52	155	88.75	1.11	76.534	No
277	8.7	1.27	5.1	162	88.75	0.752	132.2	No
278	8.2	0.76	3.4	131	88.75	0.998	163.23	No
279	8.1	1.18	4.54	212	88.75	0.92	176.38	No

280	8.6	1.28	3.3	157	124.25	1.32	273.8	No
281	8.5	1.56	1.4	152	71	0.336	198.89	No
282	8.2	1	4.11	150	71	0.648	167.38	No
283	8.1	1.1	4.85	158	106.5	0.693	321	No
284	8	0.8	2.43	153	71	0.209	252.2	No
285	8.22	0.9	3.87	154	88.75	1.67	213.3	No
286	8.3	1.2	3.55	150	106.5	0.983	198.3	No
287	8.6	1.1	3.92	161	71	0.349	176.4	No
288	8.12	1.1	2.82	155	53.25	0.967	154.3	No
289	8.1	0.6	3.423	151	88.75	1.28	99.23	No
290	8.4	0.5	4.43	159	106.5	0.665	120.2	No
291	8.3	0.55	4.13	160	88.75	0.93	78.45	No
292	8.5	0.9	3.12	153	88.75	0.887	93.113	No
293	8	0.8	4.5	153	124.25	0.284	97.573	No
294	8.22	1	6.44	155	106.5	0.38	99.287	No
295	8.7	1.3	7.1	154	53.25	0.956	91.3	No
296	8.34	1.22	4.81	152	71	0.31	50.378	No
297	8.5	1.1	5.3	156	71	0.89	111.2	No
298	8.11	0.73	1.62	160	88.75	0.462	132.2	No
299	8.2	0.66	4.39	162	106.5	1.32	124	No
300	8.6	0.38	2.53	150	88.75	1.11	98.78	No

Further discussion of the parameters is discussed further.

3.2 pH

In the Low Income Area, the pH was within limits with only a few samples lower than the standard pH and a few samples with pH higher than the standard limit. The pH of the drinking water samples from the Middle income area were all within the 6.5-8.5 range. On the other hand, the samples from the High Income Area mostly had values of 8 pH. Only a few of the samples were above the 8.5 limit. The graphs for the three areas are as shown in the fig 4.1, 4.2 and 4.3.

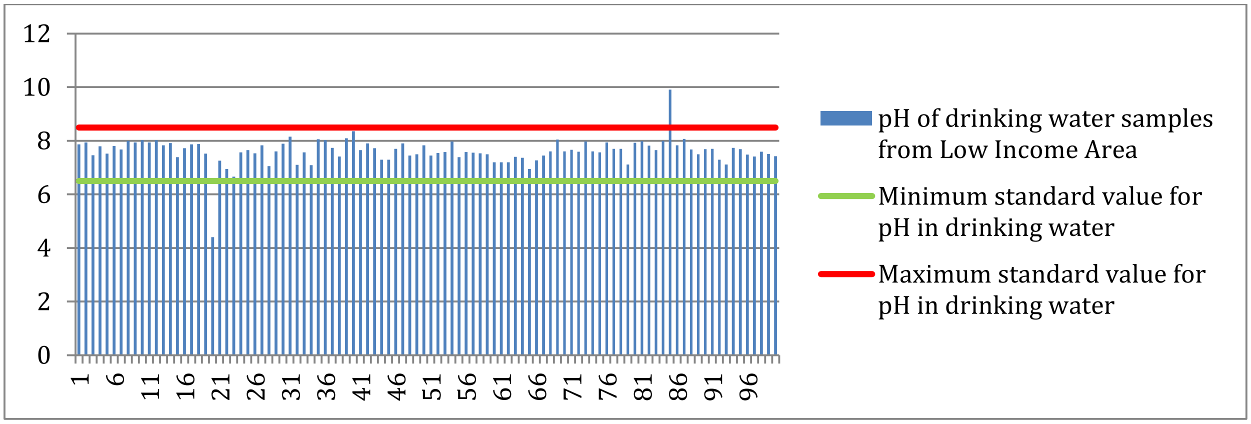

Fig 1: Ph of drinking water samples from low income area

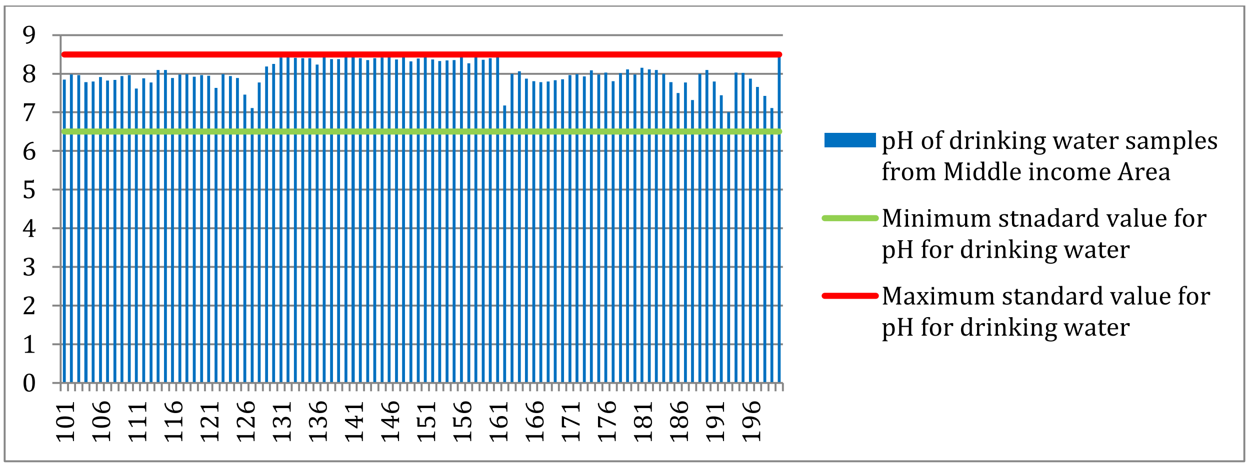

Fig 2: pH of drinking water samples from middle income area

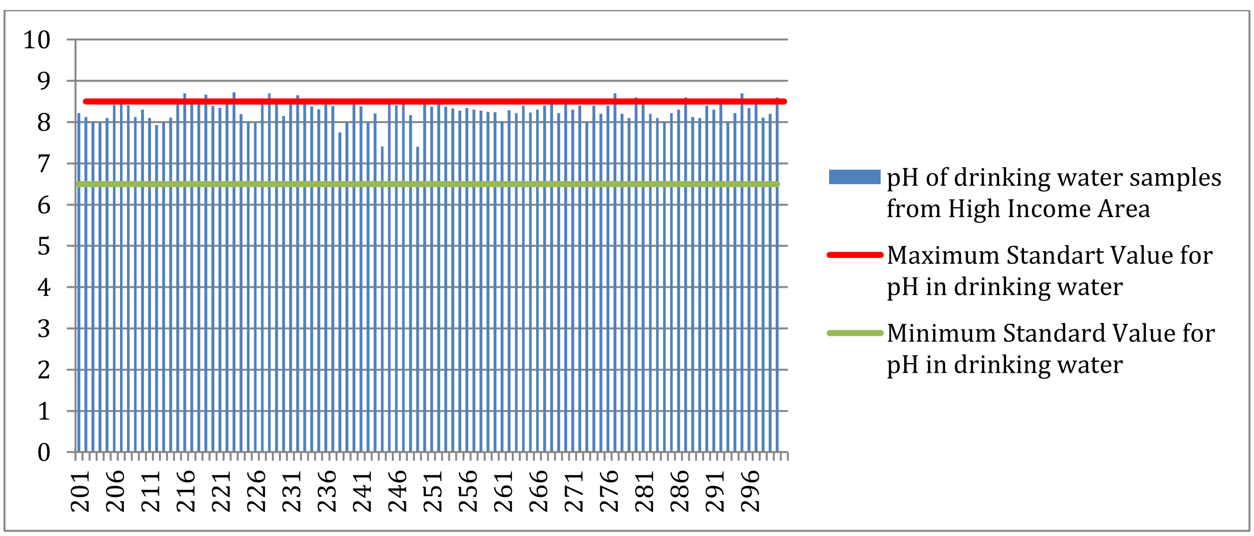

Fig 3: pH of drinking water samples from high income area

3.2 Turbidity

The standard limit for turbidity is 5NTU. Low income area showed variation in the samples. 13 samples from low income area exceeded the standard limit while most of the samples were above 2NTU. Samples from both Middle- and High-Income Areas were within the standard limit for turbidity except for one sample from Middle area which crossed the limit. The highest value recorded for the low-income area was 6.9 and highest value recorded for the middle-income area was 15. The highest turbidity value for high income area was 2.5. The turbidity for the High Income Area drinking water samples was well within the standard limit. The turbidity values for low, middle and high income areas are shown in the figures 4, 5 and 6.

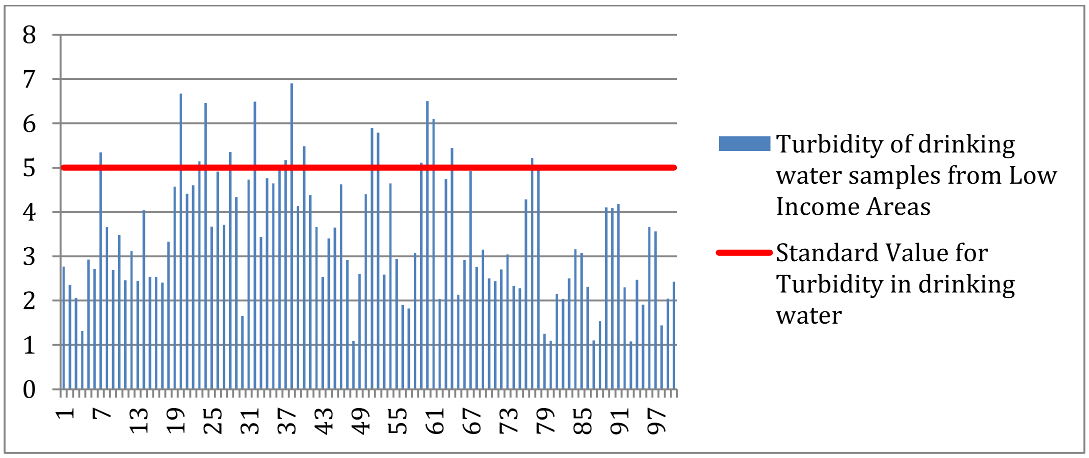

Fig 4: Turbidity of drinking water samples from low income area

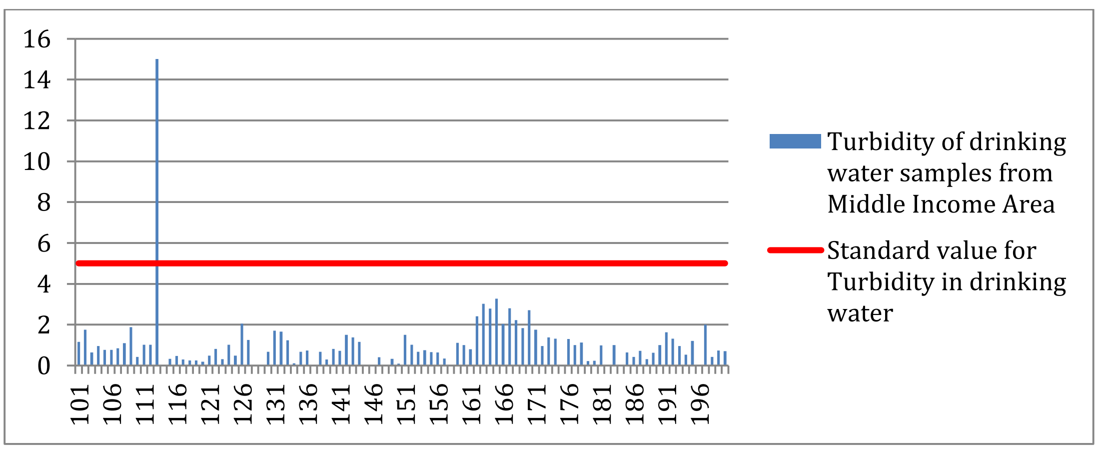

Fig 5: Turbidity of drinking water samples from middle income area

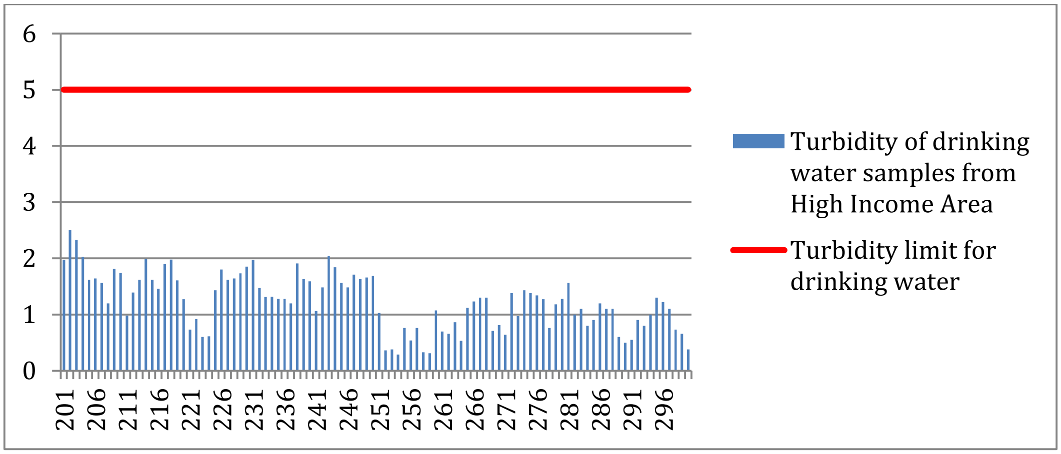

Fig 6: Turbidity of drinking water samples from high income area

3.3 TSS

TSS values in drinking water should be below 25 mg/l in water. Drinking water samples from low income area showed fluctuations in the values and exceeded the limit. 12 samples were above the limit and highest vale recorded to be 29.62 mg/l. TSS values from middle- and high-income areas were below the limits. Highest value from middle income area was recorded to be 7.9 mg/l while highest value showed by high income area was 9.4 mg/l.

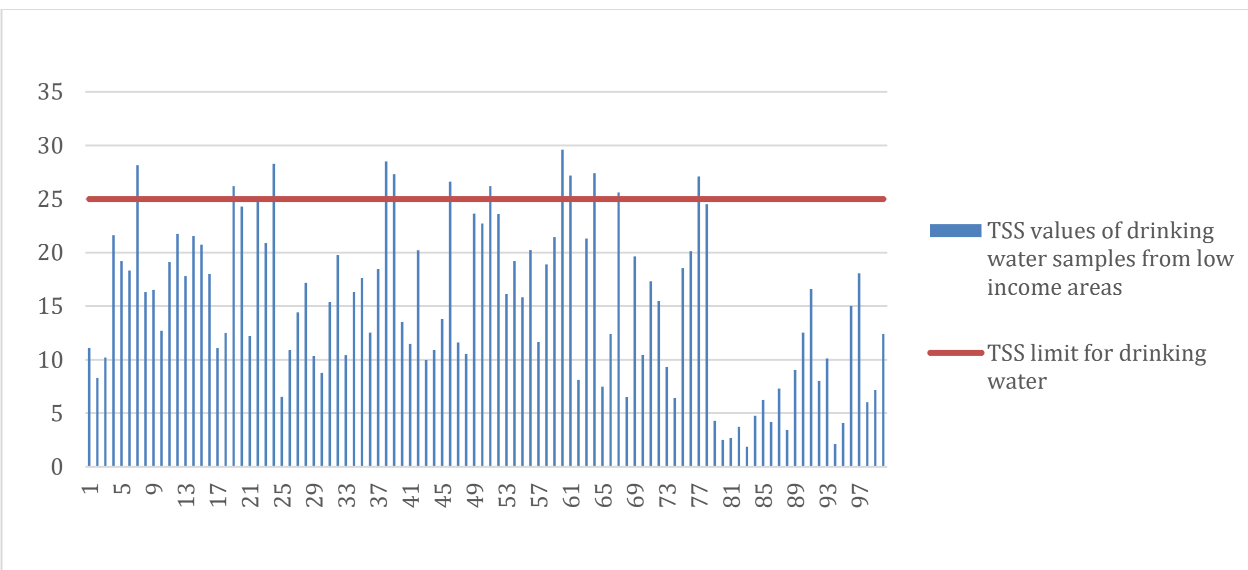

Fig 7: TSS values of drinking water samples from low income area

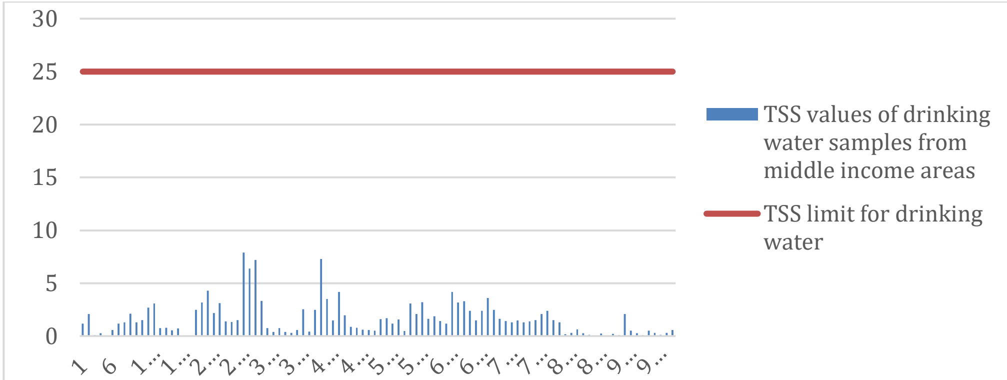

Fig 8: TSS values of drinking water samples from middle income area

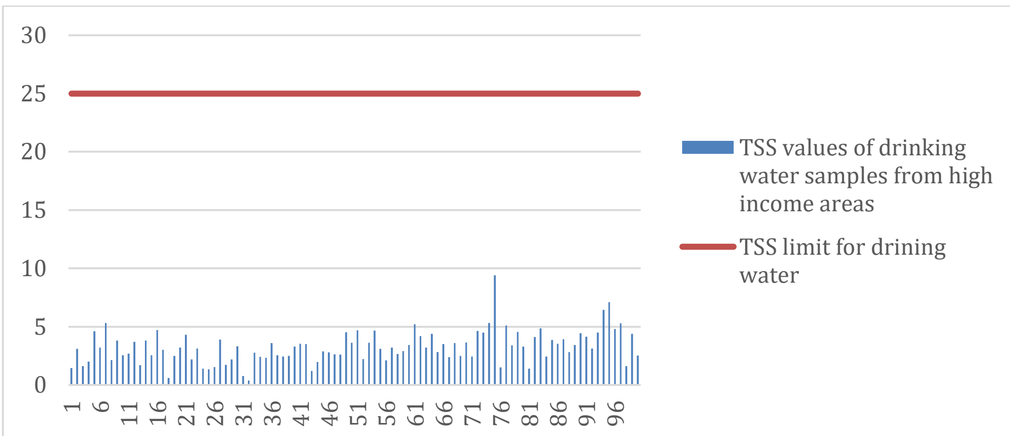

Fig 9: TSS values of drinking water samples from High income area

3.4 TDS

The Total Dissolved Solids values in low income area exceeded the limit. The standard limit for TDS in drinking water is 1000ppm. The TDS values for low income areas were recorded in the range of 112.3-1307.5ppm and they were highly fluctuating. TDS values for middles income area were in the range of 98.5- 494 ppm. The TDS values recorded for high income areas were mostly under 200ppm. The highest value in the low-income area was recorded to be 1307.5 ppm as shown in the figures 10, 11 and 12.

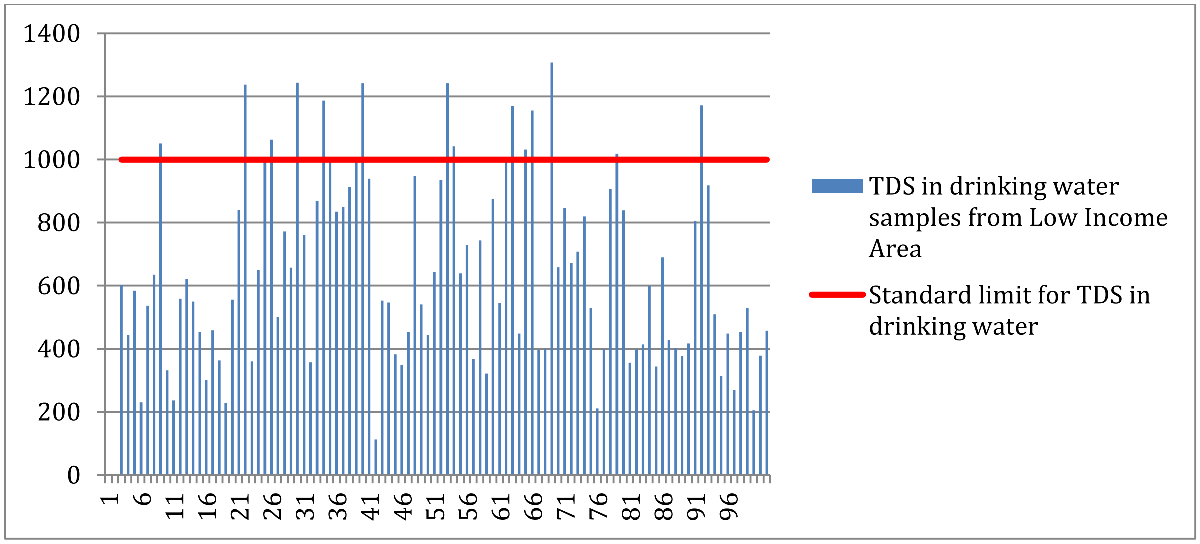

Fig 10: TDS in drinking water samples from low income area

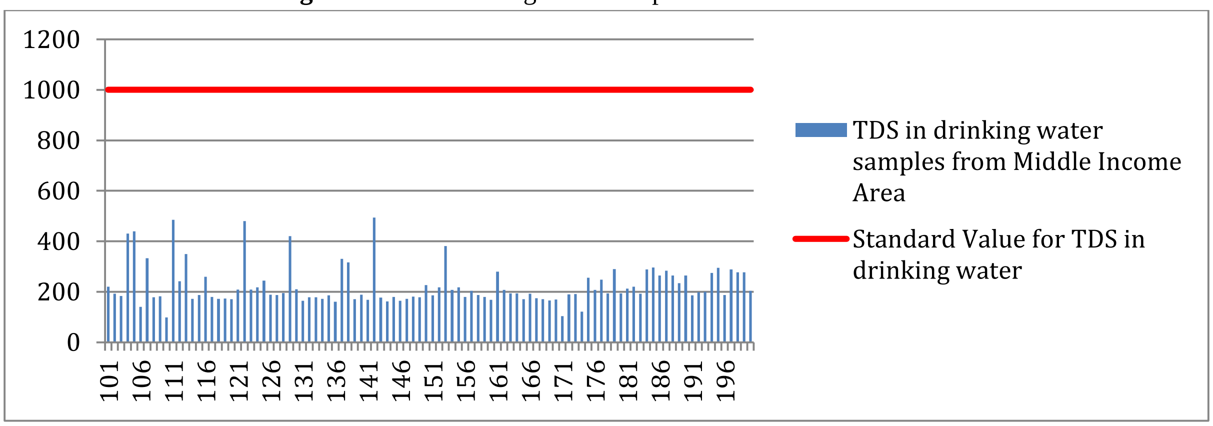

Fig 11: TDS in drinking water samples from middle income area

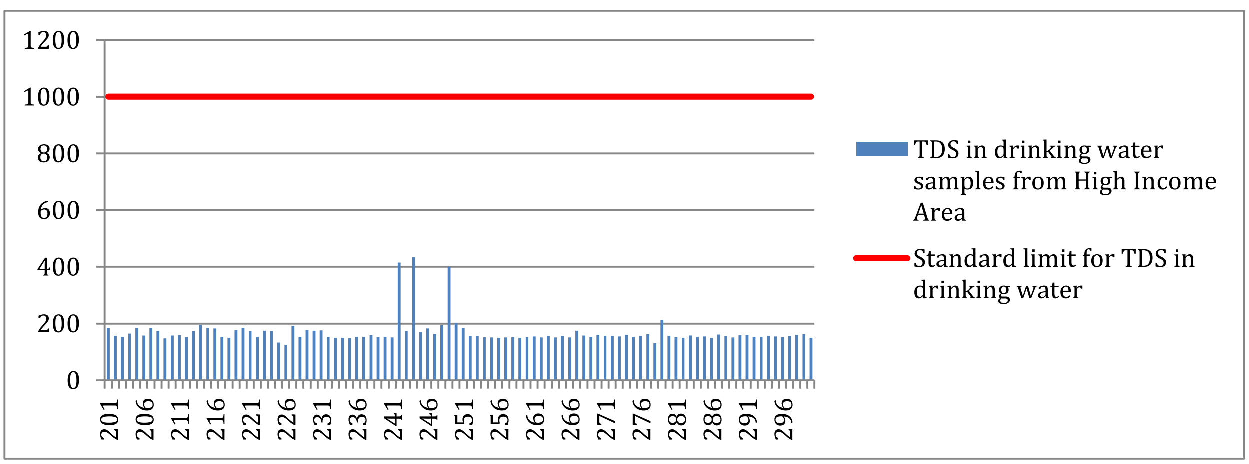

Fig 12: TDS in drinking water samples from high income are

3.5 Total Hardness

The standard limit for hardness in drinking water is 500 mg/l. The hardness in drinking water of low, middle and high income areas was below the standard set by WHO. The highest value recorded in the low income area was 430.81 mg/l. The total hardness values in the middle-income area were fluctuating and the highest value recorded was 453 mg/l. The highest value for the high-income area was recorded to be 327.2 as shown in figures 13, 14, 15.

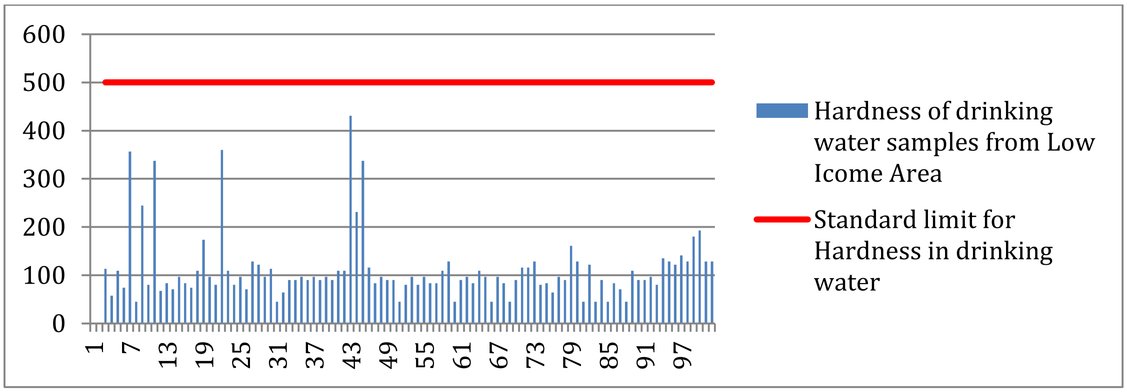

Fig 13: Total hardness in drinking water samples from low income area

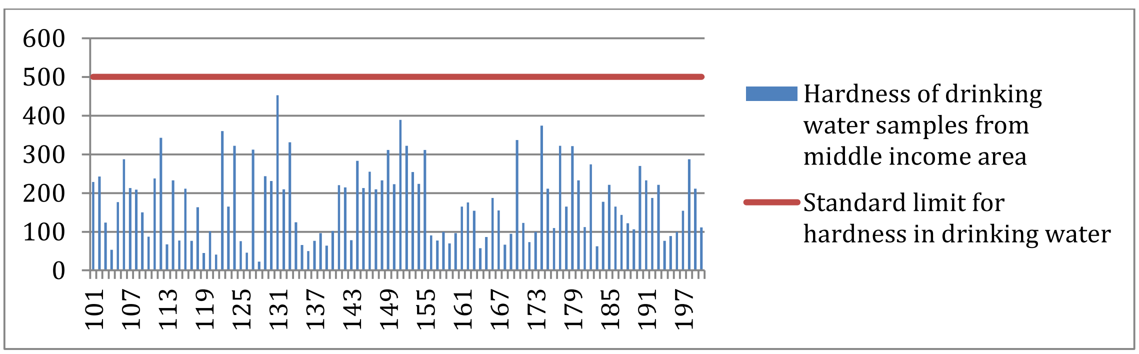

Fig 14: Total hardness in drinking water samples from middle income area

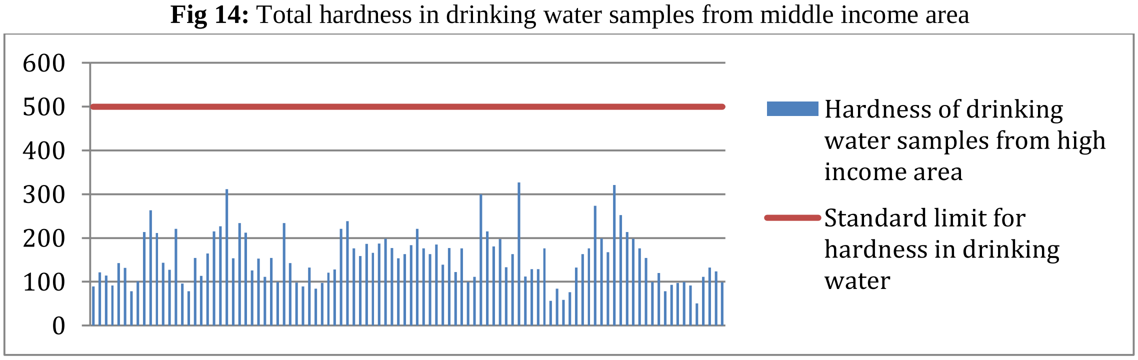

Fig 15: Total hardness in drinking water samples from high income area

3.6 Chlorides

250 mg/L is the standard limit for Chlorides in drinking water. The value for chlorides in drinking water for low income areas was mostly in the range of 5.325-213 mg/l. Some of the values exceeded the standard and recorded to be 284 mg/l (Fig 4.16). The chloride values for the middle income area were mostly under the limit. 5 samples exceeded the standard and recorded to be in the range of 250-288 mg/l. All the values of chloride in high income areas were in the standard range. The highest chloride value recorded was 213 mg/l.

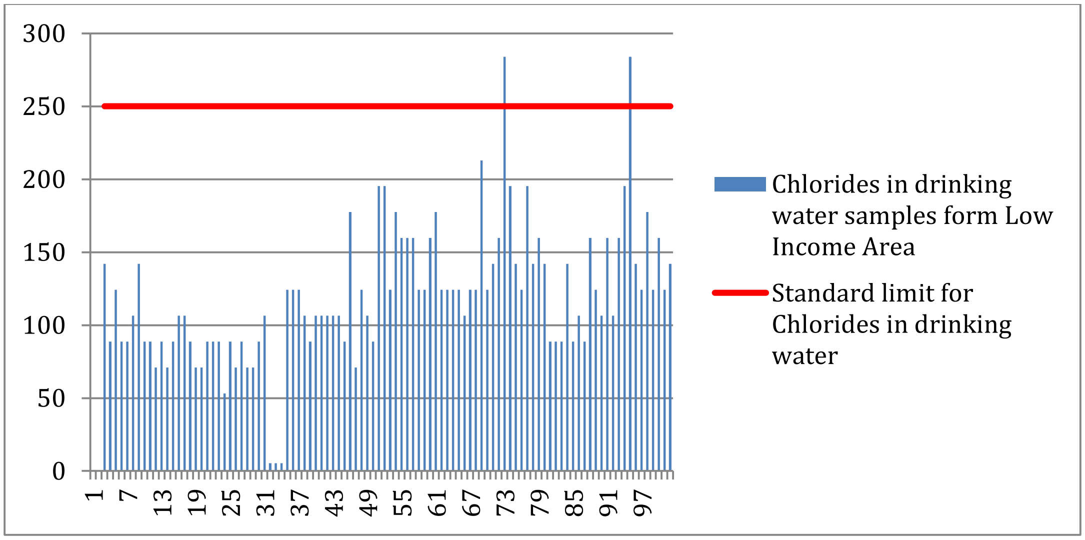

Fig 16: Chlorides in drinking water samples from low income area

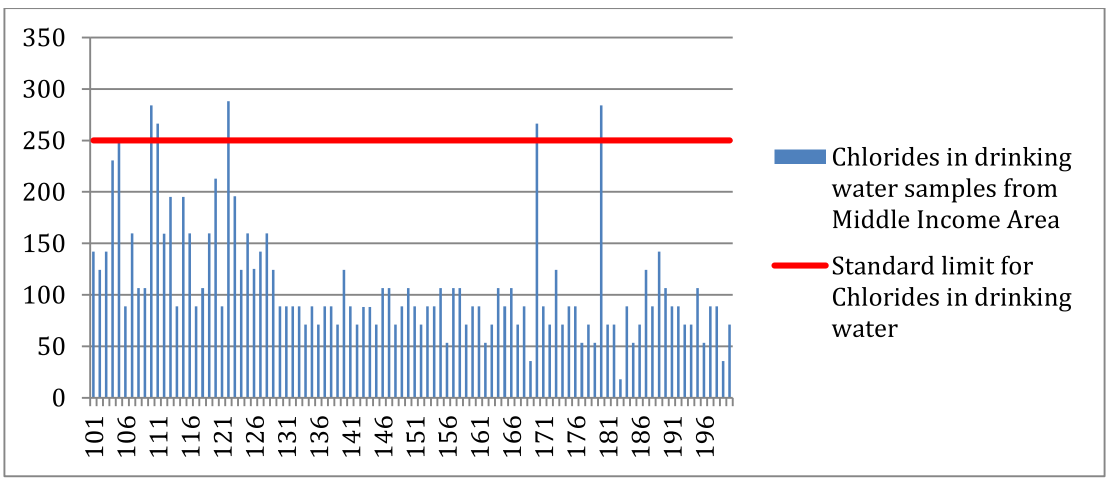

Fig 17: Chlorides in drinking water samples from middle income area

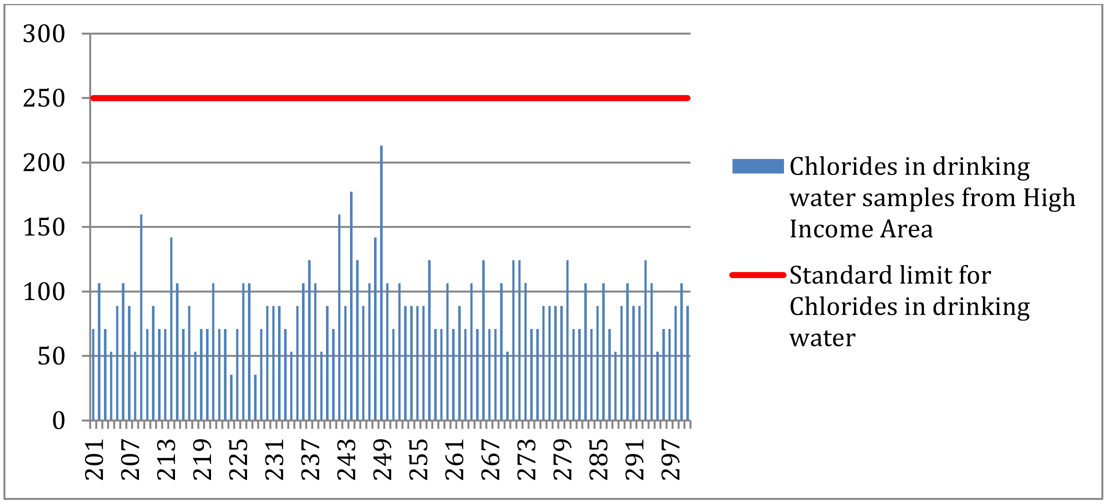

Fig 18: Chlorides in drinking water samples from high income area

3.7 Fluorides

The standard limit for fluorides in drinking water is 1.5 mg/L. The values in drinking water samples were highly fluctuating but mostly remained in the limits. Few samples in low, middle and high income areas showed values more than the standard; for low income area the highest value recorded was 1.9 , for middle income area the highest value recorded was 1.971 and for high income area the highest fluoride value recorded was 1.69.

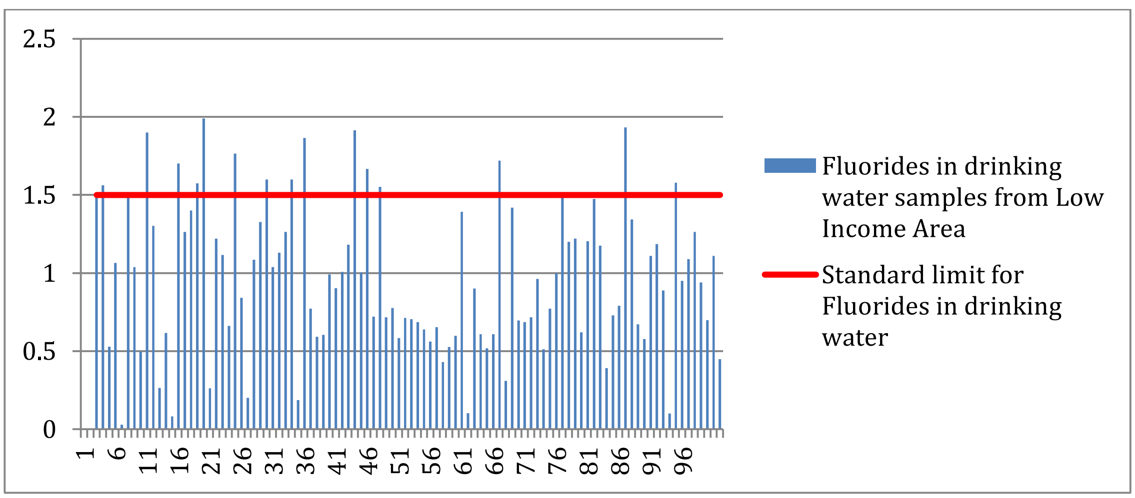

Fig 19: Fluorides in drinking water samples from low income area

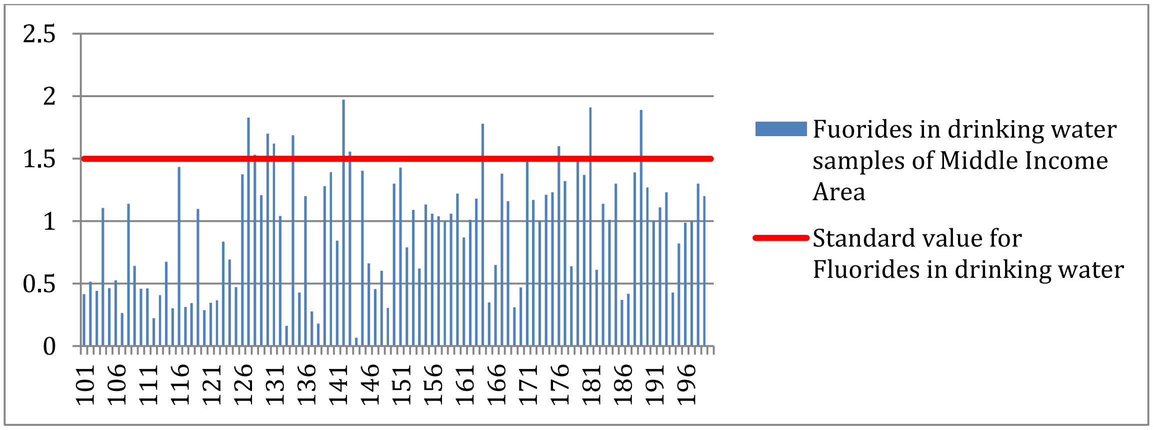

Fig 20: Fluorides in drinking water samples from middle income area

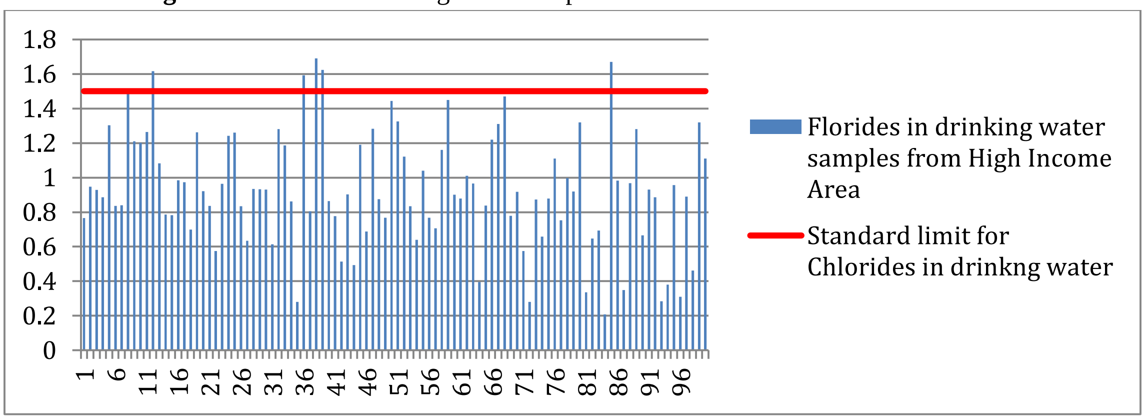

Fig 21: Fluorides in drinking water samples from high income area

3.8 Fecal Coliform

In drinking water, no fecal coliform should be found. Drinking water should be clean from any kind of biological organisms. The Low income and the High-Income areas water samples showed no presence of any biological organisms but 12 samples out of 100 from the Middle-Income area showed presence of biological organisms.

4. Discussion

The study explored the drinking water quality of Samanabad, Lahore through the collection of 300 samples from the area divided into low, middle and high income. Many studies have shown that in many areas of Pakistan water quality is deteriorating [22, 23, 25], as per the results we can depict that the water quality of the Samanabad area is also deteriorating. The water samples collected from the low income area revealed high levels of TSS, TDS, turbidity and worst of all presence of fecal coliform. Few of the samples from middle income area also showed presence of fecal coliform. It can be predicted that the water quality of the Samanabad area might deteriorate further in the coming years as some other parameters also showed fluctuating values. pH is considered to be a significant parameter in water quality analyses. pH indicates the alkaline or acidic nature of water. If the pH of the water sample is below 7, the sample is considered acidic. If pH of water is above 7, the water sample is alkaline. As seen in figure 4.1, 4.2 and 4.3 the samples were all within range for pH with only some samples crossing the limit. The samples with exceeding values might be an apparatus error or could be some other external factor. Turbidity values of the samples are shown in Figures 4, 5 and 6. The values were above the standard limit for the low income areas. The middle income and high income samples were well within range with a few fluctuations only. Turbid water indicates the presence of TSS and TDS. The high turbidity values indicate that the water is not as clean as it might appear. High levels of turbidity even make the water cloudy and hinder its ability to pass light. There is a huge change that the water with high levels of turbidity contains disease causing organisms. Turbidity itself does not cause any kinds of health impacts. However, it does lower the disinfection rate of the water and provides a medium for microbial growth. Therefore, turbidity values higher than the standard limit indicate risk of disease causing microorganisms. It is advised to boil turbid water before consumption as boiling generally kills any microbial organisms that might be present in the water. TSSs are the suspended solids which can be separated from water with the help of a filter paper as their size is generally bigger than the TDSs. Figures 7, 8, and 9, show the TSS values of the drinking water samples from low, middle- and high-income areas, respectively. As it can be seen from the graphs, the samples from low income area revealed high TSS values. TSS first and foremost affects the aesthetics of the water. Due to presence of suspended solids the water does not appear clean. If we talk about the health impacts related to TSS, they are completely dependent on the type of the suspended solid. If the solids found in the drinking water sand or silt they do not cause any harm to the body in minor amounts; just give the water a dirty look. On the other hand, in case of bacteria and algae or metals [31], human health impacts do occur. Bacteria and algae casue gastrointestinal issues and metals have very serious health impacts which in worst case scenario may even lead to death. But as mentioned before, there are very low chances of metals being present in the drinking water samples of Samanabad area. Therefore, the suspended solids are most probably sand or silt or dirt mixed into water due to old pipe lines. The inorganic matter and minute amounts of organic matter dissolved in water are Total Dissolved Solids. Figures 10, 11 and 12 show TDS values in drinking water samples from low, middle and high income areas, respectively. TDS values were also seen to be crossing the standard value in the low income samples. Drinking water with high TDS values is considered unfit for consumption as it indicates the presence of ions like sodium [23], potassium [25], chloride and other toxic ions. Due to the presence of such ions the water might taste salty, bitter or even metallic. These elements are not safe for human consumption as they can cause a variety of health impacts including nausea, vomiting, dizziness, lung irritation, etc. Consumption of water with high levels of TDS for a longer period of time can even cause the development of chronic health conditions like cancer and nervous system disorders. Other health impacts related to high levels of TDS include liver and kidney failure, weak immunity, new born babies born with birth defects. Hardness, which is the measure of minerals like magnesium and calcium, was determined using the titration method. Figures 13, 14, and 15 show that all the samples from low, middle- and high-income areas were within range. As mentioned before, chloride in drinking water mainly occurs due to disinfection of water. Other sources include drilling for oil and natural gas, fertilizers, landfill leachate, mining, etc. Figure 4.18 shows that all the samples from high income areas were well within range. On the other hand, figure 4.16 and 4.18 show that some of the samples were crossing the set limit. [25] The cause behind this might be the chlorination process required for disinfection of water. As mentioned, TDS presence indicates presence of chloride ion as well; hence some of the low income area samples were seen showing presence of chloride. Fluoride values were highly fluctuating and many samples were above the limits. Higher concentration of fluoride than 1.5 mg/l in ground water might be due to weathering and leaching of fluoride bearing minerals from rocks and sediments [36]. High levels of Fluorides in water can cause dental fluorosis in people. Chance of getting fluorosis is high in people who drink water well. Dental fluorosis was slightly greater in patients who drank water well. [37] Figure 4.19, 4.20 and 4.21 show the fluorides in the samples. As it can be seen quite a few of the samples were seen to be crossing the limit. This may be due to the weathering of minerals or it might be occurring due to anthropogenic activities. The exact cause should be determined and appropriate action should be taken. Fecal coliform was confirmed in the low and the middle income samples which confirm the suspicion that biological impurities are common in drinking water. [32] High income area samples were all clear. It is a health hazard. Fecal coliform can arise in water from combined sewer overflows, sewer malfunctions etc. [38]. Fecal coliforms are not themselves pathogenic, but they are indicator organisms for pathogenic bacteria and sewage contamination. Waterborne diseases can occur due to these pathogenic organisms. Some of the diseases include typhoid fever, viral and bacterial gastroenteritis and hepatitis A [39]. The presence of fecal coliform indicates that there might be a leakage in the underground pipeline system causing the contamination of the drinking water. Since the low income area samples were mostly affected it means that the underground pipeline is majorly affected it that particular area. For the middle income area, the issue can still be handled as the problem was only occurring in one neighborhood.

References

Ahmad M, Rafiq M, Akram W, Tasneem MA, Ahmad N, Iqbal N, *et al*. Assessment of aquifer system in the city of Lahore, Pakistan using isotopic techniques. International Atomic Energy Agency. 2002;184:109–33.

Ask the Doctors. Ask the Doctors – Is water with a high pH safe to drink? https://connect.uclahealth.org/2018/08/31/ask-the-doctors-is-water-with-a-high-ph-safe-to-drink/ [Retrieved on August 31, 2021]

Baig NM, Laghari Z, Panhwar AF, Qambrani MR, Palh ZA. Perception of Drinking Water and its Associated Diseases in the Residents of Hyderabad Sindh, Pakistan. Pakistan Sindh Univ Res Jour (Sci Ser). 2017;49(2):279–82.

Bibi S, Khan RU, Nazir R, Khan P, Rehman HU, Shakir SK, *et al*. Heavy Metals Analysis in Drinking Water of Lakki Marwat District, KPK, Pakistan. KPK, Pakistan World Applied Sciences Journal. 2016;34(1):15–9.

Dahunsi SO, Owamah HI, Ayandiran TA, Oranusi SU. Drinking Water Quality and Public Health of Selected Towns in SouthWestern Nigeria. Water Qual Expo Health. 2014;6:143–53.

Das G, Tirth V, Arora S, Algahtani A, Kafeel M, Alqarni AHG, *et al*. Effect of fluoride concentration in drinking water on dental fluorosis in Southwest Saudi Arabia. Int J Environ Res Public Health. 2020;17(11):3914.

Daud MK, Nafees M, Rizwan AS, Bajwa M, Shakoor RA, Arshad MB, *et al*. Review Article, Drinking Water Quality Status and Contamination in Pakistan. BioMed Research International. 2017;2017.

Drinking water. WHO. https://www.who.int/news-room/fact-sheets/detail/drinking-water [Retrieved on August, 31, 2021]

Durmishi BH, Ismaili M, Shabani A. Drinking Water Quality Assessment in Tetova Region. American Journal of Environmental Sciences. 2012;8(2):162–9.

Fecal Coliform and E. coli, Response to 2005 Hurricanes (2016) https://archive.epa.gov/katrina/web/html/fecal.html [retrieved on April 29, 2022]

Fecal Coliform Bacteria in Water. https://www.knowyourh2o.com/outdoor-4/fecal-coliform-bacteria-in-water [retrieved on May 15, 2022]

Forstinus NO, Ikechukwu NE, Emenike MP, Christiana AO. Water and Waterborne Diseases: A Review. International Journal of TROPICAL DISEASE & Health. 2016;12(4).

Forstinus NO, Ikechukwu NE, Emenike MP, Christiana AO. Water and Waterborne Diseases: A Review. International Journal of TROPICAL DISEASE & Health. 2016;12(4):1–14.

Ghaderpoori M, Kamarehie B, Jafari A, Ghaderpoury A, Karami M. Heavy metals analysis and quality assessment in drinking water - Khorramabad city. Iran Data in Brief. 2018;16:685–92.

Google map. https://goo.gl/maps/yWTuBxntCNJKxAC39 [Retrieved on August 31, 2021]

Hardness in Drinking Water (Background document for development of WHO Guidelines for Drinking-water Quality). 2011.

How Much Water is There on Earth?. Usgs.gov. https://www.usgs.gov/special-topic/water-science-school/science/how-much-water-there-earth?qt-science_center_objects=0#qt-science_center_objects [Retrieved on August, 31, 2021]

Ilyas M, Khan S, Khan A, Amin R, Khan A, Aamir M. Analysis of drinking water quality and health risk assessment- A case study of Dir Pakistan. Journal of Himalayan Earth Sciences. 2017;50(1A):100–10.

Jabeen A, Huang X, Aamir M. The Challenges of Water Pollution, Threat to Public Health, Flaws of Water Laws and Policies in Pakistan. Journal of Water Resource and Protection. 2015;7.

Jha SK, Singh RK, Damodaran T, Mishra VK, Sharma DK, Rai D. Fluoride in groundwater: toxicological exposure and remedies. J Toxicol Environ Health B Crit. 2013;16(1):52–66.

Ji Y, Wu J, Wang Y, Elumalai V, Subramani T. Seasonal Variation of Drinking Water Quality and Human Health Risk Assessment in Hancheng City of Guanzhong Plain, China. China Exposure and Health. 2020;12:469–85.

Khalid S. Assessment and public perception of drinking water quality and safety in district Vehari, Punjab, Pakistan. Journal of Cleaner Production. 2018;181.

Khan K, Lu Y, Khan H, Zakir S, Khan IS, Khan AA, *et al*. Health risks associated with heavy metals in the drinking water of Swat, northern Pakistan. Journal of Environmental Sciences. 2013;25(10).

Khan S, Shahnaz M, Jehan N, Rehman S, Shah MT. Din, I. Drinking water quality and human health risk in Charsadda district. Pakistan Journal of Cleaner Production. 2013;60:93–101.

Khoso S, Wagan FH, Tunio AH, Ansari AA. An Overview on Emerging Water Scarcity in Pakistan, Its Causes, Impacts and Remedial Measures. Journal of Applied Engineering Science. 2015;13(311):35–44.

Kosek M, Bern C, Guerrant RL. The global burden of diarrhoeal disease, as estimated from studies published between 1992 and 2000. Bulletin of the World Health Organization. 1992;81(3):197–204.

Lahore, Pakistan Metro Area Population 1950-2022. MacroTrends.net. https://www.macrotrends.net/cities/22046/lahore/population [Retrieved on August 31, 2021].

Memon M, Soomro MS, Akhtar MS. Drinking water quality assessment in Southern Sindh

(Pakistan). Environ Monit Assess. 2011;177:39–50.

Mohsin M, Yadav A. Assessment of drinking water quality and its impact on residents health in Bahawalpur city. 2017;

Population Council. Landscape Analysis of The Family Planning Situation in Pakistan. https://www.popcouncil.org/uploads/pdfs/2016RH_LandscapeDistrictProfile_Lahore.pdf [Retrieved on August 31, 2021]

Reyes-Toscano CA. Hydrogeochemical Characteristics and Assessment of Drinking Water Quality in the Urban Area of Zamora, Mexico. Mexico Water. 2020;12.

Salehi M. An investigation of spatial and temporal drinking water quality variation in green residential plumbing. Building and Environment. 2020;169.

Shahid N, Zia Z. Assessing Drinking Water Quality in Punjab, Pakistan. Pakistan Polish Journal of Environmental Studies. 2015;24(6):2597–606.

WaterSources.https://www.cdc.gov/healthywater/drinking/public/water_sources.html [Retrieved on August 31, 2021]

WHO W. Guidelines for Drinking water quality, Chapter 10 Acceptability aspects: Taste, odour and appearance WHO Turbidity paper

WHO W. Guidelines for drinking-water quality, Chlorine in Drinking water (Background document for development of WHO Guidelines for Drinking-water Quality).

Who W. Guidelines for drinking-water quality, Total Dissolved Solids in Drinking water (Background document for development of WHO Guidelines for Drinking-water Quality).

WHO, World Health Organisation. In: Guidelines for Drinking-Water Quality. Geneva; 2008.

Zhang J. The impact of water quality on health: Evidence from the drinking water infrastructure program in rural China. China Journal of Health Economics. 2012;31:122–34.