PHYSICOCHEMICAL, BIOLOGICAL AND HEAVY METALS ANALYSIS OF DRINKING WATER OF TENCH BHATA, RAWALPINDI DISTRICT, PAKISTAN

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ABSTRACT

Pakistan is ranked 80th out of 122 countries in terms of drinking water quality. Coliforms, harmful metals, and pesticides are found in drinking water sources around the country, including surface and groundwater. Various WHO guidelines are routinely broken. Typhoid, giardiasis, intestinal worms, diarrhea, cryptosporidium infections, and gastroenteritis are all waterborne illnesses in Pakistan. According to the Intergovernmental Union for Conservation of Nature (IUCN), Pakistan has the highest rate of infant fatalities due to water-related diarrhea in Asia, at 60%. So, this study aims to determine the drinking water quality at Tench Bhata Rawalpindi district, Pakistan. It investigates whether the drinking water quality parameters are within the WHO permissible limits or not.

In this research, physical, chemical, biological, and Heavy metals analysis of water samples collected from different locations of Tench Bhatta Rawalpindi district, Pakistan were studied. 35 points were selected for drinking water samples through the city distribution system, according to the city map. Samples were collected in sterilized plastic bottles for analysis. The Physical parameters were measured using a Multi Parameter Tester. Chemical parameters were calculated by standard methods, Levels of some Heavy metals were determined by Atomic Absorption Spectroscopy.

These results suggest that Some indicators were found to be outside of WHO's allowed limits, putting consumers at risk. The residents in the area were found to be unaware of the drinking water's quality. People discard their rubbish in open areas near water sources. There are no water treatment facilities. When it rains, the water turns murky, and as it flows down the hill, it picks up a variety of impurities.

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ABRREVIATIONS

WHO	World Health Organization
EPA	Environmental Protection Agency
SS	Salmonella Shigella
NA	Nutrient Agar
EMB	Eosin methylene blue
E Coli	Escherichia coli
EC	Electrical Conductivity
TDS	Total Dissolve Solids
Ppm	Parts Per Million
Cfu	Colony Forming Units
TNTC	Too Numerous to Count

Contents

Figures List

Tables List

CHAPTER 1

INTRODUCTION

Water is essential for human existence as well as environmental health. Surface and subsurface aquifers near rivers and canals provide most of the water used for drinking. The influx of raw urban and industrial effluents, as well as agricultural runoff, into water resources is rapidly degrading the quality of surface water. When river levels are at their peak, considerable suspension occurs. The aquatic life in most rivers has been diluted and enlarged. The fecal contamination of these bodies of water necessitates proper treatment to make them safe for human consumption. The quality of the source of drinking water, the volume and effectiveness of treatment, and the state of the water supply pipelines all contribute to the overall quality of drinking water. Since fresh water sources are limited and soil water is salty, most people in Pakistan have little choice but to consume this kind of water. The most vexing concern is microbial pollution of water. Islamabad, Karachi, Rawalpindi, and Hyderabad are the four major cities in Pakistan that utilize surface water. (S. Mehmood, 2013)

As per the World Health Organization, "safe drinking water" is water that offers no major health risk when consumed, including any sensitivities that may develop throughout life stages. (Javed, 2016). The World Health Organization (WHO) estimates that bacterial pollution of water contributes 80% of all human infections in impoverished countries. (Haydar, 2009). The drinking water quality has been debated across the globe due to increased demand for human use and the negative effects of expanding urbanization and industrialization. (Daud et al., 2017).

This Study aims at investigating the current drinking water quality situation at Tench Bhata Rawalpindi, Pakistan by analyzing physical, chemical, biological, and heavy metals parameters in drinking water to make sure that this water is safe for drinking purposes and within the permissible limits set by WHO or not.

1.1 Study Area

The study was conducted at Tench Bhatta, Rawalpindi district, Pakistan from 35 different Locations. In Rawalpindi, the main source of water is Surface water and ground water. Simli Dam and Khanpur Dam are two of most important water sources in Rawalpindi and Islamabad. Along with Khanpur Dam, Rawal dam also provides water to Rawalpindi. Study area features a humid subtropical climate due to hot and humid summers, and cools to mild winters. (Sanjrani, 2017).

1.2 Drinking Water Crisis in Pakistan

In most Pakistani cities, ground water, which contains a variety of illnesses including as virus, bacterial, and microorganism agents, is the most basic source of supply, leading in 2.5 million fatalities each year from endemic diarrheal sickness. (Malik, 2010).

1.3 Reasons for Drinking Water Crisis in Pakistan

1.3.1 Changes in the climate

In Pakistan, a lack of water was coupled by increasing heat. In Karachi, Pakistan's southern metropolis, at least a 50 people died of heatstroke in May. In 2015, over 1,200 individuals died because of very hot weather. Pakistan is experiencing extreme weather and droughts because of climate change." "Forests accounted for roughly 5% of the country's land when Pakistan was created in 1947, but they have now shrunk to just 2%," says Mian Ahmed Naeem Salik, an environment expert and research associate at Islamabad's Center of Strategic Studies. Pakistan must invest in the building of water reservoirs as well as the planting of more trees "he said. Only around 20% of Pakistan's population gets safe drinking water. Because there are few clean and healthy drinking water sources, the remaining 80% of the population is forced to utilise contaminated water. Pakistan is ranked third in the world among countries with severe water shortages, according to the International Monetary Fund (IMF). Pakistan may face a total water shortage by 2025, as according to UNDP and Pakistan Council of Research in Water Systems

(PCRWR) studies. Pakistan, according to researchers, would become the region's most water-stressed country by 2040. Pakistan reached the "water stress line" in 2016, according to PCRWR. (Malana, 2011)

1.3.2 Water Politics

The country's two largest water reserves, the Offer high - quality and Mangla dams, reportedly hit "dead" levels last week, according to news sources. The announcement triggered a discussion on social media over the authorities' inaction in the face of the disaster. "We only have two massive reservoirs and can store water for about 30 days." India has a 190-day water storage capacity, whereas the US has a 900-day capacity. Muhammad Khalid Rana, a representative for the Indus River System Authority, said (IRSA). Every year, Pakistan gets more than 145 million acres of water, but only 13.7 million acres can be preserved. Pakistan needs 40 million acres of water; however, 29 million acres of floodwater are wasted owing to a shortage of dams. New Delhi has raised the issue with international bodies, claiming that it should be allowed to utilize the western rivers since Pakistan is unable to do so." Rana Sai claims that. (Nazeer et al., 2016)

1.3.3 Water Wastage

Aside from storage of water, experts warn that wasting water is a huge concern in the nation. Mismanagement happens on numerous levels, as according Abid Suleri, executive director of the Sustainability Development Policy Institute in Islamabad. As Pakistan's water crisis worsens, foreign diplomats and activists have turned to social media to push Pakistanis to save water. Pakistan ranks third among water shortage nations. Excessive use is one of the main reasons. (Tahir et al., 1998)

1.4 Pakistan's drinking water situation

Pakistan has an abundance of both surface and groundwater resources. Because of industrialisation, urbanisation, and fast population increase, water resources have been severely stretched. Drinking water may include a range of physical, microbiological, and chemical contaminants because of technological advancements. The most harmful impurity is organic in nature, and it may cause serious health issues or even death in humans. (Qadeer, 2004)

In Pakistan, the drinking water purification and sewer lines are both operational at the same time, leading in leaking and intermixing, lowering water quality. In most Pakistani communities, ground water, which carries a variety of diseases, including numerous viral, bacterial, and protozoan agents, is the primary source of supplies, resulting in 2.5 million fatalities from chronic diarrheal sickness. (Inamullah et al., 2014)

According to community health studies, poor quality of drinking water is responsible for roughly 50% of illnesses and 40% of fatalities in Pakistan. In the Khyber Pakhtunkhwa Province (KP), more than 80% of population consume drinkable water from underground and surface sources. Surface water resources in KP are clear and safe to drink, whereas water supply in the south is purple. The present water supply in Pakistan is roughly 79 percent. Because of increased demand, Pakistan's hygiene and sewerage institutions have focused on quantity rather than quality of water. Lack of information, treatment technology, facilities, skilled workers, and quality control are all contributing factors. Human health has been demonstrated to be harmed by viruses, bacteria, minerals, and chemical substances found in polluted drinking water. Poor water quality is said to be responsible for 30 percent of all diseases and 40 percent of all deaths in Pakistan. Diarrhea, a waterborne illness, has been identified as the leading cause of mortality among Pakistani newborns and children, with one out of every five persons suffering from it. (Podogoroski, 2017)

Methods for ensuring clean drinking water have reached acceptable levels in Pakistan. According to Reference, around 25% of the population has access to safe drinking water. A scarcity of water sources was the reason of the insufficient water supply. The extensive use of water for national, agricultural, and industrial purposes is the primary source of water contamination. The addition of urban and industrial wastewater at varying locations all along water distribution system, as well as a shortage of wastewater remediation and water management at treatment facilities, are the main causes of waterborne infections in Pakistan. Water-related imperfections for

40% of all infectious diseases in Pakistan, as per the National Conservation Strategy. (Hussain, 2012)

1.4.1 Pakistan's Water Resources

Pakistan has rich soil and subsurface water resources thanks to Mother Nature. Unfortunately, human activity such as industrialisation, population growth, and excessive consumption reduce quantity and quality. So according Jamshed Iqbal Cheema, the individual surface water and groundwater in Pakistan at the time of inception was 5.600 cubic metres. (President, Pakistan Agricultural Scientists Association), The volume of water has decreased from 5.260 cubic metres in 1951 to 1.038 cubic metres in 2010. Pakistan's yearly water availability will shrink to 877 cubic metres by 2020 if present trends continue., 660 cubic metres by 2025, and 575 cubic feet by 2050. (Mustafa, 2012)

1.4.2 Water Quality of Pakistan

Near rivers and canals, drinking water is usually sourced from surface and subterranean aquifers. Surface water quality is rapidly deteriorating due to the influx of raw urban and industrial effluents, as well as fertiliser waste, to water resources. People in Pakistan who live in locations where fresh water is limited and groundwater is salty are forced to drink this sort of water. (Ahmed, 2014)

The most pleasant worry is water pollution due to germs. The delivery of drinking water in urban areas does not meet WHO standards. The combination of wastewater and drinking water supply lines is the most common cause of microbial contamination. In the majority of rural areas, there are no water filtering pre-treatment facilities. All of this is due to microbial contamination and poor water quality. Hand pumps and wells are vulnerable to surface runoff and flooding. (Yousaf, 2013)

“The worsening of quality of water caused by waste from the industrial, national, and agricultural sectors is known as water pollution. The use of such water for positive purposes has detrimental repercussions for the ecology and public health. The release of wastewater into natural water resources, because of industrialization and urban development, has a significant impact on water resources and has a negative impact on the quality of soil and surface water”. (Mahurpawar, 2015)

1.5 Water quality studies in Pakistan

Various studies have been conducted to access the water quality situations as it is a matter of great concern. Growing urbanization and industrialization show adverse effect on quality of water so water quality assessment should be done to identify any contamination present in water. (soomro, 2011)

1.5.1 The state of the water in Pakistan's twin cities: -

Water samples were collected from schools and institutions in Islamabad to test the drinking water quality. Twenty of the thirty samples tested positive for faecal bacteria, making them unfit for human consumption. (saddozai, 2009)

To evaluate microbiological pollution in Islamabad and Rawalpindi drinking water, A total of 130 samples were collected from nine different sites. In 56.1 percent of the water samples, microbial contamination was discovered. E. coli, faecal coliforms, and total coliforms microbial contamination levels were found to be 23.8 percent, 20 percent, and 12.3 percent, respectively. “The most prevalent and persistent concern connected with polluted drinking water is microbial contamination. More than half of the samples taken from various water filtering facilities around Total coliform, faecal coliform, and E. coli contamination was found in Islamabad, followed by capital expansion, and digging water lines, with less contamination seen in tanker water.” (Hisam, 2014)

Geographic Information System and Water Quality Index Due to over-exploitation of groundwater, environmental consequences, and direct discharge of contaminants, more than half of the sample from boreholes and open wells in Islamabad and Rawalpindi had poor drinking quality. (Mashiatullah, 2010)

The presence of E. coli and fecal coliforms in drinking water indicates that it has been contaminated with human and animal waste. Water distribution pipes and treatment plants in Rawalpindi were also discovered to be contaminated with faeces. Rawalpindi's principal source of drinking water is Rawal Lake and its distribution channels, which have been found to be highly contaminated with germs. Islamabad's water quality has been assessed. According to the results, around 77 percent of the total 271 samples evaluated were biologically polluted and unfit for human consumption. (Amin etal., 2012)

Alkalinity, hardness, and total dissolved solids in all samples were within permissible limits, according to the Pakistan Standard and Quality Control Authority's physicochemical requirements for the water quality of Islamabad. (PSQCA). All water tests, however, included coliform and E. coli, suggesting that the water was unsafe for human consumption, as advised by the WHO. (Azhar, 2014)

The water quality in Islamabad and Rawalpindi isn't much better than all the rest of the nation. The water quality in the capital's natural waterways has also deteriorated. Complete and faecal coliform bacteria have infiltrated water reservoirs, necessitating extensive water treatment for drinking and national usage. (Jadoon, 2012)

1.5.2 Punjab, Pakistan's water quality situation

The quality of drinking water in two settlements in south Punjab was investigated, as well as the effects of chlorination. “Prior to actual disinfection process, all 53 samples obtained from two villages had substantial amounts of E. coli bacteria, according to the results of this investigation. Drinking water should include not much more 0/100 mL Coli or fecal coliform, as per the WHO and PEPA.”. (Jensen, 2003)

Due to a lack of treatment equipment, Faisalabad is renowned as a filthy industrial town. Near the Samundri dam in Faisalabad, ground water quality was determined to be the poorest, with 90 percent of samples exceeding WHO TDS, Na, K, Cl, and SO4 guidelines. (Nasir, 2016)

The town of Faisalabad's drinking water quality was assessed using physicochemical methods. Within the safe confines of the WHO recommendations, turbidity, hardness, pH, and TDS have been determined. “All the samples had been infected with complete coliforms and E. coli, according to the microbiological analysis. Groundwater physicochemical qualities in Faisalabad surpass WHO essential guidelines, according to a study of the influence of urban and industrial effluent on water resources. Bottles and supply lines, on the other hand, were inside critical range" (zulfiqar, 2016)

According to chemical and biological examination, the pH of drinking water samples collected from three different sites in Faisalabad was found to be within WHO-recommended range, although electrical conductivity was determined to be over the approved limits. The breakdown of subsurface minerals and the seepage of ground water generate higher electrical conductivity (EC). Bacteria were also found in faeces-contaminated water samples. All this evidence suggests that the water is dangerous to consume. In samples collected from a variety of sources at the University of Punjab, Lahore, the concentration of As and coliform bacteria above the threshold level. (shahid, 2015)

Arsenic contamination in Punjab and Sindh

Arsenic contamination is a major problem in Punjab and Sindh, the country's main industrialized and agricultural regions. Arsenic levels in the ambient air in Punjab are substantially higher than in any other country on the planet. In Punjab, an estimated 50 million people are at danger of arsenic poisoning. Arsenic is naturally prevalent in water, particularly in deep aquifers. The WHO standard for arsenic is 10ug/L, whereas the highest level in Punjab is 50mg/l, which is 5 times higher than the safe limit. (Podogoroski, 2017)

"The WHO standard for arsenic is 10ug/L, whereas the highest level in Punjab is 50mg/l, which is 5 times higher than the safe limit. As Punjab is the country's agriculture powerhouse, farmers utilize both surface and groundwater for irrigation. Because groundwater is utilized for crop irrigation, arsenic contamination can be discovered in vegetables, which can subsequently enter the food chain. Onion, carrot, and potato all have minor levels of arsenic". (Sanjrani, 2017)

Arsenic poisoning can cause diabetes, as well as an increased risk of cancer, including skin cancer and liver cancer, as well as lung, bladder, and kidney cancer. (Nafeez, 2011)

1.5.3 KPK's water quality situation

Water samples were taken from pipe wells and storage tanks in Peshawar's rural districts to examine the quality of the water. Only 13% of the samples were found to be contaminated with germs, 40% were found to be in excellent condition, and 47% were found to be severely infected with E. coli. Physicochemical examination of drinking water samples obtained from thirty various locations throughout Peshawar's metropolitan districts indicated that, although the EC was within range, the pH in seven of them did not meet WHO criteria. TDS, turbidity, carbonates, and bicarbonate ions were all within WHO guidelines, however magnesium levels were much beyond the essential limit. (Khan, 2005)

The quality of the water was poor and below WHO quality guidelines, according to physicochemical and microbiological examination of several portable water samples collected in Banu and Haripur districts. Drinking water samples were obtained for bacteriological analysis, and nearly all the samples were confirmed to be contaminated. (Hamida, 2016)

1.5.4 Baluchistan's water quality situation

Biological and chemical quality of water in Baluchistan has been demonstrated to be poor in several investigations. Bacteria have considerably contaminated the water in four Baluchistan towns, namely Ziarat, Loralai, Quetta, and Khuzdar, leaving the water unsafe for human consumption. In these places, the quantity of NO3 in the water was greater than the WHO's recommended levels. "The water samples from Ziarat were considerably polluted with NO3 in around half of them. According to a study of the drinking water quality in numerous Quetta City colonies, all samples had pH, Salinity, and hardness within the WHO range, although 50% of the samples had an increased EC value, and all samples had COD levels that above the WHO critical limits. The drinking water in Quetta was of low quality, with a horrible taste, a foul odour, a change in appearance, and bacteria". (Mustafa, 2012)

1.5.5 Sindh's water quality situation

Water shortage is a major issue in Karachi, which is exacerbated in slum areas with inadequate infrastructure and equipment. The physicochemical parameters of drinking water pipes in Korangi Town, Karachi, were determined to be within WHO criteria, except for sulphates. According to the microbiological investigation, all samples were considerably contaminated with total coliform, faecal coliform, and E. coli. The presence of bacteria in the sewerage systems indicated that there was a problem with the systems. (Alamgir, 2015)

"According to microbiological and physicochemical water characteristics reported by WASA in Gulshan-e-Iqbal, only three samples were contaminated with germs owing to faulty water systems and cross-connections between drinking water supply lines and sewage. The pH, temperature, turbidity, resistivity, TDS, and As levels all complied with WHO standards.". (Hussain, 2016).

1.6 Water quality Studies around the World

1.6.1 Drinking water quality assessment at Ethiopia Africa

The quality of drinking water was tested on the Wondo genet campus in Ethiopia. According to the data, the Wondo Genet Campus had a mean turbidity of 0.98 NTU and an average temperature of 28.49 ° C. The average complete dissolved solids concentration was 118.19 mg/l, and the EC value was 192.14 S/ cm at the Wondo Genet Campus. The average chloride concentration in this drinking water was 53.7 mg/l, with a sulphate concentration of 0.33 mg/l. Magnesium values vary from 10.42 to 17.05 mg/l in the study fields, with a mean of 13.67 mg/l. Calcium concentrations range from 2.16 to 7.31 milligrams per litre, with an average of 5.0 milligrams per litre. "In the research fields, sodium levels averaged 31.23 mg/1 while potassium levels averaged 23.14 mg/1. Total coliform bacteria count in Wondo Genet Campus water samples ranged from 1 to 4/100 ml, with an average of 0.78 colonies per 100 ml. All physicochemical properties in the research domains were derived from drinking water, according to the findings. The World Health Organization Drinking Water Standard was met at all drinking water sample locations on campus (WHO)". (Ayenew, 2016)

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1.6.2 Drinking water quality assessment at Nepal

The purpose of this research was to look at the drinking water quality in Arthunge VDC, Myagdi district, which came from a variety of natural resources, lakes, and collecting taps. All 84 water samples tested (from natural sources, lakes, and tap water) were determined to meet WHO and national drinking - water standards (excluding arsenic and total coliform). 15.48 percent of the samples collected had a pH of 13, which was greater than the WHO's recommended standards. (Nepal, 2012).

"Similarly, an Arsenic value (72) larger than the WHO guideline was found in 85.71 percent of the water samples. Furthermore, statistical analysis revealed no statistically significant differences in the physicochemical properties (P0.05). Microbiological examination revealed the presence of complete coliform in 86.90 percent of the water samples." The findings of the physicochemical examination of water samples, except for arsenic, were compatible with domestic and WHO requirements. In the investigation, coliform contamination was also discovered to be a big issue with drinking water. (Korenberg et al, 1988).

1.7 Objectives of the study

The study was created with the following aims in mind due to water quality, scarcity, and a lack of appropriate information on the presence of pollutants, microbiological, physicochemical, and heavy metals quality in the study area.:

1. Evaluate the physical and chemical parameters of water samples collected at Tench Bhata, Rawalpindi, Pakistan.
2. To carry out heavy metals Analysis and determine microbial counts of the water samples.

CHAPTER 2

METHODS AND MATERIAL

2.1 Description of Study Area

The study took place in 35 different locations in Pakistan's Rawalpindi region, including Tench Bhata. Following the selection of the various location locations, we took two samples from each location point. One is dedicated to physicochemical and biological analysis and one for Heavy Metals analysis from which the water is accessed by the residents of Tench Bhata. (Haykin, 1999).

Reason for selection of sample location:

The reason behind selecting Rawalpindi as my sample location is the Rawalpindi's poor water quality, including the replacement of outdated pipelines and the construction of water purifying plants which is still not improved. It's still unclear whether the water quality has improved. People on the streets continue to complain about the quality of the water, and hospital records show a rise in gastrointestinal disorders. Natural and manmade factors have combined to degrade the environment and water quality. (Heckhausen, 2015)

The major cause of tube well pollution at Rawalpindi is the Nullah Lai and Korang River's recharge system, which transports wastewater from the twin cities of Islamabad and Rawalpindi. Due to enormous urban expansion in the catchments and recharge area, the Rawal Lake, a surface water source, has also been poisoned. These contaminated water sources have surrounded the ground water aquifer, contaminating, or having already poisoned the whole ground water aquifer. The ageing water distribution system is in terrible shape. Due to undersized and leaky pipes, the City's current water supply is insufficient and unhealthy for its citizens. The majority of distribution lines run through sewer drains, resulting in pollution at the consumer's end.

Sample Collection

Between September and October, 70 samples were collected at various locations. For the testing of physical, chemical parameters and analysis of Heavy Metals samples were collected according to standard protocol in plastic bottles of 500 ml which were cleaned by distilled water thoroughly. While collecting the sample from each location its coordinates were noted down and if the sample was to be collected from bore supply than its depth was also noted down. Each Location point had two sample bottles that were collected one for Physicochemical and Biological parameters and one for Heavy metals Analysis. (Lee et al., 1983

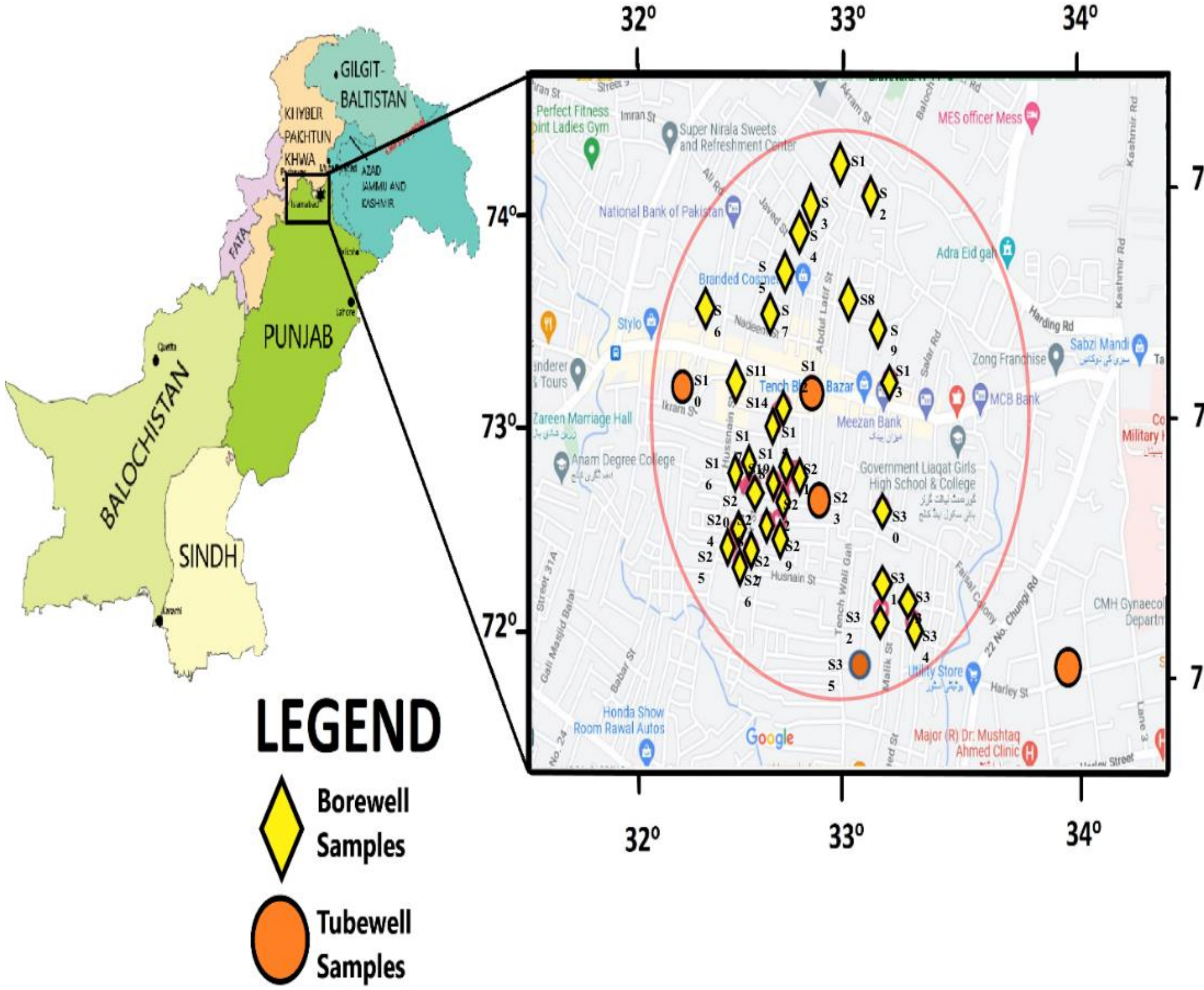

Figure 2. 1. Study area Map showing Sampling Location points

S.no	Latitude	Longitude	Water Source	Depth (meters)
S1	**33.5802746**	73.0341785	**Borewell**	33.5
S2	**33.5803250**	73.0354435	**Borewell**	35.05
S3	**33.5800522**	73.0345147	**Borewell**	36.57
S4	**33.5794883**	73.0348842	Borewell	39.6
S5	**33.5799362**	73.0352941	**Borewell**	39.62
S6	**33.5790795**	73.0344368	**Borewell**	33.5
S7	**33.582796**	73.034947	**Borewell**	35.0
S8	**33.582846**	73.033186	Borewell	53.3
S9	**33.5791612**	73.0338368	Borewell	39.6

S10	**33.5788535**	73.0341433	**Borewell**	36.5
S11	**33.580288**	73.035685	**Borewell**	33.5
S12	**33.580254**	73.034218	**Borewell**	42.6
S13	**33.578121**	73.038049	**Borewell**	36.5
S14	**33.579348**	73.034027	**Borewell**	44.1
S15	**33.578266**	73.038804	**Borewell**	33.5
S16	**33.577936**	73.038927	**Borewell**	35.0
S17	**33.582964**	73.037162	**Borewell**	48.7
S18	**33.578571**	73.038088	**Borewell**	42.6
S19	**33.580117**	73.035059	**Borewell**	30.4
S20	**33.579711**	73.038092	**Borewell**	82.2
S21	**33.577323**	73.043220	**Tubewell**	85.3
S22	**33.581300**	73.035338	**TubeWell**	82.2
S23	**33.579921**	73.036285	**TubeWell**	86.8
S24	**33.579348**	73.034027	**Tubewell**	33.5
S25	**33.579517**	73.035216	**Borewell**	41.1
S26	**33.581658**	73.033998	**Borewell**	39.6

S27	**33.581212**	73.035206	**Borewell**	36.5
S28	**33.581624**	73.036118	**Borewell**	33.5
S29	**33.581708**	73.038277	**Borewell**	42.6
S30	**33.582528**	73.037966	**Borewell**	36.5
S31	**33.584440**	73.036100	**Borewell**	44.1
S32	**33.584049**	73.035820	**Borewell**	33.5
S33	**33.585138**	73.036899	**Borewell**	35
S34	**33.584652**	73.037741	**Borewell**	48.7
S35	**33.583418**	73.035369	**Borewell**	33.5

Table 2. 1. Sample names and GPS location of Samples collected from study area.

The three parameters that were measured after the samples were collected were:

- Physical Characteristics
- Chemical parameters
- Heavy Metals Analysis

2.2 Physical Parameters

"pH, temperature, electrical conductivity, salts, total dissolved solids, and turbidity were among the characteristics assessed. To get the best results, the instrument was adjusted before use, and the electrodes were rinsed with distilled water before being used. The samples were forcefully shaken and left to settle till no air bubbles existed to confirm that the findings were not tampered with.". (Ghumman, 2011)

The following instruments were used:

- Beaker
- Graduated Cylinder

- Tester with Multiple Parameters

Chemicals that were utilized

- Water that has been distilled
- A sample of water

Procedure

Before beginning our sample, we calibrated the multi parameter tester with standards. After putting 50 mL of water into a measuring cylinder and putting it into the beaker, a Multi Parameter Tester was plunged in it, and the results of every physical parameter were provided after one minute. On a sheet of paper, the numbers were scribbled. (Nasir, 2016)

2.3 Chemical Parameters

"Chemical parameters including **Na^{+}** (Sodium)**,** **Cl^{-}** (Chloride)**,** **NaCl** (Sodium chloride**),** Carbonates, Alkalinity and Hardness were calculated by standard methods".

2.3.1 Test of Chlorides

Instruments

- Burette
- Dropper
- Erlenmeyer Flask
- Burette Stand

Chemicals

- Potassium Chromate
- Silver Nitrate (Ag_2NO_3 0.01 M)

Formula

Chloride's mg/L= $\frac{\mathrm{V \times N \times 35.54 \times 1000}}{\mathrm{Sample\ Volume}}$

V =Volume of Reagent Used

N = Normality of Silver Nitrate

Procedure

Chloride (Cl), Sodium chloride (NaCl), and Sodium (Na^+) are all measured in this test. We set up three drops of indicator into the Erlenmeyer flask with the help of a dropper, which turned the sample light yellow, and then after neutralization, the end point was a reddish tint, which was its end point. Three measurements were taken to prevent human error. (Ali etal., 1994)

2.3.2 Test of Carbonates

Instruments

- Burette
- Burette Stand
- Erlenmeyer Flask
- Dropper

Chemicals

- Methyl Orange
- Hydrochloric acid (HCL 0.1 M)

Formula

$$\frac{m1\ v1}{n1} = \frac{m2v2}{n2}$$

n = Number of Moles

m = Molarity

v = Volume of Solution

Procedure

We refilled the burette with 0.1 M solution hydrochloric acid, calculated 10 ml of water in a graduated cylinder, put it into an Erlenmeyer flask, and added two drops of indicator methyl orange using a dropper for the carbonate test. The sample changes the color from orange to pink after titration, with pink becoming the end point. To avoid human error, three measurements were taken for each sample. (Gleick et al., 2010)

2.3.3 Test of Alkalinity

Instruments

- Burette
- Dropper
- Burette Stand
- Beaker
- pH Meter
- Erlenmeyer Flask

Chemicals

- Methyl Orange
- Sulfuric Acid (H_2SO_4 0.02M)
- Phenolphthalein ($C_{20}H_{14}O_4$)

Formula

Alkalinity mg/L = $\frac{N \times V \times 1000}{Sample\ \boldsymbol{Volume}}$

V = Volume of Reagent Used

N = Normality of Sulfuric Acid

Procedure

The beaker was filled with 0.02 M H2SO4 acid, 50 ml of sample was measured in a measuring cylinder and then dropped into the beaker, and the pH of the samples was evaluated., and if it was below 8.5, methyl orange was used as an indicator, and if it was above 8.5, phenolphthalein was used as an indicator, and the water sample was poured in the Erlenmeyer flask with phenolphthalein Three measurements were taken from each sample to remove human error. (vaux, 2005)

2.3.4 Test of Hardness

Instruments

- Burette
- pH Meter
- Burette Stand
- Erlenmeyer Flask
- Beaker
- 2Syringe (1ml)

Chemicals

- Eriochrome Black T (EBT)
- Ethylene Diamine Triacetin Acid (EDTA)
- Ammonium Chloride (NH4CL)

Formula

Total Hardness = $\frac{A \times B \times 1000}{Sample\ volume}$

A = EDTA consumed for a sample – EDTA consumed for a Blank Sample (distilled water)

B = 0.01

Procedure

Calcium (Ca^{+2}) and potassium (K) are measured in this assay. We loaded the burette with Ethylene Diamine Triacetin Acid (EDTA), evaluated 50 ml of water in a measuring cylinder, and injected it into an Erlenmeyer flask, then used a 1 ml syringe to add two ml of Ammonium chloride NH4Cl to the blank water sample, checked the pH with a pH metre to see whether it was greater or equal to 10, and added two drops Water samples were collected using the same technique. The EDTA value used for the blank sample was deducted from the EDTA value utilized for the water samples. (Latif et al., 1999)

2.4 Heavy Metals Analysis

"Five heavy elements were examined in all samples: As, Cd, Cr, Pb, and Ni. Heavy metals such as Cd, Cr, Pb, and Ni were measured at Quaid e Azam University, using a Perkin Elmer Atomic Absorption Spectrometer Model No. (AAS PG-990)". The samples were kept in plastic bottles with a capacity of 100 mL The samples were first filtered using filter paper, and then 2-3 mL of nitric acid were added. After that, the samples were taken to Quaid e Azam University for analysis. As was determined using an arsenic test kit supplied at Bahria University Islamabad's Chemistry Laboratory. The entire technique is outlined below: (Mehmood, 2012)

2.4.1 Arsenic Test

Instrument used

- Arsenic kit
- Tissue
- Graduated Cylinder

Chemicals used

- Reagent 1
- Reagent 2
- Reagent 3

Procedure

For arsenic testing, we used an arsenic testing kit, this kit contains three reagents (reagent 1,2 and 3) and three spoons (pink, red, white), strips and data sheet along with red cap bottles and special caps with strip opening. After measuring 50 ml of water in the graduated cylinder, the sample is put into the red cap container. reagent 1 added with the pink spoon the bottle was closed and shaken for 10 sec then reagent 2 was added with red spoon and again the bottle was closed and shanked for 10 seconds and was left to rest for 2 minutes the bottle was opened and the corner of the bottle were cleaned with a tissue after that reagent 3 was added with the white spoon and the red cap was replaced with the white cap with the strip intact and closed and left to rest for 10 minutes in a well ventilated area after 10 minutes the strip was taken out and color of the strip was compared to data sheet and value was noted down. (Scott et al., 1993)

2.4.2 AAS (PG-990)

AAS Sample Preparation:

First, the sample is rendered into a state that the instrument can process for elemental analysis during sample preparation and introduction. After that, the sample is subjected to a radiation source, which is usually a light source. The metal atoms in the sample absorb the wavelengths of this light source, which have been tuned to certain wavelengths (or not). When light is absorbed, it produces a light spectrum with reduced light intensity in one or more places. This decreased intensity is distinctive of a certain element and aids in its identification as well as concentration determination. (Thermo Fisher Scientific , 2017)

The AAS (PG-990) high-performance Atomic Absorption Spectrometer is a user-friendly software that runs on the Windows operating systems Win95, Win98, WinNT, Win 2000, and WinXP. The system uses a series of software wizards to walk the user through the setup process. The PG990 Atomic Absorption Spectrophotometer is a low-cost entry-level instrument featuring a computer-controlled Air/Acetylene flame for common laboratory use Because of its high sensitivity and excellent performance, the instrument may be used in a broad variety of applications, including agricultural, clinical, environmental, food, and metal analysis. (Ming, 2013)

The flame and graphite furnace are combined into a single device. Simple keystrokes within the software are used to switch from one strategy to another. The instrument features a motorized 8 hollow cathode lamp turret that allows the software to automatically place and optimize each hollow cathode light. Controlling the gas flows for the burner's fuel gas (C2H2) is also done directly from the software, allowing the instrument to be optimized for the analytical parameters for a specific analysis. Background adjustment can be done in two ways. The first uses a Deuterium Arc light, while the second is the tried-and-true Self Reversal method. High quality minimum optics guarantee maximum light flow to the computer-controlled Czerny-Turner Monochromator. (Shrestha, 2017)

The AAS nebulizer was brought into the blank for the first time (distilled water). The nebulizer is cleaned using the blank function. The sample was then shaken vigorously before being put in a nebulizer. The sample was absorbed by the nebulizer, which then made three measurements of each sample and displayed the average result on the screen. (Tariq etal., 1981)

2.5 Biological Parameter

Instruments

- Petri Dishes
- Funnel
- Graduated Cylinder
- Beakers
- Autoclave
- Aluminum Foil/Newspaper
- Tape
- Spatula
- Glass Spreader
- Nozzles
- Spirit Lamp
- Marker
- Weight Machine
- Micro pipette
- Incubator

Chemicals

- Distilled Water
- Spirit
- Nutrient Agar
- Eosin-Methylene Blue (EMB) Agar
- Salmonella and Shigella (SS) Agar

Procedure

The day before the sample collection, the lab produced Nutrient Agar (NA), Eosin-Methylene Blue (EMB) Agar, and Salmonella and Shigella (SS) Agar., as per the sample size, by adding them in distilled water according to their quantity in a beaker with the help of a funnel and graduated cylinder in a beaker, blending them thoroughly with a spatula, and wrapping them with aluminum foil or newspaper with tape. Everything was sterilized in the autoclave for 30 minutes at 121 degrees Celsius before being opened in the laminar flow. Each medium was put into petri dishes and let to harden in the laminar for 24 hours. (Aremu, 2011)

The second day, biological parameter samples were gathered and opened one by one in the laminar flow. After every dish, a pipette was used to extract the samples from the bottle, pour it over the media, and then use a glass spreader to equally disperse the water sample across the medium. The spreader was washed with spirit, then dried and chilled under the light of a spirit lamp. In its place, new nozzles were attached. After each sample, the Petri dishes were closed and labelled, inverted upside down, and put in the incubator (30-36 C) for 24 hours. The plates were maintained under observation, and the plates were separated into four equal sections with a marker to aid in bacterial counting. (soderstorm, 1989)

CHAPTER 3
RESULTS AND DISCUSSION

Different criteria were examined in water samples from the research region to determine their quality in this study. Data on the physicochemical characteristics of selected region water samples taken between September 2021 and January 2022. The samples' results were compared to the World Health Organization's drinking water quality standards.

3.1 Physically analyzed water samples

3.1.1 pH

pH is a critical metric for determining the acid-base balance of water. It's also a good indicator of whether the water is acidic or basic. The pH is determined by the quantity of dissolved CO2 in water that produces acid. The World Health Organization recommends a pH range of 7.5 to 8.5 as the highest allowable level. (Aremu, 2011).

The pH of the water in this research was measured using a pH meter and varied from 7.4 to 8. Samples S1 (6.5), S2 (6.8), S7 (7.3), and S8 (8.5) had the highest pH, whereas samples S1 (6.5), S2 (6.8), S7 (7.3), and S8 (8.5) had the lowest pH. (7.3). Therefore, the results showed that pH of most of the samples were within the recommended limit by WHO (7.5 – 8.5) except some of the bore well water samples.

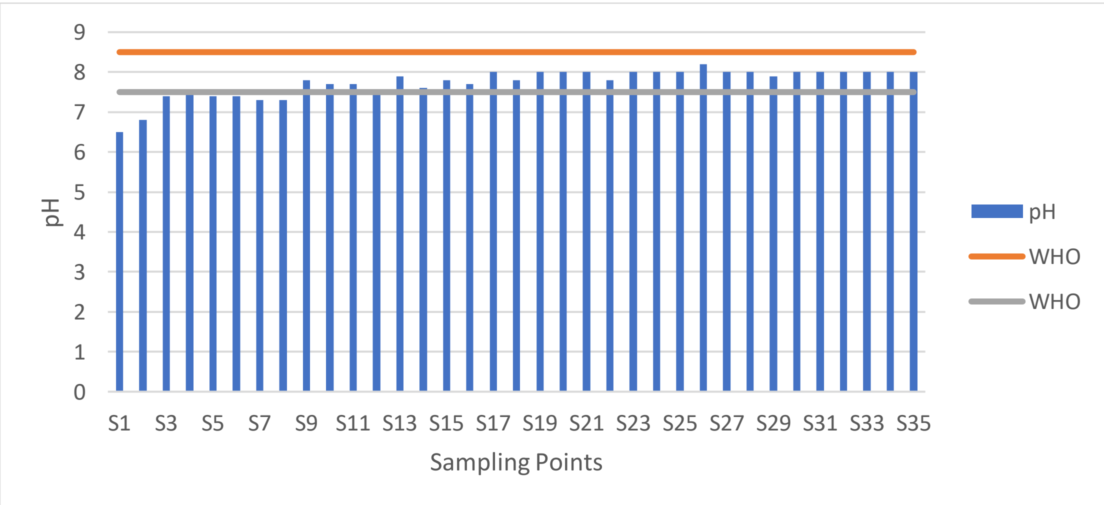

Figure 3. 1. pH values of Water Samples

3.1.2 Electrical Conductivity (EC)

Electrical conductivity is a measurement of an electrolyte solution's capacity to conduct electricity. Siemens per meter (S/m) is the SI unit for conductivity. Total dissolved solids and conductivity are inextricably connected (T.D.S.). At 25°C, high-grade distilled water has a conductance of around 5.5 S/cm, whereas standard drinking water has a conductance of 400 S/cm, according to WHO rules. (Shrestha, 2017).

The current investigation indicates that sample ID S1, S2, S4, S5, S7, S8, S10, S11, S12, S13, S14, S15, S16, S17, S18, S20, S21, S22, S26, S27, S29, S30, S31, S32, S33, S34 and S35 have exceeded from standard value which includes mostly bore well samples and two tube well water samples as well whereas, sample ID S3, S6, S9, S19, S23, S24, S25 and S28 are within the WHO permissible limits. Maximum E.C was recorded in Sample S8 (983) which is a bore well sample, whereas least E.C was recorded in Sample ID S25 (S24) which is again a bore well sample.

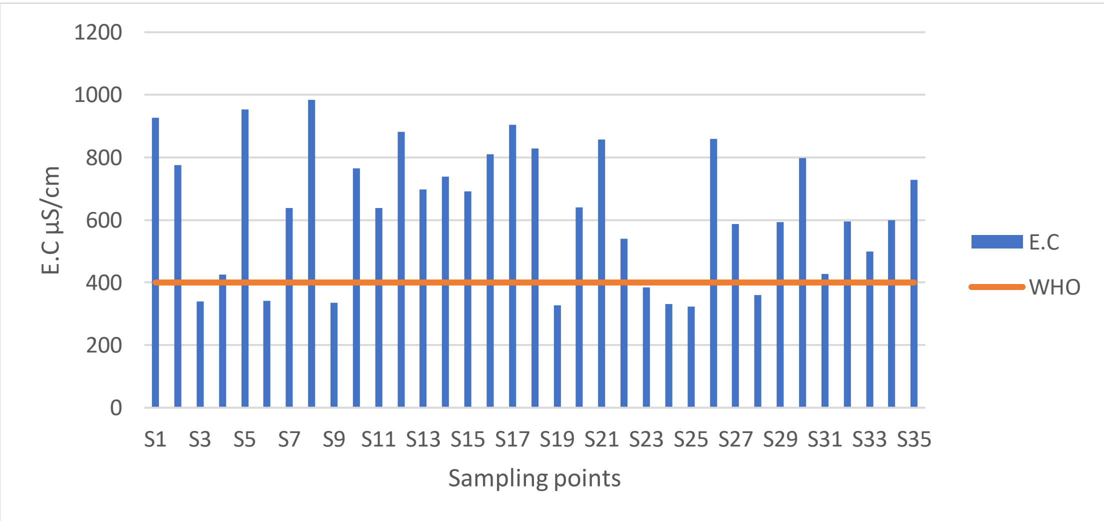

Figure 3. 2. Water samples' Electrical conductivity

The conductivity of water is used to determine what is dissolved in it. A greater conductivity value in the drinking water implies that there are more chemicals dissolved in the water. Water that has been distilled is a poor conductor of electricity. Salts and other inorganic substances dissolve in water to form ions, which are small electrically charged particles. Ions improve the capacity of water to carry electricity.

If conductivity levels get too high, it might indicate that undesired contaminants are present in the water or have just entered it. Excess ions that contribute to increased conductivity can harm human and animal health if consumed over long periods of time. (Sanyal, 2020)

3.1.3 Total Dissolve solid (TDS)

Potassium, calcium, sodium, bicarbonates, chlorides, magnesium, sulfites, and other inorganic and organic minerals or salts can all be dissolved by water. These minerals imparted a disagreeable odour and a diluted tint to the water. This may be the most essential water-use criteria. The presence of a high TDS value in water indicates that it has a high mineral content. For drinking purposes, TDS has an allowed limit of 500 mg/l and a maximum value of 1000 mg/l. TDS levels in ground water are usually not dangerous to people, but excessive concentrations can influence people suffering from excretory organ and cardiopathy. Water with a high solid content may have laxative or constipating effects. (Sasikaran, 2012).

The concentration of TDS was evaluated in this investigation, and the minimum value is S25 (232) which is a bore well sample and the maximum value is S8 (698 mg/l) which is again a bore well sample. The Sample ID S1, S2, S5, S8, S10, S12, S14, S16, S17, S18, S21, S26, S30 and S35 were exceeding the WHO permissible limit which includes mostly bore well and one tube well water sample as well. Our sample's residual TDS levels were below the World Health Organization's (WHO) limit of 500 mg/l.

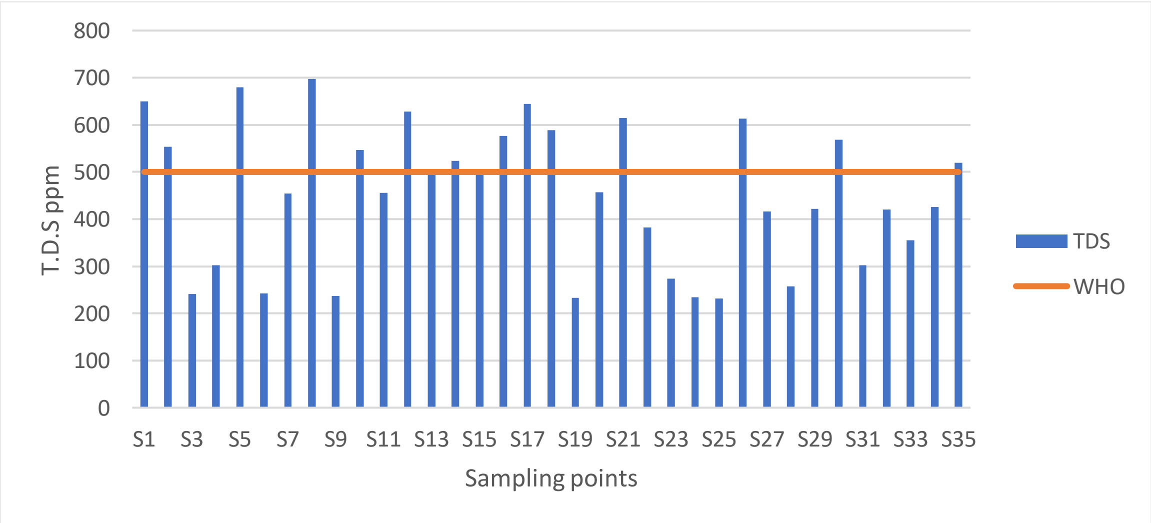

Figure 3. 3. Water Samples with Total Dissolved Solvents

Total dissolved solids can have an impact on the quality of your water, your health, your home plumbing system, and even everyday chores like cooking and cleaning. By testing your water for TDS, you may have a better understanding of the quality of your water and how it impacts your daily life, allowing you to make an informed choice about how to resolve your water quality issue.

Tap water with a high total dissolved solids (TDS) percentage can have a harsh flavor and odor. The higher the total dissolved solids content, the more bitter your water will be. However, drinking water with a high TDS level is not always harmful. (Woodard, 2021)

3.1.4 Salt

Sodium is necessary for the physical body's normal functioning. It's found in all bodily tissues and fluids, and it's not usually regarded to be dangerous at customary levels of consumption through food and water sources. The allowed maximum for salts, according to the WHO, is 200mg/l. There isn't a single health-based guideline value that is so meticulously prepared. Metal levels more than 200 mg/liter, on the other hand, may have an impact on the taste of drinking water. (Klenow, 2016).

The samples ID S1, S2, S5, S7, S8, S10, S11, S12, S13, S14, S15, S16, S17, S18, S20, S21, S22, S26, S27, S29, S30, S32, S33, S34 and S35 have exceeded the permissible limit of 200 ppm. The remaining water samples were inside the permissible limit recommended by WHO.

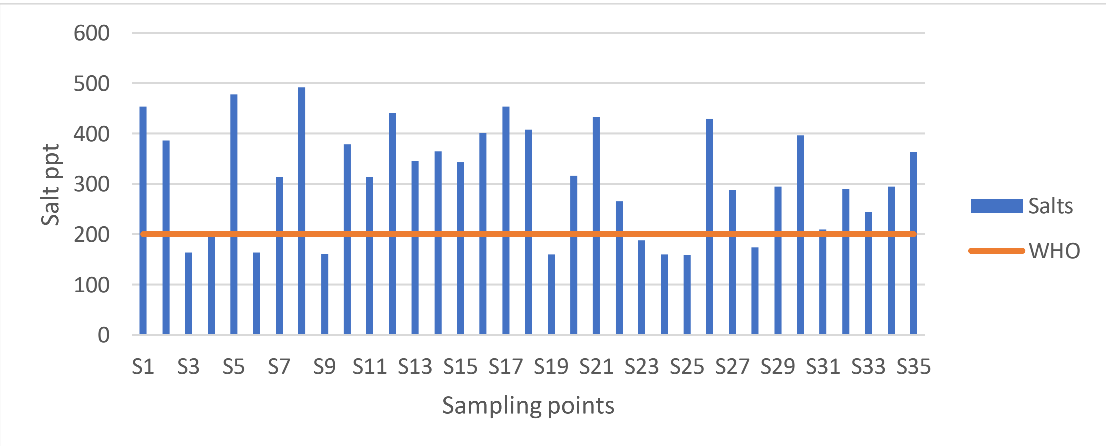

Figure 3. 4. Salts Concentration in Water Samples

While there is no salt guideline for drinking water, state and federal authorities suggest that sodium levels in water do not exceed 20 mg/L for extremely low sodium diets and 270 mg/L for moderately limited sodium diets.

If you have a medical condition like high blood pressure or certain heart, kidney, or liver problems, sodium in drinking water is a greater worry. If you're concerned about salt levels in your drinking water and how they can influence your health, speak with your doctor.

3.1.5 Temperature

The temperature of a body of water is an important component in determining whether it is safe to drink and use. Because most consumers complain about water that is 19°C or above, this is the case. When the water is at normal temperature, the flavour is at its strongest, and when it is chilled or heated, the flavour is considerably lessened. Even though it has no negative health consequences. (Ezeribe, 2012).

Temperatures below 20 degrees Celsius are the safest. 13.1°C was the average temperature found. As a result, the temperature throughout this investigation was determined to be within the World Health Organization's (30 °C) permitted range. (Tahir et al., 1998).

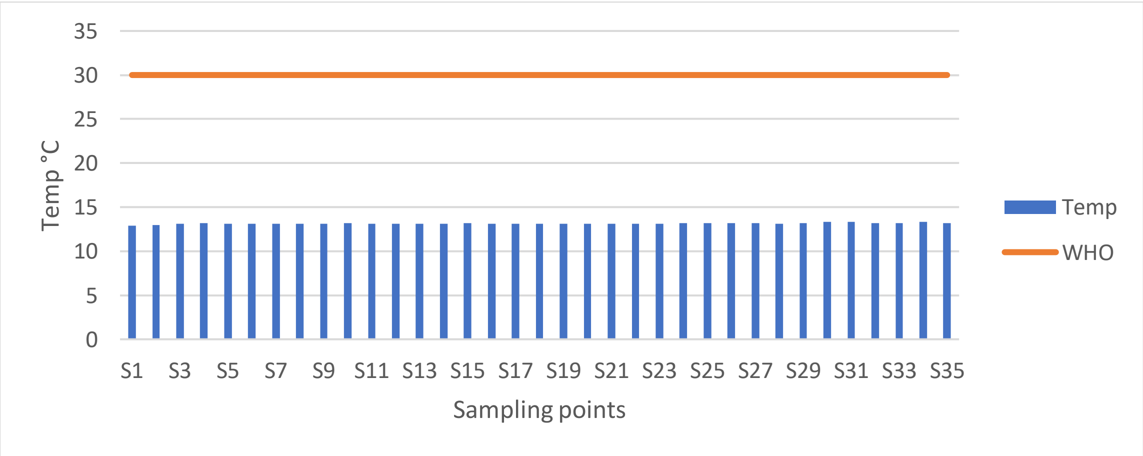

Figure 3.5 Temperature Concentration in Water Samples

Location	pH	EC (µS/cm)	TDS (ppm)	Salts (ppm)	Temperature (°C)
S1	6.5	926	650	453	12.9
S2	6.8	775	554	386	13.0
S3	7.4	340	241	164	13.1
S4	7.5	425	302	207	13.2
S5	7.4	953	680	478	13.1
S6	7.4	341	242	164	13.1
S7	7.3	639	454	314	13.1
S8	7.3	983	698	492	13.1
S9	7.8	335	237	161	13.1
S10	7.7	764	547	379	13.2
S11	7.7	639	455	314	13.1
S12	7.5	881	628	441	13.1
S13	7.9	697	495	345	13.1
S14	7.6	738	523	365	13.1
S15	7.8	692	494	343	13.2
S16	7.7	810	576	402	13.1
S17	8.0	905	644	454	13.1
S18	7.8	828	589	408	13.1
S19	8.0	327	233	160	13.1
S20	8.0	641	457	316	13.1

S21	8.0	857	614	433	13.1
S22	7.8	539	383	265	13.1
S23	8.0	385	274	188	13.1
S24	8.0	331	235	160	13.2
S25	8.0	324	232	158	13.2
S26	8.2	860	613	429	13.2
S27	8.0	586	416	288	13.2
S28	8.0	360	258	174	13.1
S29	7.9	593	422	294	13.2
S30	8.0	797	569	396	13.3
S31	8.0	427	302	209	13.2
S32	8.0	595	420	290	13.2
S33	8.0	498	355	244	13.2
S34	8.0	600	426	294	13.3
S35	8.0	728	520	363	13.2
WHO	**6.5-8.5**	**400 µS/cm**	**500 ppm**	**200 mg**	**30°C**

Table 3. 1. Physical Parameters of Water Samples Results

3.2 Chemically Analyzed Water Samples

3.2.1 Alkalinity

The capacity of water to neutralize acids or H ions is measured by alkalinity. "Carbonate hardness" is a term used to describe alkalinity. If there are any changes to the pH scale value of the water, alkalinity functions as a buffer. The pH of the water can help to maintain the pH scale of the water stable. Drinking water, like all water, should have a pH of seven, which implies it's neutral. High alkalinity in our drinking water is desirable since it maintains the water safe to consume. The amount of alkalinity in normal drinking water should be between 20 and 200 mg/L. Alkalinity is mostly made up of dissolved minerals in water that help to neutralize the water we consume.

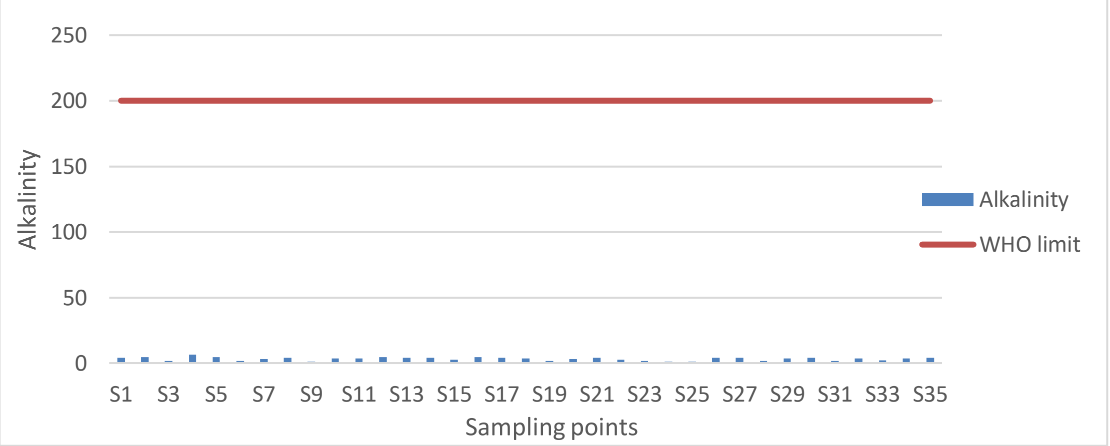

Figure 3. 6. Water Samples' Alkalinity

If alkalinity is substantially lower, it might indicate high chloride, nitrate, or sulphate levels. Such water is known as soft water. Corrosiveness is more likely in water with low alkalinity (less than 150 mg/L). (Saddozai, 2010)

3.2.2 Hardness

The highest allowable hardness level, according to the WHO, is 500 mg/l. The maximum number of water samples allowed has been reached.

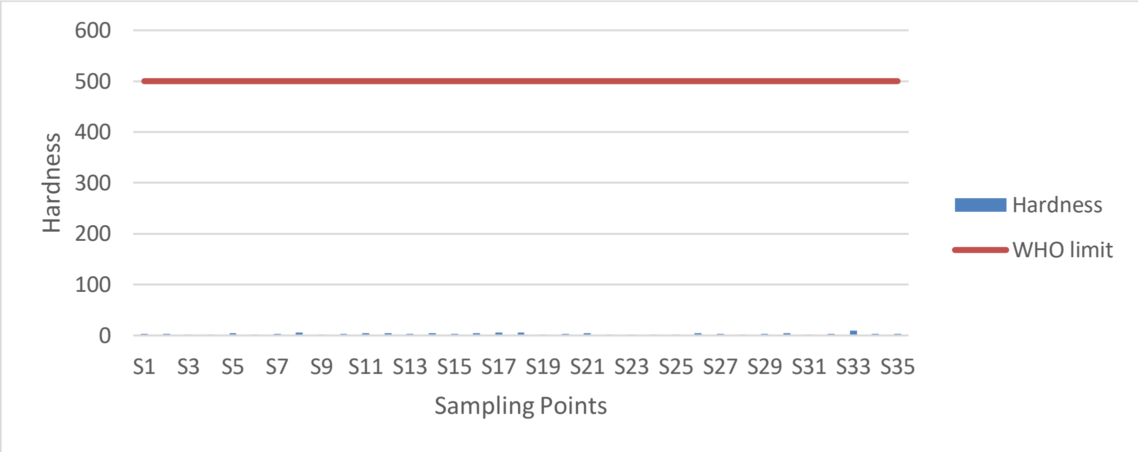

Figure 3. 7. Water samples' Hardness

Total hardness is a test for overall water quality; total hardness has no health implications. From an aesthetic standpoint, values about 150 mg/L are optimal. Water with less than 150 mg/L is considered soft, whereas water with more than 200 mg/L is considered hard.

Table 3.2 Hardness and Alkalinity Test Results

Sample Name	Alkalinity	Hardness Test (Ppm)
S1	4.2	3.2
S2	4.6	3.5
S3	1.4	1.4
S4	6.6	2.2
S5	4.7	4.1
S6	1.4	1.5
S7	2.9	3.3
S8	4.2	6.3

S9	1.3	1.5
S10	3.4	3.8
S11	3.5	4.2
S12	4.4	4
S13	4	3.5
S14	3.9	4.7
S15	2.6	3.1
S16	4.4	4.3
S17	4.1	5.2
S18	3.7	5.5
S19	1.4	1.5
S20	3	3.6
S21	4.1	4.1
S22	2.4	2.2
S23	1.8	1.7
S24	1.3	1.5
S25	1.3	1.5
S26	4	4.3
S27	4.1	3.3
S28	1.6	1.7
S29	3.7	3.4
S30	4.2	4.9
S31	1.8	1.7
S32	3.4	3.3
S33	2.1	9.2
S34	3.4	3.4
S35	4	3.5

WHO	20- 200 mg	500 ppm

3.2.3 Chlorides

An argentometric titration was used to determine the amount of chloride in water samples. Silver nitrate (AgNO3) interacts with chloride to generate solid white silver chloride crystals in this titration method. Excess silver nitrate interacts with the indicator potassium chromate to produce reddish yellow silver chromate. The steps mentioned below make up the whole procedure:

Equations

$AgNO3 + NaCl \rightarrow AgCl + NaNO_3$

Chlorides Cl are below the WHO-recommended acceptable level of 250 mg/l. Water Sample S18 has an excessive amount of sodium chloride (NaCl) (207.9). In all the water samples, the sodium content was determined to be within the allowed range of 200mg/l.

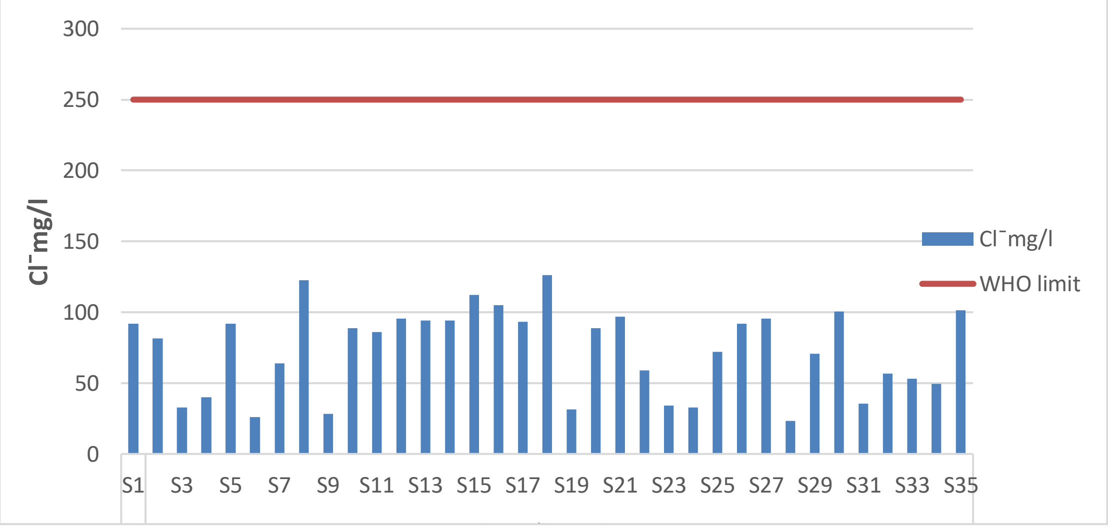

Figure 3. 8. Chlorides Concentration in Water Samples

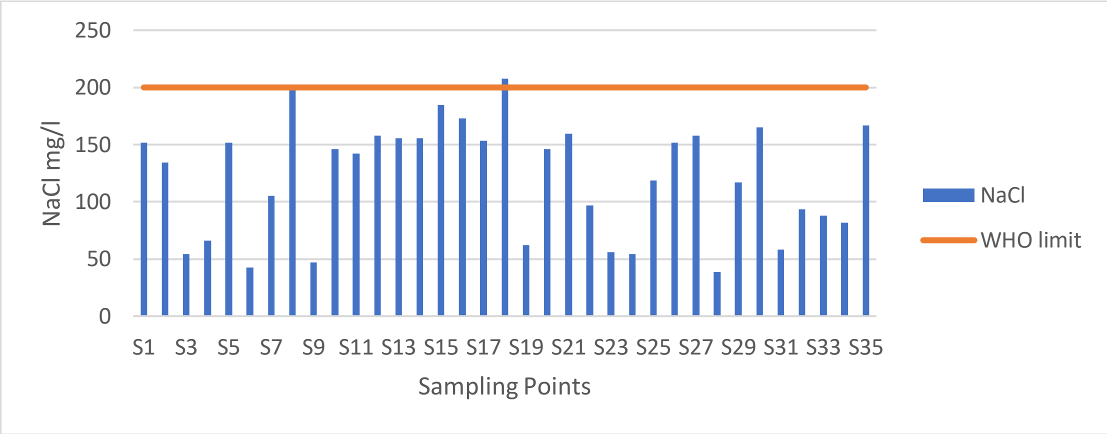

Figure 3.9. Sodium Chloride Concentration in Water Samples

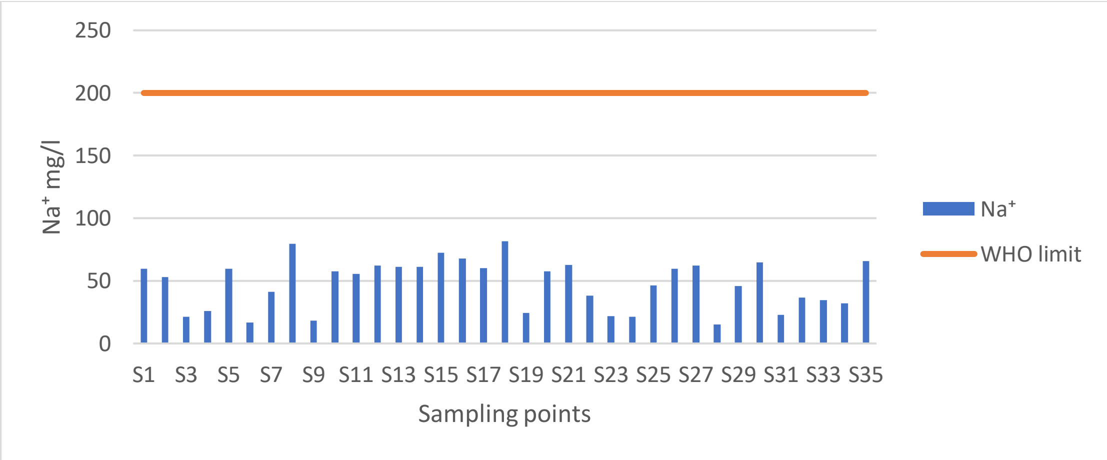

Figure 3.10. Sodium Concentration in Water Samples

3.2.4 Carbonates

Carbonate is a polyatomic ion with the formula CO3-2 that has a symmetrical planar molecular structure with one atom surrounded by three oxygen atoms. Because the carbonate particle is a reasonably robust base, it attracts protons in liquid solutions of a Lewis base. It has a suitable charge of -2 on it. Carbonate forms insoluble compounds when it links to metal cations. The term "carbonate" is usually used to refer to one of the salts or carbonate minerals found in it. Calcium carbonate (CaCO3) and sodium carbonate are two of the most well-known carbonates (Na2CO3) (Ming, 2017)

Sample ID	Cl^-	NaCl	Na^+	CO_3^- mg/l	HCO_3^- mg/l	$Na_2CO_3^-$ mg/l	$NaHCO_3^-$ mg/l
S1	92.1	151.9	59.7	540	549	953	756
S2	81.5	134.4	52.8	336	341	593	470
S3	32.9	54.3	21.3	180	183	317	252
S4	40	66	25.9	240	244	423	336
S5	92.1	151.9	59.7	480	488	847	672
S6	25.8	42.6	16.7	156	158	275	218
S7	63.8	105.9	41.3	336	341	593	470
S8	122.6	202.2	79.5	480	488	847	672
S9	28.3	46.7	18.3	144	146	254	201
S10	88.6	146.1	57.4	300	305	529	420
S11	86.1	142	55.8	216	219	381	302
S12	95.7	157.7	62	540	549	953	756
S13	94.2	155.4	61.2	384	390	678	537
S14	94.2	155.4	61.2	300	305	529	420
S15	112	184.5	72.5	336	341	593	470
S16	104.9	172.8	67.9	540	549	953	756
S17	93.2	153.6	60.3	528	536	932	739
S18	126.2	207.9	81.7	312	317	551	436
S19	31.5	61.9	24.3	180	183	317	252
S20	88.6	146	57.4	360	366	635	504
S21	96.7	159.4	62.6	480	488	847	672

S22	58.8	96.9	38.1	324	329	572	453
S23	34	56.06	22	192	195	339	268
S24	32.9	54.31	21.3	180	183	317	252
S25	71.9	118.5	46.5	168	170	296	235
S26	92.1	151.8	59.6	480	488	847	672
S27	95.7	157.7	61.9	360	366	635	504
S28	23.3	38.5	15.1	216	219	381	302
S29	70.9	116.8	45.9	420	427	741	588
S30	100.3	165.2	64.9	384	390	678	537
S31	35.4	58.4	23	216	219	381	302
S32	56.7	93.5	36.7	384	390	678	537
S33	53.1	87.6	34.4	264	268	466	369
S34	49.6	81.8	32.2	384	390	678	537
S35	101.3	167.02	65.7	240	244	423	336
WHO limits	250mg/l	200 mg/l	200 mg	-	-	-	-

Table 3.3. chemical test results of water samples

3.3 Heavy Metals Analysis

Heavy Metals like Cadmium (Cr), Chromium (Cr), Lead (Pb), Nickel (Ni) were analyzed through AAS (PG 990) at Quaid e Azam University Islamabad and Arsenic (As) was tested through Arsenic kit at Bahria University Islamabad.

Sample ID	Cd	Cr	Pb	Ni	As
S1	0.014	BDL	0.01	0.01	0
S2	BDL	0.01	0.011	0.015	0
S3	0.015	0.014	0.01	0.02	0
S4	0.01	0.012	BDL	0.01	0
S5	BDL	0.01	0.012	BDL	0
S6	0.01	0.02	0.01	0.01	0
S7	0.01	0.014	0.01	0.015	0
S8	0.01	0.015	0.02	0.02	0
S9	0.014	0.014	0.01	0.015	0
S10	0.015	0.01	BDL	0.014	0
S11	BDL	BDL	0.01	0.01	0
S12	0.01	BDL	0.013	0.01	0
S13	0.015	0.014	0.01	BDL	0
S14	BDL	0.02	BDL	0.014	00
S15	0.01	0.014	BDL	0.02	0
S16	0.015	0.01	0.01	0.014	0

S17	BDL	BDL	0.01	BDL	0
S18	0.02	BDL	0.014	0.01	0
S19	0.019	0.01	0.012	0.015	0
S20	0.015	0.014	0.01	0.02	0.01
S21	0.01	0.01	0.013	0.01	0
S22	0.02	0.014	0.02	0.019	0
S23	0.014	0.014	0.014	0.016	0
S24	0.023	0.018	0.01	0.02	0
S25	0.01	0.01	0.011	0.021	0
S26	0.01	0.013	0.01	0.01	0
S27	0.015	0.01	BDL	0.01	0
S28	0.02	0.02	0.013	BDL	0
S29	0.021	0.01	0.01	0.021	0
S30	0.015	0.01	0.025	0.01	0
S31	0.01	BDL	0.01	0.014	0.01
S32	BDL	0.012	0.013	0.01	0
S33	BDL	0.014	0.01	0.01	0
S34	0.01	BDL	0.01	0.012	0
S35	0.014	0.014	0.012	0.011	0
WHO	**0.003**	**0.05**	**0.01**	**0.01**	**0.01**

Table 3.4 Heavy Metals Analysis Results of Water samples

3.3.1 Cadmium (Cd):

Cd levels in drinking water that surpass the WHO recommended limit of 0.003 mg/l can harm the kidneys. (Qadeer, 2004). Activities like fossil fuel combustion, use of fertilizers, waste disposal and its burning and auto workshop activities are responsible for Cd in the groundwater of these towns. (Qadeer, 2004)

The concentration of cadmium in Sample ID S1, S3, S4, S6, S7, S8, S9, S10, S11, S13, S15, S16, S18, S19, S20, S21, S22, S23, S24, S25, S26, S27, S28, S29, S30, S31, S34 and S35 were exceeding the permissible limit of WHO i.e., 0.003 including mostly bore well samples and some tube well water samples as well. The maximum Cd was recorded in Sample S24 (0.023) which is a tube well sample. The Sample ID S2, S5, S12, S14, S17, S32 and S33 showed zero Cadmium concentrations.

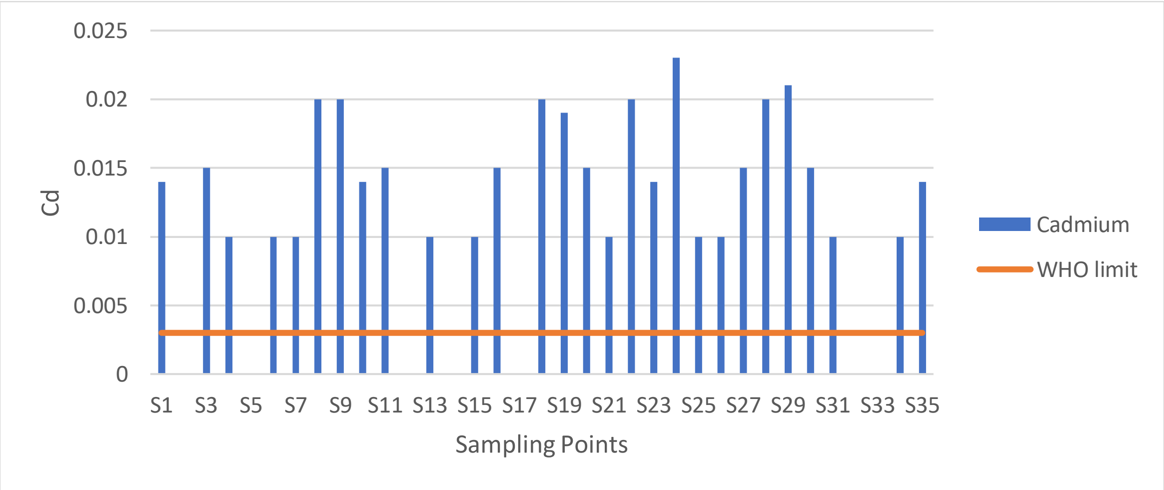

Figure 3.11 Cadmium Concentration in Water Samples

EPA has discovered that short term effects of elevated levels of cadmium can induce nausea, vomiting, diarrhoea, muscular cramps, salivation, sensory changes, liver damage, convulsions, shock, and renal failure. Long-term exposure to cadmium at levels over the maximum contamination limit has the potential to harm the kidneys, liver, bones, and blood. (Idrees, 2018)

3.3.2 Chromium (Cr):

Chromium is an important element in a variety of sectors, including steel, pigment, and metallurgy. Hypersensitive dermatitis can occur in those who use water-based chromium more than the authorized maximum fixation level for numerous years. (Qadeer, 2004)

All the water samples had Cr concentrations that were within WHO's acceptable limits, i.e.., (**0.05).** The Sample ID S1, S11, S12, S17, S18, S31 and S34 showed zero Chromium concentrations.

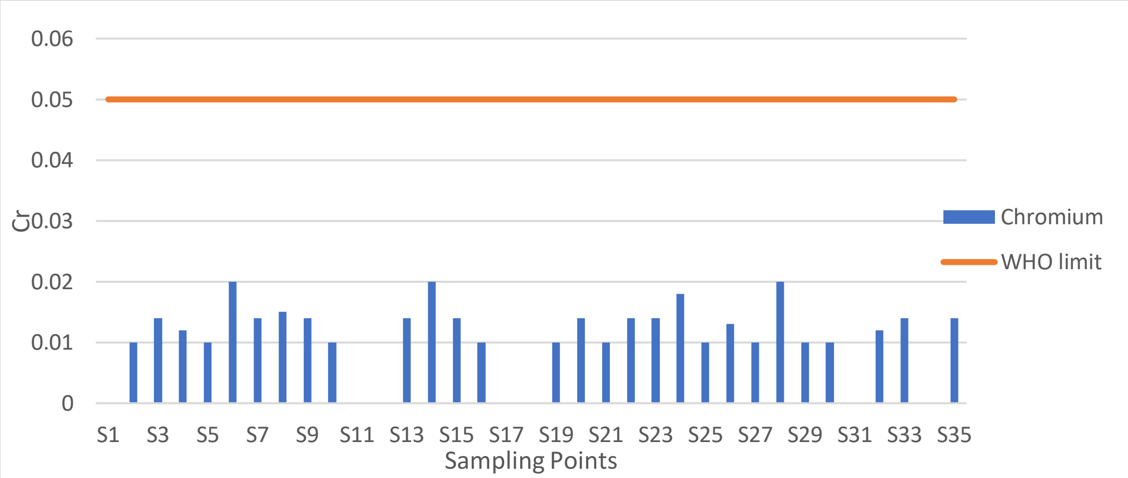

Figure 3.12 Chromium Concentration in Water Samples

3.3.3 Lead (Pb):

Higher lead levels in drinking water can cause physical and mental development delays in infants and children, as well as kidney disease and hypertension in adults. (Qadeer, 2004)

The Pb concentration in Sample ID S2, S5, S8, S12, S18, S19, S21, S22, S23, S25, S28, S30, S32 and S35 were exceeding the WHO limit of 0.01 which mostly includes bore well samples and some tube well samples too. The maximum recorded limit was 0.025 in Sample S30 which is a bore well sample. The Sample ID S4, S10, S14, S15 and S27 showed zero Lead concentrations.

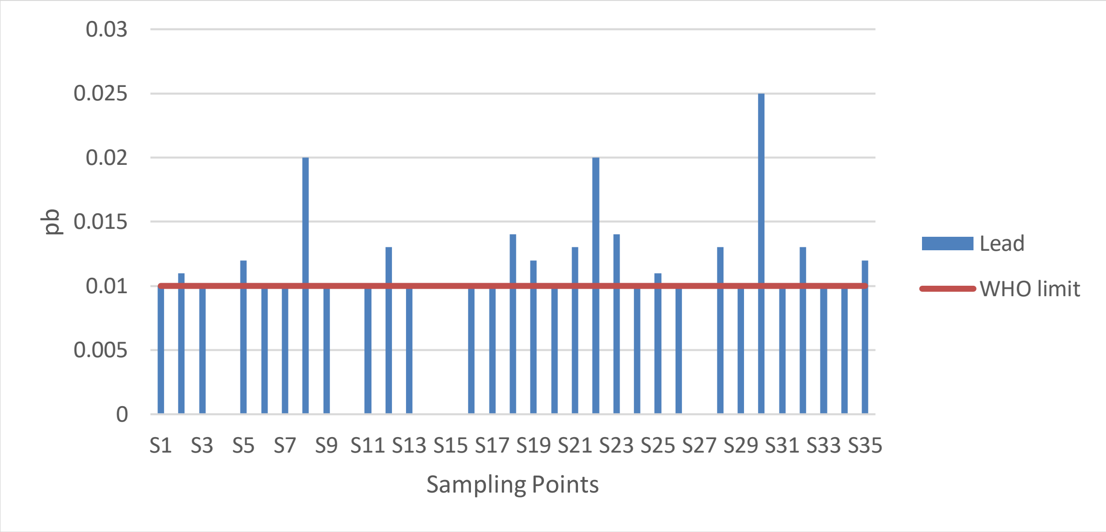

Figure 3.13 Lead Concentration in Water Samples

Elevated levels of lead in drinking water can seriously affect the health. If such water reaches the bloodstream, it generates a high blood lead level, and can have negative health consequences. It can harm the brain and kidneys, as well as disrupt the creation of red blood cells, which transport oxygen throughout the body. Infants, young children, and pregnant women are the most vulnerable to lead poisoning. Lead may also affect a child's mental and physical development, as well as cause hearing difficulties. (Hashem, 2017)

3.3.4 Nickel (Ni):

Nickel (Ni) is important for humans but in large amounts can be harmful to health. Ni occurs in an environment in very low concentrations. It is used as a raw material in the steel and metals manufacturing. (Mahurpawar, 2015)

The Nickel concentrations in Sample ID S2, S3, S7, S8, S9, S10, S14, S15, S16, S19, S20, S22, S23, S24, S25, S29, S31, S34 AND S35 were exceeding the WHO permissible limit of 0.01 including both bore well and a few tube well samples. Whereas The Sample ID S5, S13, S17 and S28 had zero nickel concentrations. The rest of the Samples were within the permissible limit.

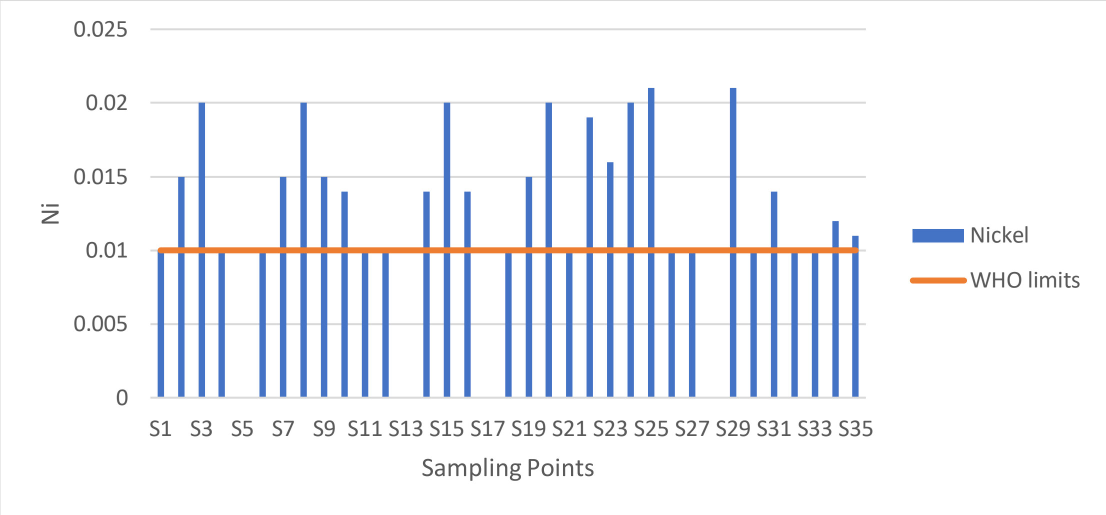

Figure 3.14 Nickel Concentration in Water Samples

Nickel compounds can produce nausea, vomiting, diarrhoea, headaches, coughing, and shortness of breath if consumed in excess. Ingestion of high quantities of a nickel compound can be fatal in some situations. High quantities of nickel compounds that dissolve easily in water (soluble) have been linked to cancer. (Malik, 2010)

3.3.5 Arsenic (As):

Arsenic is found in significant concentrations in the groundwater of many nations. In its inorganic form, it is very poisonous. The most severe concern to human health from arsenic is polluted water used for drinking, preparing food, and agriculture cultivation. The arsenic concentrations were under WHO's acceptable limit of 0.01 mg/kg. The Sample ID S20, S25 and S31 were 0.01. The remaining water samples had zero Arsenic concentrations. (Mahurpawar, 2015)

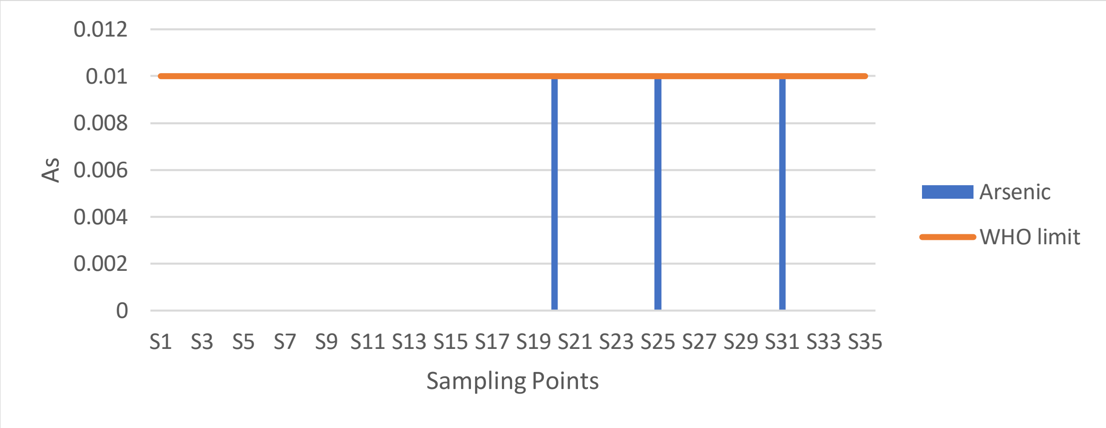

Figure 3.15 Arsenic Concentration in Water Samples

3.4 Microbiological Examination

3.4.1 Counts of Microbes

After 24 hours, the CFU counts of bacteria grew on three different Medias are shown in the table. In diverse water samples, microbial counts ranges from zero to too numerous to count (TNTC). The CFU count on Nutrient Agar (NA) was greater than the other media in general (SS and EMB).

Sampling Points	Nutrient Agar (NA)	Salmonella Shigella (SS)	Eosin Methylene Blue (EMB)
S1	26	0	0
S2	24	0	0
S3	59	1	1
S4	14	2	1
S5	10	1	0
S6	25	0	0
S7	6	2	0
S8	3	1	1
S9	9	4	0
S10	20	1	0
S11	17	4	0
S12	8	0	0
S13	22	0	0
S14	3	0	0
S15	7	0	0
S16	61	0	0
S17	109	5	7
S18	16	4	0
S19	4	0	0
S20	TNTC	0	0

S21	25	0	0
S22	77	0	5
S23	0	0	0
S24	31	0	2
S25	1	0	0
S26	2	0	0
S27	10	1	0
S28	15	0	0
S29	49	0	2
S30	TNTC	0	0
S31	13	0	3
S32	216	1	4
S33	14	1	3
S34	10	0	0
S35	2	2	0

Table 3. 5. Counts of microorganisms in water samples on various mediums

The results of microbial analysis suggested that Salmonella and shigella are positive mostly at bore well locations of study area. Because these pathogenic bacteria are harmful they are thought to be responsible for a variety of disease outbreaks, including typhoid, dysentery, and other diseases in humans. (Scallan et al., 2011).

The existence of coliform bacteria in drinking water, especially E. coli (a kind of coliform bacteria), signals that the water may include pathogens that cause diarrhoea, vomiting, cramps, nausea, headaches, fever, exhaustion, and even death. Pathogens in drinking water are more likely to sicken or kill infants, children, the elderly, and persons with compromised immune systems. Salmonella is one of the most common organisms responsible for foodborne illness outbreaks. Shigella bacteria can cause food poisoning, which includes diarrhoea and stomach discomfort. (Farid, 2012)

CONCLUSION

The physicochemical tests of pH, E.C, TDS, Salts, Temperature, Hardness, Alkalinity, Chlorides Test, Carbonate Test, and Heavy Metals including Cadmium, Chromium, Lead, Nickel, and Arsenic were performed on water samples taken from various locations in this study. Results showed that pH of most of the samples were within the recommended limit by WHO except some of the bore well water samples. TDS was detected in elevated levels at some location points of mostly bore well water samples and one tube well water sample as well. E.C was also exceeding the permissible limit at many location points in variable amounts and Salts were also found at elevated levels at mostly bore well and a few tube well location points. The chlorides were under the WHO-recommended acceptable limit. The alkalinity and hardness of the water samples were both lower than the permissible levels.

According to the findings of the heavy metals study, all the samples were found to be contaminated with one or more heavy metals. Cadmium and nickel levels were found to be over the threshold including mostly bore well and some tube well water samples too. At other locations, lead has also showed an upward tendency mostly in bore well samples. In all the water tests, Chromium and Arsenic were determined to be below permitted levels. In virtually all the water samples, there was no trace of arsenic. Relatively higher level of heavy metals found in Tench Bhata's drinking water is a great matter of concern because the human body is unable to release these metals, they accumulate inside the body. It has no immediate effect on the body, but it can cause serious long-term problems, with most of them affecting the brain. It can cause mental and central nervous system dysfunction. The lungs, liver, kidneys, and other important organs are also affected. Heavy metals are carcinogenic, meaning they can cause cancer.

In microbial analysis Salmonella and shigella are positive at mostly bore well locations of study area. Because these bacteria are harmful, they are thought to be responsible for a variety of disease outbreaks in people, including typhoid, dysentery, and other illnesses.

The entire city is breaking the drinking water supply network's norms and ethics. Land use laws should be limited, particularly in the water supply sector since this will assist to enhance water sustainability and quality. To modify the community's behavior around water consumption, conservation, and disposal, a lot of effort and battle is necessary. The government should invest massive resources to make big changes to the infrastructure of the water supply system to eliminate pollution issues. To enhance management systems, modern and cutting-edge approaches are necessary.

Major cause of pollution at Rawalpindi is the Nullah lai and korang rivers recharge system which transports wastewater from the twin cities. Due to enormous expansion in recharge area the Rawal Lake has also been poisoned. These contaminated water sources have surrounded the ground water aquifer, contaminating it.

The majority of distribution lines run through sewer drains, resulting in pollution at the consumers end and due to undersized and leaky pipes the water distribution is insufficient and unhealthy for citizens.

In general, the current investigation discovered that this water is not fit for drinking purpose as some parameters were outside of WHO's acceptable limits, posing a risk to consumers. People in the neighborhood were found to be uninformed of the drinking water's quality. People dump their trash near water sources in open locations. There is no treatment facility for the water. When it rains, the water becomes murky, and a variety of contaminants mix with it as it travels down the hill.

RECOMMENDATIONS

Today's environmental issues are complicated, needing a wide range of solutions. Interdisciplinary techniques enable assessment at several levels at the same time, allowing for the inclusion of site-specific factors.

Following are some recommendations based on the research:

1. Water usage Master Plans must be created that consider technological, budgetary, and political constraints.
2. Technical and scientific experts who are familiar with aquifer systems, water balances, and water volumes from precipitation, storage, recharge, and consumption must evaluate economic and social factors.
3. Users' awareness, as well as stakeholders' and decision-makers' engagement, are equally as crucial as any type of water treatment or reuse.
4. Pumping permits, definition of permissible uses, delineation of protection zones, identification of pollutants, and monitoring are all part of the legal framework that must be defined.
5. Concerned authorities, such as Punjab-EPA, should take efforts to ensure that the drinking water quality in Tench Bhata is continuously monitored.
6. In Tench Bhata, water treatment facilities should be developed.
7. Public awareness programmes should be developed to raise public understanding about the importance of clean drinking water and the health risks connected with polluted water.
8. Measures should be adopted to prevent individuals from disposing of their trash near water bodies in open places.
9. A comprehensive study should be conducted to determine the source identification of pollutants in the water source.

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APPENDICES

Figure 3.16 Performing Carbonates test in Lab.

Figure 3.17 Petri dishes with different mediums

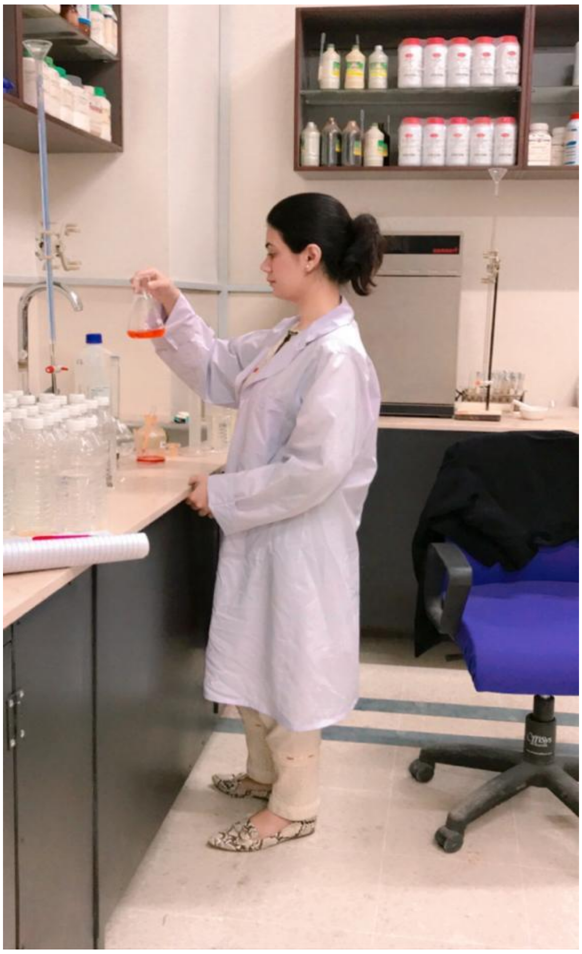

Figure 3.18 Performing Alkalinity Test in Lab.