GROUNDWATER QUALITY ASSESSMENT FROM SECTOR I-10/2 AND E-11/3, ISLAMABAD

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We dedicate this thesis to our beloved parents who stood by our side and supported us wholeheartedly

ABSTRACT

The primary supply of water for drinking, industry, and residential use in urban areas is groundwater, which is frequently over-utilized. Groundwater is frequently degraded in metropolitan areas due to increasing industrialization, urbanization, and poor solid and toxic waste management. A study was carried to examine the quality of groundwater in two of the industrial and urban sectors of Islamabad, I-10/2 and E-11/3. 30 groundwater samples were collected from both the sectors, 15 from each sector covering the whole area, the collected samples underwent microbiological, and physiochemical analysis. The collected samples were also analyzed for heavy metals, arsenic (As) and iron (Fe). The standard analytical techniques were followed to acquire the water samples. According to the physical parameters, all parameters were within the acceptable range, with the exception of electrical conductivity (EC), which is higher than the WHO allowable range. The chemical parameters showed chloride (Cl), sodium chloride(NaCl), sodium (Na) and alkalinity all were within the acceptable range except for total hardness, calcium, and magnesium which were above the permissible limits in all samples. The microbiological analysis showed the growth of total bacteria in all samples. The growth of total bacteria in water samples from sector I-10/2 exceeded the permissible limit whereas the water samples from E-11/3 showed growth of total bacteria within the allowable range. The growth of microbial organisms in water samples makes it clear that water is not suitable for drinking purpose as it will cause stomach related diseases. The results of heavy metals analysis showed that all collected water samples had no arsenic(As). The levels of iron (Fe) in collected water samples were within the permissible limit except for one groundwater sample from sector E-11/3 which exceeded the permissible limit. According to the results, water quality of both the sectors cannot be considered good. The water cannot be used for drinking purposes. If we compare the results of both the sectors, highest counts were found in sector I-10/2 compared to E-11/3, which makes it clear that the water quality of sector I-10/2 is poorer. The findings of this study highlight the necessity for local municipal authorities to manage groundwater sources effectively and to promote knowledge about the significance of clean water and groundwater resource. Improvements must be made to the policies governing water quality.

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ABBREVIATIONS

WHO	World Health Organization
PSQCA	Pakistan Standards and Quality Control Authority
PCRWR	Pakistan Council of Research in Water Resource
CDA	Capital Development Authority
ICT	Islamabad Capital Territory
TDS	Total Dissolved Solids
TSS	Total Suspended Solids
DO	Dissolved Oxygen
EC	Electrical Conductivity
E-coli	Escherichia coli
HEPA	High Efficiency Particulate Air
EDTA	Ethylenediaminetetraacetic acid
EBT	Eriochrome black T
PTE	Potentially hazardous element
NEQs	National environmental quality standard
THQ	Tetrahydroquinoline
ADI	Average daily intake
HQ	Hazard quotient
ADD	Average daily dose
SS	Salmonella Shigella
MAC	MacConkey
NA	Nutrient agar
IWM	Integrated Water Management
UV	Ultraviolet

CHAPTER 1

INTRODUCTION

Almost 71% of the Earth's surface is covered by water, and all living things rely on it. It happens on Earth in big water areas like oceans, and also underground in aquifers. Only a small amount, 1. 6%, is underground, and even less, 0. 001%, is in the air as vapor, clouds, and rain. 97% of the water on Earth's surface is in the oceans. Only a small amount, 2. 4%, is locked in glaciers and polar ice caps. Another small portion, 0.6%, is found in other surface waters like lakes, rivers, and wetlands (Gorde & Jadhav, 2013). Water is essential to life and is a key component of the ecosystem of the world (UNICEF, 2010). One of the most important, rare, priceless, and replenishable natural resources available is water (WWAP, 2009). The primary supply of water for drinking, industry, and residential use in urban areas is groundwater, which is frequently over-utilized. Groundwater is frequently degraded in metropolitan areas due to increasing industrialization and poor solid and toxic waste management techniques, which makes the water drinkable for future use. In addition to lowering water quality, ground water pollution also poses a risk to social progress, economic growth, and public health (Kavitha, 2010).

In addition to humans, all other living forms on Earth depend on freshwater resources. The use of water resources is made up of subsurface water (95–96%) and surface water (e.g., lakes, rivers, etc.) (3.5%). Groundwater extraction is the simplest solution to meet the rising water demands as water scarcity issues arise in many places worldwide (Lockhart, 2013). An estimate of the average daily water use for residential purposes, personal cleanliness, planting, drinking water, and cooking in developed nations is 315 liters. The most crucial amount for survival is 8 liters per day, which comes from preparing food and using water that is drinkable (Díaz-Cruz, 2008). Over the past few decades, a shortage of availability to clean, drinkable water has caused millions of deaths. According to calculations that include the manufacturing process, urban and rural consumption of water, and other factors, it is estimated that each individual has access to a very low quantities of water per day (Giordano, 2009).

Due to the whims of the monsoon and a lack of surface water, the majority of the world's semi-arid and dry areas are becoming increasingly dependent on groundwater. This is especially true for Pakistan, one of the driest countries on earth, which has been labeled as water challenged and is projected to experience water scarcity in the coming years (Hamazah, et al., 1997). The amount of water in rivers, lakes, and groundwater is also decreasing as a result of a mix of lower rainfall and increasing evaporation. Long-lasting droughts and the failure to develop new water supplies worsen the condition of water scarcity (Fordyce, et al., 2007). Thousands of people are now forced to drink brackish water due to the severe drought that has destroyed livelihoods in the nation's semi-arid regions, especially in Sindh Province. Additionally, it is said that the subsurface aquifers in Baluchistan Province are disappearing at a rate of 3.5 meters per year and will dry up in the next fifteen years (Sial JK, 1999).

Additionally, in the past ten years, growing population, urbanization, and industrialization have led to increased pollution, one of the biggest threats to water resources and overuse of the country's water resources, particularly groundwater (Khahlown, et al., 2002). The state of groundwater, and degradation in general and in particular is a major problem (Qadir, et al., 2008). According to reports, unregulated release of untreated wastewater from municipalities and industries and overuse of fertilizers and insecticides are to blame for the poor quality of water in major cities like Sialkot, Gujarat, Faisal Abad, Karachi, Qasur, Peshawar, Lahore, Islamabad, Rawalpindi, and Sheikhupura (Bhutta, et al., 2002).

In addition to lowering groundwater levels, excessive withdrawal from a subsurface aquifer for agricultural and industrial purposes has also damaged drinking water quality (Ahmed, et al., 2019). The most essential element of our system for maintaining life is groundwater, which also makes a considerable contribution to economic growth (Umar, et al., 2022). Despite its significance, rising consumption by humans and industrial activity have drastically degraded groundwater (Rammohan, 2015). At the time of its independence, Pakistan had a population of just 32.5 million, which increased dramatically to 231.4 million in 2021. This information is from the Pakistan Bureau of Statistics (2019). Our country's finite natural resources are severely threatened by this expanding population trend (Saatsaz, et al., 2011).

Pakistan's once-abundant water supply has run dry, and the country is currently experiencing a severe water scarcity. The supply of water per person has dropped from 5300 m^3 in 1951 to 1105 m^3 in the present, exceeding the 1000 m^3 threshold of water scarcity

(Qureshi A. , 2015). The main factors contributing to a decrease in the availability of water are an increasing population, declining water storage capacity, and environmental harm caused by the discharge of unregulated agricultural and sewage wastes into streams and rivers (Li, et al., 2019). The treatment of home and industrial wastewater is a significant issue because it jeopardizes freshwater supplies, public health, and agricultural growth. The quality of groundwater deteriorates as a result of water infiltration from drains and settling basins (Qureshi, et al., 2010).

1.1 Groundwater pollution

Since fresh water is a scarce commodity and a vital component of life, excessive use of it lowers the quantities that will be accessible for future generations. All living things that rely on the hydrologic cycle are directly impacted by water resource pollution (Sajjad, et al., 2022). Due to excessive abstraction, excessive use, and a lack of conservation efforts, most developed nations, including Pakistan, lack freshwater resources. Urban, agricultural, and industrial developments, require significant amounts of water and are characteristics of big urban areas in the developed world. The regional water supplies are degraded qualitatively as a result of excessive usage. In developed places, the quality of subsurface water varies from good grade fresh water (potable), through medium quality (domestic, industrial), to unsuitable quality for any application. A variety of synthetic and natural pollution sources contribute to the deterioration of water quality (Nickson, et al., 2005).

Over pumping, wastewater treatment facilities and their waste products discharge, excessive use of fertilizers, mining operations, garbage dumps, and burial grounds are just a few examples of direct anthropogenic activities. Indirect impacts of humans include raised urban development, expansion of infrastructure, climate change water reservoirs, and disruption of river networks (Abbas, et al., 2014). Naturally deterioration of water takes place as a result of saltwater intrusion and infiltration, which has adverse effects similar to those of over abstraction, geothermal saltwater penetration, which takes place in geothermal areas, interactions among rock and water, and radioactive decomposition of uranium and thorium series, which leads to radon gas pollution and can raise levels of elements that harm underground water quality. All these factors contribute to the degradation of groundwater and may lead to health impacts among consumers used for various purposes (Khalid, et al., 2018).

1.2 Sources of groundwater pollution

Pollution of groundwater and declining water quality are two usual sources of pollution. Household and municipal trash, waste from industries (organic, inorganic, trace elements, etc.), and mining activities (chemical, minor elements, intrusion, etc.) are a few examples of the sources of contamination. Installation, usage, and recycling of water supply sources can lead to deterioration due to infiltration, over-pumping, saltwater mixing, pollution of surface water, and rock-water interactions.

Numerous human activities that alter the physicochemical properties of water lead to the decline of groundwater quality and the subsequent contamination of water resources. The majority of pollution sources are water usage discharge of harmful substances. It is simpler to find pollution in sources of surface water. In contrast, it is challenging to locate the sources of underground water contamination, which persists for years.

1.2.1 Anthropogenic and natural sources of groundwater pollution

The majority of pollution comes from sources that are generated by humans. This category often consists of the removal and releasing of effluent and solid waste; the removal and burial of industrial waste; the application of chemicals such as pesticides and insecticides; the removal and burial of waste from mining operations; and the removal and burial of nuclear energy waste. Human-caused sources can result from a variety of activities, including excessive withdrawal of groundwater, unrestricted application of fertilizers, mining operations, garbage disposal, extended urban development, improper use of chemicals, burial of inorganic and organic substances, and sewage storage (infiltration), disruption of river networks, the extraction and processing of toxic minerals, and waste from graveyards, which may also seep into the deep undisturbed soil.

Elements that are trace and other chemicals, such as those produced by extraction of minerals, wastewater from cities and farms, nutrients, energy sources, and other anthropogenic activities, can be found in the waste matter and water and can be hazardous and fatal to people. For example, many elements have all been found in underground water sources. Additionally, the usage of fertilizers, farm animals, farming activities, and wastewater leaks have all been related to contamination by greater amounts of essential nutrients, this may include ions or organic substances of nitrogen and phosphorus. Petroleum hydrocarbons and biological waste (bacteria, viruses, and parasites) are other pollutants that have been found in groundwater and are linked to human activity. The contamination of various inorganic substances, which can be harmful and are linked to the salt content of water resources due to elevated levels of Ca, Mg, Na, Cl, and F, is caused through the penetration of disposals, extraction operations, and wastewater leaks.

Additionally, due to weathering, erosion processes or other natural occurrences, groundwater can become contaminated. This group involves the following kinds of sources: easily dissolved rocks (such as gypsum and mineral salt), disintegration of rocks can also contaminate the water aquifers underground, strong evaporation, particularly in shallow waterways that elevates groundwater and leads to salt accumulation in water channels, deterioration of water sources in locations near hot geothermal and volcanic fields which may also alter the chemical properties of water, rock oxidation, contamination by seawater, decay of radioactive substances from uranium-rich rock foundations, and the chemical breakdown involving substances in the air or in the water. This process can occur both naturally and due to the impact of human activities.

1.2.2 Point and non-point sources of pollution

There are many potential causes of water pollution, and they can be divided into point sources and diffused contamination sources (see the figure below). The point sources are mostly from one identifiable source which is easy to locate whereas non-point or diffused sources of pollution are exceedingly difficult to identify as they come from multiple sources. According to the figure below, surface water pollution is closely related to subsurface water pollution, thus when surface water pollution occurs, the corresponding groundwater pollution also occurs. Public and commercial treatment facilities for waste products, which can be found in urban, industrial, or agricultural environments, are significant point sources. (Pal et al., 2010; Lapwoth et al., 2012). The wastewater from treatment plants and other sources may occasionally combine to harm groundwater and surface water bodies. Such waste and chemicals in the water have a significant impact on changing the quality of the water. (Stefanakis et al., 2014). Manufacturing operations like food production, mining operations, producing goods, animal farms, and dumps are additional point causes of groundwater pollution. Additionally, dumping pollutants into percolating water bodies, water seepage holes, excavations, dry streambeds, dumping boreholes, and wells for injection are other human activities that may lead to groundwater pollution.

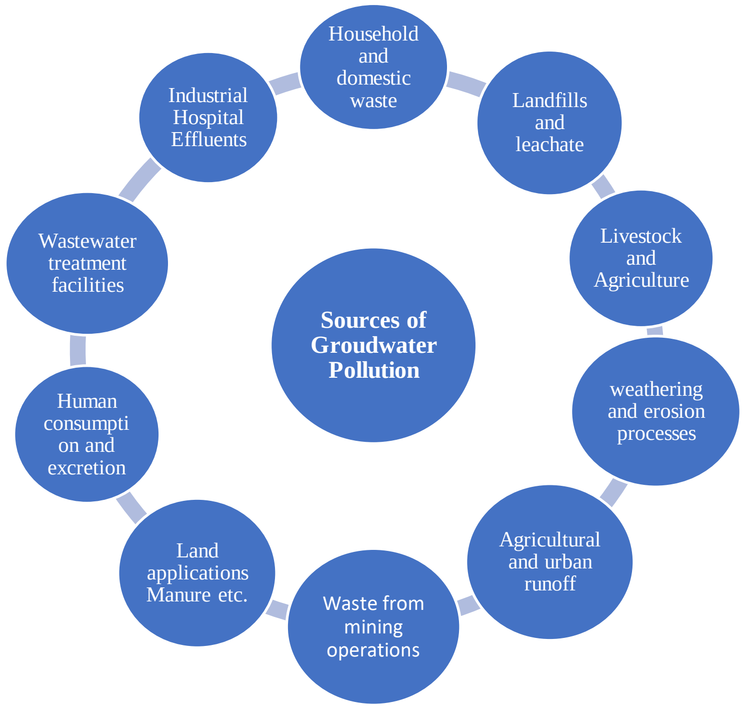

Figure 1.1: Potential point and non-point sources of groundwater pollution

1.3 Effects of groundwater pollution

In Pakistan, poor water quality is the main issue affecting both the environment and public health. Both groundwater and surface water in the country have been polluted with many toxic substances and microbes that make them unfit for drinking. Drinkable water has become contaminated due to poor living circumstances and some lack of attention (Azizullah, et al., 2011). Only a few urban places have water purification facilities installed; however, some of them are ineffective and fail to detect microbial contamination. According to a government survey on clean and safe drinking water, just 56% of all residents in the country have access to it, while 44% of residents living in rural regions lack access to clean water (Rasheed, et al., 2009). According to multiple studies, 70% of people lack the availability of safe drinking water. The polluted conditions in Pakistan have led to a high number of people being affected by diseases like typhoid, hepatitis, dysentery, cholera, and diarrhea. In fact, around 20-40% of hospital beds are occupied by patients with these water-related diseases.

Furthermore, waterborne diseases are responsible for a significant portion of fatalities in the nation, accounting for 33% of all deaths (Amin, et al., 2012).

One of the primary causes of health-related issues is the contamination of surface and groundwater. According to the 2003 UN World Water Development Report, 2.3 billion people worldwide suffer from diseases caused by contaminated water (Rakib, et al., 2020). The World Health Organization estimates that each year more than 2.2 million people of underdeveloped nations pass away from illnesses brought on by a lack of accessibility to clean water and sufficient sanitation. Infectious and parasitic disorders, the majority of which are water-related, are responsible for almost 60% of premature deaths globally. In the past 20 years, there has been a 200% increase in the number of people with water-borne illnesses who are being treated in Pakistani hospitals (Ahmed K, 2000). According to the National Conservation Strategy (NCS) study, water-borne infections are thought to be responsible for 40% of fatalities. 60 percent of baby deaths are related to the same diseases, which account for around 25 to 30 percent of every admission to the hospital. The most common ways for diseases with symptoms including stomachache, weakness in the body, lack of appetite, eye infections, discomfort of the skin, and fever to spread are through drinking and bathing in contaminated water. According to reports, more people are being diagnosed with such diseases, especially in Sindh Province (Ishaque M, 2001).

In water bodies, where the concentration of sodium is higher, people usually suffer from hypertension and kidney issues. The surplus amount of heavy metals in water bodies are carcinogenic for humans. In Pakistan, it is estimated that due to water borne diseases about 230,000 infants (less than five years old) die each year (Ezeribe, et al., 2012). Reproductive and endocrinal damage is caused by the excess amount of chlorides in the water. The spread of these diseases can be prevented by proper monitoring and filtration techniques. Although, for the emerging contaminants the conventional filtration methods for water purification are not efficient as these contaminants are often not even evaluated (Jehan, et al., 2009).

Due to the contamination of surface or ground water various diseases spread. Human health is affected by contaminated water and can be fatal sometimes. When the physical, chemical, and biological parameters exceed the permissible limit, they have an adverse effect on human health. Pathogenic organisms, which are responsible for water pollution may cause intestinal infections like cholera, dysentery, fevers, skin diseases, and food poisoning. Due to the poor water quality in Asia, diarrhea is one of the leading causes of death among infants and cause illness to every fifth person (Noori, et al., 2013).

The region of Punjab has a problem with the quality of its drinking water due to inadequate treatment, surveillance, and drainage systems. The presence of hazardous metals, artificial chemicals, and microbes in water has a negative effect on people's health. People have been suffering from waterborne infections, and feces are a major factor.. Waterborne illnesses such diarrhea, typhoid, hepatitis, and cholera are effectively detected in both rural and urban regions of the region. In any event, it is extremely difficult to gauge the likelihood of diseases. Smith (1999) highlighted the ailments and inadequate record-keeping in hospitals, clinics, and hospital emergency rooms that were known to have infections brought on by contaminated water (Smith, 1999).

1.4 Review of literature

Groundwater is an important source of water in Pakistan, supplying all the water required for commercial procedures and activities, approximately sixty percent for agriculture and crop production, and ninety-three for use by humans. Everyone is entitled to drill as many boreholes as they like and draw water from anywhere because there is no governing body for groundwater in Pakistan, which has led to a disturbing rate of decline in resources. The problem is getting worse in a number of Pakistani cities, and it is even worse in Baluchistan where the water level has dropped by three meters (Farooq, et al., 2008).

A big problem that is worrying people locally, nationally, and internationally is when groundwater gets contaminated with heavy metals. This is a problem because it can harm the environment and affect people's health. (Goldhaber, 2003) Ullah and his team did a study in 2009 to check how polluted groundwater was with heavy metals and how it was affecting people's health. Water samples were taken from 25 places in Sialkot, a city in Pakistan, during October and November 2005. The experts assessed the characteristics of the subterranean water in this industrialized municipality. (Singh, et al., 1993). A researcher looked at 22 different measurements of water quality, such as pH, temperature, and the amounts of certain substances like sulfate and iron. The results were measured against the recommended criteria for water quality determined by both the Pakistan Standard Quality Control Authority

(PSQCA) and the World Health Organization (WHO).The sites were grouped into four different categories using cluster analysis. This was done by looking at how similar or different the physical and chemical measurements were in each location. (Clarke, et al., 1995). Site 1 had a lot of dirtiness and pollution. The levels of EC, TDS, SO4, Cl, total hardiness, Zn, Pb, and iron were higher than the allowable limit. 19 places discovered the chemical chromium. According to statistical analysis and quantitative evaluation, important variables were found that have a direct effect on the condition of groundwater and can alter the chemistry of water. The study discovered that a sizable portion of the subterranean water in the region is highly turbid (57% of all locations) and contains excessive amounts of Zn, Fe, and Pb. These levels are higher than what is considered safe by the WHO and PSQCA. Therefore, it is incorrect to claim that the quality of this water is satisfactory. (Uma KO, 1985). The utilization of a Geographic Information System (GIS) enabled to generate visual representations pinpointing the locations where various water quality measurements were taken. The maps showing how water is distributed were particularly important for understanding the environment of the underground water systems. They helped us find out which factors of water quality were too high according to WHO standards. We also used the maps to find places where water treatment facilities or innovative technology could be helpful in Sialkot. (Ullah, et al., 2009).

One of the biggest dangers to people's health, especially in poor countries, is when the water they drink is contaminated with harmful tiny organisms. Abbas M. T., (2012) conducted research and assessed the drinking water quality in Punjab Province. It focuses on the presence of harmful bacteria in the water, its chemical properties, and how it affects people's health. Investigating pollution levels in the drinking water across various regions in Punjab province was the primary objective of this study. The water was getting worse because more people were living there, the area was growing quickly, and people were not disposing of waste properly. (Abbas M. T., 2012). In a recent investigation conducted in the Punjab area, it was observed that the majority of spots suffer from the issue of polluted drinking water.

The water that people drink in the province has become unsafe due to the presence of harmful bacteria, hazardous metals, and chemicals. This includes water from rivers, lakes, and underground sources. In the area, the bad air is making people extremely sick and even causing death. The rules for clean drinking water made by the WHO are often not followed. The main reasons why water quality is getting worse are the wrong use of chemicals in farming, improper throwing away of city waste, and releasing polluted water from factories (Qasim, et al., 2014). Diarrhea, cholera, and typhoid are the three main diseases caused by contaminated drinking water in Punjab. Stomach problems, intestinal worms, and bacterial infections are also caused by drinking dirty water, leading to higher rates of infant deaths. We must take immediate action to prevent water deterioration and ensure people's protection against waterborne illnesses. It is crucial to expedite the enforcement of laws, regulations, and the WHO's suggestions to establish the safety of drinking water. (Riaz O. A.-u.-M., 2016).

In the south part of Lahore, research investigated the groundwater's state by gathering two distinct water samples prior to and following the rainy season. They did this to gather significant data on the physical and chemical properties as well as the presence of bacteria in the water. According to the research, the samples' water quality ranged from 50% to 62%.5% before the monsoon. Post-monsoon, there was a notable improvement, with the percentage rising to 75% (Farid, et al., 2012). Water pollution occurred because of leaks in the pipes that carry and supply water. It happened because these pipes are all connected to each other. Water samples collected from the city areas of Faisalabad have been analyzed, discovering that it is unfit for consumption. Many of the samples had considerable amounts of TDS (total dissolved solids), alkalinity, sulphate, and chloride. Dirty water containing waste from toilets and drains made the quality of the groundwater in Faisalabad's cities worse (Hayder, et al., 2009).

Khattak and others made a discovery close to the drain channel of the Hudiara factories in Lahore. In 2012, experts checked how good the water in the ground was for drinking and farming. The results indicated that the water samples obtained from different areas were good in terms of quality and showed no evidence of contamination caused by human activities. Only 21% of the samples were somewhat suitable for farming if changes were made and special methods were used, while 79% of the samples had harmful substances and were not suitable for eating or farming (Batool, et al., 2018). An investigation was conducted in Bahawalpur City to examine the characteristics of underground water. The results of the study found that the water underground was not good enough, which led to many people getting sick from water-related diseases. The Islamic colony had a particularly high rate of serious illnesses, with approximately 36% of the community affected. The occurrence of waterborne diseases was less prevalent among the individuals residing in Satellite Town and Shahdrah, in comparison to those in the Islamic colony (Khattak, et al., 2012)

The assessment of the water in Bhalwal City revealed that it contains excessive amounts of TDS, EC, and potassium. The THQ statistics revealed the information relating to the patients. According to hospital records, there were differing amounts of kidney stone cases every month in 2017. (Farooqi, et al., 2007). Checking the quality of groundwater is crucial in determining its safety for consumption and its impact on personal well-being. Deeba et al. In a study conducted in 2019, researchers investigated the groundwater quality in Sahiwal and Sheikhupura. In Sheikhupura, the water was discovered to be high in fluoride, iron, nickel, cadmium, and microorganisms according to the study. Conversely, Sahiwal's water samples exhibited elevated alkalinity and electronic conductivity levels. (Deeba, et al., 2019).

There are 115 local water supply sources in Mianwali, where the analysis of drinking water samples and their origins focused on both microscopic and chemical qualities. To check if there are germs in water, biological parameters in water samples were evaluated. In addition, the study results indicated that a higher percentage of tap water samples (71%) were polluted compared to samples from WSS, which showed a contamination rate of 41%.Due to the fact that WSS was accountable for 30% of the water pollution in Mianwali, there was a lack of consistent provision of safe drinking water. (Akhtar, et al., 2019).

Abbas and his team conducted research in the city of Jhang in 2018, a study examined how the water quality is affected by the waste produced by cities. The study found that the EC was high in 90% of the samples, TDS in 75% of the samples, hardness in 60% of the samples, chloride in 35% of the samples, calcium in 30% of the samples, and alkalinity in 25% of the samples. The study showed that the water near the landfill is not safe to drink. . The objective was to assess its adequacy for practices such as agriculture and residential purposes. The aim was to determine if it was suitable for activities like farming and household activities. (Rehman, et al., 2019). The correlation between ten various substances submerged in the water was investigated. Calcium, sodium, potassium, magnesium, copper, iron, nitrates, sulfates, and chloride, are among the substances. The results indicate that groundwater cannot be consumed as it is not safe to drink. However, it can still be useful for farming purposes. (Abbas, et al., 2018).

In simpler terms, Munir and his team studied the features of substances and materials in relation to their chemistry and the Earth's processes. In 2011, researchers checked how good the groundwater was in the area near Lei Nala in Islamabad. Researchers collected 10 water samples from the surface of Lei Nala and 12 water samples from deep underground at four different spots for investigation. Bicarbonate and Ca, Mg type fluids were detected in the groundwater samples, suggesting the breakdown of limestone (Asadi, et al., 2019). The tested area contains 53. 86% water consists of calcium and magnesium. In most of the samples (96. 15%), the water had a higher concentration of the HCO3 type of anions. Most of the chemicals present in the water within the study area originate from natural sources, as there have been no noticeable variations in their types. This happens because water underground moves through rocks that are made of sand and mud, and as it moves, it mixes with rocks, which mainly contains substances called HCO3 and Calcium and magnesium. (Munir, et al., 2011).

Overwhelming metals can be present in water sources through normal or human exercises, and the utilization of contaminated water can result in cancer or persistent health issues in people. A study in Islamabad, Pakistan, explored the presence of arsenic (As) and overwhelming metals (HM) different drinking water sources. Tests from tube wells, taps, bottled water, filtration plants, and bore wells were gathered and evaluated for different parameters. The results revealed concentrations of arsenic, lead, nickel, press, and cadmium that surpassed the allowable limits set by WHO (Abeer, et al., 2020).

Due to the destitute framework, Faisalabad is regarded as a contaminated industrial city. In order to distinguish the social variables that impact the use of clean potable water, 225 tests of water were collected. The Logit Show (LM) was at that point utilized to assess the information. The results appeared a negative affect which all tests were contaminated with microscopic organisms such add up to coliform, add up to plate tally, and E. coli (0157), fair as elevated levels of add up to hardness and turbidity had been predicted. Atomic Absorption Spectrometer (ASS) estimations were made on water tests collected for physiochemical think about from Sargodha city at haphazardly (Riaz O. A.-u.-M., 2016). The comes about when compared to WHO appear that all factors, with the exemption of pH and Ca, are profoundly concentrated within the investigate range. As a result, it turns out that the tested area's groundwater quality is unfit for human utilization. In an additional examination, the effect of Sargodha's ground water on populace wellbeing was inspected physio-chemically (Faruqui, 2004). The study's discoveries demonstrated that area 1 had the most noteworthy rate of water-related ailments. Concurring to study assessment, 43.49% of individuals had waterborne contaminations, whereas the predominance in other zones was distant way better, with 29.68%, 26.33%, and 25.83% of people affected in local areas 2, 3 and 4. (Gadgil, 1998).

To survey the state of the groundwater within the Kalalanwala region inside the Kasur locale, another examination was conducted. The study's discoveries appeared a noteworthy level of contamination from specific factors. The large profundity of the aquifer and a more profound groundwater test were compared. Whereas contamination from fluoride was missing from the subsurface aquifer, it was found to be exceedingly concentrated near to the ground. The comes about of this examination illustrated the high SO_4, F, and As concentrations in both rain and groundwater. (Farooqi et al., 2007).

Contamination from the environment can have a negative effect on the wellbeing of people. Dry and semi-arid regions all around the world are affected by this problem. In a few parts of Pakistan, human exercises are impacting the overall quality of the groundwater. In case not appropriately kept, mechanical, and urban waste can leak into the soil, enter aquifers, and debase the quality of groundwater (Jain, et al., 2005).

1.5 Problem statement

Pakistan is using more groundwater as surface water supplies are becoming scarcer. Groundwater systems are now being used more frequently, which has resulted in the depletion of the resource (Shakoor, et al., 2015). Excessive use and the ongoing drought in Pakistan are two potential reasons why there are not enough supplies of drinking water and that groundwater aquifers are not being adequately replenished (Mohsin, et al., 2013). The population of Islamabad, the capital of Pakistan, is one million. The aquifers are not getting recharged at the rate, the rate at which the water is discharged or pumped out. There has been an increase in population and construction activity. Due to economic and infrastructure expansion, city has become a center for immigrants over time (Memon, et al., 2011). The majority of the city's water supply needs are fulfilled by groundwater, with the exception of

Rawal and Simly Lakes. However, these groundwater resources now face significant contamination risks as a result of population growth and industrial development.

Therefore, the objective of the current study is to evaluate the state of Islamabad's groundwater quality in selected areas. The purpose of the study is to evaluate the physical, chemical, biological, and heavy metal (Fe, As) levels in groundwater. The current state of events suggests that government improvements are necessary to safeguard this groundwater resource. Governments must implement rules and regulations in institutions and foster advances in technology in order to improve the policies.

1.6 Research objectives

Thirty water samples were collected from the study area as part of the current study's attempt to assess the groundwater quality status in the urban sector E-11/3 and the industrialized sector I-10/2 of the capital city Islamabad. The objectives of the study are:

1. To analyze the physiochemical and microbiological parameters in the groundwater samples.
2. To analyze the heavy metals, Arsenic (As) and Iron (Fe) in the groundwater samples.
3. To compare the groundwater quality of both the sectors I-10/2 and E-11/3, Islamabad.

The findings of this study can be used to know the quality of groundwater resources in the study areas. So, the research is important for people who are experts in local government, the department that manages water resources, and other government officials. This will help them make better plans to deal with changes in specific areas, improve the quality of underground water, and save this resource for the future.

CHAPTER 2

METHODOLOGY

2.1 Study Area

Water is an essential element for sustaining life and has a profound impact on human health. However, in many regions, access to clean and filtered drinking water is limited, leading people to rely on groundwater sources for their drinking needs. Unfortunately, the use of untreated groundwater in such areas, coupled with poor hygienic and sanitary conditions, increases the risk of waterborne diseases.

To address this critical issue and assess the drinking water quality in specific sectors of Islamabad, namely I-10/2 and E-11/3, a comprehensive sampling effort was undertaken. Groundwater samples were carefully collected from these areas using sterile bottles. The use of sterile bottles was essential to preserve the integrity of the water samples and prevent any external contamination during the collection process. The sampling focused on evaluating multiple aspects of water quality, covering microbiological, chemical, physical, and heavy metal parameters. This thorough approach aimed to obtain a comprehensive understanding of the safety and suitability of the groundwater for drinking purposes.

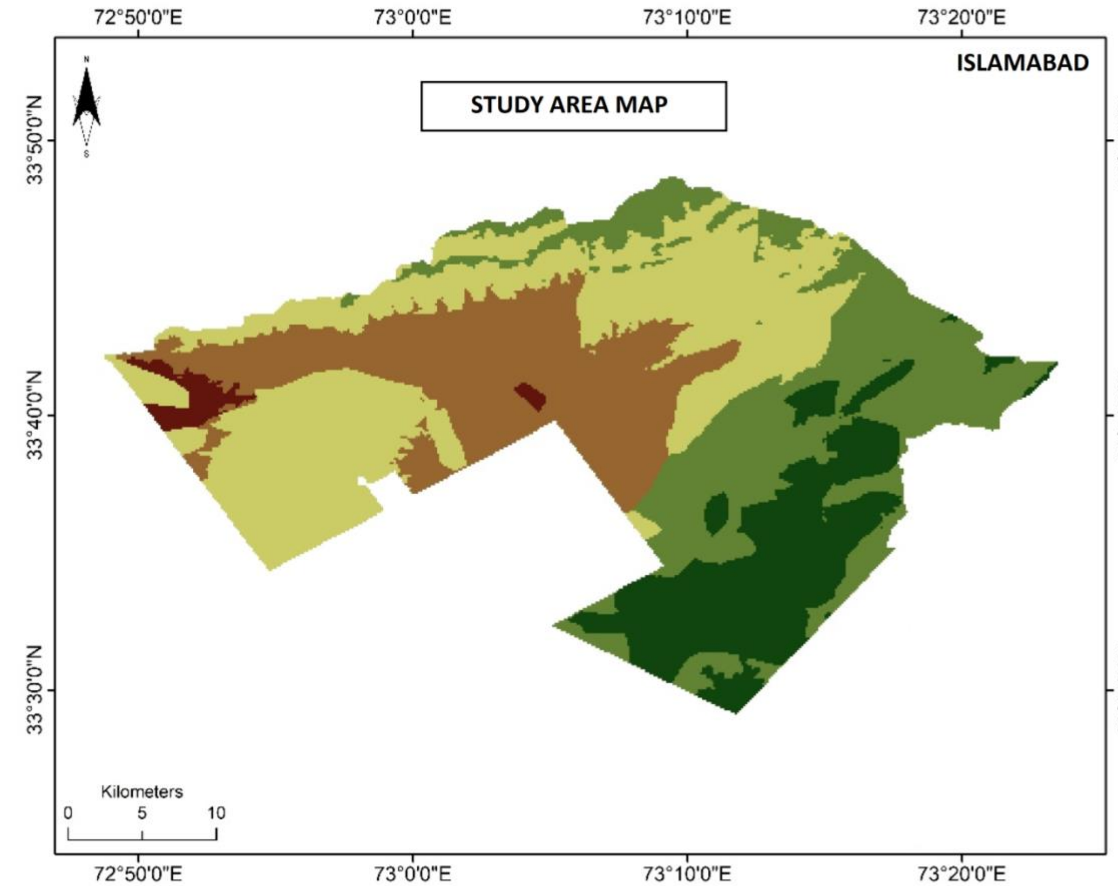

Figure 2.1: Map of study Area

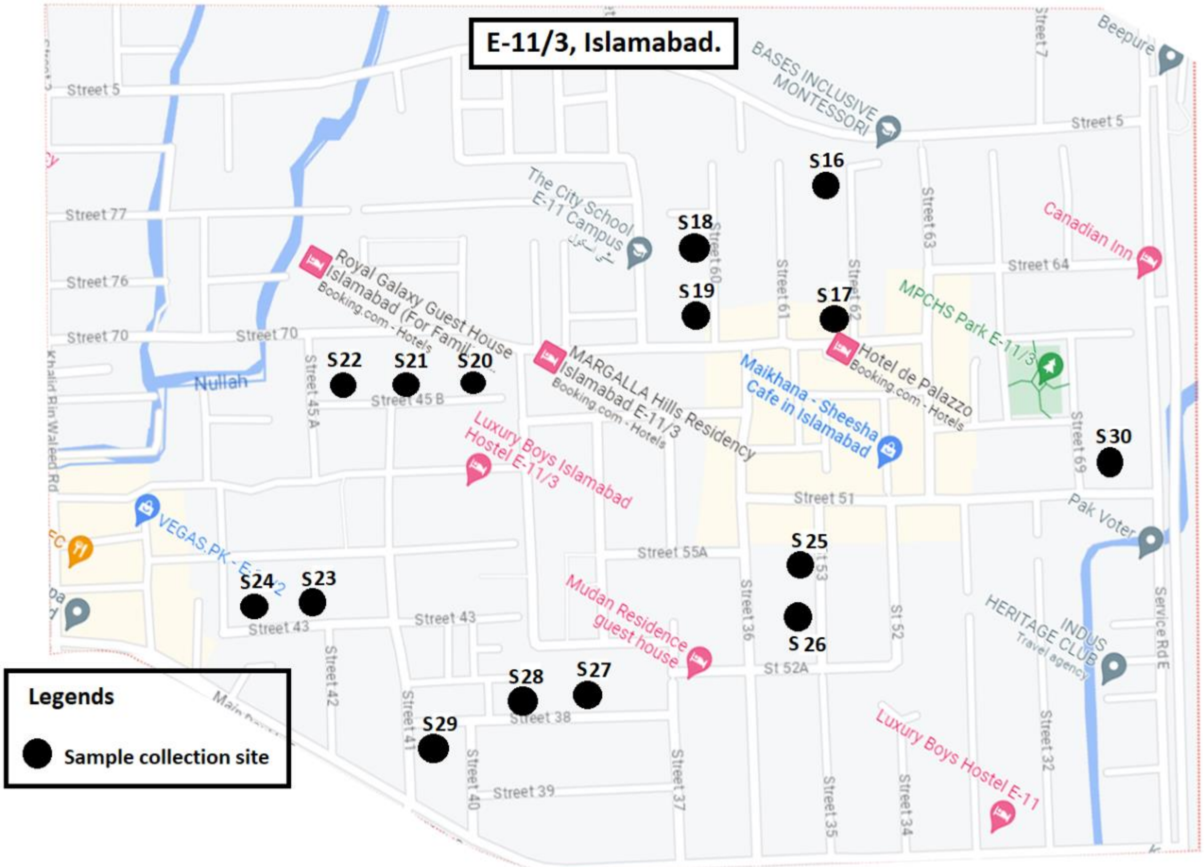

Figure 2.2 (a): Sampling locations in sector E-11/3

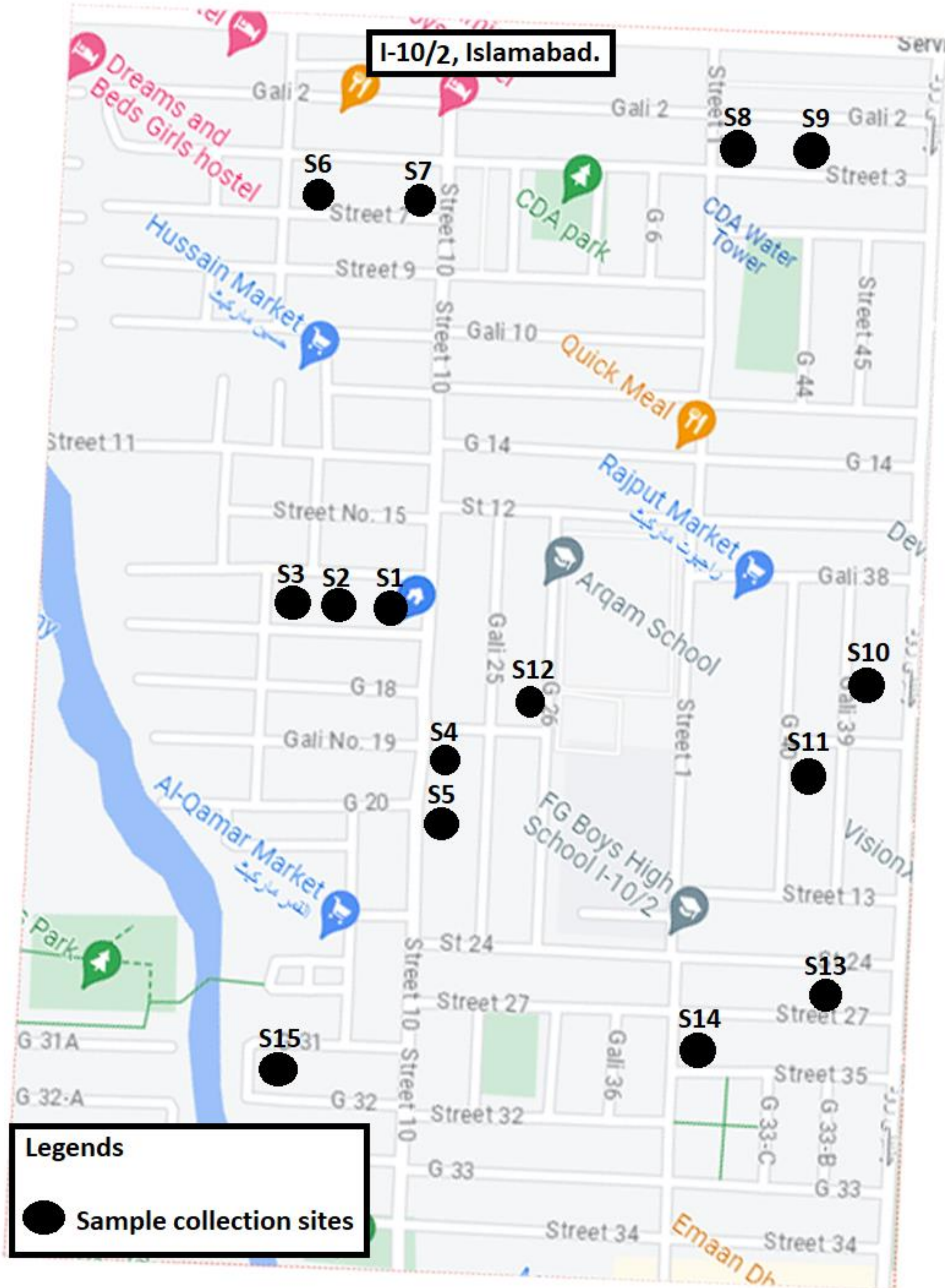

Figure 2.2(b): Sampling locations in sector I-10/2

2.2 Water sample collection

Groundwater samples were diligently gathered from various locations within the sectors I-10/2 and E-11/3. The samples were collected from different houses' boreholes in each sector. To ensure a comprehensive assessment, each groundwater sample was meticulously collected in an individual bottle for testing of physical, chemical parameters, and heavy metals. For this purpose, a specific procedure was followed: the collection bottle was first rinsed thoroughly with the respective groundwater sample to prevent any potential contamination from previous contents. After rinsing, the bottle was carefully filled with the same groundwater to be used for subsequent testing. On the other hand, when testing biological parameters, a distinct approach was adopted to maintain the integrity of the samples. Sterilized bottles were utilized for collecting groundwater samples for biological testing. This practice helps prevent the introduction of any external microorganisms that could interfere with the accurate assessment of biological parameters in the water.

Prior to collecting the water samples, precautionary measures were implemented to maintain sanitary conditions and minimize the risk of contamination. The hands of the personnel involved in the sampling process were sanitized thoroughly. This step was taken to ensure that any potential bacteria or other contaminants from hands would not be transferred to the water samples during collection.

2.3 Sample size

A total of 30 groundwater samples were gathered, with 15 samples collected from the I-10/2 sector and another 15 samples from the E-11/3 sector. These samples were collected to conduct comprehensive testing, covering physical, chemical, biological parameters, and heavy metals assessment. The collection process strictly adhered to established standard protocols, and all samples were carefully stored in plastic bottles.

Each groundwater sample was obtained from individual boreholes located in different households within the respective sectors. To ensure the accuracy of microbial analysis, special attention was given to timely processing. Therefore, the microbial analysis was promptly conducted within 24 hours of collecting the water samples to maintain the samples' integrity and obtain reliable results.

2.4 Data collection and analysis

Primary and secondary data were gathered for the study. The primary data was obtained directly on-site by collecting groundwater samples and the necessary information from the designated locations. On the other hand, the secondary data comprised the permissible limits or standards of various parameters for drinking water as set by the World Health Organization (WHO).

2.5 Physical parameters analyzed

The physical parameters were examined at the Environmental Laboratory of Bahria University H-11/4 Campus.

The analysis was performed using a pH/TDS/Conductivity/Salinity/Temperature Meter (IMCTS-08), which allowed for the assessment of various physical characteristics. These parameters included pH levels, electrical conductivity, total dissolved solids (TDS), salinity, and temperature of the water samples.

2.5.1 pH

The pH measurement of the samples was conducted using a pH meter. To ensure accurate results and prevent any cross-contamination, the pH meter's probe was thoroughly rinsed with distilled water before each measurement. Similarly, the beaker used for holding the water sample was also rinsed with distilled water to avoid any interference from previous samples.

The water sample was carefully poured into the rinsed beaker, and the pH meter's probe was immersed in the sample for a few minutes. After allowing sufficient time for stabilization, the pH reading was recorded(Akter et al., 2016; Napacho & Manyele, 2010).

2.5.2 Total dissolved solids (TDS)

The measurement of total dissolved solids (TDS) in the water samples was conducted using the same meter that was used for pH measurement, following a similar procedure. Once the pH reading was recorded, the mode button on the meter was pressed to switch to the TDS measurement mode. The TDS readings were then observed and noted after the meter's values had stabilized (Akter et al., 2016).

2.5.3 Electrical conductivity (EC)

The electrical conductivity of the water sample was determined using a similar procedure as that used for pH and TDS measurements. The same meter employed for pH and TDS analysis was utilized for this purpose. The resulting electrical conductivity reading was then observed and noted (ji, 2019).

2.5.4 Temperature

The temperature of the water sample was measured using the same meter, following a procedure similar to that used for measuring pH, TDS, and electrical conductivity. The meter's probe was immersed in the water sample, and the temperature reading was promptly displayed on the screen (Omar, 2009).

2.5.5 Salts

The measurement of salts in the water sample was conducted using the same meter, following a procedure similar to that used for other parameters. The salts reading was observed and recorded after it had stabilized. Once all the necessary readings were noted, the meter's probe was rinsed with distilled water to ensure that any residues from the previous measurements were removed (Akter et al., 2016).

2.6 Methods of chemical parameters

The chemical parameters for the drinking water samples are as follows.

1. Chloride (Cl)
2. Sodium (Na)
3. Sodium chloride (NaCl)
4. Total hardness
5. Calcium (Ca)
6. Magnesium (Mg)
7. Alkalinity

2.6.1 Estimation of chlorides (Cl)

To assess the chlorides in the drinking water sample, a titration method was employed. Before conducting the titration, the burette, titration flask, and measuring cylinder were thoroughly washed and rinsed with distilled water. This step was taken to eliminate any potential contamination and ensure the accuracy of the test results. By diligently preparing the equipment, reliable and precise measurements of chlorides in the drinking water sample could be obtained.

2.6.2 Reagents

1. Standard solution AgNO3 (0.01 N)
2. Indicator K2CrO4
3. 10 ml water sample

2.6.3 Procedure for the analysis of sample

The titration process involved the use of a standard solution of 0.01 N AgNO3, which was carefully added to the burette. A 10 ml water sample was then measured using a measuring cylinder and transferred to a titration flask. To indicate the endpoint of the titration, K2CrO4 was employed as the indicator. Three drops of the indicator were added to the water sample in the flask. The titrant from the burette, containing the standard solution of AgNO3, was added drop by drop to the water sample until a noticeable color change occurred, signifying the reaction between Cl (chlorides) and AgNO3. At this point, insoluble white precipitates appeared. To determine the volume of standard solution used, the initial and final levels of the standard solution in the burette were noted before and after the titration process. The difference in levels indicated how much standard solution was consumed during the titration. This titration procedure was repeated three times to minimize the chances of error, and the average of the differences in the initial and final levels of the standard solution was calculated to obtain the average used (District et al., 2012; Napacho & Manyele, 2010)

2.6.4 Calculations

The calculation to know the concentration of chloride is done by the following formula.

$Cl\ (\,/\,l\,) = \quad Normality \times Volume \times Molecular\ weight \times 1000 \div$ Sample Volume

2.6.2 Determination of NaCl

The NaCl in the water sample is determined by putting the value of normality, volume, molecular weight of NaCl and the sample volume and perform calculation according to the following formula.

$$Nacl\ (\quad) = Normality \times Volume \times Molecular\ weight \times 1000 \div Sample\ Volume$$

2.6.3 Determination of Na

The determination of Na in the water sample is done by subtracting the value of NaCl from Cl.

$$Na = NaCl\ concentration - Cl\ concentraion$$

2.6.4 Estimation of total hardness

The total hardness in the drinking water was determined using a certified method by PCRWR. To ensure accurate results and prevent any contamination, the burette, volumetric flask, and cylinder were meticulously washed and rinsed with deionized water before conducting the estimation. This careful preparation of the equipment helped maintain the integrity of the samples and ensured reliable measurements of the total hardness in the drinking water.

2.6.4.1 Reagents

1. Standard solution EDTA (0.01 N)
2. Buffer inhibitor mixture
3. Indicator EBT
4. 20 ml Distilled water
5. 10 ml water sample

2.6.4.2 Reagents

1. Conc. HCl
2. 2-Aminoehtanol
3. Magnesium salt of EDTA

2.6.4.3 Procedure

To prepare the buffer inhibitor mixture, a 1000 ml volumetric flask and a 500 ml measuring cylinder were thoroughly washed and rinsed with distilled water to prevent any contamination. Next, 55 ml of concentrated HCl was carefully measured using the measuring cylinder and then transferred to the volumetric flask. Subsequently, 400 ml of deionized water was added to the cylinder.

In another step, 300 ml of 2-aminoethanol was measured and then transferred to the same volumetric flask. Lastly, 5g of Magnesium salt of EDTA was precisely measured using an analytical balance and added to the same flask. These meticulous procedures ensured the accurate preparation of the buffer inhibitor mixture, free from any external contaminants and adhering to the required measurements.

2.6.4.4 Procedure for analysis of sample

The standard solution of 0.01 N EDTA was carefully filled into the burette. A 10ml sample of the drinking water was accurately measured and added to a titration flask. Subsequently, 20ml of deionized water was added to the same flask. Using a syringe, 1ml of buffer inhibitor was introduced into the flask. To facilitate the titration process, Eriochrome Black T (EBT) was employed as the indicator. A few drops of the indicator were added to the flask, and the contents were gently shaken until a uniform wine-red color was achieved. With the flask properly prepared, the standard EDTA solution from the burette was added drop by drop into the flask. Throughout this process, constant stirring was maintained. Titration continued until the solution exhibited a distinct sky-blue color, signifying the completion of the reaction and marking the endpoint of the titration process. This color change indicated that the EDTA had fully reacted with the metal ions present in the water sample, enabling the determination of water hardness (Napacho & Manyele, 2010).

2.6.4.5 Calculation

We multiplied the EDTA burette reading with 100. Result showed the total hardness of the sample.

2.6.5 Estimation of calcium

The calcium content in the drinking water was determined using a certified method recommended by PCRWR. To ensure accurate results and prevent contamination, the burette, volumetric flask, and cylinder were thoroughly washed and rinsed with deionized water prior to the estimation process.

2.6.5.1 Reagents

1. Standard solution EDTA (0.01 N)
2. Indicator Murex ide
3. Buffer NaOH (1M)
4. 10 ml Distilled water
5. 10ml sample

2.6.5.2 Procedure for analysis of sample

A standard solution of 0.01 N EDTA was carefully filled into the burette. Then, a 10ml sample of the drinking water was accurately measured and added to a titration flask. To the same flask, 10ml of distilled water was added. Using a syringe, 0.5 ml of NaOH buffer was introduced into the flask. Murexide was utilized as the indicator for this titration. After adding a few drops of the indicator, the contents were gently shaken until a homogeneous pink color was observed. The titration process began with the drop-wise addition of the standard EDTA solution from the burette while continuously stirring the mixture. Titration continued until a clear purple color appeared, signifying the completion of the reaction, and indicating the endpoint of the titration process. This color change confirmed that the EDTA had fully reacted with the calcium ions in the water sample, allowing for the estimation of calcium content in the drinking water (Napacho & Manyele,2010).

2.6.5.3 Calculation

Multiply the EDTA burette reading with 40, this will be equal to the calcium concentration in the sample.

2.6.6 Estimation of magnesium

The magnesium in the water sample was estimated after the estimation of calcium and total hardness by the following formula:

2.6.6.1 Calculation

$$Mg\ (/ l) = \frac{(Total\ hardness\ (as\ mg\ CaCO3/ l) - calcium\ hardness\ (as\ mg\ CaCO3/ l)}{0.243}$$

2.6.7 Estimation of Alkalinity

Alkalinity refers to the water's capacity to neutralize both acids and bases, thereby helping to maintain a stable pH level. It is also known as the water's buffering capacity, as it plays a crucial role in preventing significant fluctuations in pH (Addy et al., 2004). To assess the alkalinity in the drinking water sample, a titration method was employed. Prior to conducting the titration, the burette, titration flask, and measuring cylinder were thoroughly washed and rinsed with distilled water to eliminate any potential contamination. During the titration process, a standard acid solution (H2SO4) was used, and selective indicators such as methyl orange or phenolphthalein were utilized to measure alkalinity. These indicators assist in identifying the endpoint of the titration and provide valuable information about the water sample's alkalinity level (Omer N. H., 2016).

2.6.7.1 Reagents

1. Standard solution H_2SO_4 (0.02 M)

2. Indicator for basic sample is Phenolphthalein
3. Indicator for acidic sample Methyl orange(2 to 3 drops)
4. 50 ml water sample

2.6.7.2 Procedure for analysis of sample

The burette was initially rinsed with distilled water and then filled with a standard solution of 0.02 M sulphuric acid. A 50 ml water sample was accurately measured and transferred to a titration flask. The phenolphthalein indicator was used for testing basic water samples, while methyl orange indicator was used for testing acidic water samples. The titration process involved adding the acid solution drop by drop from the burette into the water sample in the flask, while continuously stirring. The initial and final levels of the standard solution in the burette were noted before and after dripping to determine the amount of standard solution used. By calculating the difference between the initial and final levels and then taking the average, the average volume of the standard solution used could be determined. In the case of basic water samples, the media changed to a pink color during titration, while in the case of acidic water samples, it changed to a red to orange color. These color changes are indicative of the completion of the titration and provide valuable information about the alkalinity or acidity of the water sample.

2.6.7.3 Calculation

$$Alkalinity = Normality\ of\ acid \times Volume\ of\ acid \times 50{,}000 \div Sample\ volume$$

2.8 Microbiological parameters

Water samples collected from various locations underwent biological analysis to assess parameters such as total coliform, salmonella, shigella, and total bacterial load. To ensure accurate results during this assessment, a crucial step involved the sterilization of hands and equipment used in the process. Sterilized bottles were employed to prevent any potential contamination during the collection and handling of the samples. This meticulous approach aimed to maintain the samples' integrity and ensure reliable data for the biological analysis.

Nutrient agar, SS agar, and MacConkey agar mediums were prepared to match the number of samples. Each petri dish required approximately 20ml of media. The quantity of media was adjusted accordingly to ensure sufficient coverage for the samples on each agar plate. Therefore, the amount of media was calculated by the following formula:

- 1 petri dish = approx. 20ml
- Total samples = 30
- Quantity required = 20 x 30 = 600ml

The entire process consisted of two phases. In phase 1, a total of 30 samples were prepared following the specified procedure. Similarly, in phase 2, another 30 samples were prepared in a comparable manner. Consequently, the combined number of samples prepared in both phases amounted to 60.

2.8.1 Estimation of total bacteria by using nutrient agar (NA)

28 grams of nutrient agar was added in 1 liter of water to prepare the solution.

$$1\ liter = 1000\ milliliter$$

$$= 28g \div 1000$$

$$= 0.023g$$

$$0.028 \times 600 = 16.8g$$

The nutrient agar of 16.8g was measured in the analytical balance and mixed with 600ml distilled water in a glass bottle and covered by a cotton plug.

2.8.2 Estimation of total coliform by using MacConkey agar (MAC)

51 grams of MacConkey agar was added in 1 liter of water to prepare the solution.

$$1\ liter = 1000\ milliliter$$

$$51g/1000 = 0.051g$$

$$0.051 \times 600 = 30.6g$$

The MacConkey agar of 30.6g was measured in the analytical balance and mixed with 600 ml distilled water in a glass bottle and covered by a cotton plug.

After all the media was prepared, it underwent wet sterilization in an autoclave at 121°C for 15 minutes. The petri dishes were then filled within a laminar flow hood, which was enclosed on three sides and equipped with a HEPA filter to effectively eliminate bacteria from the environment. Prior to filling the petri dishes, it was crucial to sterilize hands using methylated spirit. The filling process was conducted inside the laminar flow hood to prevent any potential contact with bacteria. Once the media solidified within the petri dishes, they were sealed with lids. To add the samples to the petri dishes, a micropipette was utilized.

A 100-microliter water sample was taken and sprinkled evenly over a petri dish using a sterilized glass spreader. The spreader was first sterilized with methylated spirit and then heated over a spirit lamp before spreading the sample at a 45° angle. To prevent any contamination, the petri dishes were sealed with tape after the spreading process. Each petri dish was labeled with a specific sample number, and the medium's name was written on the lid for easy identification. Next, the sealed petri dishes were placed in an incubator in an inverted position for a duration of 18 to 24 hours at a temperature of 36.6°C. Placing the dishes in an inverted manner allowed any excess moisture to accumulate on the lid, preventing the bacteria from coming into contact with excessive moisture, which could cause them to slide or move undesirably (Brenner et al., 1993). After 24 hours, put out the petri dishes from the incubator and note the results of microbial parameters.

2.9 Heavy metals

The ground water samples from both sectors were subjected to testing for heavy metals, specifically Iron (Fe) and Arsenic (As). The analysis of Iron(FE) in these water samples was performed using the UV 4000 Spectrophotometer method. Prior to conducting the analysis, the instrument was properly calibrated and adjusted to the specified wavelength for each heavy metal being measured. Arsenic testing was conducted using an arsenic testing kit, where the water samples were prepared by adding specific reagents provided in the kit.

Reagent 1: This reagent is designed to help stabilize the arsenic present in the water sample and prevent any unwanted reactions during the testing process.

Reagent 2: Reagent 2 is the primary agent responsible for the chemical reaction that occurs with arsenic in the water. It helps to form a color complex with arsenic ions, resulting in a visible color change on the test

Reagent 3: This reagent serves as a catalyst or enhancer to improve the sensitivity and accuracy of the color reaction when arsenic is present in the water sample.

The contents were mixed thoroughly by stirring. Next, test strips were immersed into the prepared water samples and allowed to react for approximately 10 minutes. The reaction resulted in a color change on the test strips, and the intensity of this color was then matched with a color chart supplied in the testing kit. By comparing the strip's color with the chart, the amount of arsenic present in the water sample was determined.

CHAPTER 3

RESULTS AND DISCUSSION

3.1 Groundwater quality assessment

The main objective of the study was to assess the condition of the groundwater in Islamabad's two sectors I-10/2 and E-11/3. Tests were done on the physical, chemical, and biological characteristics, as well as for the presence of Arsenic (As), and Iron (Fe) in groundwater samples. The results of physiochemical, microbiological, and heavy metal variables are all discussed in this chapter.

3.2 Results of physical parameters

The physical parameters evaluated for ground water quality include, pH, Temperature, Total Dissolved Solids (TDS), Salts, and Electrical Conductivity (EC). The results are shown in table 3.1, and 3.2, respectively. In some samples taken from two sectors, the results showed a higher EC in water samples, exceeding the recommended limit by WHO, which indicates the inadequate quality of water. The more minerals, chemicals, and dissolved substances there are in the water, the higher the conductivity.

Table 3.1: Results of the physical characteristics assessed in the sector I-10/2 water samples

Physical Parameters					
Sample No	pH	EC(µS/cm)	TDS(mg/l)	Salts(mg/l)	Temp(°C)
1	6.3	820	566	377	15.5
2	6.5	770	551	370	15.3
3	6.9	760	554	376	15.4
4	7.0	737	527	354	15.5
5	7.0	880	625	423	15.9
6	7.4	529	380	254	15.6
7	7.2	868	623	423	15.7
8	7.0	908	652	441	15.6
9	7.1	891	635	428	15.6
10	7.0	830	588	396	15.4

11	7.2	827	588	398	15.7
12	7.0	865	615	414	15.7
13	7.3	791	560	376	15.8
14	7.3	664	472	310	15.8
15	7.4	672	477	319	15.5
WHO Standards	6.5-8.5	400	1000	-	25

Table 3.2: Results of the physical characteristics assessed in the sector E-11/3 water samples

Physical Parameters					
Sample No	pH	EC(µS/cm)	TDS(mg/l)	Salts(mg/l)	Temp(°C)
1	7.4	665	473	318	15.6
2	7.3	600	429	285	15.3
3	7.3	488	349	231	15.5
4	7.0	687	487	325	15.7
5	7.4	670	477	318	15.7
6	7.1	800	570	383	15.5
7	7.5	315	224	147	15.7
8	7.3	666	475	315	15.5
9	6.9	647	458	300	15.6
10	6.4	590	417	279	15.6
11	7.5	629	449	300	15.7
12	7.4	688	491	325	15.7
13	7.5	685	486	325	15.7
14	7.2	609	334	290	15.7
15	7.5	755	539	362	15.5
WHO Standards	6.5-8.5	400	1000	-	25

The electric conductivity of water serves as an indicator for its electrical charges. Due to the existence of minerals and inorganic elements in water, a higher EC level points towards the inadequate quality and pollution of water. The water samples taken from both the sectors had concentrations of EC greater than the acceptable limit by WHO.

3.2.1 pH concentrations in samples

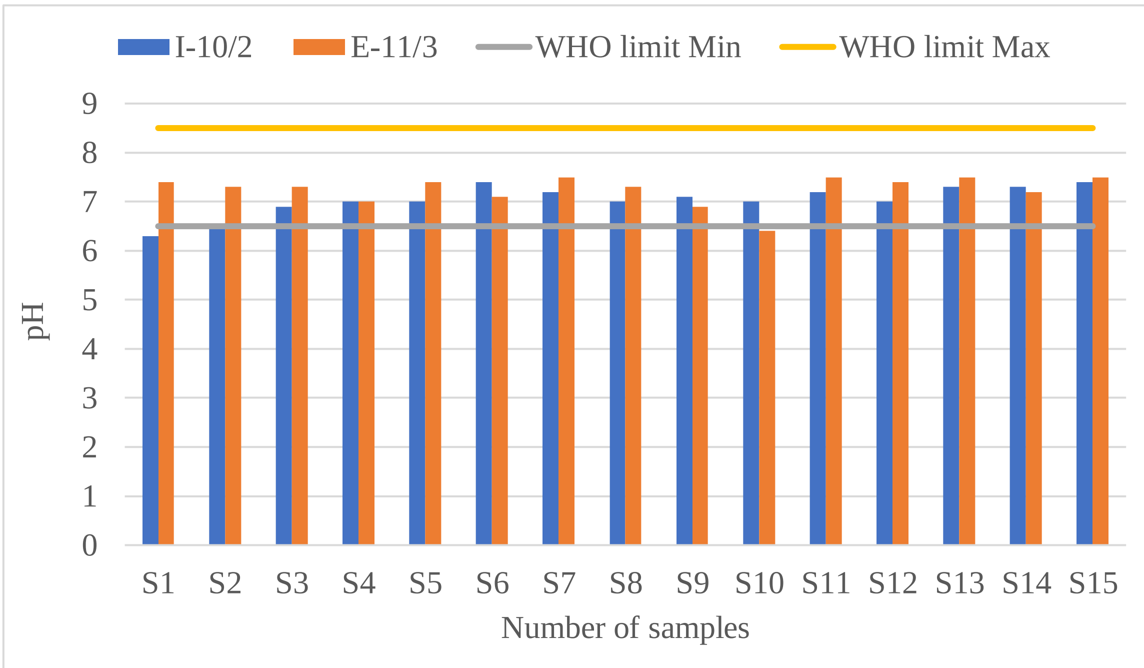

Figure 3.1: Comparative pH concentrations in water samples

According to the results, the mean pH level in I-10/2 sector was 7.04, while in E-11/3 Islamabad it was 7.24. These results are within the acceptable limit of WHO i.e., 6.5-8.5, if these limits exceed then the water is basic and if it is below then the water becomes acidic. Despite the fact that pH has no immediate effect on the well-being of humans, it provides a suitable environment for microbes and different chemical reactions. The pH concentrations of the sample are shown in figure 3.1.

3.2.2 TDS (mg/L) concentration in samples

According to the results, the mean TDS levels in I-10/2 sector were 443.8, while in E-11/3 Islamabad it was 560.8. The results were within the recommended limit of WHO i.e., 1000mg/l. The TDS concentration of samples are shown in figure 3.2.

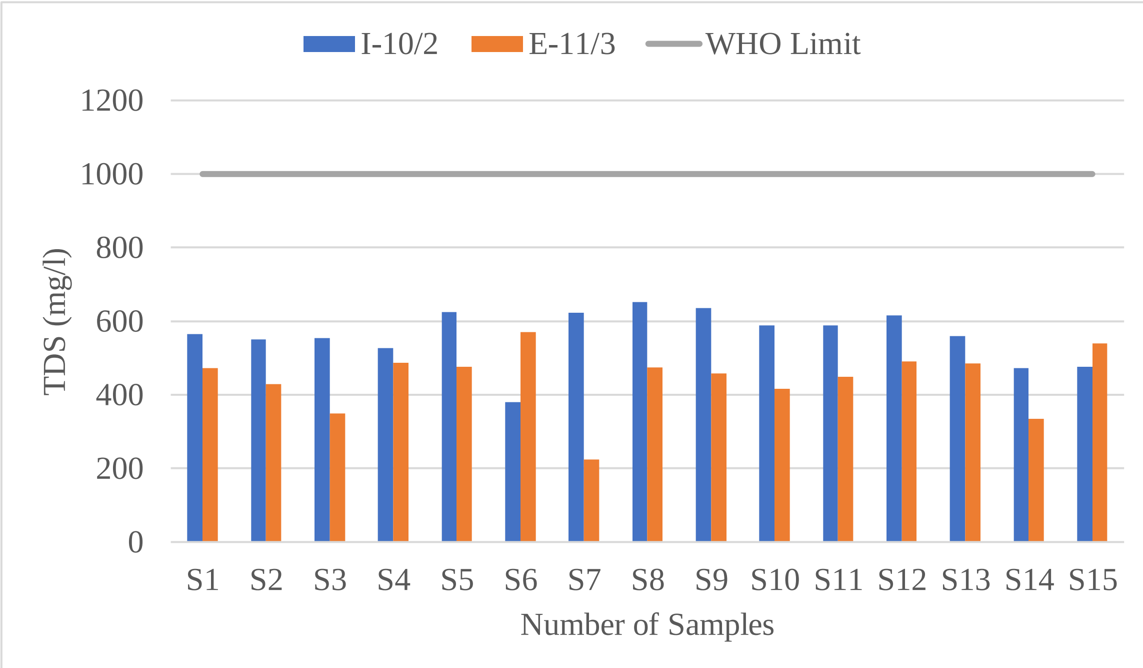

Figure 3.2: Comparative TDS concentrations in water samples

If this limit exceeds the acceptable limit, then the taste of water changes and becomes bitter, salty, and unfit for human consumption. If certain ions included in TDS such as arsenic, lead, nitrate, copper, and aluminum are in high amount it can cause adverse health effects (Chapman et al., 2000). Higher amount of TDS also causes several diseases like lung irritation, nausea, dizziness, vomiting and rashes.

3.2.3 Electrical conductivity (µs/cm) concentration in samples

According to the results, the mean EC levels in I-10/2 sector were 787.4 µS/cm, while in E-11/3 Islamabad it was 632.9 µS/cm. The results of EC for all three villages were above the recommended limit of WHO i.e., 400µS/cm. The EC concentration of samples is shown in figure 3.3.

The electrical conductivity of water serves as a gauge for its electrical charges. Due to the abundance of minerals and inorganic particles in water, if the amount of EC is greater, it points towards the contamination of water.

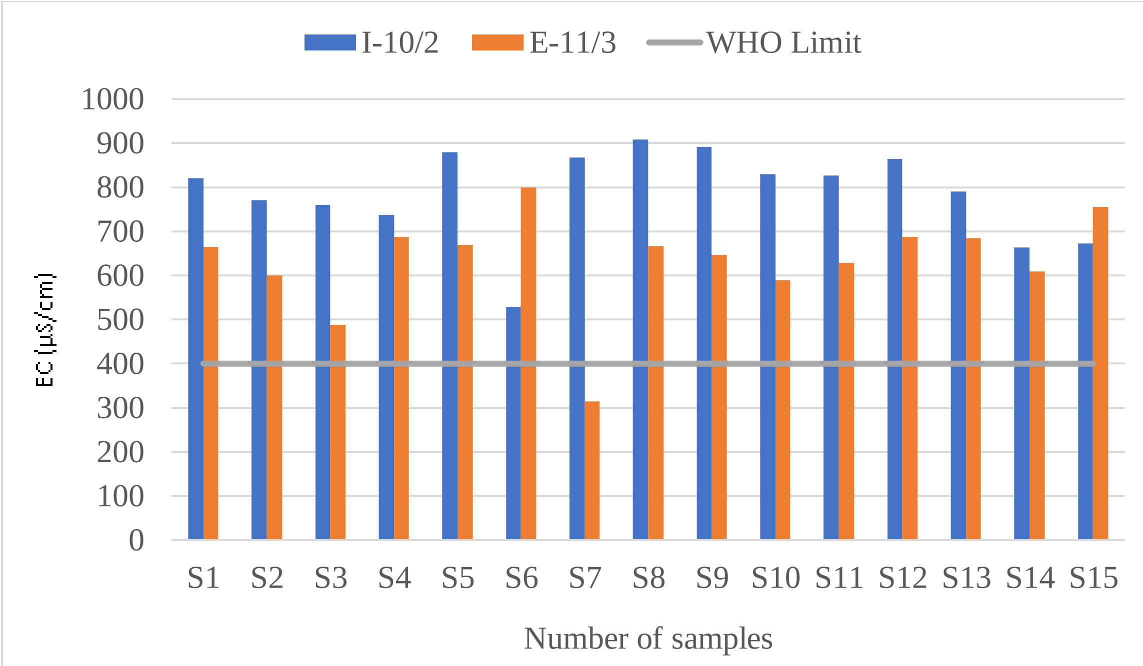

Figure 3.3: Comparative EC concentrations in water samples

3.2.4 Salt (mg/L) concentration in drinking water

According to the results, the mean salt levels in I-10/2 sector were 377.2 mg/l, while in E-11/3 Islamabad it was 300.2 mg/l. Although, the standard acceptable value of overall salts is not given in literature whereas, WHO has defined the value of sodium permissible limit. The presence of salts in higher level can cause adverse health effects including vomiting, muscle twitching, nausea and chronic exposure can cause heart diseases. On the contrary, low levels of salts in water area are also not good for health as it causes headache, and fatigue.

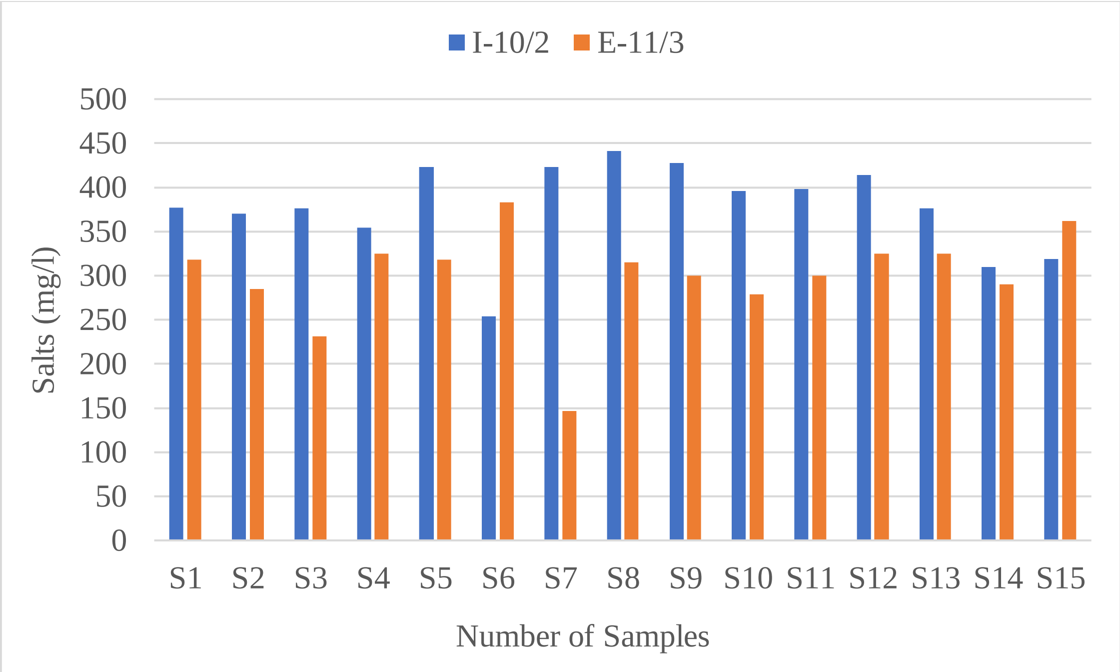

Figure 3.4: Comparative salt concentrations in water samples

3.2.5 Temperature (℃) of samples

According to the results, the mean temperature levels in water samples collected from I-10/2 sector were 15.6 ℃, while in E-11/3 Islamabad it was also 15.6℃. The acceptable limit by WHO is 25°C which shows that all the collected water samples had values under the acceptable limit. Temperature provides favorable conditions for certain chemical reactions and habitat for various microorganisms. These organisms can cause waterborne diseases which compromise the health of individuals. Figure shows all the samples have temperature within the permissible limit.

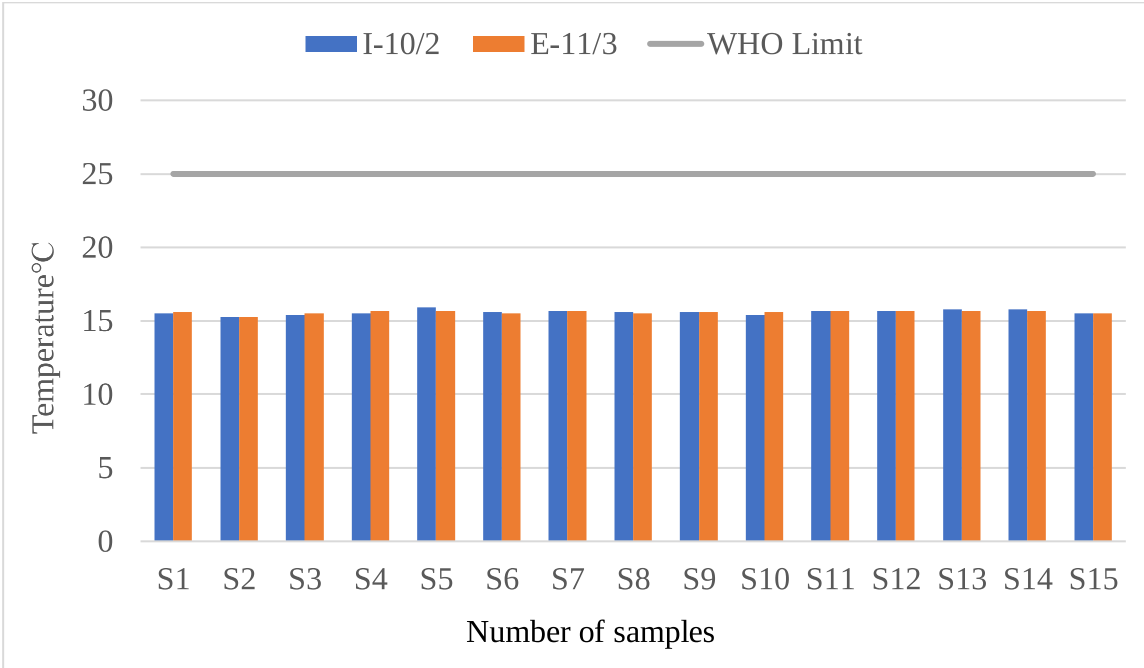

Figure 3.5: Comparative temperature concentrations in water samples

3.3 Results of chemical parameters

Table 3.5: Results of the chemical characteristics assessed in the sector I-10/2 water samples

Chemical Parameters							
Sample No	Alkalinity (mg/l)	Total hardness (mg/l)	Na (mg/l)	Cl (mg/l)	NaCl (mg/l)	Ca (mg/l)	Mg (mg/l)
1	186	200	261.6	1.59	263.3	396	196
2	174	180	57.5	88.7	146.2	204	124
3	152	1070	57.5	88.7	146.2	156	914
4	142	500	48.3	74.5	122.8	140	360
5	158	450	66.7	102.9	169.6	192	258
6	120	320	29.9	46.1	76.0	124	196
7	68	480	78.6	120.7	198.9	232	248
8	160	690	80.5	124.2	204.7	148	542
9	136	790	73.6	113.6	187.2	116	674

10	134	650	59.8	92.3	152.1	120	530
11	140	700	75.2	88.7	146.2	172	528
12	136	630	57.5	88.7	146.2	64	566
13	134	400	46	71.0	117.2	300	100
14	120	380	43.7	67.4	111.1	124	260
15	120	740	46	71.0	117	140	600
WHO Standards	200	500	200	250	NIL	200	150

Table 3.6: Results of the chemical characteristics assessed in the sector E-11/3 water samples

Chemical Parameters							
Sample No	Alkalinity (mg/l)	Total hardness (mg/l)	Na (mg/l)	Cl (mg/l)	NaCl (mg/l)	Ca (mg/l)	Mg (mg/l)
1	116	450	32.2	49.7	81.9	236	214
2	114	370	36.8	56.8	93.6	84	286
3	82	330	34.2	53.2	87.7	52	278
4	124	650	34.2	53.2	87.7	232	418
5	132	400	41.4	63.9	105.3	208	380
6	130	460	41.4	63.9	105.3	264	196
7	34	390	55.2	85.2	140.4	96	294
8	128	260	41.4	63.9	105.3	144	116
9	130	750	36.8	56.8	93.6	92	658
10	102	790	36.8	56.8	93.6	232	558
11	118	500	36.8	56.8	93.6	228	272
12	120	280	36.8	56.8	93.6	160	120
13	132	340	36.8	56.8	93.6	188	152
14	118	610	27.6	42.6	70.2	120	490

15	140	500	43.7	67.4	111.1	56	444
WHO Standards	200	500	200	250	NIL	200	150

3.3.1 Concentration of alkalinity (mg/L) in samples

According to the results the average alkalinity from both the sectors I-10/2 and E-11/3 were 138.6 mg/l, and 114.6 mg/l from the collected water samples. The results of both sectors were in the acceptable range of WHO i.e., 200mg/l.

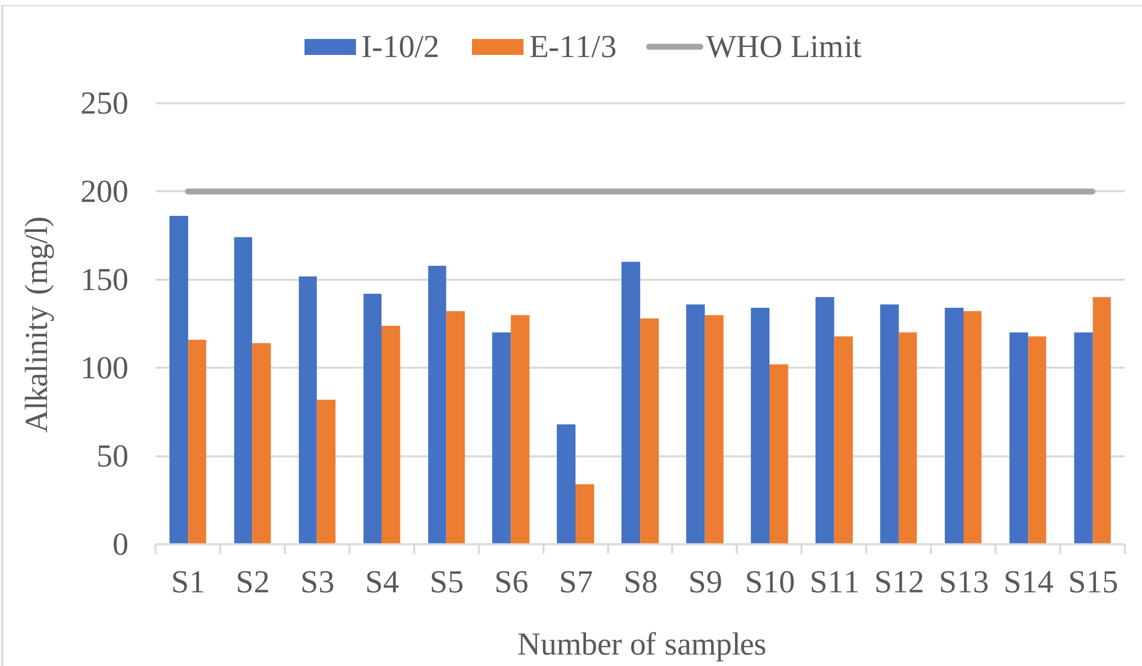

Figure 3.6: Comparative results of alkalinity in collected water samples

Alkaline water does not provide any significant health risks unless you suffer from kidney problems. Alkalinity is a property of water to balance acid and base in order to preserve a comparatively steady pH. Figure shows the level of alkalinity in samples collected from three villages.

3.3.2 Concentration of total hardness (mg/L)

According to the results an average value of total hardness concentrations for both the sectors was 545.3mg/l, and 472mg/l. The results of most of the water samples were above the acceptable range of WHO i.e., 500mg/l except for a few samples. Additionally, it has been noted that too much hardness might lead to cardiac issues, renal stones, bloating, and diarrhea. Some additional health effects related to hardness on human health includes, it can cause dry skin and hair. The result of total hardness concentration is shown in the figure.

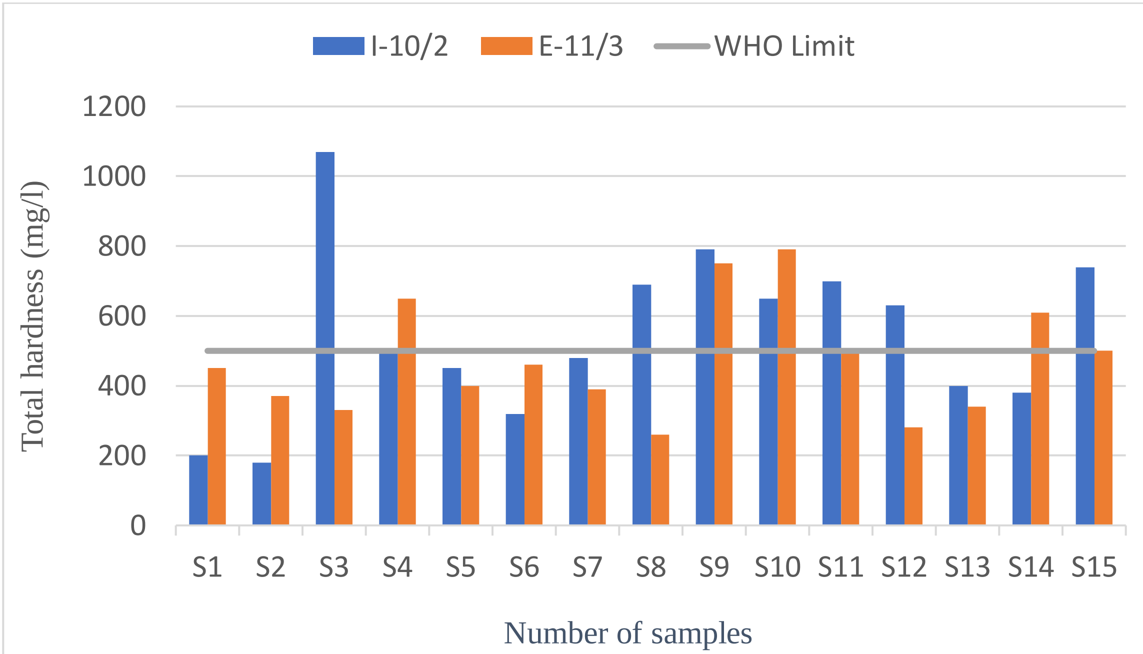

Figure 3.7: Comparative results of total hardness in collected water samples

3.3.3 Concentration of chloride (mg/L) in samples

According to the results an average of chloride concentrations for both the sectors in water samples were 82.6 mg/l, and 58.92mg/l. The results for the groundwater samples were within the acceptable range of WHO i.e., 250mg/l. The chloride concentration is shown in the figure. Chloride in water that is consumed has no detrimental effects on the general public's wellbeing as chloride is required by the human body in certain amount. whereas excessive quantities of chloride can give unpleasant, salty taste and cause adverse health effects like gastrointestinal tract such as nausea and diarrhea.

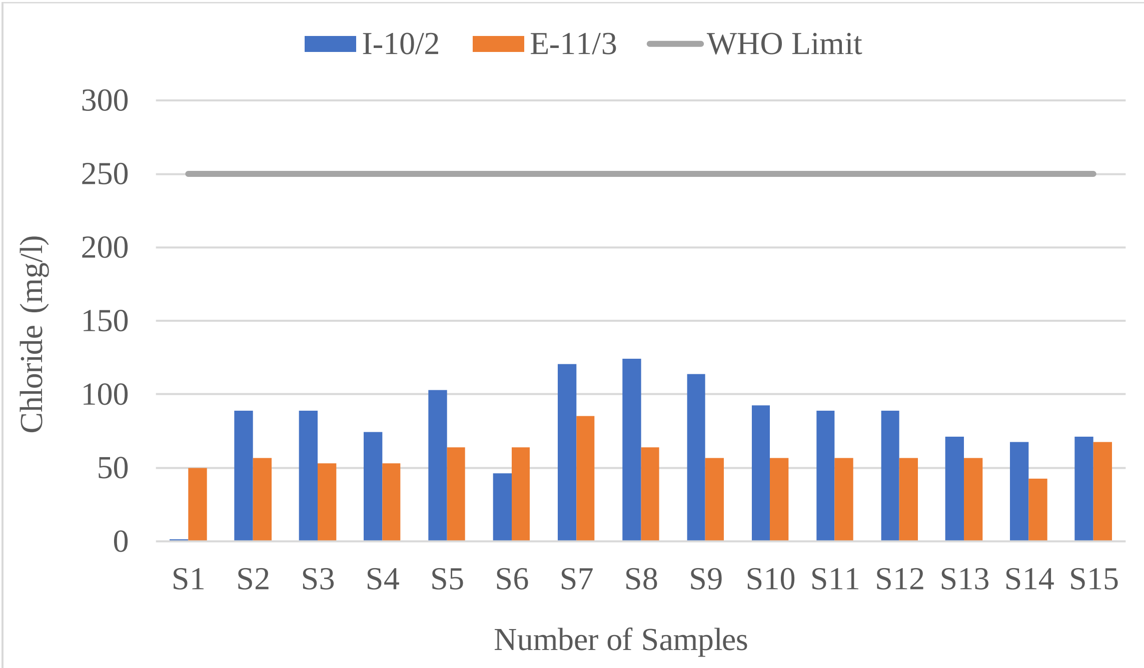

Figure 3.8: Comparative results of chloride in collected water samples

3.3.4 Concentrations of sodium (mg/L) in samples

According to the results the average chloride concentrations for I-10/2 and E-11/3 sectors were 72.16mg/l, and 38.14mg/l. The results of water samples from both the sectors were within the 200mg/l, WHO acceptable range except for one sample from I-10/2 which exceeded the limit.

The human body needs salt to function normally, but if it contains excessive amounts of sodium which exceeds the defined limit it causes harmful effect to human health. For the body to operate normally, sodium is needed. Whereas, if the levels of sodium in the body exceed it can cause health related issues like blood pressure, strokes, and cardiovascular diseases. Figure 3.8 shows the concentration of sodium in samples.

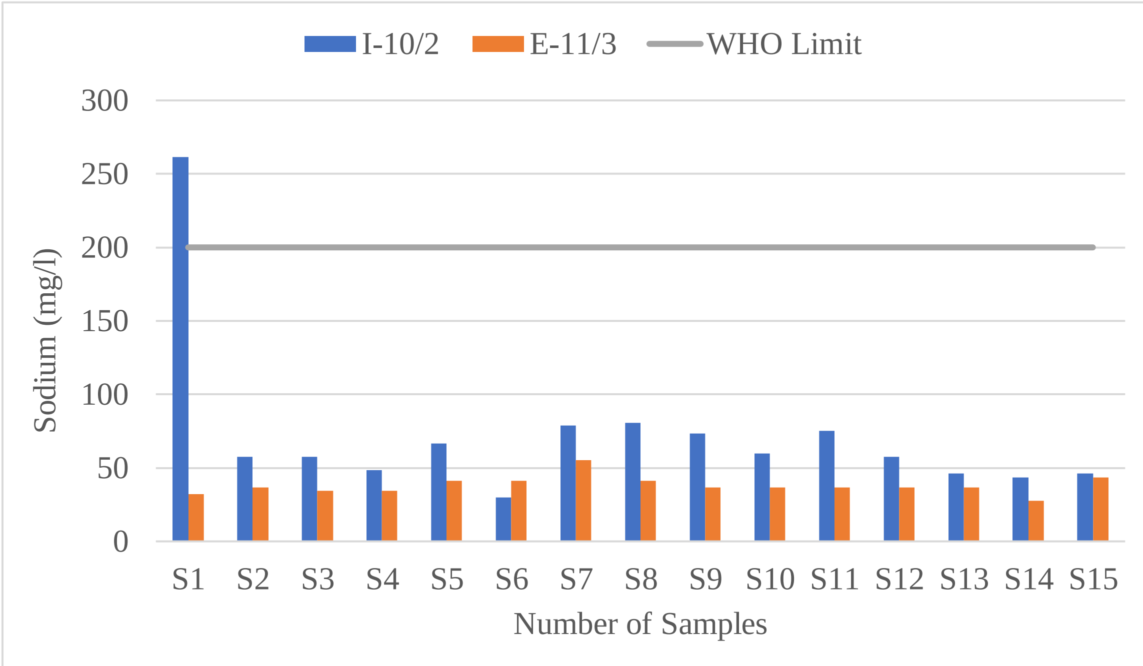

Figure 3.9: Comparative results of sodium in collected water samples

3.3.5 Concentration of NaCl (mg/L) in samples

According to the results the average chloride concentrations for sector I-10/2 and E-11/3 are 152.6mg/l, and 97.1mg/l. The permissible limit of NaCl is not defined by WHO but, the concentration of Na and Cl are within the acceptable range limit for both the sectors. Figure below displays the NaCl levels.

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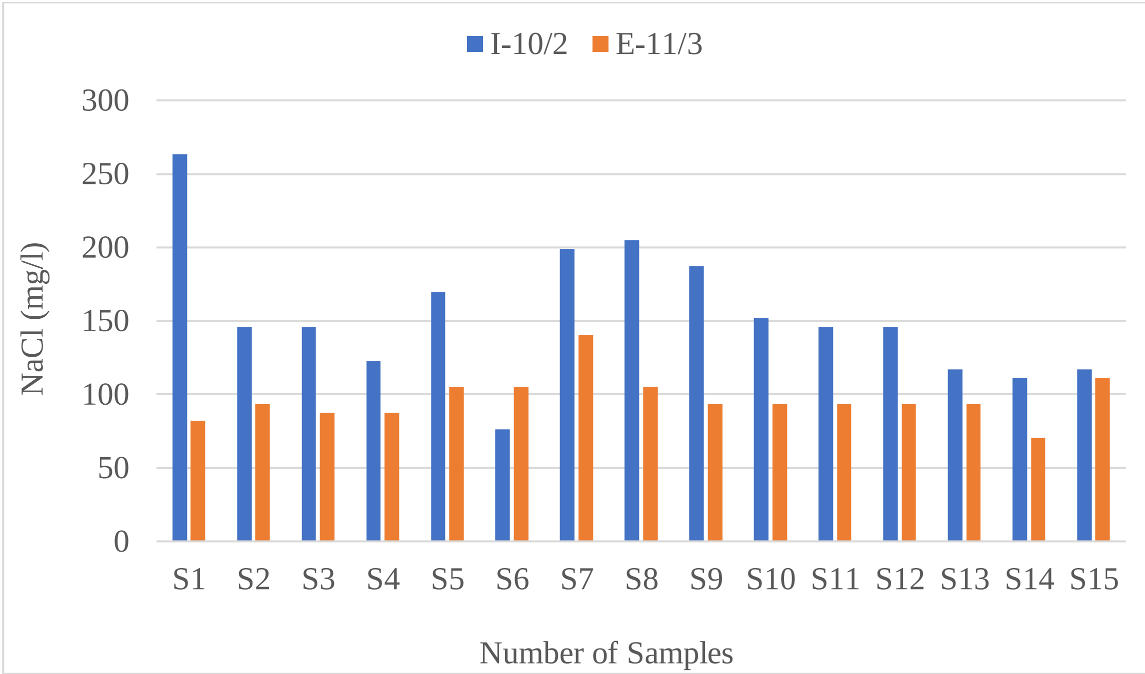

Figure 3.10: Comparative results of NaCl in collected water samples

Higher concentration of sodium will cause drinking water to taste salty. The sodium content of drinking water should be taken into consideration if a person is required to maintain a diet with little sodium because they have symptoms of high blood pressure, heart disease, problems with their kidney, or a history of cardiovascular disease.

3.3.6 Concentration of magnesium (mg/L) in samples

According to the results the average magnesium levels of 406.4mg/l, and 325.1mg/l were found in water samples collected from both the sectors. The results of magnesium for both the sites were not under the WHO acceptable range which is 150 mg/l.

In addition to calcium, which is necessary for the functioning of the body, magnesium also has to be present in a certain amount. An excessive magnesium intake can result in low blood pressure, tiredness, excessive breathing, muscle weakness and heart issues. Low levels of magnesium are not good as well. It results in excessive blood pressure, blocked arteries, and osteoporosis. The magnesium levels in each sample are shown in the figure.

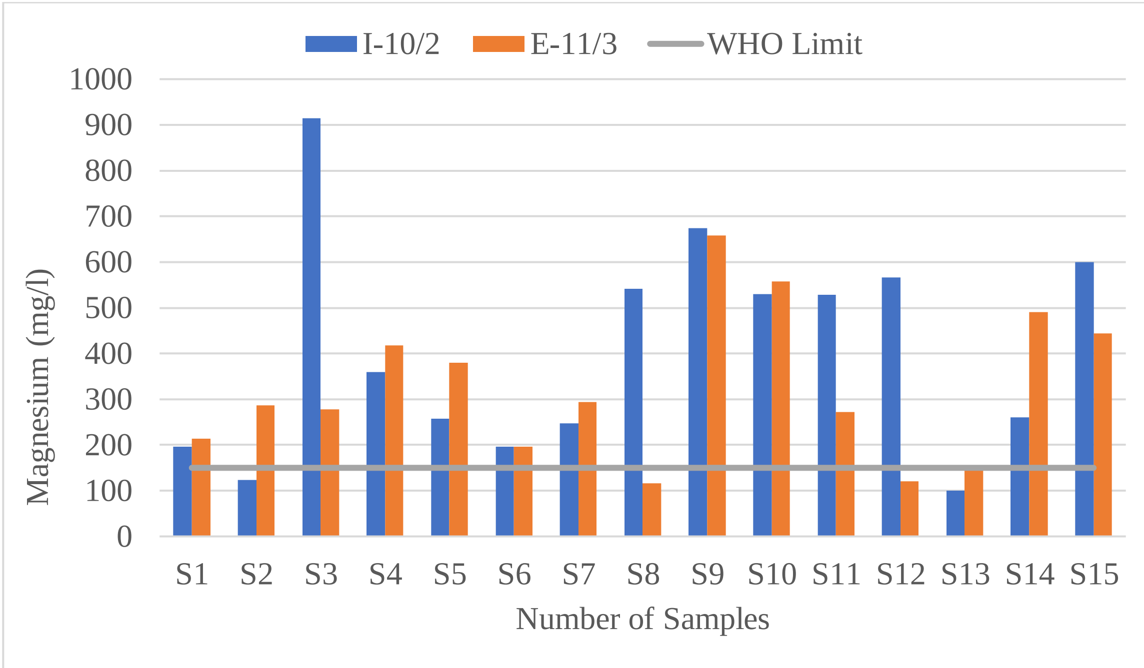

Figure 3.11: Comparative results of magnesium in collected water samples

3.3.7 Concentration of calcium (mg/L) in samples

According to the results the average magnesium levels of 175.2mg/l, and 159.4mg/l were found in water samples collected from both the sectors. The results of calcium for both the sites were not under the WHO acceptable range which is 200mg/l.

In several aspects calcium is essential for the human body to perform several processes like blood clotting and nerve impulse transmission and is required in certain amount. It can have adverse effect if calcium is taken in inadequate amount. The health problems associated with adequate intake of calcium are osteoporosis, coronary artery disease, kidney stones, and colorectal cancer. Figure 3.13 shows the concentration of calcium in all samples.

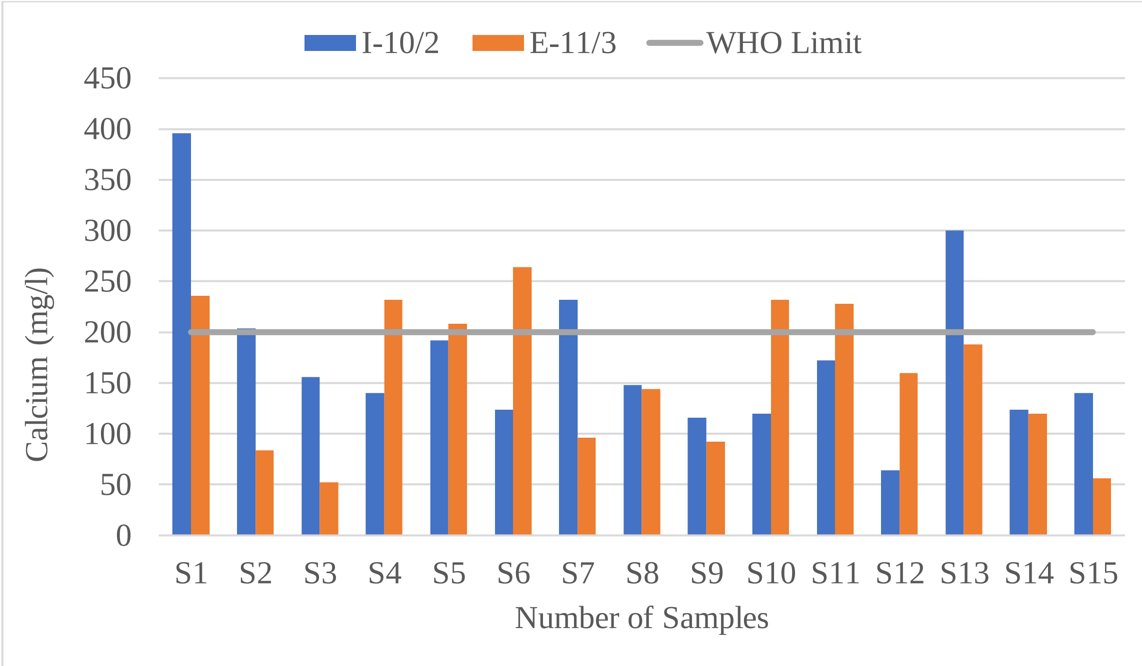

Figure 3.12: Comparative results of calcium in collected water samples

3.4 Results of microbiological samples

The water samples ten from each sector, respectively, were collected from I-10/2, and E-11/3 Islamabad. The collected samples were analyzed for microbial or bacterial contamination using MacConkey (MAC) and Nutrient agar (NA). MacConkey agar is specific for coliforms, Enterobacteriaceae and E.coli species whereas Nutrient agar is for total bacterial growth, it shows all kinds of bacterial growth. The results of microbiological contamination in groundwater samples are shown in the table below.

3.4.1 Microbiological results of sector I-10/2 :

The collected fifteen samples from I-10/2 showed no growth of broad gram-negative Enterobacteriaceae and coliforms, except for two samples but the nutrient agar specific for total bacteria, had shown bacterial growth, many colony forming units (CFUs) which exceeded the limit. The permissible limit of total bacteria is 100. If total bacteria exceed the limits, it has negative effect on those consuming the water and on human health.

Table 3.3: Results of biological parameters assessed in collected water samples from I-10/2

I-10/2		
Sample No.	**MAC (CFU)**	**NA (CFU)**
1	3	Uncountable
2	0	195
3	0	97
4	0	120
5	0	71
6	0	238
7	0	17
8	0	140
9	Uncountable	32
10	0	3
11	0	Uncountable
12	0	76
13	0	110
14	0	Uncountable
15	0	Uncountable

3.4.2 Microbiological results of sector E-11/3:

The collected fifteen samples from E-11/3 sector showed no growth of broad gram-negative Enterobacteriaceae and coliforms except for one sample, but the nutrient agar specific for total bacteria, had shown growth of bacteria but were within the acceptable range except for one sample. The acceptable range of total bacteria is 100. If total bacteria exceed the limits, it has negative effect on those consuming the water and on human health.

Table 3.4: Results of biological parameters assessed in collected water samples from E-11/3

Microbiological Parameters		
Sample No.	**MAC (CFU)**	**NA (CFU)**
1	0	13
2	0	24
3	0	21
4	0	6
5	0	27
6	0	17
7	0	18
8	0	40
9	0	3
10	0	46
11	0	37
12	0	2
13	2	Uncountable

14	0	14
15	0	Uncountable

Figure 3.13: Growth of bacteria on collected water samples on petri dishes

If we compare the biological results of both sectors, there are more bacterial counts found in water samples collected from sector I-10/2 compared to water samples collected from E-11/3. Therefore, the water from sector I-10/2 cannot be used for drinking purposes as it can cause a number of diseases in consumers.

3.5 Results of Heavy metals

Table 3.7: Results of arsenic and iron concentrations in collected water samples from sector I-10/2

I-10/2		
Sample No.	Arsenic (mg/l)	Iron (mg/l)
1	0	0.217
2	0	0.175
3	0	0.138
4	0	0.203
5	0	0.208
6	0	0.125
7	0	0.245
8	0	0.219
9	0	0.25
10	0	0.236
11	0	0.189
12	0	0.178
13	0	0.148
14	0	0.247
15	0	0.233
WHO standard	0.05mg/l	0.3mg/l

Table 3.8: Results of arsenic and iron concentrations in collected water samples from sector E-11/3

E-11/3		
Sample No.	Arsenic (mg/l)	Iron (mg/l)
1	0	0.041
2	0	0.037
3	0	0.039
4	0	0.037
5	0	0.046
6	0	0.039
7	0	0.043
8	0	0.013
9	0	0.018
10	0	0.032
11	0	0.034
12	0	0.437
13	0	0.208
14	0	0.062
15	0	0.013
WHO standard	0.05mg/l	0.3mg/l

3.5.1 Cocnentartion of iron and arsenic in water samples

According to the results the mean concentration of iron in water samples collected from both the sector I-10/2 and E-11/3 were 0.200mg/l and 0.073mg/l. The values of water samples were within the recommnded limit by WHO except for one sample from E-11/3. Even though a lot of iron is not harmful to health, it does contain tiny organisms that could potentially be bad for humans. Moreover, an excessive amount of iron water in the body can lead to complications such as diabetes, hemochromatosis, digestive disorders, as well as severe illnesses.Additionally, it has the potential to cause damage to the liver, pancreas, and heart.It can also clog and harm skin cells. It can also causes outbreaks.

According to results of water samples collected from sector I-10/2 and E-11/3 sectors had shown no arsenic (As) in water sanples. The acceptable limit for arsenic in water is 0.05mg/l. If you are exposed to arsenic for a long time through drinking-

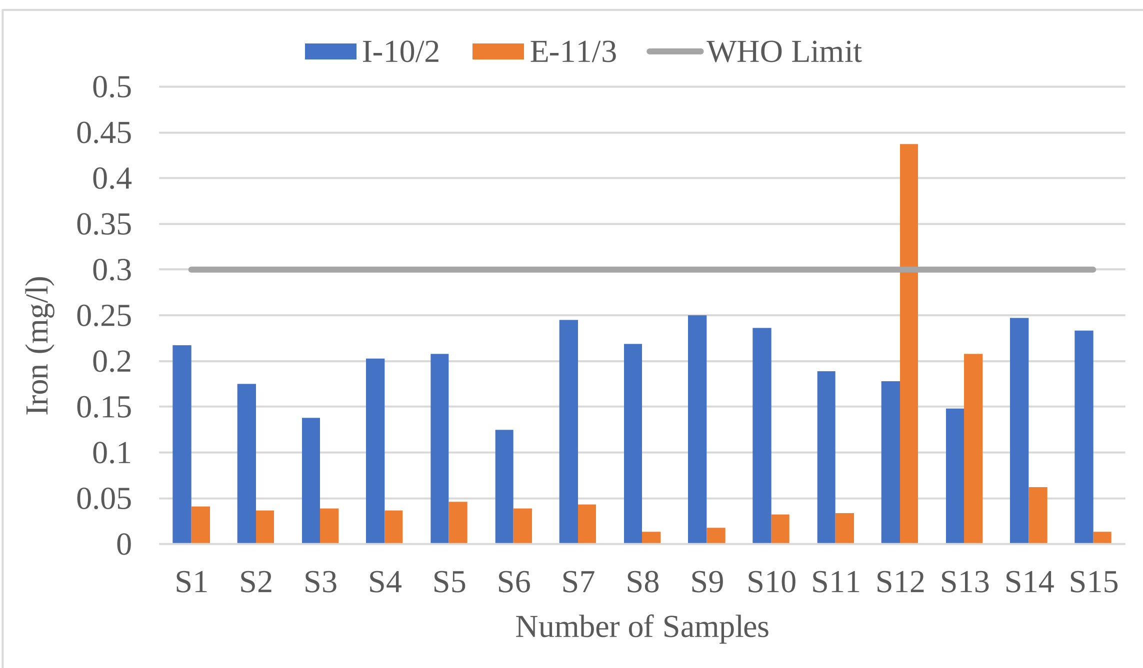

Figure 3.14: Comparative concentration of Iron in water samples collected from both sectors

water and food, it can lead to cancer and skin problems. It is also linked with heart disease and diabetes.

Groundwater serves as one of the main sources of drinking and agricultural use throughout and surrounding the city of Islamabad. due to neglected sewage from both industries and cities being discharged, its quality is deteriorating. All of the water needs of urban residents are met by drilled wells, boreholes, hand pumps, and tube wells (Khahlown, et al., 2005). The primary contributors of groundwater contamination include unregulated industrial and urban waste disposal as well as the use of fertilizers, herbicides, and pesticides in farmland (Qadir, et al., 2008).. The ground water quality of water samples collected from Islamabad I-10/2 and E-11/3 cannot be considered good. The concentration of physical paramters, pH, temperature, salts and total dissolved solids were within the acceptable range except for electrical conductivity which exceeded the recommended value. The chemical parameters, Na, Cl, NaCl, and alkalinity, were all within the permissible limits except for magnesium, calcium and total hardness which were above the recommended limit. The micronbiological paramters i.e., enterobacteriae were not detected in collected water samples but for total bacteria all collected water samples from sector I-10/2 showed the bacterial growth which exceeded the acceptable range whereas the bacterial growth in water samples collected from E-11/3 where within the acceptable range.

CONCLUSION

1. According to the physiochemical parameters, all physical parameters were within the acceptable range, with the exception of electrical conductivity (EC), which is higher than the WHO allowable range. The chemical parameters, chloride (Cl), sodium chloride (NaCl), sodium (Na) and alkalinity were all within the acceptable range except for total hardness, calcium, and magnesium which were above the recommended levels in all samples. The microbiological analysis for collected groundwater samples showed the growth of total bacteria in all samples. The growth of total bacteria in water samples from sector I-10/2 exceeded the recommended limit whereas the water samples from E-11/3 showed growth of total bacteria within the allowable range 100CFU/ml. The groundwater samples from both the sectors showed the growth of microbial organisms therefore it is concluded that water is not suitable for drinking purpose as it will cause stomach related diseases.
2. The results of heavy metals showed that all collected water samples had no presence of arsenic and the levels of iron were within the permissible limit except for one from sector E-11/3 which exceeded the recommended level.
3. According to the results of all parameters, physiochemical, microbiological as well as heavy metals, water quality of both the sectors cannot be considered good. The water cannot be used for drinking purposes. If we compare the results of both the sectors, highest counts were found in sector I-10/2 compared to E-11/3, which makes it clear that the water quality of sector I-10/2 is poorer.

RECOMMENDATIONS

On the basis of the results the following recommendations are drawn.

1. The quality of the water should be assessed regularly by the concerned management. Adequate filtering must be achieved before the water becomes available for use.

2. Keeping a sufficient distance across sewerage pipelines and water pipes is an excellent strategy to prevent cross-contamination of the water sources.
3. The groundwater sources should be monitored and cleaned, and the hygienic conditions should be maintained. To guarantee the availability of safe water to be utilized by human beings, strict regulations should be made. The rules should be vigorously enforced without compromising the quality of the water.
4. The findings of this study highlight the necessity for local municipal authorities to manage groundwater sources effectively and to promote knowledge about the significance of clean water and groundwater resource. Improvements must be made to the policies governing water quality.
5. The disposal of waste that has not been treated near groundwater sources must be strictly regulated, and pollution control laws must be properly implemented to stop groundwater water pollution. The groundwater quality in urban areas and surrounding sectors in Islamabad needs to be assessed in general.

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APPENDICES

Physico-chemical parameters

Water Samples Collection


Microbiological parameters


Petri dishes