ASSESSMENT OF DRINKING WATER QUALITY IN PUBLIC PRIMARY SCHOOLS OF URBAN PUNJAB, PAKISTAN

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ABSTRACT

The availability of safe drinking water is necessary for healthy life but access to safe drinking water has become a major problem around the world, especially in developing countries like Pakistan. Young children are more vulnerable to the health impacts due to contaminated water which often lead to waterborne diseases, affecting the overall well-being of students The study's goal was to assess the drinking water quality in primary schools of Punjab, and 17 of physio-chemical and bacteriological parameters were considered to determine the water quality. For analysis, 300 samples of drinking water were collected from primary public schools registered in urban areas across 36 districts of Punjab.The findings revealed that majority of the water quality parameters were within the permissible limits with reference to the physicochemical parameters.The measured pH for water samples ranged from 7 to 10. Majority of the samples had pH within the limit. Noticeable variation was observed in the turbidity levels of the collected samples from tap as compared to the samples collected from the tanks. The turbidity levels ranged between 8.22 NTU and 10.25 NTU.7.3% of the samples exceeded the permissible limit of WHO for turbidity. The maximum TSS value i.e 670 mg/l was observed in the samples collected from Vehari.For TDS,15.6 % of the samples exceeded the limit.In addition, colonies of E. Coli and fecal coliform were detected in majority of the samples. Moreover, in some samples colonies of E. Coli and colonies of fecal coliform were uncountable.The highest value of F^- was observed in the samples of Sialkot(7.2 mg/L).21% of the samples exceeded the limit set by WHO and NDWQS. The highest detected concentration for As was 67.21 µg/l with 55 % of the samples exceeded the permissible limit which is 10ug/l.The Cancer Risk(CR) values ranged from 0.1863 to 7.787. The calculated CR values were significantly higher than the permissible limit of 10 to 6 set by USEPA. Drinking Water Quality Index categorized, 0.66 % asexcellent,10.3%, 19%, 11.3%, 8% and 1% water samples as good, fair,poor,very poor and unfitfor drinking respectively. The questionnaire survey also indicated that 52% of the studentssuffered from cholera and typhoid while, 46% suffered from other waterborne diseases.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

AAS	Atomic Absorption Spectroscopy
APHA	American Public Health Association
As	Arsenic
Cd	Cadmium
Cl	Chloride
CDC	Centers for Disease Control
CDI	Chronic Daily Intake
DO	Dissolved Oxygen
EC	Electrical Conductivity
HQ	Hazard Quotient
HRI	Health Risk Index
IARC	International Agency for Research on Cancer
MDG	Millenium Development Goals
NDWQS	National Drinking Water Quality Standards
NTU	Nephelometric Turbidity Units
ppm	Parts per Millions
TDS	Total Dissolved Solids
TSS	Total Suspended Solids
USEPA	United States Environmental Protection Agency
WASH	Water, Sanitation, and Hygiene
WHO	World Health Organization
WQI	Water Quality Index

CHAPTER I

INTRODUCTION

The quality of drinking water is considered an important factor that affects human health. According to the World Health Organization (WHO), access to clean water can significantly impact the health of an individual. Drinking water quality in the developing countries is not as per the guidelines of WHO and consumption of contaminated drinking water causes waterborne diseases including cholera, diarrhea, dysentery, and polio. Every individual has a right to get clean water for drinking. One of the objectives of Sustainable Development goals (Goal 6) is the provision of clean and affordable water for drinking. Consumers' health is being negatively impacted by the quality of drinking water. Drinking water contaminated by bacteria is a global issue. Lack of clean water is a major cause of disease in underdeveloped countries with an estimated 88% of acute gastroenteritis being caused by unsafe water supplies [1].

According to an estimate, around 1.9 million people rely on water from sources that are fecally contaminated. It has long been recognized that providing people with sufficient and safe drinking water is crucial for meeting the Millenium Development Goals (MDG). Several studies have revealed that water from improved sources is not always secure for the purpose of drinking. Populations which rely on unsafe and unreliable supplies of water are frequently exposed to water associated diseases [2].

Families suffer from inadequate access to safe water in a variety of ways, including the deaths of children caused by the infections that could have been prevented. Poorer cognitive function and lower academic success are amongthe two more severe effects.Numerous schools serve as sources for diseases for the children, brought on by poor water supply, sanitation and hygiene [3]. According to a report byWHO (2017), water-related diseases caused 3.4 million deaths annually, especially among children, this condition is significantly severe in the underdeveloped countries. A survey done on the risks of infection and the burden of acute diarrhea worldwide, concluded that the countries experiencing unsafe supplies of water are responsible for 17.2 million diseases each year, including 5.25 million cases of dysentery, 109 000 DALYs (disability -adjusted life-years), and 1600 fatal cases [4].

The health issues associated with consumption of chemically contaminated water are different than those related to microbiological impurities. Pathogenic organisms are the most harmful pollutants to human health worldwide. These water-related illnesses are responsible for at least 25 million deaths worldwide each year, including approximately two-thirds of those in children under the age of five. Unprocessed and unconventional treatment of human waste is the primary and significant source of biological agents [5].

Increase in population growth, industrialization, and development in Pakistan have strained the availability of water as well as degraded quality of water, that has a detrimental effect on children's academic performance. According to one survey, 21 million Pakistanis are deprived of clean drinking water. In addition, Pakistan also ranks among the 10 nations that have the lowest accessibility to clean and safe water for consumption. Microbial contamination has been identified as one of the major issues in both rural and urban areas of Pakistan. This is the consequence of pipe leaks, sewage line contamination seeping into drinking water supplies, and other factors. Gastroenteritis, typhoid, dysentery, cholera, and Hepatitis A are among the waterborne illnesses caused by contaminated water that are the primary factors contributing to the disease and deaths amongst Pakistani children. A survey performed by Pakistan Council of Research in Water Resources (PCRWR) in all 4 provinces of Pakistan indicated that majority of the samples of water are not safe for consumption. The turbidity level was found to be high in the samples taken from Sindh, the samples taken from Punjab had a high concentration of arsenic while high concentration of iron was found in the samples of Khyber Pakhtunkhwa [6].According to one study, water-related illnesses cause 670,000 students in Pakistan to miss their classes each day.According to the Population Action International (PAI), about 75% of population in Pakistan have inadequate availability of clean drinking water which is the cause of 30% of communicable diseases and 40% deaths [7].

Poor Water, Sanitation, and Hygiene (WASH) services contribute to a significant number of communicable diseases around the world, particularly in countries with low incomes where diarrhoea, intestinal infections, and respiratory tract infections are the main contributors to children's mortality and morbidity. Although improving water sanitation and hygiene in primary schools is a requirement for the right to a fundamental education, insufficient WASH services in the school environment have a negative impact on health and academic achievements. WHO claims that children are more susceptible to environmental risks than adults, and because of this, schools need to take additional precautions to provide clean water as well as proper sanitation. The current state of WASH in Pakistan is mainly the result of numerous problems, including a lack of evidence-based planning, budgeting or donor assistance, irrational policing, ineffective implementations, and a lack of community participation at any step of the planning process [8].

Only twenty five percent of local schools in Pakistan have treatment facilities on-site. While only one out of 14studied water filtration facilities in schools, met the country's standards for water quality. The results of these two studies suggest that monitoring of quality of water should be performed to ensure availability of safe drinking water at schools [9].Children need more water than adults as they lose fluid more quickly because they are more active, engage in more frequent and strenuous activities.Children who have easy access to clean drinking water do better academically and behaviorally, maintain healthy water balance, and stay healthy. On the contrary, children who lack access to safe drinking water are at a risk of dehydration, which may result in less effective brain metabolism. The children also need good quality water to prevent exposure to harmful elements. Most of a child's time is spent in school. Unsafe drinking water sources could expose pupils to dangerous microbes, causing epidemics of water-borne illnesses[10].

Physical, chemical, and microbiological water parameters are used to describe water quality, and human health is placed in jeopardy if values exceed permissible bounds. WHO and the Centers for Disease Control (CDC) have established exposure guidelines or safe limits for chemical pollutants in drinking water. The most accurate method for evaluating the quality of water is the Water Quality Index (WQI). Several factors of water quality are incorporated into a numerical computation to evaluate the quality of water and assess whether it is safe for consumption. The index was designed by Horton in 1965 to evaluate water quality using the ten most frequently used water indicators. WQI transforms a complicated dataset into information that is clear and useful. The WQI's classification of water quality indicates how suitable the water is for drinking [11].

Water quality is defined by physical, chemical, and microbiological criteria; values that above allowable limits endanger human health. For drinking water, the World Health Organization

(WHO) and the Centers for Disease Control (CDC) have established thresholds for chemical pollutants. For the assessment of overall water quality, the Water Quality Index (WQI) is often used. Numerous water quality factors are compiled into a numerical computation to assess the safety of the water to consume.Horton created the index in 1965 to assess the quality of water by utilizing the 10 most frequently utilized water indicators. WQI transforms a complicated dataset into information that is clear and useful. The WQI's classification of water quality indicates how suitable the water is for drinking.To have a good representation of all water quality indicators, it is essential and crucial to choose relevant water quality criteria. Multiple studies report use of pH, dissolved oxygen, temperature, conductivity, coliform bacteria, total dissolved solids (TDS), total suspended solids (TSS), chloride (Cl^-), turbidity, hardness and nutrients as indicators of water quality. Each parameter is assigned a value based on its individual criteria and the magnitude of that value indicates how significant and influential the parameter is on the scale [12]. An essential measure of water quality is its pH, since too high or too low a pH might have negative effects. A high pH produces an unpleasant taste, deposits form on water pipes and equipment that consume water, and chlorine disinfection is less effective and necessitates the use of increased dosage of chlorine. At low pH, metals and other materials will corrode or dissolve, which could have an indirect negative impact on human health. Color,odor and taste are the aesthetical parameters of drinking water that are also important to observe because changes in these parameters provide evidence of presence of impurities in water.While the temperature of drinking water itself does not pose a direct risk to public health, slight changes in temperature can have an impact on its physical, chemical, and microbiological characteristics. Chloride may serve as an indicator of pollution. Drinking water may contains chloride which originates from sewage, industrial effluents, saline intrusion in urban runoff, and natural sources.Typically, excessive Cl^-concentrations along with nitrate or ammonium levels indicate that the water may have been polluted by domestic sources.The Cl^- and salt in drinking water leads to bladder cancer (about 80 %), colon and rectal cancer (about 35 %) and heart diseases Presence of Cl^- may affect the taste of drinking water and excess concentration leads to hypertension and heart convulsions in most of the cases[13].

The amount of solid matter present in the suspended state determines the turbidity of water. The quantity of light scattering brought on by particle debris in the water is often measured to assess turbidity. Using a device called a nephelometer, it is measured in Nephelometric Turbidity Units

(NTU). The amount of dissolved particles in water determines its electrical conductivity (EC).As ion concentration rises, so does the EC of water. The entire quantity of dissolved organic and inorganic substances in water is expressed as total dissolved solids. The total solids in a water or wastewater sample that are retained by filtration are characterized as TSS [13].

Water's hardness is determined by the total amount of calcium and magnesium ions it contains. These ions are mostly introduced into water by contact with rocks and soil, especially limestone deposits.An appropriate amount of fluoride (F^-) in drinking water is good for teeth. It helps prevent tooth decay, especially in children. However, if there is too much fluoride in the water, it can lead to a condition called dental fluorosis, which causes teeth to become discolored. One of the most crucial aspects of water quality is dissolved oxygen (DO). It is an important test for pollution in water. The quality of the water improves with increasing DO level.Nitrogen in the form of nitrate (NO_3^-) is an essential nutrient for plant growth and can play a role in limiting their growth. Nitrates can enter groundwater through the use of chemical fertilizers in agricultural areas. Drinking water containing too much NO_3^- presents an instantaneous and significant health danger, especially to young children [14].

Microbial contamination of water is another serious issue of concern.The main microbiological contaminants that are found in drinking water include viruses, pathogenic protozoa and bacteria.Coliform bacteria are classified into three groups i.e. fecal coliform, E.coli and total coliform. Total coliform bacteria include a wide range of different kinds of bacteria. Fecal coliform pathogens are categorized as components of total coliform bacteria. The most commonly used indicator of faecal contamination is E. coli. Although, like other coliform markers, it is more susceptible to disinfection than many pathogens and is also frequently used as a treatment efficiency indicator [14].

Heavy metals are equally important in determining the quality of drinking water. Some heavy metals are essential but their excessive ingestion may cause negative impacts on human health. One of the important heavy metal of concern in drinking water supplies, regarding both environmental and individual health perspective, is arsenic (As)and is reportedly hazardous and carcinogenic [15].As reported by the International Agency for Research on Cancer (IARC), the inorganic As and cadmium (Cd) are carcinogenic. A study performed in Bangladesh concluded that the exposure of children to As (more than 50 g L^{-1}) through the consumption of contaminated water had lower intellectual function. Overexposure to iron and manganese can have harmful effects on health, including neurological problems i.e hyperkeratosis e.t.c. The contamination of groundwater due to As in Punjab and Sindh has emerged as a threat to public health. It is extremely important to assess the potential human health risk for children to better comprehend the critical exposure concentrations of As to school children [8].

The assessment of quality of water is essential for both human health and aquatic life. The quality of water greatly influences the supply of water and frequently affects the possibilities for supply. It is crucial to identify the sources and keep a track of quality of water used for water distribution because of the rise in demand of water and persistent decline in the accessibility of freshwater. Potential threats to the public's health can be reduced by determining the source(s) of contamination and creating effective management plans. Water quality monitoring and evaluation provide scientific data to support public health and environmental policies. Measures of water quality are useful and reliable indicators of variations in the biological, chemical or physical status of water in management processes [16].

According to United States Environmental Protection Agency (USEPA), estimating the likelihood and characteristics of adverse health effects in individuals, can be done using human health risk assessment.The process of health risk assessment involves identifying possible sources of environmental risk releases, calculating the number of potentially hazardous factors that will come into direct contact with people, and assessing the impact of this contact on human health.. Hazard analysis, dose-response evaluation, exposure assessment, and risk management models are the four main stages that must be accomplished to carry out assessment of health risks [17].

According to a report by the government of Pakistan (2015-2016), water and hygiene-related diseases are causing a big problem for the country's economy. They are leading to annual losses of around US$380 to 883 million in the country's total income.Additionally, a heartbreaking fact is that about 250,000 children under the age of five die every year in Pakistan due to diarrheal diseases.Shockingly, about 62% of the urban population in Pakistan does not take any steps to make their water safe before drinking it. This leads to millions of cases of diarrhea disease being reported in hospitals every year. Based on the National Water Quality Monitoring Programme conducted by PCRWR, the major types of harmful contaminants detected in drinking water sources in Pakistan were bacteria (68%), As(24%), NO_3^- (13%), and F^- (5%) [18].

Urban areas frequently face issues including industrial pollution, agricultural runoff, and deteriorating infrastructure, which can result in water contamination. The study would identify hazardous substances including heavy metals (As), bacteria, or other pollutants that might harm children's health by examining water samples from primary schools. It is essential to conduct a study on the drinking water quality in primary schools of urban Punjab to make sure that rules are followed, detect and address potential risks to students, promoting awareness and education and safeguarding students health.Such a study provides a solid foundation for putting into action sensible policies that will improve water quality and protect the wellbeing of the entire school community and make policy measures to ensure supply of clean drinking water in schools especially government schools.

1.1 Study Area

The study was carried out in the public primary schools of urban Punjab. Punjab is known as the most prosperous, populated, and developed province in Pakistan and is home to over 60% of the nation's inhabitants. The lifeline of Pakistan is Punjab, a region with five rivers and a former title of "the granary of the east". The province of Punjab makes up around 26% of Pakistan's total land area by covering an area of 205 344 sq km. It shares borders with the provinces of Khyber Pakhtunkhwa, Baluchistan, Sindh, the Islamabad Capital Territory, and Azad Kashmir. Additionally, it has borders with the Indian states of Jammu & Kashmir, Rajasthan, and Punjab. Punjab's soil was left behind by the Indus River and its tributaries during the Quaternary Period. In Summer, the temperature in Punjab ranges from 25^0C- 50^0C and can touch down to -10^0C in winter. It has 36 districts, 144 Tehsils (subdivisions), 3,464 union councils, and 25,914 villages. It is the most populous province with around 98 million people living there. In rural areas of Punjab, access to tap water is very limited, only 13%, compared to 43% in urban areas. Unfortunately, the quality of drinking water in Punjab is not good. Most people rely on hand pumps and turbines to get water, but these sources often provide contaminated or salty water. Even the piped water supply in Punjab is at risk of contamination due to old and leaking pipes.

One of the main reasons for the spread of waterborne diseases is the mixing of drinking water with sewage pipelines. Plastic pipes are used to supply water, but they are easily damaged, leading to contamination of the drinking water. The financial impact of waterborne diseases in Punjab is significant [19].

Sixty eight percent of the population of Punjab gets water either from hand pump or motor pump and only five percent of the population depend on wells, rivers, canals or streams. In most parts of Punjab, the groundwater is being overexploited for irrigational purposes. Apart from the shortage of water, the quality of water is also deteriorated and is not suitable for drinking purposes. Numerous studies conducted in recent years have shown that Punjab's drinking water quality has considerably declined in terms of specific contaminants such total coliform, nitrates, chlorides, and arsenic[20].

All the primary schools in urban areas registered with the Education Department of Punjab were considered as the target population. 36 districts which are the representative of Punjab were selected.

RATIONALE

Drinking water contamination is of fundamental concern regarding human health especially children. Children spend a considerable amount of time at school. They are the future and asset of any nation. Every year children die of waterborne diseases. Children are more vulnerable to the health impacts of contaminated water. Regular consumption of contaminated water can lead to both short-term and long-term health issues, potentially hindering students' ability to attend school regularly and perform well academically. Provision of safe water is important for a child physical and mental development and well being. Therefore, monitoring of potable water quality at schools to ensure compliance with established health and safety standards and guidelines.Adhering to these standards is essential for providing a safe and conducive learning environment for students, promoting their health and minimizing the risk of waterborne diseases. Contaminated water can serve as a vector for various waterborne diseases, such as diarrhea, cholera, and typhoid, which can lead to absenteeism and affect the overall health of the school community.Assessing water quality enables the identification and mitigation of potential health risks, contributing to disease prevention and promoting public health within the school setting. Assessing water quality in public primary schools fosters community awareness about the importance of safe drinking water. Keeping this in view, the study was conducted to assess the quality of water available at primary schools of Urban Punjab.It will help in identifying schools using unsafe water sources so that necessary measures can be taken to ensure supply of safe water and avoid instances of water borne diseases among school children.The findings of the assessment can serve as a basis for advocating policy changes and improvements in water infrastructure within educational institutions.

OBJECTIVES

The study was carried out with the following objectives:

- Evaluation of the physicochemical and bacteriological contamination of drinking water in primary schools of urban Punjab.
- Determination of the incidence of water-borne diseases in children of urban primary schools.
- Geospatial mapping of potential health risk areas.

CHAPTER II

LITERATURE REVIEW

For the purpose of protecting children' health and wellbeing, public primary schools must evaluate the quality of their drinking water.Evaluating the chemical and microbiological characteristics of water samples in schools has been the subject of several research. Findings often highlight issues such as fecal contamination, high levels of heavy metals, and inadequate disinfection. Additionally, visual inspections of water sources reveal infrastructural problems and improper maintenance practices. The existing literature emphasizes the importance of consistently monitoring water quality in schools and taking appropriate actions to rectify issues. These measures are crucial for protecting the health of students and creating an environment that is conducive to learning. Therefore, it is necessary to regularly assess and address water quality concerns through effective interventions.

Everyone has the right to access clean water and proper sanitation. The United Nations recognizes this as a fundamental human right. The UN has set Sustainable Development Goals, including Goal 6, which aims to ensure equal access to water and sanitation for all. Goal 10 also focuses on reducing inequality and promoting inclusiveness. However, according to a report from the WHO and UNICEF in 2017, 844 million people still do not have basic access to clean water, and 2.3 billion people lack access to basic sanitation services [21].

According to the WHO, contaminated water sources are responsible for nearly 1.7 million casualties annually. Drinking water contamination is a serious challenge that is becoming more prevalent, especially in urban areas. Drinking water contaminated with the pathogenic bacteria causes various waterborne diseases like cholera, dysentery, typhoid, diarrhea, gastroenteritis e.t.c. In order to examine the condition of quality of drinking water in urban areas, 100 samples were taken during pre-monsoon period from groundwater sources and piped supplies in various residential, commercial and industrial areas of Lucknow City (India). Analysis for fecal coliform bacteria, heavy metals and organo-chlorine pesticides (OCPs) were performed. In comparison to residential and industrial regions, samples from commercial areas were found to have higher levels of bacterial contamination. ICP was used to detect the presence of heavy metals in 55 samples including manganese (Mn), aluminium (Al), arsenic (As), nickel (Ni), molybdenum (Mo), lead (Pb) , zinc (Zn), vanadium (V), selenium (Se), tin (Sn), copper (Cu) and iron (Fe). The concentration of aluminium and iron were higher according to the guidelines [22].

In another study, carried out in the urban areas of Myanmar, Yangon and Nay Pyi Taw. The current state of the water supply and conduct a survey of water quality was assessed. Drinking water samples were collected from different sources including bottled waters, public pots, non-piped taps and piped taps. A commercial kit was used to quantify the number of heterotrophic plate counts, E.coli and total coliform bacteria. Dissolved heavy metal ions were detected through Inductively Coupled Plasma Mass Spectrometry (ICP-MS). Arsenic and fluoride were found to be at high concentration. The highest heterotrophic plate counts were found in pots, followed by samples of bottled water, non-piped tap water, and piped tap water. The results revealed that all pots, all non-piped taps, one piped tap and one bottle of water had water quality that was above standards and unsafe to drink. It is necessary to take action to improve the appalling condition of the water in pots and unpiped taps [23].In another study,carried out in the urban areas of Myanmar, Yangon and Nay Pyi Taw. A survey was conducted to evaluate the quality of the water and the current state of the water supply. A variety of sources, including public pots, non-piped taps, bottled waters, and piped taps, were used to get samples of drinking water. A commercial kit was used to quantify the number of heterotrophic plate counts, E.coli and total coliform bacteria. Dissolved heavy metal ions were detected through Inductively Coupled Plasma Mass Spectrometry (ICP-MS). Arsenic and fluoride were found to be at high concentration. The highest heterotrophic plate counts were found in pots, followed by samples of bottled water, non-piped tap water, and piped tap water. The results revealed that all pots, all non -piped taps, one piped tap and one bottle of water had water quality that was above standards and unsafe to drink. It is necessary to take action to improve the appalling condition of the water in pots and unpiped taps [24].

Another study was done to evaluate the bacteriological and physicochemical properties of water and health risk posed to children in primary schools in Kalapara upazila, Pataukhali district, Bangladesh. 65 tube wells were selected to collect samples of water. The results revealed that pH was in the range of 6.9-8.3, the range of electrical conductivity was 774.3-1987.0 µS/cm and As varied between 0.0-0.03 mg/L. Seven of the tube wells indicated carcinogenic hazards for children. The results reveal that drinking water from certain tube wells may expose children to lifetime cancer risks [25].

Another research study was performed in Bangladesh for the assessment of the possible health impacts to children of high schools due to consumption of As contaminated water. For this purpose, 180 water samples were obtained from the tube wells from high school campuses. Analysis was carried out for As, Mn,Ca and Mg. Physicochemical characteristics were examined as well. Results indicated that the groundwater is slightly alkaline. The concentration of As was higher than the guidelines of WHO. The risk to human health was calculated using the Hazard Quotient for As, Fe, and Mg. The findings showed that kids are more vulnerable to dangers. Girls were at higher risk as compared to the boys [26].

Another study was done to evaluate the bacteriological and physicochemical properties of water and health risk posed to children in primary schools in Kalapara upazila, Pataukhali district, Bangladesh. 65 tube wells were selected to collect samples of water. The results revealed that pH was in the range of 6.9-8.3, the range of electrical conductivity was 774.3-1987.0 µS/cm and As varied between 0.0-0.03 mg/L. Seven of the tube wells indicated carcinogenic hazards for children. The results reveal that drinking water from certain tube wells may expose children to lifetime cancer risks [27].

In the Punjab and Khyber Pakhtunkhwa, the health hazards associated with consuming trace elements in drinking water were determined.The calculation of the health risk index (HRI) took chronic daily intake (CDI) into account. According to the findings, the concentrations of Asin Lahore, Vehari, Multan, and Jhang were 51, 50.4, 24, and 22 ng/g, respectively, which were higher than the WHO's permissible limits. The concentrations of Cr, Ni, and Mn were 2593, 1306, and 695 ng/g, respectively, in Lahore and Jhang.The order of the CDI values was determined to be Cr > Ni > Mn > Cu > As > Pb > Co > Cd. Similar to this, numerous cities had HRI readings that were higher than the acceptable limits (e.g., Cr and Ni in Lahore and As in Vehari, Jhang, Lahore, and Multan).The study showed that consuming water contaminated with trace elements poses a growing health danger to the affected populations. Additionally, the analysis revealed that both human activities and natural factors contribute to the contamination of drinking water in the investigated areas[28].

A healthy existence depends on having access to clean drinking water, yet this is a major issue in many regions of the world, particularly developing nations like Pakistan.An investigation was conducted in Pakistan's Gujranwala district to see whether the groundwater there was suitable for human consumption. Eighty water samples were gathered from various locations and analyzed. Additionally, a survey was carried out to find out how common waterborne illnesses are in the region. The study aimed to identify potential health risks associated with consuming groundwater. The outcomes demonstrated that, for the most part, the water's chemical and physical characteristics complied with drinking water regulations.97.5% of the samples were contaminated with bacteria. The study also measured the concentrations of different metals in the water, and while most were within safe limits, Cd and As showed higher levels. These metals posed potential health risks, with some samples showing values above the safe threshold. Overall, the study concluded that the groundwater quality in Gujranwala had mostly deteriorated, emphasizing the need for improved access to safe drinking water in the area[29].

The quality of drinking water in urban areas of three tehsils (Vehari, Mailsi, and Burewala) in Vehari district, Pakistan was analysed and its relationship to water-borne diseases was determined. Forty-one water samples were collected from different locations and analyzed for physical, chemical, and microbial contamination. The results showed that most of the sampled areas met the WHO limits for pH, phosphate, sulphate, magnesium, iron, copper, zinc, and manganese. However, microbial contamination, specifically Escherichia coli and coliforms, was found in certain areas of Tehsil Vehari. Additionally, some parameters such as EC, TDS, sodium, calcium, potassium, chloride, and nitrate exceeded the WHO limits in specific areas of Vehari district [30].

The high concentration of F^-, NO_3^-, and nitrites in water causes methemoglobinemia and gastrointestinal cancer.Nitrate ion (NO_3^-) and nitrite ion (NO_2^-) being components of the nitrogen cycle exist naturally in water. To determine the risk of F^-,$NO_3^-$and NO_2^-levels in water and its impact on public health , a study was conducted in Ahmadpur East, Punjab, Pakistan in which 36 water samples were collected from the area.The average values for nitrate, nitrite, and fluoride were found to be 0.4197, 0.006, and 0.67 mg/L, respectively. The Total Health Index (THI), Hazard Quotient (HQ), and CDI were taken into consideration while determining the health risks for individuals in various age groups. In the urban area of the research area, the CDI and HQ of fluoride predicted a higher allowable limit in various age groups than those of nitrite and nitrate. In the urban area, THI was shown to be higher in infants and children than in other age groups. Due to fluoride, nitrate, and nitrite, infants and children are more vulnerable to health problems than other age groups. It's critical to routinely check the water quality to guarantee public safety [31].

Evaluation of water quality of supply schemes (WSS) in Mianwali was carried out by analyzing the physico-chemical and bacteriological contamination. A total of 115 WSS were evaluated as part of the study, and sources of drinking water that had substantially increased bacterial contamination were identified. According to the data, 71% of the WSS contained fecal germs so drinking the water was harmful. In 30% of the schemes, the water storage tanks were a significant contributor to the contamination. Compared to ground water sources (41%), tap water sources (71%) were more polluted. Due to their 30% bacterial contamination of water samples, Mianwali's WSS was therefore not considered safe [32].

Earlier, a large-scale study was conducted in 36 districts of Punjab to assess the quality of water. The results showed that most of the samples had acceptable levels of pH, color, and odor, except for groundwater in Kasur and Khanewal districts. However, about 66.67% of the samples had TSSabove the recommended limit by the WHO. The conductivity of all samples exceeded the permissible limit set by the WHO. Only 22% of the groundwater samples met the WHO limit for total coliforms, and only eight districts had no E. coli contamination. Salmonella spp. was found in samples from 13 districts, while Pseudomonas spp. was present in samples from all districts except eight. Overall, only six groundwater samples from Punjab districts were considered safe for drinking according to the WHO standards. The study also analyzed the presence of trace metals and ions in the water samples and identified unsafe levels of certain elements in some districts [33].

Human health concerns resulting from elevated amounts of trace metals in drinking water include cancer, renal diseases, cardiovascular illnesses, and effects on the nervous system. Children in high-income countries are less likely than those in low-income ones to be exposed to metals.In 2021, a study to assess the concentrations of Pb, Cd, Mn, and Fe in drinking water sources at primary schools in Sindh Province, Pakistan was conducted. The research covered 425 primary schools, and risk assessment models were used to estimate metal index, pollution index, lifetime cancer risk, and HQ index. Alarmingly, in many schools, heavy metal levels exceeded WHO permissible limits;67% samples exceeded Pb limit, 17% Cd while 15% samples were above WHO limit for Fe. Lead, in particular, posed significant concerns due to its potential adverse effects on children's growth, development, academic performance, and long-term health [34].

The prevalence of waterborne diseases is relatively high in the developing nations. As a result, the rate of casualties, especially among newborns, is of concern. Pakistan is categorized as a country with water stress due to its per capita availability. Some reports have revealed that Pakistan's poor water quality is responsible for forty percent of all fatalities and 30% of all ailments. A study was performed for evaluation and comparison of the quality of drinking water and diseases that are related to it in Bahawalpur city (Pakistan). Islamic colony, Shahdrah and Satellite town were chosen as study areas and two water samples were collected from each area. Physical and chemical characteristics were assessed. The results revealed that pH, EC, hardness and TDS were above the standards of WHO. The Islamic colony, which was one of the three study sites, had the worst conditions overall, with 48% of inhabitants consuming diluted water, 55 %of inhabitants using brackish water and 41 % using water with a mild odour. 36% of residents have been facing serious diseases like cholera, diarrhea etc. The study suggests that to save the inhabitants, frequent drinking water quality monitoring is required, and municipal authorities should construct more water filtration plants to offer access to clean drinking water to protect the residents from water-related diseases [35].

The quality of drinking water in public and private sector medical colleges in Lahore, Pakistan was analysed by collecting samples from 10 different colleges. Most of the parameters measured, such as odor, taste, color, and pH, were within acceptable ranges set by standards. However, in six samples, the level of As was higher than the WHO recommended limit, although it was still within the limits set by local standards. One sample showed the presence of E. coli bacteria and other coliforms, and another sample had higher levels of fecal coliforms. Overall, the water quality in most medical colleges met the standards set by*Punjab Environmental Quality Standards*(PEQS), but improvements are still needed to ensure a better water supply system [36].In another study on the quality of water from water coolers installed in educational institutes in Lahore, Pakistan was examined. Drinking water from these coolers can be contaminated with harmful microbes and chemicals, potentially causing waterborne diseases. A total of 55 water samples were collected and tested for physical, chemical, and bacterial characteristics. The results were compared to the drinking water guidelines set by the WHO. The analysis showed that the physical and chemical quality of the water samples was acceptable according to WHO standards. However, 80% of the samples tested positive for bacterial contamination, with 17 samples containing E. coli, a type of bacteria found in feces. Alarmingly, 8 of these samples had a strain called E. coli O157: H7, which can cause severe infections even at low doses. The contamination may be due to leakages or cross-contamination between sewage and drinking water pipes, as well as inadequate disinfection and filtration processes. The study concluded that the water quality in Lahore's educational institutes is unsatisfactory and getting worse. To prevent microbial contamination, it recommends regular chlorination and monitoring of water quality in the coolers [37].

A common issue is drinking water with high levels of naturally occurring F^- and As. Individuals who are exposed to fluoride may experience bone and teeth fluorosis as well as reproductive complications while individuals who are exposed to arsenic experience bladder, skin and lung cancer. Neurological complications are also associated with F^- and As. A study was performed to investigate the relationship between child’s IQ and exposure to F and As in drinking water. The study was carried out in the three rural communities in Mexico. 132 children (6-10 years old) were involved. In two communities, the fluoride levels in drinking water were 3-6 times higher than WHO recommended levels. The levels of As in water were on average 17-19 times higher than WHO limits. According to the findings of this study, F^- and As in drinking water may have neurotoxic effects on children [38].

If there is no appreciable health risk associated with drinking water over the course of a lifetime, it is deemed safe. The WHO stipulates that any sample of 100 milliliters of drinking water must be free of coliform bacteria[39].An assessment of the drinking water quality was carried out at Alipur, Pakistan. According to the findings, the bulk of the samples' physical and chemical characteristics fell within allowable bounds. Nevertheless, it was determined that over 50% of the samples were unsafe for human consumption due to bacterial contamination. Because consuming bacteriologically contaminated water leads to waterborne diseases and even cancer in some cases [40].

Public health is dependent on the quality of the water supply, especially for children as they require additional protection. In Brazil's public primary schools, students can spend 5-8 hours/day in a class. The condition of drinking water and its influence on the wellbeing of children were studied at the schools in Brazil. Microbiological characteristics, physicochemical properties and chemical characteristics of the samples were analyzed in three schools in Santarem city and one school in rural area. The USEPA recommendations were followed for assessing the health risks associated with human exposure and water intake. A total of 36 water samples were analyzed. In 28 samples of drinking water, total coliforms were identified with E.coli was found in 16 samples. School A (240-1144 CFU/100mL) and school C (396-1694 CFU/100mL) had the highest values. The children in schools who drink water that is polluted with bacteria are at risk of contracting acute diarrheal diseases. The findings of this study also indicated that the water used in schools had low pH. According to the assessment of the health risk for students in schools, NO_3^- and Al both significantly increased the risk [41].

Most diseases are transmitted primarily through schools because of inadequate water supply, sanitation and hygiene. To identify the status of the drinking water in schools, a research study was conducted in Peshawar. This study targeted the assessment of condition of drinking water.Bacteriological quality of drinking water was determined and a total of 30 water samples were collected from government and private schools. Multiple test tube method was used for all the samples by following the standard procedures. E.coli was identified in 53 % samples from private schools and 73% in the samples from government schools.Only 1 sample in this study was free of coliforms per 100ml while the rest of the samples were contaminated with coliforms including *E.coli*. The majority of drinking water samples in this study have high total coliform and *E.coli* count which shows that drinking water in these schools is not suitable for drinking. Action should be taken by the government so that we can save our new generation from the health risks associated with contaminated water [42].

Natural and human activities both contaminate the ground water. The intake of drinking water contaminated with As affects around 150 million people worldwide. A research study was performed for the evaluation of the drinking water containing As and its influence on health in

Mailsi (Punjab), Pakistan. 44 samples were taken from Sargana and Mailsi. As was identified through an atomic absorption spectrophotometer. To examine the health hazards for individuals exposed to arsenic, a health risk assessment model was used. According to the results, the concentration of As was higher in the samples collected from Mailsi.It was concluded that the residents of Mailsi had a higher toxic risk index. The highest value of Average Daily Dose (ADD) was found in sample 17 of Mailsi. The range of HQ of drinking water was from 1.3-73.3 in Sargana and 1-76.6 in Mailsi [43].Arsenic is regarded as the silent toxin, since the adverse impacts of As poisoning are only apparent after a long period.In Kushtia district, Bangladesh, researchers studied the drinking water from 50 samples using a hydrochemical approach. They were particularly interested in checking for As levels and other trace metals (TMs) present in the water. The results showed that the shallow aquifers' drinking water had very high levels of arsenic, ranging from 6.05 to 590.7 μg/L. Around 82% of the samples exceeded the safe limit (10 μg/L) recommended by the WHOfor drinking water. However, the concentrations of other trace metals like silicon (Si), boron (B), manganese (Mn), strontium (Sr), selenium (Se), barium (Ba), iron (Fe), cadmium (Cd), lead (Pb), fluorine (F), uranium (U), nickel (Ni),lithium(Li), and chromium (Cr) were within safe limits, posing no immediate health concerns [44].

Water is vital for all living things, but when it gets contaminated, it harms living beings. A study examined the biological pollutants found in drinking water and how they affected human health. Common contaminants include harmful bacteria, viruses, parasites, and worms, leading to prevalent diseases like diarrhea and fever, mostly in developing countries with limited access to clean water. Around 1.7 billion children suffer from diarrhea annually, causing 525,000 deaths, and nearly 1 million adults also die from it each year. To address this, various treatment methods like oxidation, ultraviolet radiation, and nanotechnology are used to purify drinking water and remove biological contamination [45].

A large scale study was conducted in Nepal to check the quality of drinking water in different regions. 506 water samples were collected over a two-year period. Analysis showed that 88.5% samples had total coliform, and 56.5% had fecal coliform (Escherichia coli). The presence of these bacteria varied across regions, with the highest rates in the Far-western Development Region. The study showed that many water sources were contaminated, posing a serious health risk for people who rely on this water for drinking and other purposes [46].

Drinking water quality is still the cornerstone for the prevention and management of waterborne illnesses and is a significant environmental factor of health. There exist multiple variations of the faecal-oral routes that lead to the transmission of water-borne diseases. These include the water distribution system and the pollution of drinking water catchments by faecal pathogens, human or animal feces.A study was performed to examine the microbial quality of tap water and groundwater in Karachi, Pakistan. For this purpose 50 water samples were collected, 25 from taps and 25 from boreholes, from different areas of five administrative districts in Karachi. The samples were tested for bacteria, and a survey was conducted to understand the impact of the drinking water on people's health. The results of the microbial analysis showed that 48 out of 50 samples (96%) had total coliform bacteria present. The total viable plate count, indicative of bacterial contamination, exceeded the limits set by the WHO and the Pakistan Environmental Protection Agency. To assess the health risks associated with contaminated water, 744 residents were interviewed. The results showed that waterborne illnesses including diarrhoea, vomiting, skin issues, malaria, persistent fever, eye issues, and jaundice were highly prevalent. The report recommends increasing awareness and putting in place regular monitoring procedures for proper waste disposal and water management in order to address these water and environmental challenges [47].

Neglecting the role of water in causing bacterial infections, the focus has been on treating infections rather than preventing them. To raise awareness about the careful use of water, its bacteriological and physiological analysis is essential. Water quality is declining rapidly due to various factors. A study in Gujrat, Pakistan, examined drinking water samples for physical and microbial attributes. The analysis revealed the presence of Staphylococcus, Bacillus, Streptococcus, Streptomyces, Escherichia, Enterococcus, and Citrobacter, which can potentially cause infections. Additionally, these bacteria were found to have the ability to form biofilms, contributing to the spread of infections within the local community [48].

In many cities of Pakistan, including Multan, groundwater is the primary source of drinking water supplied through taps. Studies have found that this water often contains substances like As and F^-, which can be harmful to human health when consumed regularly. To address this issue, a study was conducted using a three-fold approach. Firstly, the drinking water quality was assessed in Multan, which is densely populated and has significant industrial activity. Secondly, a nano-adsorbent, using kitchen waste, was developed to effectively and affordably remove both As and F^- from the water.30 water samples were collected and found that a large percentage exceeded the maximum safe limits for As and F^-. However, after treating the water with the newly developed nano-adsorbent, the researchers achieved remarkable removal rates of 81-100% for F^- and 13-100% for As, ensuring safer drinking water for the population [49].

According to report on water, sanitation, and hygiene services in Khyber Pakhtunkhwa and Punjab Provinces, Pakistan access to these services differs between the two regions. In KP, around 89% of households have improved water sources, and 85% have improved sanitation. In Punjab, the figures are approximately 94% for improved water sources and 72% for improved sanitation. Gender disparity affects sanitation access for women and girls.The report highlights issues like water contamination, poor hygiene, and untreated drinking water leading to waterborne diseases in both regions [50].In developing countries, poor water quality has led to the deaths of approximately 5 million children annually. A study in Faisalabad, Pakistan, aimed to assess water quality and factors influencing the consumption of safe drinking water. Drinking water samples were collected from 225 households and found that most water samples were contaminated with harmful microbes and had higher levels of hardness, turbidity, and dissolved solids than recommended. Factors like household income, residential status, awareness level, and the smell of groundwater were positively related to safe drinking water consumption. On the other hand, the age of the family head and previous waterborne diseases were negatively linked to safe water consumption. To improve the situation, educational and awareness campaigns should be implemented across urban and rural areas [51].

This literature review provides a comprehensive assessment of the drinking water quality in Punjab. The findings indicate that while efforts have been made to improve access to improved water sources and sanitation, there are still significant challenges to address. Various studies have highlighted the importance of ensuring safe and clean drinking water for schoolchildren to protect their health and well-being. The presence of contaminants, such as heavy metals and microbial pathogens, poses significant risks to children's health, potentially leading to various diseases and long-term health issues. Safeguarding the health and safety of young students is paramount, and addressing the issue of drinking water quality in public primary schools must remain a top priority for policymakers, educators, and the community at large.

CHAPTER III

METHODOLOGY

3.1 Collection of Data

The internet and library were utilized to gather secondary data in order to obtain published papers, journals, and reports. Field visits to the chosen locations and a reconnaissance survey were used to gather primary data.

3.2 Site Selection

This study was performed to determine the quality of drinking water at government primary schools of urban Punjab. Thirty six (36) districts of Punjab were selected for this study. These included Toba Tek Singh, Bahawalnagar, Bahawalpur, Bhakkar, Chakwal, Chiniot, D.G Khan, Faisalabad, Gujranwala, Gujrat, Hafizabad, Jhang, Jhelum, Kasur, Khanewal, Khushab, Lahore, Liyyah, Lodhran, Mandi Bahauddin, Nankana Sahib, Muzaffargarh, Attock, Multan, Vehari, Sialkot, Pakpattan, Sahiwal, Okara, Sargodha, Rajanpur, Rawalpindi,Narowal, Sheikhupura, Mianwali and Rahim Yar Khan. Figure 3.1 shows the location map and sampling points of the study areas.

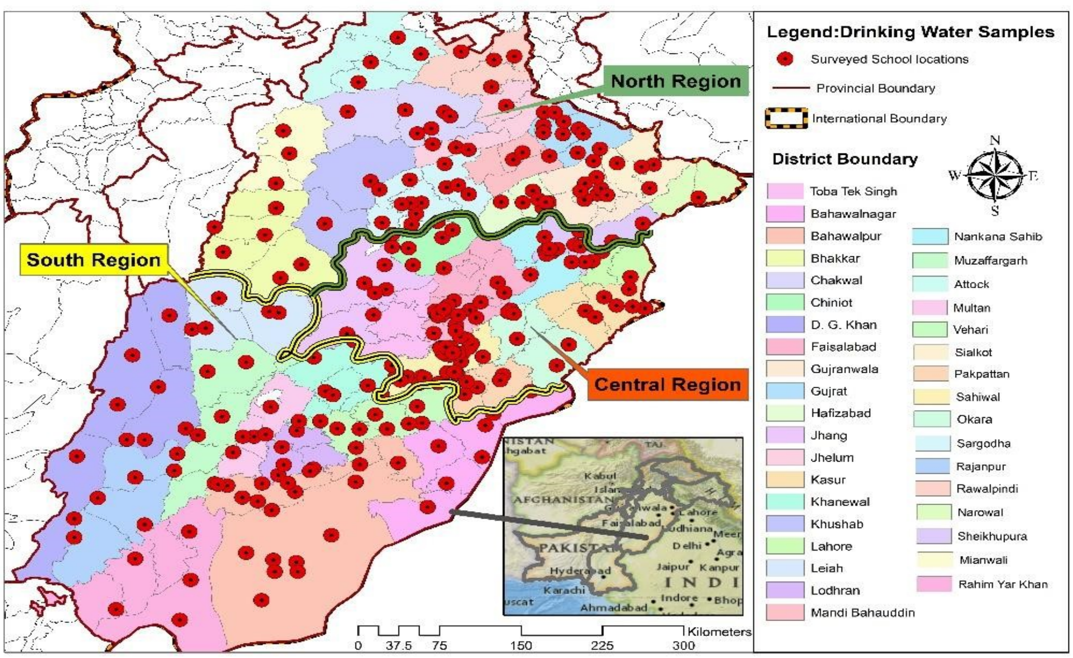

Figure 3.1: Sampling points in the Punjab province (urban areas) of Pakistan.

3.3 Sample Collection

Three hundred samples of water for drinking were gathered from taps and some of the samples were collected from the tanks within urban Punjab primary schools.US EPA provides guidelines for collecting drinking water samples to ensure accurate and safe analysis and testing.1000 milliliters of drinking water were collected, and the polythene bottles were sanitized for the purpose of collecting water samples. After being delivered to the lab, the samples were maintained at 4^0 C. Samples were gathered, kept, and conserved in accordance with US EPA rules [52]. The Global Positioning System (GPS) was used to capture the sampling spots' coordinates.

3.4 Sample Analysis

Physicochemical and bacteriological analysis of the drinking water samples was done to evaluate the drinking water quality of study areas. The physicochemical parameters which were investigated include pH,TDS, EC, Total Hardness, As, NO_3^-, DO, Cl, and Turbidity. EC, DO, pH, turbidity and TDS were analyzed through EC meter, DO meter, pH meter, turbidity meter and TDS meter respectively. Detection of bacteria *(E.coli)* was carried out by Heterotrophic Plate Count (HPC) Method. While the analysis of NO_3^- and F^- were carried out by Ion electrode meter, Total hardness through EDTA titrimetric method, As through atomic absorption spectrometer and chloride through Argentometric titration. Standard methods and protocols were followed for determining the quality of drinking water samples. The techniques and standard methods for the analysis of selected parameters are mentioned below in Table 3.1.

3.5 Analysis of Physicochemical Parameters

3.5.1 pH and temperature

Temperature and pH of drinking water samples was determined using pH meter.

3.5.2 Odor and Color

Evaluationof the odor and color of water samples was done at the time of collection as it is a crucial initial assessment that offers valuable insights into potential water quality concerns. This preliminary evaluation relies on human senses, specifically smell and sight, to provide essential information about the water's condition.

Table 3.1: Standard methods for the analysis of selected parameters[53,54]

Parameter	Technique/Instrument	Method
pH	pH meter, EUTECH Instrument PC 510,	USEPA Method 150.1
Odor	Sensory test	------
Temperature	pH meter	APHA 2550B
Color	Sensory test	------
TDS (mg/L)	Gravimetric method	USEPA Method 2540C
TSS (mg/L)	Gravimetric method	USEPA Method 2540D
EC (mS/cm)	Conductivity meter, EUTECH Instrument PC 510	USEPA Method 120.1
Total Hardness (mg/L)	EDTA Titrimetric Method	US EPA Method 130.1
Arsenic (µg/L)	Atomic Absorption Spectrophotometer	USEPA Method 200.8
Nitrate (ppm)	Ion meter, Spectrum scientific 930	US EPA Method 353.2
Fluoride (ppm)	Ion meter, Spectrum scientific 930	US EPA Method 340.1
DO (mg/L)	DO meter, JENWAY	APHA 4500-O (G)
Chloride (mg/L)	Titrimetric method	APHA 4500-Cl^- (B)
Turbidity (NTU)	Turbidity Meter, HANNA HI 93703	APHA 2130B
Bacteriological Detection (*E.coli* and Fecal Coliforms)	Heterotrophic Plate Count (HPC) Method	APHA 9215B

3.5.3 Total Dissolved Solids

For the measurement of concentration of TDS,10 mL of the sample was evaporated, leaving behind the dissolved solids. The remaining residue was then weighed to calculate TDS concentration using the following formula

TDS (mg/L) = (Weight of Residue / Volume of Sample) * 1000[54] equation 3.1

3.5.4 Total Suspended Solids (TSS)

TSS were measured through gravimetric method. Filter paper was first weighed to determine its initial weight (referred to as B). The collected raw water samples (20 mL each) were then filtered using filter paper. Subsequently, the damp filter papers were put into labeled aluminum trays and placed in a drying oven set at temperatures ranging from 103°C to 105°C.After drying, the filter papers were allowed to cool to room temperature before being weighed once again. The difference was calculated by the following formula:

TSS (mg/L) = (A-B) x 1000/C[54] equation 3.2

Where A = weight of filter paper + residue (mg)

B = initial weight of filter (mg)

C = volume of sample filtered

3.5.5Electrical Conductivity and turbidity

Electrical Conductivity was measured by using conductivity meter (EUTECH Instrument PC 510).To assess turbidity in the samples, a properly calibrated turbidity meter was used. A turbidity vial was filled with 15 mL of water and inserted into the device to note the measurement. Following the analysis of each sample, the vial was carefully rinsed with distilled water to prevent any potential inaccuracies [54].

3.5.6 Dissolved Oxygen

DO was measured by the DO meter Compared to titration, this method is more precise, compatible, and faster. This is because it uses a sensing electrode, which enhances accuracy and efficiency.

3.5.7Chloride Ions

Using argentometric titration, the amount of chloride present in drinking water samples was ascertained. The silver nitrate by 0.1 molarity was taken into burette. Two to three drops of potassium chromate indicator were put to a conical flask containing 10 milliliters of water sample. Then silver nitrate was added until the color changed from brown to brick red [54].

M_1 = Molarity of chloride in water

V_1= Volume of sample

M_2 = Molarity of silver nitrate

V_2 = Volume of silver nitrate

Molarity of chloride in water = $\frac{Molarity\ of\ silver\ nitrate}{Volume\ of\ sample} \times Volume\ of\ silver\ nitrate$ equation 3.3

Concentration of chloride = Molarity of chloride (M_1) × atomic weight×100equation 3.4

3.5.8 Total Hardness

Five milliliters of drinking water sample and one milliliter of buffer solution were added to a conical flask in order to determine the overall hardness of the water. A pinch of Eriochrome black-T was added and pink color appeared into flask. The solution was titrated against EDTA until the end point i.e. blue color. Total hardness was calculated by using the following formula [54].

M_1 = Molarity of $Ca^{++} + Mg^{++}$

V_1= Volume of sample

M_2 = Molarity of EDTA

V_2 = Volume of EDTA

Molarity of calcium and magnesium = $\frac{Molarity\ of\ EDTA}{Volume\ of\ sample} \times Volume\ of\ EDTA$ equation 3.5

Concentration of Ca^{++} = Molarity of calcium × molecular massequation 3.6

Concentration of Mg^{++} = Molarity of magnesium× molecular massequation 3.7

Total hardness = Concentration of Ca^{++} + concentration of Mg^{++}equation 3.8

3.5.9 Fluoride and Nitrate Ions

Calibrated ion electrode meter was used to determine the concentration of F^- and NO_3^- ions. For analysis, 30 mL of each sample was taken in a beaker and ion selective electrode was immersed in the sample and readings noted. To ensure the accuracy, the ion meter was periodically calibrated using standard solutions.

3.5.10 Arsenic

Concentration of total As was determined by using atomic absorption spectrophotometer.The AAS instrument measures the absorption of light by free atoms in the gas phase. The amount of the analyte in the sample that is absorbed depends on its concentration. Calibration curves were generated using standard solutions of the metal.

3.6 Bacteriological Analysis

i. Preparation of Agar

Conical flasks and glass petri dishes were all disinfected by autoclaving at 121°C for 15 minutes after being wrapped in aluminum foil. In a conical flask, 1000 milliliters of distilled water were added together with 50 grams of weighed MacChonkey agar. The medium was entirely dissolved by heating the flask on a hot plate with a magnetic stirrer. The agar-containing conical flask was subsequently autoclaved for 15 minutes at 121°C to sterilise it once again. It was then cooled to 40-50°C.

ii. Sample Inoculation

Alcohol lamp was burnt and placed near the petri dishes. 5ml of agar was poured into each sterile petri dish. Petri dishes were allowed to cool at room temperature and agar was solidified. 1ml of sample was spread evenly on the solidified agar with the displacement pipette by using sterile tips. To avoid any contamination, the tips were changed after inoculating each petri dish.

iii.Incubation

MacConkey Agar petri dishes were stacked upside down to prevent condensation on the surface. Petri dishes were placed in an incubator set at 37°C for 24-48 hours.

After incubation, petri plates were examined for the bacterial growth. Colonies of E.coli appeared in pink color while colonies of fecal coliforms appeared in light yellow/white color. Colony counter was used to count the colonies.

After the analysis all used material was autoclaved and was disposed properly.

3.7 Statistical Analysis

The results obtained after analysis were recorded and interpreted by using IBM SPSS version 21 by running descriptive statistics which include mean, mode, median and standard deviation. For the determination of correlation between physicochemical parameters, Pearson’s correlation coefficient values were used.

3.8 Water Quality Index (WQI)

A number of significant factors were taken into account when calculating the Water Quality Index: (a) the parameter's importance; (b) the statistical relationship between the parameter concentration and the corresponding index; (c) parameters associated with the water quality; and (d) the classification of the water quality, which includes excellent, good, poor, very poor, and unfit for human consumption. Here, the Environmental Protection Agency of the Government of Pakistan and the World Health Organization's suggested requirements were applie[10,55]. WQI was calculated employing previously reported procedures [27, 28, 29].

3.8.1 Calculation of Unit Weight

Estimating the unit weight (Wn) of each physicochemical parameter is the first stage in the WQI computation process. For every parameter, the unit weight (Wn) is inversely proportional to thestandards that have been prescribed [56].

$$Wn = \frac{k}{Sn} \qquad \text{equation 3.9}$$

Where, Wn = unit weight for the nth parameter ,Sn= Standards permissible value for nth parameter and k= proportionality constant which is calculated by following formula [56].

$$K = \frac{1}{\sum(\frac{1}{Vs})} \qquad \text{equation 3.10}$$

3.8.2Calculation of Quality Rating

The second step is to use the following equation to estimate the quality rating scale (Qn) for each parameter [56].

$$Qn = [\frac{Vn - Vi}{Vs - Vi}]x100 \qquad \text{equation 3.11}$$

Where,

Qn = Quality rating of nth water quality parameters

Vn = Observed value of the water quality parameter obtained

Vi = Ideal value

Vs = Recommended WHO standard of the water quality parameter

3.8.3 Calculation of WQI

WQI was calculated by aggregating the quality rating with the unit weight linearly by using the following equation [56]:

$$WQI = \frac{\sum QnWn}{\sum Wn} \text{equation 3.12}$$

Where, Qn is the quality rating of nth water quality parameter, Wn is the unit weight of nth water quality parameter. In last step, the calculated WQI value was classified into five categories in order to testify its suitability for human consumption.

Table 3.2: Characterization of water quality based on water quality index (WQI) value

[56,57]

WQI	**Status**
0-25	Excellent
25-50	Good
51-75	Fair
76-100	Poor
101-150	Very Poor
> 150	Unsuitable for drinking

3.9 Human Health Risk Assessment

Health risk assessment was done to evaluate the health risks in children exposed to arsenic. Several steps are involved to calculate the health risk assessment i.e., hazard identification, dose-response assessment, exposure assessment and risk characterization [58].

3.9.1 Exposure Dose

To estimate the exposure of pollutants/chemicals to the individuals, the following formula is used [59].

$$ED = C \times IR \times ED \times \frac{EF}{BW} \times AT \qquad \text{equation 3.13}$$

Where ED= Exposure Dose, C= concentration of pollutant/chemical in water (mg/l), IR= Intake Rate (1L/day), EF= Exposure Frequency (230 days/year), BW= Body Weight (40 kg based on the responses obtained from the questionnaire), AT= Average Lifetime (1150 days based on number of days students spend in a primary school).

Where = reference dose (mg/kg/day). If the value of HQ =1 or HQ>1, the consumption of such water is considered as a health risk.

3.9.2 Hazard Quotient

The formula for calculating HQ [59] is as follow

$$HQ = \frac{ED}{R_fD} \text{equation 3.14}$$

Where = reference dose (mg/kg/day). If the value of HQ =1 or HQ>1, the consumption of such water is considered as a health risk.

3.9.3 Cancer Risk

The formula for calculating Cancer Risk (CR) [59] is mentioned below:

$$CR = ED \times CSF \qquad \text{equation 3.15}$$

Where CSF = cancer slope factor.

3.10 Questionnaire Survey for status of health of students and drinking water quality and facilities provided in school:

Two types of questionnaires were designed. One questionnaire was administered by the parents to evaluate the health status of their children in primary schools in urban areas of Punjab This questionnaire consisted of close ended questions. Second questionnaire was designed for principal/headmaster of primary schools to inquire about the drinking water quality and facilities provided in school.

3.11Geospatial mapping:

ArcGIS 10.7 was used for generating, specifically maps illustrating the distribution of As levels, TSS, turbidity, and fecal coliform concentrations were generated for Punjab. These maps, akin to those displaying arsenic concentration, TSS and turbidity employed a color-coded scheme to depict various concentrations or levels of these environmental factors across different regions within Punjab. The results were presented in the form of GIS maps through interpolation employing Inverse Distance Weighting (IDW) method.

The complete methodology summarizes below in figure 3.2

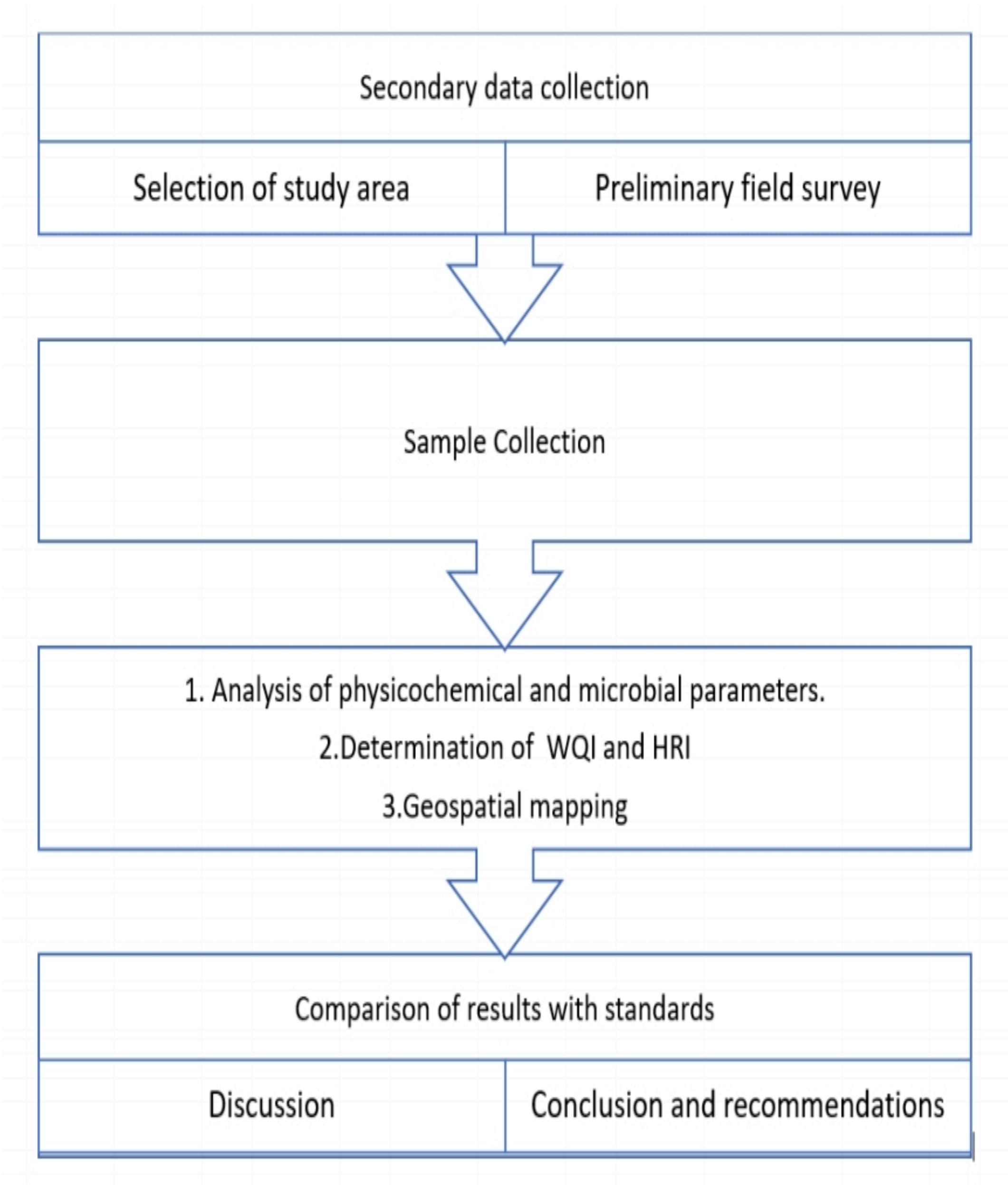

Fig 3.2: Flowchart of methodology

CHAPTER IV

RESULTS

This chapter highlights the results of a study conducted through experiments on specific parameters related to the quality of drinking water. These parameters include aspects like physical and chemical properties, the presence of microorganisms, and levels of heavy metals.

4.1 Physical Parameters

The physical parameters of drinking water are those parameters that characterize the physical attributes of water. These factors provide important information about how suitable and high-quality the water is for human consumption. The results of analysis of physical parameters of drinking water are summarized in Table 4.1:

Table 4.1: Results of Physical Parameters

Sr #	Sample code	Temperature (°C)	Color	Odor	Taste	Turbidity(NTU)	TSS (mg/L)
WHO and NSDWQ standards		**--------------**	**Colorless**	**Acceptable**	**Acceptable**	**<5 NTU**	**----------**
				Sahiwal			
1	SWL 1	24.2	Colorless	Odorless	Tasteless	0.75	36
2	SWL2	23.4	Colorless	Odorless	Tasteless	0.8	52
3	SWL3	23.4	Colorless	Odorless	Tasteless	1.55	60
4	SWL4T	23.4	Pale yellow	Odorless	Salty	5.43	100
5	SWL4TK	23.4	Colorless	Odorless	Tasteless	1.96	32
6	SWL5	23.4	Colorless	Odorless	Tasteless	1.86	240
7	SWL6	23.4	Colorless	Odorless	Tasteless	1.29	12
8	SWL7	23.4	Colorless	Smelly	Slightly salty	0	0
9	SWL8	23.3	Colorless	Odorless	Tasteless	0.95	35
10	SWL9	23.2	Colorless	Odorless	Tasteless	1.83	50
11	SWL10	23.3	Light yellow	Odorless	Tasteless	4.2	50
12	SWL11	23.5	Pale yellow	Odorless	Tasteless	5.34	230
13	SWL12T	23.5	Colorless	Odorless	Tasteless	1.41	180
14	SWL12TK	23.5	Colorless	Odorless	Tasteless	0	0
15	SWL13	23.5	Colorless	Odorless	Tasteless	1.37	10
16	SWL14	23.5	Colorless	Odorless	Bitter taste	1.15	20
17	SWL15	23	Colorless	Odorless	Tasteless	1.04	40
18	SWL16	23.2	Pale yellow	Odorless	Tasteless	1.29	50
19	SWL17	23.2	Pale yellow	Odorless	Tasteless	0.48	30
20	SWL18	23.3	Light yellow	Odorless	Tasteless	7.12	230

21	SWL19	23.4	Colorless	Muddy Smell	Tasteless	0.23	40
22	SWL20	23.2	Colorless	Odorless	Tasteless	0	0
23	SWL21	23.2	Colorless	Odorless	Tasteless	0.45	30
24	SWL22	23.2	Colorless	Odorless	Tasteless	0.78	120
25	SWL23	23.2	Colorless	Odorless	Tasteless	0.33	230
26	SWL24	23.2	Colorless	Odorless	Tasteless	0.89	20
27	SWL25	24.3	Colorless	Odorless	Tasteless	5.56	130
28	SWL26	24.3	Colorless	Odorless	Salty	0.58	70
Pakpattan							
29	PKP27	24.3	Colorless	Odorless	Tasteless	0.5	40
30	PKP28	24.2	Yellow	Odorless	Tasteless	0	0
31	PKP29	24.2	Yellow	Odorless	Tasteless	0.49	20
32	PKP30	23.3	Pale yellow	Odorless	Tasteless	0.81	50
33	PKP31	23.3	Colorless	Odorless	Tasteless	0.47	25
34	PKP32	23.4	Colorless	Odorless	Tasteless	0.59	40
35	PKP33	23.2	Colorless	Smelly	Tasteless	0.48	10
36	PKP34	23.4	Colorless	Smelly	Tasteless	0.68	30
37	PKP35	23.2	Colorless	Odorless	Tasteless	0.34	0
38	PKP36	23	Colorless	Odorless	Tasteless	0.49	60
Okara							
39	OKC37	24.5	Colorless	Odorless	Slightly salty	0.33	0
40	OKC38	24.5	Light yellow	Odorless	Tasteless	0.82	50
41	OKC39	24.3	Colorless	Odorless	Tasteless	0.34	80
42	OKC40T	22	Light yellow	Odorless	Tasteless	0.01	10
43	OKC40TK	23.4	Light yellow	Odorless	Tasteless	0.32	100
44	OKC41	26	Light yellow	Odorless	Tasteless	0.05	110
45	OKC42	25	Colorless	Odorless	Tasteless	0	0
46	OKC43	26	Colorless	Odorless	Tasteless	1.76	70
47	OKC44	26	Colorless	Odorless	Tasteless	0.4	20
48	OKC45	24.4	Colorless	Smell like sewage	Tasteless	1.57	30
49	OKC46T	24.2	Colorless	Odorless	Slightly salty	1.11	98
50	OKC46TK	27.2	Colorless	Odorless	Tasteless	2.5	30
Chichawatni							
51	CWI47	27.8	Colorless	Odorless	Tasteless	0.68	40
52	CWI48	28	Yellow	Odorless	Tasteless	0.6	90
53	CWI49	28	Yellow	Odorless	Tasteless	0.51	40
54	CWI50	28	Colorless	Odorless	Tasteless	0.67	20
55	CWI51	26.4	Colorless	Odorless	Tasteless	0.8	70
56	CWI52	22.3	Pale yellow	Odorless	Tasteless	1.23	0
57	CWI53	28.4	Light yellow	Odorless	Salty	0.09	30
58	CWI54	28.4	Colorless	Odorless	Slightly salty	1.19	90

59	CWI55	28.4	Colorless	Odorless	Tasteless	1.72	150
60	CWI56	28.4	Colorless	Odorless	Tasteless	1.39	80
Sargodha							
61	SGD57	28.4	Colorless	Odorless	Tasteless	0.88	0
62	SGD58	24.3	Yellow	Odorless	Tasteless	0.39	85
63	SGD59	24.2	Colorless	Smelly	Bitter taste	0.5	40
64	SGD60	24.2	Colorless	Odorless	Tasteless	0.27	30
65	SGD61	23.3	Colorless	Odorless	Tasteless	0.94	60
66	SGD62	23.3	Colorless	Odorless	Tasteless	0.4	30
67	SGD63	23.4	Colorless	Odorless	Tasteless	0.61	140
68	SGD64T	28.5	Colorless	Muddy Smell	Tasteless	3.28	200
69	SGD64TK	28.5	Colorless	Odorless	Tasteless	1.06	98
70	SGD65	28.5	Colorless	Odorless	Tasteless	0.74	50
Mianwali							
71	MW66	28.5	Colorless	Odorless	Tasteless	1.62	100
72	MW67	28.5	Colorless	Odorless	Tasteless	0.79	40
73	MW68	28.5	Colorless	Odorless	Tasteless	1.62	90
74	MW69	28.5	Colorless	Odorless	Tasteless	0.79	60
75	MW70T	28.5	Colorless	Odorless	Tasteless	1.52	120
76	MW70TK	28.5	Colorless	Odorless	Tasteless	2.48	200
77	MW71	26.5	Colorless	Smelly	Tasteless	8.4	340
78	MW72T	26.9	Colorless	Odorless	Tasteless	2.39	120
79	MW72S	27.2	Light yellow	Odorless	Tasteless	1.88	70
80	MW73	27.8	Yellow	Odorless	Tasteless	0.74	30
81	MW74	28	Colorless	Odorless	Tasteless	0.15	20
82	MW75	28	Colorless	Odorless	Tasteless	2.94	120
Khushab							
83	KHB76	28	Colorless	Odorless	Tasteless	0.62	40
84	KHB77	28	Colorless	Muddy Smell	Tasteless	0	0
85	KHB78	23.3	Colorless	Odorless	Tasteless	0.17	20
86	KHB79	23.3	Colorless	Odorless	Tasteless	2.18	140
87	KHB80T	23.3	Colorless	Odorless	Tasteless	1.26	100
88	KHB80TK	23	Colorless	Odorless	Tasteless	0.02	20
89	KHB81	23.2	Colorless	Odorless	Tasteless	1.88	100
90	KHB82T	23.2	Pale yellow	Odorless	Tasteless	2.38	130
91	KHB82TK	23.2	Pale yellow	Odorless	Tasteless	0.88	30
92	KHB83	24.5	Yellow	Odorless	Tasteless	1.38	20
Bhakkar							
93	BKR84	24.5	Colorless	Odorless	Tasteless	0.98	40
94	BKR85T	21.3	Colorless	Odorless	Tasteless	1.35	190
95	BKR85TK	21.4	Colorless	Odorless	Tasteless	2.02	200

96	BKR86	21.2	Colorless	Smell like sewage	Bitter taste	0.85	60
97	BKR87	21.2	Colorless	Odorless	Tasteless	0.79	54
98	BKR88	21.3	Colorless	Odorless	Tasteless	0.5	45
99	BKR89	21.7	Colorless	Odorless	Tasteless	0.89	65
100	BKR90	23.2	Colorless	Odorless	Tasteless	0.77	60
Chakwal							
101	CKW91	23.4	Colorless	Odorless	Tasteless	1.05	80
102	CKW92	23.3	Light yellow	Odorless	Salty	0.51	75
103	CKW93	23.2	Light yellow	Odorless	Tasteless	0.77	110
104	CKW94	23.1	Colorless	Odorless	Tasteless	0.86	65
105	CKW95	24.5	Colorless	Odorless	Tasteless	0.66	30
106	CKW96	24.5	Colorless	Odorless	Tasteless	0.9	40
107	CKW97	24.3	Colorless	Odorless	Tasteless	0.96	50
108	CKW98	24.4	Colorless	Smelly	Tasteless	1.09	80
109	CKW99	24.2	Colorless	Odorless	Tasteless	0.84	100
110	CKW100	21	Colorless	Odorless	Tasteless	0.99	230
Rajanpur							
111	RJP101	21.2	Colorless	Odorless	Tasteless	1.48	220
112	RJP102	21.2	Colorless	Odorless	Slightly salty	0.73	210
Muzzafargarh							
113	MZJ103	21.2	Pale yellow	Odorless	Tasteless	0.86	150
114	MZJ104	21.2	Colorless	Odorless	Tasteless	0.47	10
Attock							
115	ATC105	21.2	Colorless	Odorless	Tasteless	0.75	40
116	ATC106	21.2	Colorless	Smelly	Tasteless	0.51	45
117	ATC107	21.2	Colorless	Odorless	Tasteless	0.8	200
118	ATC108	20.7	Colorless	Odorless	Tasteless	0.48	30
119	ATC109	20.5	Colorless	Odorless	Tasteless	1.22	150
120	ATC110	20.4	Yellow	Odorless	Tasteless	1.19	190
121	ATC111T	20.7	Light yellow	Odorless	Tasteless	4.14	290
122	ATC111TK	20.5	Light yellow	Smell like sewage	Tasteless	0.55	110
123	ATC112	21.2	Colorless	Odorless	Tasteless	0.84	60
124	ATC113	21.3	Colorless	Odorless	Tasteless	1.35	80
Jhelum							
125	JHE114	24.3	Colorless	Odorless	Tasteless	6.01	400
126	JHE115	24.2	Colorless	Odorless	Tasteless	5.44	310
127	JHE116	23.4	Colorless	Odorless	Tasteless	2.41	140
128	JHE117	23.2	Colorless	Odorless	Tasteless	0.04	0
129	JHE118T	23.4	Colorless	Odorless	Slightly salty	3.45	200
130	JHE118TK	24.4	Colorless	Odorless	Tasteless	1.33	97

131	JHE119	24.6	Pale yellow	Muddy Smell	Tasteless	6.54	400
132	JHE120	27.8	Pale yellow	Odorless	Tasteless	0.73	95
133	JHE121	27.9	Colorless	Odorless	Tasteless	1.32	100
134	JHE122T	28.1	Colorless	Odorless	Tasteless	4.54	120
135	JHE122TK	28.2	Colorless	Odorless	Tasteless	0.06	80
136	JHE123	28.2	Yellow	Muddy Smell	Tasteless	10.25	620
137	JHE124	27.3	Colorless	Odorless	Tasteless	5.01	500
Lodhran							
138	LDH125	27.2	Colorless	Odorless	Bitter taste	1.44	100
139	LDH126	27.1	Colorless	Odorless	Tasteless	0.04	35
140	LDH127T	27.2	Light yellow	Odorless	Tasteless	4.35	210
141	LDH127TK	27.1	Colorless	Odorless	Tasteless	0.44	50
142	LDH128	27	Colorless	Odorless	Tasteless	0.24	240
Rawalpindi							
143	RWP129	26.3	Colorless	Odorless	Tasteless	0.34	120
144	RWP130	26.3	Colorless	Odorless	Tasteless	0.29	30
145	RWP131	26.3	Colorless	Odorless	Tasteless	1.12	190
146	RWP132T	26.5	Colorless	Odorless	Salty	0.55	45
147	RWP132TK	25.2	Light yellow	Smelly	Tasteless	8.22	440
148	RWP133T	24.6	Pale yellow	Smell like sewage	Tasteless	6.21	540
149	RWP133TK	24.4	Colorless	Odorless	Tasteless	4.11	200
150	RWP134	24.6	Colorless	Odorless	Bitter taste	1.32	100
151	RWP135	26	Colorless	Odorless	Tasteless	1.15	150
152	RWP136	25	Colorless	Odorless	Tasteless	0.41	60
153	RWP137	26.5	Colorless	Odorless	Tasteless	0.55	95
154	RWP138	20.1	Colorless	Odorless	Tasteless	1.45	120
155	RWP139	20.5	Colorless	Odorless	Tasteless	1.98	90
156	RWP140	20.5	Colorless	Odorless	Tasteless	0.73	210
157	RWP141	19.2	Pale yellow	Odorless	Tasteless	4.41	290
158	RWP142T	19.4	Colorless	Odorless	Tasteless	0.16	40
159	RWP142TK	19.2	Colorless	Odorless	Tasteless	0.08	30
160	RWP143	19	Yellow	Odorless	Tasteless	5.1	500
161	RWP144	20.5	Colorless	Odorless	Tasteless	0	0
162	RWP145T	21.2	Colorless	Muddy Smell	Tasteless	1.21	100
163	RWP145TK	21.3	Light yellow	Odorless	Tasteless	3.2	230
Khanewal							
164	KWL146	24.3	Colorless	Odorless	Slightly salty	0.43	60
165	KWL147	24.2	Light yellow	Odorless	Tasteless	5.96	400
166	KWL148	23.4	Colorless	Odorless	Tasteless	0.64	160
167	KWL149	23.2	Colorless	Smelly	Tasteless	0.58	95
168	KWL150T	23.4	Colorless	Odorless	Salty	0.07	40

169	KWL150TK	22.3	Pale yellow	Odorless	Slightly salty	4.21	200
170	KWL151	22.4	Light yellow	Odorless	Salty	10.64	600
171	KWL152T	22.3	Colorless	Odorless	Tasteless	0.05	0
172	KWL152TK	22.4	Colorless	Odorless	Tasteless	0.51	110
173	KWL153	22.5	Colorless	Odorless	Tasteless	0.06	20
174	KWL154	24.5	Colorless	Odorless	Tasteless	0.61	10
175	KWL155T	24.4	Yellow	Odorless	Tasteless	9.21	450
176	KWL155TK	24.3	Colorless	Smell like sewage	Tasteless	0.77	170
177	KWL156	24.6	Colorless	Odorless	Tasteless	0.58	45
178	KWL157	25.5	Colorless	Odorless	Tasteless	0.08	70
179	KWL158	25.6	Yellow	Smelly	Tasteless	3.23	400
180	KWL159	26.3	Colorless	Odorless	Tasteless	0.16	40
Vehari							
181	VHR160	26.3	Colorless	Odorless	Tasteless	0.14	60
182	VHR161	26.3	Colorless	Odorless	Tasteless	0.09	0
183	VHR162	26.5	Pale yellow	Odorless	Tasteless	2.12	110
184	VHR163	25.2	Colorless	Odorless	Tasteless	0.12	20
185	VHR164	24.6	Colorless	Odorless	Bitter taste	0.03	0
186	VHR165	22.3	Pale yellow	Muddy Smell	Tasteless	7.11	670
187	VHR166	22.4	Colorless	Odorless	Tasteless	1.14	45
188	VHR167	22.4	Colorless	Odorless	Tasteless	5.44	190
189	VHR168	22.3	Light yellow	Odorless	Tasteless	4.43	200
190	VHR169	22.4	Colorless	Odorless	Tasteless	5.01	110
191	VHR170	24.4	Colorless	Odorless	Salty	4.2	110
Multan							
192	MUL171T	24.6	Colorless	Odorless	Salty	0.05	65
193	MUL171TK	26	Pale yellow	Odorless	Tasteless	5.33	30
194	MUL172	25	Yellow	Odorless	Tasteless	12.52	40
195	MUL173	26.5	Pale yellow	Odorless	Tasteless	3.21	50
196	MUL174	21.3	Colorless	Smelly	Tasteless	0.32	80
197	MUL175	24.3	Colorless	Smelly	Salty	0.01	100
198	MUL176	24.2	Colorless	Odorless	Tasteless	0.34	230
199	MUL177	23.4	Colorless	Odorless	Tasteless	0.28	220
200	MUL178	23.2	Colorless	Odorless	Tasteless	0	210
201	MUL179	23.4	Colorless	Odorless	Tasteless	0.44	150
202	MUL180	23.4	Colorless	Odorless	Salty	0.41	10
203	MUL181	23.4	Colorless	Odorless	Slightly salty	0.88	40
204	MUL182	25.1	Pale yellow	Odorless	Tasteless	6.54	45
205	MUL183	25.3	Colorless	Odorless	Tasteless	0.58	200
206	MUL184	25.3	Colorless	Odorless	Tasteless	0.13	30
207	MUL185T	25.1	Colorless	Odorless	Tasteless	0.16	150

208	MUL185TK	25.2	Colorless	Odorless	Tasteless	0.08	190
209	MUL186	25.3	Light yellow	Odorless	Tasteless	2.44	290
210	MUL187	25.4	Colorless	Odorless	Tasteless	0.06	110
211	MUL188	25.2	Colorless	Odorless	Tasteless	1.35	43
Nankanasahib							
212	NNS189	25.1	Colorless	Odorless	Bitter taste	0.22	64
213	NNS190T	25.5	Light yellow	Odorless	Tasteless	2.1	60
214	NNS190TK	25.3	Colorless	Odorless	Tasteless	0.31	80
215	NNS191	25.2	Colorless	Smell like sewage	Tasteless	0.46	45
216	NNS192	25.4	Colorless	Odorless	Tasteless	0.13	65
Sheikhupura							
217	SKP193	23.1	Colorless	Odorless	Tasteless	0.42	30
218	SKP194	23.6	Colorless	Odorless	Salty	0.05	120
219	SKP195T	23.4	Colorless	Odorless	Tasteless	0.36	100
220	SKP195TK	23.2	Colorless	Odorless	Tasteless	0.66	0
221	SKP196	23.3	Colorless	Odorless	Tasteless	0.07	0
Lahore							
222	LHE197	24.2	Colorless	Odorless	Tasteless	0.14	20
223	LHE198	23.4	Colorless	Odorless	Tasteless	0.04	50
224	LHE199	23.4	Colorless	Odorless	Salty	0.12	110
225	LHE200	23.4	Colorless	Odorless	Tasteless	0.61	60
226	LHE201	23.4	Colorless	Muddy Smell	Tasteless	0.02	70
227	LHE202	23.4	Colorless	Odorless	Tasteless	0.76	80
228	LHE203	23.4	Colorless	Odorless	Tasteless	0.92	95
229	LHE204	23.4	Colorless	Odorless	Tasteless	1.12	100
230	LHE205	23.3	Light yellow	Odorless	Tasteless	5.4	20
231	LHE206	23.2	Colorless	Smelly	Tasteless	0.72	40
232	LHE207T	23.3	Colorless	Odorless	Tasteless	0.18	60
233	LHE207TK	20.1	Colorless	Odorless	Tasteless	0	110
234	LHE208	20.2	Colorless	Odorless	Tasteless	1.09	120
235	LHE209	20.1	Colorless	Odorless	Tasteless	0.38	80
236	LHE210	20.4	Colorless	Odorless	Tasteless	0.53	620
237	LHE211	20.4	Colorless	Odorless	Tasteless	0.4	500
238	LHE212	21.2	Colorless	Odorless	Tasteless	0	100
239	LHE213	21.3	Colorless	Odorless	Tasteless	0.17	35
240	LHE214	21.4	Colorless	Odorless	Slightly salty	0.49	210
241	LHE215	21.2	Colorless	Odorless	Tasteless	0.38	50
242	LHE216	21.4	Colorless	Odorless	Tasteless	0.66	240
243	LHE217	21.5	Colorless	Odorless	Tasteless	0.72	120
244	LHE218	23.4	Light yellow	Odorless	Tasteless	9.22	30
245	LHE219	23.2	Colorless	Odorless	Tasteless	1.73	190

246	LHE220	23.3	Colorless	Smelly	Tasteless	1.88	45
247	LHE221	24.2	Colorless	Odorless	Tasteless	0.26	440
Kasur							
248	KSR222	23.4	Colorless	Odorless	Tasteless	0.13	540
249	KSR223	23.4	Yellow	Odorless	Tasteless	1.19	200
250	KSR224	23.4	Colorless	Odorless	Tasteless	0	100
251	KSR225	23.4	Colorless	Odorless	Tasteless	0.46	150
MandiBahauddin							
252	MBD226	22.3	Colorless	Odorless	Slightly salty	0.81	60
253	MBD227	22.1	Colorless	Odorless	Tasteless	1.04	95
Hafizabad							
254	HFD228	22.4	Pale yellow	Smell like sewage	Tasteless	0.18	120
255	HFD229	20.1	Colorless	Odorless	Tasteless	0.76	90
Narowal							
256	NRW230	20.3	Colorless	Odorless	Tasteless	1.81	210
257	NRW231T	20.1	Colorless	Odorless	Tasteless	2.01	290
258	NRW231TK	24.5	Colorless	Odorless	Tasteless	1.72	36
Sialkot							
259	SKT232	24.4	Colorless	Odorless	Tasteless	0.91	52
260	SKT233	24.5	Colorless	Odorless	Tasteless	0.64	60
261	SKT234	24.6	Light yellow	Odorless	Salty	0.71	100
262	SKT235T	23.2	Colorless	Odorless	Tasteless	0.92	32
263	SKT235TK	23.2	Colorless	Odorless	Tasteless	0.44	240
Gujrat							
264	GRT236	21.2	Pale yellow	Odorless	Tasteless	0.22	12
Gujranwala							
265	GRW237	21.2	Colorless	Smell like sewage	Tasteless	2.11	0
266	GRW238	21.5	Colorless	Odorless	Tasteless	1.2	35
267	GRW239	21.5	Colorless	Odorless	Tasteless	0.42	50
268	GRW240	19.1	Colorless	Odorless	Tasteless	0.28	50
269	GRW241	19	Colorless	Odorless	Tasteless	0.52	230
Chiniot							
270	CHT242	19.2	Colorless	Odorless	Tasteless	2.09	180
271	CHT243	19.3	Colorless	Odorless	Tasteless	0.31	0
T.T Singh							
272	TTS244	26.3	Colorless	Odorless	Tasteless	0.03	10
273	TTS245	26.3	Colorless	Odorless	Tasteless	0.67	20
Jhang							
274	JHG246	26.7	Colorless	Smelly	Tasteless	0.26	40

275	JHG247	26.4	Colorless	Odorless	Tasteless	0.85	55
Faisalabad							
276	FSD248	25.7	Colorless	Odorless	Bitter taste	1.08	0
277	FSD249	25.8	Colorless	Odorless	Tasteless	1.17	0
278	FSD250	25.3	Colorless	Odorless	Tasteless	1.31	45
279	FSD251	24.4	Colorless	Odorless	Tasteless	0.21	60
280	FSD252	24.6	Colorless	Odorless	Tasteless	0.64	90
281	FSD253	26	Colorless	Odorless	Tasteless	0.26	80
282	FSD254	25	Colorless	Smell like sewage	Tasteless	1.11	140
283	FSD255	26.5	Colorless	Odorless	Tasteless	0.39	130
284	FSD256	21.3	Colorless	Odorless	Tasteless	0.22	100
285	FSD257T	24.3	Colorless	Odorless	Tasteless	0.48	25
286	FSD 257TK	24.2	Colorless	Odorless	Tasteless	0.41	30
Layyah							
287	LYH258	23.4	Colorless	Odorless	Salty	0.55	0
D.g Khan							
288	DGK259	23.2	Colorless	Odorless	Tasteless	0.64	110
289	DGK260	23.4	Colorless	Odorless	Tasteless	0.82	30
Rahim Yar Khan							
290	RYK261	23.4	Colorless	Smelly	Tasteless	2.03	20
291	RYK262	23.4	Colorless	Odorless	Tasteless	0.84	25
Bahawalpur							
292	BHW263	18.5	Colorless	Odorless	Tasteless	0.92	65
293	BHW264	18.5	Colorless	Odorless	Tasteless	0.96	70
294	BHW265	21.3	Colorless	Odorless	Slightly salty	0.54	85
295	BHW266	21.4	Colorless	Odorless	Tasteless	0.76	70
296	BHW267	21.2	Colorless	Muddy Smell	Salty	1.45	0
Bahawalnagar							
297	BWL268	21.2	Colorless	Odorless	Tasteless	0.55	0
298	BWL269	21.3	Colorless	Odorless	Tasteless	1.15	125
299	BWL270	21.7	Colorless	Odorless	Tasteless	0.44	100
300	BWL271	21.7	Colorless	Odorless	Tasteless	1.12	300

The table 4.1 describes about the color, odor, taste, turbidity and TSS present in drinking water samples which were collected from the public primary schools in Urban Punjab. The permissible limit set by WHO and NDWQS for turbidity is 5 NTU. Majority of the samples were tasteless, colorless and odorless however some of the samples had bitter taste, muddy/sewerage like smell and the color of some of the samples was light yellow,yellow and pale yellow.

4.2 Chemical Parameters

The quantitative results of chemical analysis are mentioned in Table 4.2

Table 4.2 Quantitative Results of Chemical Parameters

Sr #	Sample code	pH	DO (mg/L)	TDS (mg/L)	EC (µS/cm)	Hardness (mg/L)	Cl^- (mg/L)	Nitrate (mg/L)	Fluoride (mg/L)
WHO and NSDWQ standards		**6.5-8.5**	**-------**	**<1000 mg/l**	**---------**	**500 mg/l**	**250 mg/l**	**50 mg/l**	**1.5 mg/l**
Sahiwal									
1	SWL 1	7.71	2.18	1000	1563	192	160	27.5	1.5
2	SWL 2	7.91	2.22	1043	1630	380	163	25.9	2.6
3	SWL 3	7.77	2.3	1151	1799	428	131	20.3	2.7
4	SWL 4T	8.03	1.63	968	1511	462	155	5.7	2.4
5	SWL 4TK	7.69	2.17	1164	1817	152	50	27	1.9
6	SWL 5	7.53	2.58	1285	2008	264	50	20.9	5.4
7	SWL 6	8.64	2.96	1408	2200	106	90	1.5	1.7
8	SWL 7	7.75	2.9	248	389	108	55	2.5	0.6
9	SWL 8	8.14	2.84	1187.84	1857	96	180	11.43	1.34
10	SWL9	7.71	3.52	703.36	1099	128	65	14.08	0.9
11	SWL 10	8.61	1.5	1046.4	1635	214	85	18.21	1.31
12	SWL 11	7.55	1.98	224.64	351	194	260	5.81	1.44
13	SWL 12 T	7.99	2.77	1280	2000	168	86	6.23	1.37
14	SWL 12TK	7.84	2.59	653.44	1021	212	71	16	1.56
15	SWL 13	8.7	2.23	970.56	1514	414	61	3.75	1.45
16	SWL 14	9.13	3.93	1280	2000	216	55	14.2	1.29
17	SWL 15	8.53	2.97	612.48	957	220	90	10.11	0.35
18	SWL 16	8.15	2.48	940.8	1470	402	55	16.9	0.81
19	SWL 17	8.07	2.99	1280	2000	216	61	0.1	0.72
20	SWL 18	8.35	3.07	1280	2000	208	50	15.6	1.19
21	SWL 19	8.2	2.47	794	1241	194	61	2.1	0.67
22	SWL 20	7.84	2.62	880.64	1376	440	74	11.2	1.42
23	SWL21	8.14	2.72	1280	2000	208	55	2.8	1.39
24	SWL 22	8.36	2.27	802.72	1253	360	80	21.2	0.83
25	SWL 23	7.9	2.81	743.68	1162	210	55	15.7	0.95
26	SWL 24	8.78	2.93	625.28	977	530	60	12.37	0.62
27	SWL 25	7.91	4.73	167.68	262	228	71	11.95	1.48
Pakpattan									
28	PKP26	8.27	2.9	751.52	1173	230	49	12.2	0.32

29	PKP27	7.47	0.35	484.48	757	210	160	13.31	0.46
30	PKP28	7.69	3.63	1190.08	1857	230	163	16.5	0.32
31	PKP29	7.85	3.47	1280	2000	458	140	18.2	0.62
32	PKP30	8.19	3.04	910.24	1421	290	179	15.6	0.45
33	PKP31	7.71	2.41	1280	2000	218	168	16.1	0.32
34	PKP32	7.86	1.89	1280	2000	444	158	19.8	0.35
35	PKP33	7.61	2.85	1020.16	1594	418	175	20.72	0.32
36	PKP34	8.08	2.57	874.72	1363	436	136	13.59	0.61
37	PKP35	7.49	2.95	898.56	1404	406	168	11.86	0.86
38	PKP36	8.29	3.4	1280	2000	314	185	10.82	0.6
Okara									
39	OKC37	8.34	1.41	640.64	1001	250	150	15.89	0.29
40	OKC38	8.7	1.35	837.76	1309	222	162	28.12	1.5
41	OKC39	8.76	1.44	819.36	1279	366	110	33.29	0.2
42	OKC40T	8.59	1.28	652.16	1019	458	128	30.12	1.2
43	OKC40TK	8.28	1.13	782	1231	276	164	18.32	1.4
44	OKC41	10.25	0.87	855.04	1336	396	180	16.71	2.1
45	OKC42	9.49	1.3	1280	2000	292	176	29.81	3.45
46	OKC43	8.12	0.65	1011.68	1582	308	162	10.97	3.45
47	OKC44	9.03	1.89	1161.76	1814	474	120	11.7	1.15
48	OKC45	8.66	1.73	1280	2000	282	295	9.8	0.55
49	OKC46T	8.56	1.44	844.8	1320	318	310	17.51	1.55
50	OKC46TK	8.22	1.52	1280	2000	342	328	18.56	1.68
Chichawatni									
51	CWI47	8.21	1.56	999.04	1561	550	260	19.2	0.4
52	CWI48	7.98	1.8	837.76	1309	626	230	20.21	1.85
53	CWI49	7.88	2.14	388.48	607	666	290	11.62	0.68
54	CWI50	7.66	1.99	744.32	1163	124	280	21.64	0.38
55	CWI 51	7.95	1.76	204.8	320	228	205	18.21	0.37
56	CWI52	7.93	1.19	782.72	1223	254	210	29.13	1.95
57	CWI53	7.78	2.06	1145.76	1789	690	211	20.86	1.07
58	CWI54	7.92	1.81	1280	2000	410	220	22.04	1.73
59	CWI55	7.75	1.54	870.24	1359	322	164	11.38	0.76
60	CWI56	7.86	1.75	852.48	1332	400	260	24	1.6
Sargodha									
61	SGD57	7.94	1.99	1004.48	1567	408	260	19.56	1.15
62	SGD58	7.45	1.6	697.6	1090	328	187	18.63	1.73
63	SGD59	7.96	1.41	624	975	150	240	15.86	1.2
64	SGD60	8.26	1.86	864.64	1351	540	310	13.2	1.28
65	SGD61	7.56	1.73	778.56	1214	324	300	11.2	1.5
66	SGD62	7.83	1.9	864	1350	560	280	17.25	0.67
67	SGD63	7.74	1.86	980.6	1636	188	244	15.9	0.45
68	SGD64T	7.82	1.96	619.52	1531	218	260	13.2	0.41

69	SGD64TK	7.9	1.74	640	1008	274	260	10.43	0.22
70	SGD65	7.83	0.49	643.2	968	118	110	12.2	0.48
Mianwali									
71	MW66	7.94	1.72	316.8	1000	180	112	23.08	0.77
72	MW67	7.87	1.85	967.84	1005	516	90	10.1	0.61
73	MW68	7.8	1.73	446.72	495	410	65	23.4	1.1
74	MW69	7.51	2.3	300.8	1511	390	45	25.6	0.75
75	MW70T	7.69	1.59	246.4	698	206	9	27.05	0.6
76	MW70TK	7.64	1.69	494.08	470	352	8	14.83	1
77	MW71	7.57	1.39	478.72	385	212	77	13.19	0.5
78	MW72T	8.28	1.5	392.32	772	246	8	16.99	0.125
79	MW72TK	8.18	3.78	307.2	748	330	73	11	0.26
80	MW73	7.97	2.71	392.32	613	292	95	15.86	0.5
81	MW74	8.07	2.9	307.2	480	274	89	17.7	0.57
82	MW75	8.71	3.53	440.32	688	318	21	23.21	0.5
Khushaab									
83	KHB76	8.8	2.52	724.48	1132	360	15	28.47	1.6
84	KHB77	9.01	2.69	1023.36	1599	333	23	14.08	0.65
85	KHB78	8.51	2.87	924.48	1442	235	29	15.01	1.25
86	KHB79	8.41	2.79	311.04	486	322	27	12.37	0.77
87	KHB80T	8.57	3.1	743.68	1162	357	142	13.34	1.35
88	KHB80TK	8.1	2.78	775.84	1211	300	54	17.51	0.7
89	KHB81	8.03	2.9	1052.8	1645	293	63	24.91	1.7
90	KHB82T	8.34	3.25	250.24	391	303	31	13.7	1.85
91	KHB82TK	8.64	2.59	686.72	1073	367	41	21.64	1.65
92	KHB83	8.28	3.47	701.44	1096	304	69	18.8	1.8
Bhakkar									
93	BKR84	8.59	3.6	308.48	482	240	47	24.91	1.65
94	BKR85T	7.75	2.41	292.48	456	303	55	26.08	1.8
95	BKR85TK	8.39	2.97	329.28	514	324	85	17.51	2.6
96	BKR86	8.92	3.61	195.2	304	303	94	16.97	0.37
97	BKR87	8.7	1.99	870.24	1356	343	157	15.1	1.01
98	BKR88	8.36	1.78	883.2	1380	528	29	21.99	0.208
99	BKR89	8.17	1.43	1026.88	1602	280	27	20.62	1.2
100	BKR90	8.07	2.02	209.92	328	628	185	27.88	2.7
Chakwal									
101	CKW91	8.46	1.93	561.28	877	271	194	16.8	0.5
102	CKW92	8.11	1.13	700.16	1094	278	189	20.01	0.25
103	CKW93	8.01	0.92	747.68	1167	275	63	26.75	0.11
104	CKW94	7.92	2.28	749.76	1169	228	138	12.5	0.6
105	CKW95	9.29	2.17	519.68	812	243	30	9.6	1.13
106	CKW96	7.91	2.07	481.28	752	124	108	10	1.3
107	CKW97	7.83	2.21	478.72	748	53	19	10.72	1.6

108	CKW98	8.21	1.93	320.64	501	176	24	17.6	1.7
109	CKW99	8.41	1.82	308.48	482	287	61	20.8	1.5
110	CKW100	8.39	2.04	246.72	384	213	65	25.96	2.96
Rajanpur									
111	RJP101	8.48	1.99	681.6	1065	209	99	24.17	3.5
112	RJP102	7.98	1.86	287.36	449	150	90	10.2	1.81
Muzzafargarh									
113	MZJ103	8.07	1.62	313.76	489	87	73	14.3	1.75
114	MZJ104	7.94	1.22	695.2	1085	237	34	15.11	1.99
Attock									
115	ATC105	8.48	1.91	883.84	1381	342	48	10.61	3.5
116	ATC106	8.63	1.8	391.68	612	476	72	10.19	3.97
117	ATC107	8.69	1.96	760.48	1187	232	73	13.1	2.8
118	ATC108	8.49	2.05	703.52	1098	101	73	8.7	1.95
119	ATC109	8.34	2	658.24	1028	165	71	8.81	1.62
120	ATC110	8.41	1.94	360.32	562	360	13	17	1.47
121	ATC111T	8.55	2.09	714.24	1116	165	143	19.5	2.12
122	ATC111TK	8.05	1.88	511.36	799	322	101	21.84	1.22
123	ATC112	8.61	2.15	573.6	895	243	51	20.01	1.7
124	ATC113	8.35	1.86	292.48	457	231	75	17.9	1.55
Jhelum									
125	JHE114	8.14	1.01	480.64	751	331	92	10.7	2.5
126	JHE115	7.89	1.97	1075.68	1682	124	14	16.7	3.91
127	JHE116	7.95	2.03	665.76	1039	102	177	18.6	3.69
128	JHE117	8.01	1.94	638.72	998	220	126	12.5	1.74
129	JHE118T	8.12	2.13	950.4	1485	214	169	19.15	3.02
130	JHE118TK	7.94	2.18	1100.16	1719	283	125	16.81	1.3
131	JHE119	8.08	2.08	889.76	1389	213	160	13.36	1.36
132	JHE120	8.28	2.19	745.76	1164	255	100	12.76	1.28
133	JHE121	8.1	1.98	917.28	1432	209	15	16.67	1.46
134	JHE122T	8.17	2.08	160	250	233	16	14.7	1.29
135	JHE122TK	7.93	2.12	332.8	520	311	68	13.1	0.98
136	JHE123	8.22	2.03	825.6	1290	222	21	12.7	1.12
Lodhran									
137	LDH124	8.11	1.92	932.48	1457	389	17	10.3	1.26
138	LDH125	7.8	2.27	640.64	1001	321	54	7.13	0.62
139	LDH126	7.77	2.11	637.44	996	254	25	10.62	0.8
140	LDH127T	7.89	2.01	1068.64	1671	223	24	7	1.45
141	LDH127TK	8.22	1.91	743.04	1161	311	18	17.5	1.07
142	LDH128	8.35	2.17	854.4	1335	165	16	15.3	0.89
Rawalpindi									
143	RWP129	8.26	2.23	1055.36	1649	175	62	18.3	0.81
144	RWP130	7.62	2.12	514.72	803	106	63	19.2	1.42

145	RWP131	8.14	2.02	635.68	992	108	68	21.67	1.32
146	RWP132T	8.1	1.82	1280	2000	96	76	4	0.88
147	RWP132TK	7.74	2.1	467.2	730	128	81	16.38	0.79
148	RWP133T	7.91	2.05	182.4	285	214	85	11.9	1.16
149	RWP133TK	7.85	2.26	260.16	406	194	133	20.91	1.5
150	RWP134	7.77	2.6	615.04	961	168	72	13.48	0.61
151	RWP135	8.02	2.14	542.08	847	212	129	12.89	1.11
152	RWP136	8.11	2.01	246.4	385	414	59	9.88	2.5
153	RWP137	7.53	1.97	290.72	453	216	70	7.46	2.6
154	RWP138	8.28	1.93	294.4	460	220	49	8.22	2.1
155	RWP139	8.55	1.89	1280	2000	402	14	7.44	2.8
156	RWP140	8.32	2.16	1280	2000	216	14	10.22	2.3
157	RWP141	7.9	1.88	343.68	537	208	81	18.27	2.7
158	RWP142T	8.1	2	454.4	710	194	13	12.38	2.93
159	RWP143TK	8.45	1.94	327.68	512	440	77	5.35	2.75
160	RWP143	8.2	1.67	662.4	1035	208	100	3.78	2.52
161	RWP144	8.17	1.95	631.68	987	360	94	6.67	1.48
162	RWP145T	7.29	1.83	469.76	734	210	26	4.6	1.88
163	RWP145TK	7.54	2.25	640.64	1001	530	20	4.85	1.37
Khanewal									
164	KWL146	8.35	2.09	279.68	437	228	28	4.3	1.7
165	KWL147	8.24	1.9	457.6	715	230	34	14.17	1.59
166	KWL48	8.31	2.18	437.28	682	210	33	19.7	1.4
167	KWL149	7.96	2.91	440.32	688	230	148	15.96	1.15
168	KWL150T	7.89	1.85	428.8	670	458	59	11.4	1.69
169	KWL150TK	7.99	1.98	1140.16	1779	154	68	10.73	2.05
170	KWL151	8.23	2.06	841.6	1315	337	36	12.83	2.86
171	KWL152T	7.92	1.92	436.64	681	122	45	15.67	2.25
172	KWL152TK	8.36	2.09	369.28	577	211	74	13.05	2.92
173	KWL153	8.29	2.03	735.36	1149	322	52	23.91	2.58
174	KWL154	8.45	2.21	326.4	510	232	60	3.2	2.17
175	KWL55T	8.4	1.94	721.44	1126	221	90	3.7	0.79
176	KWL155TK	8.32	0.7	880.64	1376	111	99	4.4	0.62
177	KWL156	7.4	0.81	814.08	1272	118	162	4.9	0.42
178	KWL157	7.3	2.31	286.72	448	180	34	6.4	0.67
179	KWL158	7.6	2.22	156.16	244	516	32	7.5	0.55
180	KWL159	7.5	2.16	379.52	593	410	190	8.2	0.57
Vehari									
181	VHR160	7.4	2.09	290.72	453	390	199	8.7	0.63
182	VHR161	7.7	2.19	517.28	807	206	194	10.6	0.74
183	VHR162	7.2	2.05	950.56	1484	352	68	11.2	0.45
184	VHR163	7.3	2.32	621.76	969	212	143	11.5	0.93
185	VHR164	7.2	2.11	862.08	1347	246	35	12.1	0.76

186	VHR165	7.9	2.03	510.08	797	330	113	13	0.61
187	VHR166	8	1.99	556.16	869	292	24	13.8	0.76
188	VHR167	7.4	2.23	883.2	1380	274	29	14.3	0.62
189	VHR168	7.9	2.14	716.8	1120	318	66	15.1	0.83
190	VHR169	7.5	2.2	627.36	979	360	70	16.1	0.42
191	VHR170	7.4	2.1	810.4	1265	333	104	17.3	0.92
Multan									
192	MUL171T	7.4	2	921.76	1439	235	96	17.89	0.98
193	MUL171TK	7.3	1.97	1222.72	1908	213	77	18.9	0.74
194	MUL172	7.7	1.78	344.32	538	263	39	18.2	0.38
195	MUL173	7.2	1.73	162.56	254	211	55	19.5	0.92
196	MUL174	7.8	1.7	1168	1825	143	77	20.2	3.62
197	MUL175	7.3	2.18	1140.48	1782	127	78	21.9	2.02
198	MUL176	7	2.08	980.16	1528	221	78	22.7	3.31
199	MUL177	7.4	1.99	544.64	851	113	76	25.4	2.92
200	MUL178	7.3	1.86	1257.76	1964	165	18	26.3	2.58
201	MUL179	7.2	1.68	465.92	728	215	148	28.3	1.36
202	MUL180	7.2	1.82	970.72	1513	226	106	8.4	1.47
203	MUL181	7.5	2.16	636.16	994	311	55	7.9	1.26
204	MUL182	7.7	1.95	604.16	944	153	80	9.4	1.2
205	MUL183	8	1.88	549.12	858	234	97	10.1	1.17
206	MUL184	7.1	2.21	430.08	672	212	19	11.5	1.28
207	MUL185T	7.3	1.9	701.44	1096	126	182	11.9	1.18
208	MUL185TK	7.5	2.06	652.8	1020	153	131	12.2	1.26
209	MUL186	7.4	1.96	320	500	111	174	12.8	1.56
210	MUL187	7.4	1.89	751.36	1174	299	130	13.9	1.49
211	MUL188	7.6	1.79	518.56	809	247	165	14.4	1.53
Nankana Sahib									
212	NNS189	7.2	2.22	591.52	923	453	105	15.6	1.04
213	NNS190T	7.4	2.17	693.28	1082	342	20	11.1	1.32
214	NNS190TK	7.6	1.85	641.92	1003	543	73	14.6	1.68
215	NNS191	7.6	2.05	693.28	1082	222	25	12.3	1.7
216	NNS192	7.5	1.92	329.6	514	234	21	18.4	1.23
Sheikhupura									
217	SKP193	7.4	1.82	1050.72	1638	123	59	14.4	1.34
218	SKP194	7.3	4.45	1044.48	1627	143	30	17.43	1.44
219	SKP195T	7.8	3.89	317.44	496	154	29	26.7	1.3
220	SKP195TK	7.7	4.41	290.72	453	254	23	22.9	1.1
Lahore									
221	LHE196	7.5	3.56	311.04	486	345	20	23.5	1.22
222	LHE197	7.4	3.64	310.4	485	342	67	28.2	1.87
223	LHE198	7.4	4.51	1104	1715	215	69	22.8	1.27
224	LHE199	7.2	4.53	292.48	456	197	72	37.5	1.16

225	LHE200	7.4	4.01	588.16	919	327	79	19	1.46
226	LHE201	7.6	4.45	287.36	449	112	84	23.5	1.55
227	LHE202	7.5	4.42	743.68	1162	128	88	15.5	1.51
228	LHE203	7.3	4.28	306.08	478	198	136	16.4	2.91
229	LHE204	7.8	4.4	298.24	466	167	76	37.2	0.64
230	LHE205	7.9	5.01	295.68	462	321	132	34	0.52
231	LHE206	8.3	4.41	610.56	954	252	64	18.5	0.61
232	LHE207T	8.3	4.07	314.88	492	213	165	17.6	0.58
233	LHE207TK	7.1	4.3	308.48	482	250	168	22.3	0.63
234	LHE208	7.7	5.28	640	1000	222	145	26	0.57
235	LHE209	7.3	3.11	286.72	448	366	184	32.7	0.65
236	LHE210	7.9	5.23	234.24	366	458	173	34.1	0.68
237	LHE211	7.3	3.05	294.4	460	276	163	28.6	0.71
238	LHE212	7.9	3.96	302.08	472	396	180	26.6	0.76
239	LHE213	7.5	5.88	177.28	277	292	141	18.21	0.8
240	LHE214	7.7	3.55	119.68	187	308	173	12.8	0.82
241	LHE215	7.2	3.04	150.4	235	474	191	15.6	0.69
242	LHE216	7.8	3.83	141.44	221	282	155	13.4	0.55
243	LHE217	7.6	4.82	426.24	666	318	167	22.2	0.52
244	LHE218	7.2	4.57	208.64	326	342	115	16.3	0.48
245	LHE219	8.1	4.87	909.12	1418	550	133	34	0.39
246	LHE220	7.7	4.65	775.84	1211	626	169	32.9	0.45
247	LHE221	7.8	3.9	970.56	1514	666	185	28.4	3.52
Kasur									
248	KSR222	7.8	4.24	314.88	492	124	179	25.6	3.26
249	KSR223	8.1	4.42	320	500	228	184	24.2	3.09
250	KSR224	8.2	4.16	652.8	1020	254	167	19.43	1.37
251	KSR225	8.1	4.98	701.44	1096	690	124	22.8	1.2
Mandibahauddin									
252	MBD226	8.1	3.78	430.08	672	410	300	16.5	1.75
253	MBD227	7.6	5.01	549.12	858	322	315	21.6	1.36
Hafizabaad									
254	HFD228	7.9	3.92	604.16	944	400	338	34.2	1.37
255	HFD229	7.2	3.39	636.16	994	408	230	28.4	1.26
Narowal									
256	NRW230	7.3	4.86	970.72	1513	328	220	28.6	1.06
257	NRW231T	7.2	4.88	465.92	728	150	220	31.3	1.04
258	NRW231TK	7.6	4.54	1257.76	1964	540	270	27.1	1.5
Sialkot									
259	SKT232	7.8	3.86	544.64	851	324	270	20.2	1.26
260	SKT233	7.3	3.89	980.16	1528	560	193	27.3	1.22
261	SKT234	7.4	3.96	1140.64	1781	188	250	14.7	6.7
262	SKT235T	7.5	3.84	1168	1825	516	320	12.6	7.2

263	SKT235TK	7.6	3.96	162.56	254	410	310	18.5	0.56
Gujrat									
264	GRT236	7.6	4.29	344.32	538	390	290	26.1	0.5
Gujranwala									
265	GRW237	7.4	4.32	1222.72	1908	206	254	28.1	0.49
266	GRW238	7.2	4.31	921.76	1439	352	270	26.4	0.41
267	GRW239	7.6	4.68	810.4	1265	212	270	26.29	0.4
268	GRW240	7.5	4.7	627.36	979	246	120	25.98	0.44
269	GRW241	7.4	5.49	716.8	1120	330	120	29.12	2.88
Chiniot									
270	CHT242	7.3	5.4	883.2	1380	292	122	28.26	0.39
271	CHT243	7.2	5.34	556.16	869	274	102	26.24	0.33
T.T Singh									
272	TTS244	7.4	4.91	510.08	797	318	49	18.01	0.41
273	TTS245	7.4	4.8	751.36	1174	360	20	16.1	0.55
Jhang									
274	JHG246	7.6	4.98	515.84	804	333	19	16.07	1.12
275	JHG247	7.8	5.02	591.52	923	235	13	15.89	1
Faisalabad									
276	FSD248	7.2	5.11	693.28	1082	322	10	13.81	1.2
277	FSD249	7	5.24	641.92	1003	357	57	14.26	3.18
278	FSD250	7.3	4.82	693.28	1082	300	59	13.25	3.2
279	FSD251	7.5	4.97	329.6	514	293	62	14.89	2.08
280	FSD252	7.4	4.53	1050.72	1638	303	69	14.5	0.41
281	FSD253	7.4	5.21	1044.48	1627	367	74	16.1	0.39
282	FSD254	7.2	5.23	317.44	496	304	78	11.1	0.45
283	FSD255	7.3	5.16	290.72	453	240	126	10.5	0.12
284	FSD256	7.7	5.17	311.04	486	303	66	19.6	0.11
285	FSD257T	8.3	4.97	310.4	485	324	123	19.1	0.12
286	FSD257TK	8.3	5.21	1104	1715	303	54	18.8	1.22
Layyah									
287	LYH258	7.9	5.2	292.48	456	343	29	18.31	0.35
D.G Khan									
288	DGK259	7.8	4.71	588.16	919	528	43	17.93	0.33
289	DGK260	7.3	4.72	287.36	449	280	67	17.54	0.34
R.Y Khan									
290	RYK261	7.4	4.96	743.68	1162	628	68	15.25	0.38
291	RYK262	7.3	5.48	306.08	478	271	68	14.8	0.37
Bahawalpur									
292	BHW263	7.6	5.41	298.24	466	278	8	14.97	0.38
293	BHW264	7.5	5.39	295.68	462	275	66	13.77	1.11
294	BHW265	7.4	4.4	610.56	954	228	138	15.91	1.24

295	BHW266	7.9	4.56	314.88	492	523	45	14.03	1.32
296	BHW267	7.2	4.86	308.48	482	343	79	12.15	2.22
Bahawalnagar									
297	BWL268	7.5	4.91	862.08	1347	567	64	19.69	1.43
298	BWL269	7.4	4.96	621.76	969	512	56	19.05	1.28
299	BWL270	7.7	4.72	436.64	681	554	11	18.86	1.5
300	BWL271	7.6	4.65	814.08	1272	463	15	18.25	0.66

4.3 Descriptive Statistics of physicochemical Parameters:

The results of descriptive statistics of physical parameters of drinking water are shown in table 4.3

Table 4.3 Descriptive statistics of physicochemical parameters

Cities		Temp. (^{0}C)	Turbidity (NTU)	TSS (mg/L)	TDS (mg/L)	pH	DO (mg/L)	EC (µS/cm)	Hardness (mg/L)	Cl (mg/L)	Nitrate (mg/L)	Fluoride (mg/L)
WHO and NSDWQ standards		**---------**	**<5**	**----------**	**<1000**	**6.5-8.5**	**-------**	**--------**	**500**	**250**	**50**	**1.5**
Sahiwal	Min Max Mean±SD	23 24.3 23.42±0.32	0 7.12 1.73±1.92	0 240 74.89±77.27	167 1408 926±345	7.53 9.13 8.10±0.40	1.5 4.73 2.68±0.66	262 2000 1447±540	96 530 257±121	50 260 89±51.6	0.1 27.5 12.63±8.09	0.35 5.4 1.47±0.98
Okara	Min Max Mean±SD	22 27.2 24.79±1.37	0 2.5 0.76±0.80	0 110 49.83±40.45	640 1280 953±240	8.12 10.25 8.75±0.60	0.65 1.89 1.33±0.33	1001 2000 1490±375	222 474 332±78.5	110 328 190±76.3	9.2 33.29	0.2 3.45 1.54±1.05
Chichawatni	Min Max Mean±SD	22.3 28.4 27.41±1.89	0.09 1.72 0.88 ±0.48	0 150 61±43.83	204 1280 810±320	7.66 8.21 7.892±0.14	1.19 2.14 1.76±0.27	320 2000 1266±500	124 690 427±198	164 290 233±38	11.38 29 19.8±5.38	0.37 1.95 1.07±0.64
Sargodha	Min Max Mean±SD	23.3 28.4 25.66±2.45	0.27 3.28 0.907±0.87	0 200 73.3±59.81	619 1004 771±148	7.45 8.23 7.82±0.22	0.49 1.99 1.65±0.44	968 1636 1302±246	118 560 310±153	110 310 245±58.4	10.43 19.56 14.7±3.15	0.22 1.73 0.909±0.52

Mianwali	Min Max Mean±SD	26.5 28.5 27.95±0 .71	0.15 8.4 2.11±2.14	20 340 109.16±22. 2	246 967 424±188	7.51 8.71 7.933± 0.34	1.39 3.78 2.22±0. 81	385 1511 424±18 8	180 516 310±97.7	8 112 57±37	10.1 27 18.5±5.7	0.12 1.1 0.60±0.27
Khushab	Min Max Mean±SD	23 28 24.27±2 .11	0 2.38 1.07±0.88	0 140 60±51.85	250 1052 719±266	8.03 9.01 8.4±0.3 0	2.52 3.47 2.89±0. 29	391 1645 1123±4 15	235 369 49.4±37.0 1	15 142 49.4±37 .01	12.37 28.47 17.98±5.45	0.65 1.85 1.33±0.46
Bhakkar	Min Max Mean±SD	21.2 24.5 21.975± 1.21	0.5 2.02 1.01±0.46	40 200 89.25±65.8 3	195 1026 514±347	7.75 8.92 8.36±0. 37	1.43 3.61 2.47±0. 82	304 16028 02±542	304 1602 802±542	27 185 84.5±58 .6	15.1 27.88 21.38±4.63	0.2 2.7 1.4±0.9
Chakwal	Min Max Mean±SD	21 24.5 23.59±1 .07	0.51 1.9 0.86±0.17	30 230 86±56.46	246 749 511±182	7.83 9.29 8.25±0. 42	0.92 2.28 1.85±0. 45	384 1169 798±28 5	53 287 214±76	19 194 89.1±65 .4	9.6 26.75 17.04±6.34	0.11 2.96 1.15±0.85
Rajanpur	Min Max Mean±SD	21.2 21.2 21.2±0	0.73 1.48 1.10±0.53	210 220 210±7.07	287 681 484±	7.98 8.48 8.23±0. 35	1.86 1.99 1.92±0. 09	449 1065 757±43 5	150 209 179±41.73	90 99 94.5±6. 36	10.2 24.2 17.1±9.87 14.3 15.11 14.07±0.57	1.81 3.85 2.655±1.19
Muzzafargarh	Min Max Mean±SD	21.2 21.2 21.2±0	0.47 0.86 0.66±0.27	10 150 80±98.99	313 695 504±269.7	7.94 8.48 8.005± 0.09	1.22 1.62 1.42±0. 28	489 1085 787±42 1.3	87 237 162±106	34 73 53.5±27 .5	8.7 21.84 14.76±5.03	1.75 1.88 1.87±0.167
Attock	Min Max Mean±SD	20.4 21.3 20.89±0 .36	0.48 4.14 1.18 ±1.083	30 290 119.5±85.9 7	292 883 584±192	8.05 8.69 8.46±0. 18	1.8 2.15 1.97±0. 11	457 1381 913.5±3 01	101 476 263.7±111	13 143 72±33.3	8.7 21.84 14.76±5.03	1.55 3.9 2.19±0.92

Jhelum	Min	23.2	0.04	0	160	7.89	1.91	250	102	14	10.7	0.98
	Max	28.2	10.25	620	1100	8.28	2.22	1719	331	177	19.15	3.91
	Mean±SD	25.76 ±2.12	3.62±3.02	235.53±191.07	731±291	8.06±0.12	1.97±0.31	1143±454	226±66.26	90.25±62.8	14.8±2.69	1.97±1.03
Lodhran	Min	27	0.04	35	637	7.77	1.91	996	165	16	7	0.62
	Max	27.2	4.35	240	1068	8.35	2.27	1671	389	54	15.3	1.45
	Mean±SD	27.12±0.08	1.30 ±1.78	127 ±93.24	812.7±171	8.02±0.23	2.06±0.14	1270±268	277±79.5	25.6±14.7	11.3±4.28	1.01±0.30
Rawalpindi	Min	19	0	0	182	7.29	1.67	285	96	13	3.78	0.61
	Max	26.5	8.22	540	1280	8.85	2.6	2000	530	133	21.6	2.93
	Mean±SD	22.98±2.94	2.02±2.29	170.47±154.84	594±347	7.99±0.32	2.03±0.19	927±542	239±119	66±34	11.3±5.87	2.01±0.72
Khanewal	Min	22.3	0.05	0	156	7.3	0.7	244	410	28	3.2	0.42
	Max	26.3	10.64	600	1140	8.45	2.91	1779	516	190	23.91	0.92
	Mean±SD	23.85 ±1.25	2.22±3.35	168.82±181.62	537±267	8.03±0.37	1.96±0.51	838±417	252±118	73±49	10.5±6.04	1.5±0.84
Vehari	Min	22.3	0.03	0	290	7.2	1.99	453	206	24	8.7	0.42
	Max	26.5	7.11	670	450	8	2.1	1484	390	199	17.3	0.92
	Mean±SD	24.1±1.79	2.71±2.59	137.72±189.38	667±198	7.5±0.29	2.13±0.09	1084±309	301±60.7	95±62	13±2.55	0.69±0.17
Multan	Min	21.3	0	10	162	7	1.69	254	111	18	7.9	0.3
	Max	26.5	12.52	290	1257	8	2.21	1964	311	182	28.3	3.62
	Mean±SD	24.53±1.21	1.75±3.12	114.15±84.04	706±327	7.45±0.25	1.92±0.15	1103±511	197±60	93±49	16.5±6.3	1.64±0.86
Nankanasahib	Min	25.1	0.13	45	329	7.2	1.85	514	222	20	11.1	1.04
	Max	25.5	2.1	80	693	7.6	2.72	1082	54	105	18.4	1.7
	Mean±SD	25.3±0.15	.64±0.82	62.8±12.51	589±151	7.46±0.16	2.04±0.16	920±236	358±139	48.8±38.4		1.394±0.28

Sheikhupura	Min Max Mean±SD	23.1 23.6 25.3±0.15	0.05 0.66 0.31±0.25	0 120 50±56.56	290 1050 675±429	7.3 7.8 7.55±0.23	1.82 4.45 3.64±1.24	453 1638 1053±668	123 254 168±58.4	23 59 35.5±16.1	14.4 26.7 20.3±5.5	1.1 1.44 1.29±0.14
Lahore	Min Max Mean±SD	20.1 24.2 22.35±1.39	0 9.22 1.07±1.97	20 620 138.26±153.25	119 1104 970±270	7.1 8.3 7.6±0.32	3.04 5.88 4.27±0.69	187 1715 659±421	112 666 320±138	20 191 129±48	12.8 37.5 24.3±7.63	0.39 0.52 1.01±0.74
Kasur	Min Max Mean±SD	23.4 23.4 23.4±0	0 1.19 0.44±0.53	100 540 247.5±199.22	314 701 497±208	7.8 8.2 8.05±0.7	4.16 4.98 4.45±0.36	492 1096 777±325	124 690 124±35	124 184 163±27	19.4 25.3 23±2.644	1.2 3.26 2.23±1.09
Mandibahauddin	Min Max Mean±SD	22.1 22.3 22.2±0.14	0.81 1.04 22.2±0.14	60 95 77.5±24.74	430 549 489±84	7.6 8.1 7.85±0.35	3.78 5.01 4.39±0.86	672 858765 ±131	322 410 366±62	300 315 307±10.6	16.5 21.6 19.05±3.60	1.36 1.75 1.55±0.27
Hafizabad	Min Max Mean±SD	20.1 22.4 21.25±1.62	0.18 0.76 0.47±0.41	90 120 105±21.21	604 636 620±22.6	7.2 7.9 7.55±0.49	3.39 3.92 3.6±0.37	944 994 969±35.35	400 408 404±5.65	230 338 284±76	28.2 34.2 31.3±4.10	1.26 1.37 1.315±0.07
Narowal	Min Max Mean±SD	20.1 24.5 21.63±2.48	1.72 2.02 1.84±0.14	36 290 78.66±129.86	465 1257 898±400	7.2 7.6 7.2±0.20	4.54 4.88 4.76±0.19	728 1964 1401±625	150 540 339±195	200 270 236±28.8	27.1 31.3 29±2.12	1.04 1.5 1.2±0.26

Sialkot	Min Max Mean±SD	23.2 24.6 23.98±0.71	0.44 0.92 0.72±0.20	52 240 96.8±83.78	162 1168 799±434	7.3 7.8 7.5±0.19	3.84 3.96 3.90±0.05	254 1825 1247±678	188 560 345±57	193 320 268.6±51	12.6 27.3 18.6±5.66	0.56 7.2 3.38±3.26
Gujrat	Min Max Mean±SD	21.2 21.2 21.2± 0	0.22 0.22 0.22±0	12 12 12±0	344 344 344±0	7.6 7.6 7.6±0	4.29 4.29 4.29±0	538 538 538±0	390 390 390±0	290 290 290±0	26.1 26.1 26±0	0.5 0.5 0.5±0
Gujranwala	Min Max Mean±SD	19 21.5 20.46±1.29	0.28 2.11 0.90±0.76	0 230 73±90.11	622 1222 859±230	7.2 7.6 7.4±0.14	4.31 5.49 4.7±0.47	979 1908 1342±359	206 336	120 270 206±79	26.29 29.12 27.1±1.36	0.4 2.88 0.92±1.09
Chiniot	Min Max Mean±SD	19.2 19.3 19.25±0.07	0.31 2.09 1.2±1.25	0 180 90±127.27	556 883 719±231	7.2 7.3 7.25±0.08	5.34 5.4 5.37±0.04	869 1380 1124±361	274 292 283±12.7	102 122 112±14.14	26.24 28.2 27.2±1.4	0.33 0.39 0.36±0.04
T.T Singh	Min Max Mean±SD	26.3 26.3 26.3±0	0.03 0.67 0.35±0.45	10 20 15±7.07	510 751 630±170	7.4 7.4 7.4±0	4.8 4.91 4.85±0.07	797 1174 985±266	318 360 339±29	20 49 35±20.5	16 18 17±1.3	0.41 0.55 0.48±0.09
Jhang	Min Max Mean±SD	26.4 26.7 26.55±0.21	0.26 0.85 0.55±0.41	40 55 47.5±10.60	515 591 553±53	7.6 7.8 7.7±0.14	4.98 5.02 5±0.02	804 923 863±84	235 333 284±69	13 19 16±4.24	15 16 15.5±0.12	1 1.12 1.6±0.08
Faisalabad	Min Max Mean±SD	21.3 26.5	0.21 1.31 0.68±0.43	0 140 67±49.89	290 1104 616±329	7 8.3 7.5±0.43	4.53 5.24 5.05±0.23	453 1715 961±512	240 357 310±33	10 126 70.2±32.09	10.5 19.6 15±3	0.11 3.18 0.35±0

Layyah	Min Max Mean±SD	23.2 24.2 23.8±0.56	0.41 0.55 0.48±0.09	0 30 15±21.21	292 292 292±0	7.9 7.9 7.9±0	5.2 5.2 5.2±0	454 454 454±0	343 343 343±0	29 29 29±0	18.3 18.3 18.3±0	0.35 0.35 0.35±0
D.G Khan	Min Max Mean±SD	23.2 23.4 23.3±0.14	0.64 0.82 0.73±0.12	30 110 70±56.56	287 588 437±212	7.3 7.8 7.5±0.35	4.71 4.72 4.71±0.007	449 919 684±332	449 528 404±175	43 67 55±16	17.5 17.9 16.11±0.27	0.33 0.34 0.33±0.007
Rahim Yar Khan	Min Max Mean±SD	23.4 23.4 23.4± 0	0.84 2.03 1.43±0.84	20 25 22.5±3.53	306 746 524±309	7.4 7.3 7.35±0.07	4.5 5.4 5.22±0.36	478 1162 820±483	271 628 449±252	68 68 68±0	14.8 15.2 15.02±0.31	0.38 0.38 0.38±0
Bahawalpur	Min Max Mean±SD	18.5 21.4 20.18±1.53	0.54 1.45 0.926±0.33	0 85 58±33.27	295 610 571±214	7.2 7.9 7.52±0.25	4.4 5.4 4.92±0.46	462 954 329±115	228 523 67.2±47.8	8 138 67.2±47.8	12.15 15.91 1.25±0.65	0.3 2.22 1.250±0.65
Bahawalnagar	Min Max Mean±SD	21.2 21.7 21.47±0.26	0.44 1.15 0.81±0.37	0 300 131.25±124.79	436 862 683±168	7.5 7.7 7.6±0.12	4.65 4.96 4.81±0.14	681 1347 1067±264	463 567 524±46.9	11 64 36.5±27.3	18.25 19.69 18.9±0.51	0.6 1.21 1.06±0.33
Pakpattan	Min Max Mean±SD	23 24.3 21.47±0.26	0 0.81 0.48±0.21	0 60 27.5±20.44	484 1280 1022±265	7.47 8.29 7.86±0.30	0.35 3.632.6 7±0.91	757 2000 1597±415	210 458 332±101	49 185 152±37	10.8 20.7 15.3±3.29	0.32 0.86 0.47±0.17

4.4: Results of Arsenic

The quantitative results of Arsenic in drinking water samples are mentioned in table 4.4

Table 4.4:Quantitative Results of Arsenic in drinking water samples

Sr #	Sample codes	Total Arsenic (µg/L)	WHO	NDWQS
Sahiwal				
1	SWL 1	9.45	10 µg/L	10 µg/L
2	SWL 2	12.54	10 µg/L	10 µg/L
3	SWL 3	6.21	10 µg/L	10 µg/L
4	SWL 4T	8.61	10 µg/L	10 µg/L
5	SWL 4TK	5.36	10 µg/L	10 µg/L
6	SWL 5	19.05	10 µg/L	10 µg/L
7	SWL 6	4.87	10 µg/L	10 µg/L
8	SWL 7	6.55	10 µg/L	10 µg/L
9	SWL 8	14.2	10 µg/L	10 µg/L
10	SWL9	0	10 µg/L	10 µg/L
11	SWL 10	0	10 µg/L	10 µg/L
12	SWL 25	8.65	10 µg/L	10 µg/L
Min.	0			
Max.	19.05			
Mean± SD	7.95±5.51			
Pakpattan				
13	PKP26	7.96	10 µg/L	10 µg/L
14	PKP27	7.31	10 µg/L	10 µg/L
15	PKP32	3.11	10 µg/L	10 µg/L
16	PKP35	11.87	10 µg/L	10 µg/L
17	PKP36	23.82	10 µg/L	10 µg/L
Min.	3.11			
Max.	23.82			
Mean± SD	10.84±7.90			
Okara				
18	OKC40T	45.07	10 µg/L	10 µg/L
19	OKC40TK	27.65	10 µg/L	10 µg/L
20	OKC43	2.65	10 µg/L	10 µg/L
21	OKC46T	3.15	10 µg/L	10 µg/L
22	OKC46TK	6.23	10 µg/L	10 µg/L
Min.	3.15			
Max.	45.07			
Mean± SD	16.95±18.80			
Chichawatni				
23	CWI48	10.12	10 µg/L	10 µg/L
24	CWI50	7.17	10 µg/L	10 µg/L
25	CWI52	1.72	10 µg/L	10 µg/L
26	CWI56	9.55	10 µg/L	10 µg/L
Min.	1.72			
Max.	10.12			

Mean± SD	7.14±3.832571			
Sargodha				
27	SGD57	22.21	10 µg/L	10 µg/L
28	SGD59	19.66	10 µg/L	10 µg/L
29	SGD61	6.34	10 µg/L	10 µg/L
30	SGD64T	10.23	10 µg/L	10 µg/L
31	SGD64TK	8.43	10 µg/L	10 µg/L
Min.	6.34			
Max.	22.21			
Mean± SD	13.37±7.095			
Mianwali				
32	MW72T	11.23	10 µg/L	10 µg/L
33	MW 72TK	11.1	10 µg/L	10 µg/L
34	MW74	15.67	10 µg/L	10 µg/L
35	MW75	10.97	10 µg/L	10 µg/L
Min.	10.97			
Max.	15.67			
Mean± SD	12.24±2.28			
Khushaab				
36	KHB76	15.79	10 µg/L	10 µg/L
37	KHB80T	46.22	10 µg/L	10 µg/L
38	KHB80TK	35.23	10 µg/L	10 µg/L
Min.	15.79			
Max.	46.22			
Mean± SD	32.41±15.40			
Bhakkar				
39	BKR84	50.32	10 µg/L	10 µg/L
40	BKR 86	12.43	10 µg/L	10 µg/L
41	BKR87	12.43	10 µg/L	10 µg/L
42	BKR88	7.21	10 µg/L	10 µg/L
43	BKR 89	10.34	10 µg/L	10 µg/L
44	BKR90T	18.44	10 µg/L	10 µg/L
45	BKR90TK	20.12	10 µg/L	10 µg/L
Min.	7.21			
Max.	50.32			
Mean± SD	18.75 ± 14.61			
Chakwal				
46	CKW93	10.89	10 µg/L	10 µg/L
47	CKW95	23.45	10 µg/L	10 µg/L
48	CKW98	34.12	10 µg/L	10 µg/L
49	CKW100	25.67	10 µg/L	10 µg/L
Min.	10.89			
Max.	34.12			
Mean± SD	23.53 ± 9.60			
Rajanpur				
50	RJP101	14.41	10 µg/L	10 µg/L
Min.	14.41			
Max.	14.41			
Mean± SD	14.41 ±0			

Muzzafargarh				
51	MZJ103	33.11	10 µg/L	10 µg/L
52	MZJ104	BDL	10 µg/L	10 µg/L
Min.	0			
Max.	33.11			
Mean± SD	33.11 ±0			
Attock				
53	ATC105	20.02	10 µg/L	10 µg/L
54	ATC106	18.14	10 µg/L	10 µg/L
55	ATC107	27.38	10 µg/L	10 µg/L
56	ATC109	20.83	10 µg/L	10 µg/L
57	ATC111T	33.41	10 µg/L	10 µg/L
58	ATC111TK	32.77	10 µg/L	10 µg/L
Min.	18.14			
Max.	33.41			
Mean± SD	25.42 ± 6.70			
Jhelum				
59	JHE114T	19.9	10 µg/L	10 µg/L
60	JHE114TK	13.21	10 µg/L	10 µg/L
61	JHE117	22.74	10 µg/L	10 µg/L
62	JHE119	20.52	10 µg/L	10 µg/L
63	JHE121T	5.2	10 µg/L	10 µg/L
64	JHE121TK	29.37	10 µg/L	10 µg/L
Min.	5.2			
Max.	29.37			
Mean± SD	18.49±8.33			
Lodhran				
65	LDH127	26.11	10 µg/L	10 µg/L
66	LDHS128	15.86	10 µg/L	10 µg/L
Min.	15.86			
Max.	26.11			
Mean± SD	20.98±7.24			
Rawalpindi				
67	RWP130T	12.59	10 µg/L	10 µg/L
68	RWP131TK	15.86	10 µg/L	10 µg/L
69	RWP133	10.68	10 µg/L	10 µg/L
70	RWP136T	25.73	10 µg/L	10 µg/L
71	RWP136TK	44.6	10 µg/L	10 µg/L
72	RWP137T	18.8	10 µg/L	10 µg/L
73	RWP137TK	40.01	10 µg/L	10 µg/L
74	RWP138	43.91	10 µg/L	10 µg/L
75	RWP140	BDL	10 µg/L	10 µg/L
76	RWP143	13.8	10 µg/L	10 µg/L
Min.	0			
Max.	44.6			
Mean± SD	22.59±15.42			
Khanewal				
77	KWL151	18.13	10 µg/L	10 µg/L
78	KWL153	21.12	10 µg/L	10 µg/L

79	KWL154T	12.43	10 µg/L	10 µg/L
80	KWL154TK	7.21	10 µg/L	10 µg/L
81	KWL155	10.34	10 µg/L	10 µg/L
82	KWL157	18.44	10 µg/L	10 µg/L
83	KWL158	20.12	10 µg/L	10 µg/L
84	KWL159	17.14	10 µg/L	10 µg/L
Min.	7.21			
Max.	21.12			
Mean± SD	15.61 ± 5.01			
Vehari				
85	VHR164	10.22	10 µg/L	10 µg/L
86	VHR166	9.87	10 µg/L	10 µg/L
87	VHR168	44.26	10 µg/L	10 µg/L
88	VHR170	67.21	10 µg/L	10 µg/L
Min.	9.87			
Max.	67.21			
Mean± SD	32.89 ± 27.99			
Multan				
89	MUL173	55.12	10 µg/L	10 µg/L
90	MUL174	28.62	10 µg/L	10 µg/L
91	MUL176	50.84	10 µg/L	10 µg/L
92	MUL178	62.31	10 µg/L	10 µg/L
93	MUL180	35.21	10 µg/L	10 µg/L
94	MUL182	9.13	10 µg/L	10 µg/L
95	MUL184	31.93	10 µg/L	10 µg/L
96	MUL186	13.24	10 µg/L	10 µg/L
97	MUL188	23.2	10 µg/L	10 µg/L
Min.	9.13			
Max.	62.31			
Mean± SD	34.4±18.47			
Sheikhupura				
98	SKP193	10.01	10 µg/L	10 µg/L
99	SKP195T	16.12	10 µg/L	10 µg/L
100	SKP195TK	8.42	10 µg/L	10 µg/L
Min.	8.42			
Max.	16.12			
Mean± SD	11.5±4.06			
Lahore				
101	LHE196	25.12	10 µg/L	10 µg/L
102	LHE197	16.52	10 µg/L	10 µg/L
103	LHE198	28.09	10 µg/L	10 µg/L
104	LHE201	18.98	10 µg/L	10 µg/L
105	LHE204	32.83	10 µg/L	10 µg/L
106	LHE207	22.16	10 µg/L	10 µg/L
107	LHE209	19.07	10 µg/L	10 µg/L
108	LHE210	25.75	10 µg/L	10 µg/L
109	LHE211T	38.24	10 µg/L	10 µg/L
110	LHE211TK	24.97	10 µg/L	10 µg/L
111	LHE212	18.9	10 µg/L	10 µg/L

Min.	16.52			
Max.	38.24			
Mean± SD	24.60±6.58			
Kasur				
112	KSR222	9.43	10 µg/L	10 µg/L
Min.	9.43			
Max.	9.43			
Mean± SD	9.43 ±0			
Mandibahauddin				
113	MBD226	8.11	10 µg/L	10 µg/L
Min.	8.11			
Max.	8.11			
Mean± SD	8.11± 0			
Narowal				
114	NRW230	8.34	10 µg/L	10 µg/L
115	NRW231T	17.09	10 µg/L	10 µg/L
116	NRW231TK	13.67	10 µg/L	10 µg/L
Min.	8.34			
Max.	17.09			
Mean± SD	13.03 ± 4.40			
Sialkot				
117	SKT232	8.31	10 µg/L	10 µg/L
118	SKT233	11.76	10 µg/L	10 µg/L
119	SKT235T	5.98	10 µg/L	10 µg/L
120	SKT235TK	15.61	10 µg/L	10 µg/L
Min.	5.98			
Max.	15.61			
Mean± SD	10.41± 4.19			
Gujranwala				
121	GRW237	13.11	10 µg/L	10 µg/L
122	GRW238	4.33	10 µg/L	10 µg/L
123	GRW239T	18.21	10 µg/L	10 µg/L
124	GRW239TK	7.14	10 µg/L	10 µg/L
125	GRW241	31.43	10 µg/L	10 µg/L
Min.	4.33			
Max.	31.43			
Mean± SD	14.82± 10.71			
Chiniot				
126	CHT242	26.76	10 µg/L	10 µg/L
127	CHT243	3.77	10 µg/L	10 µg/L
Min.	3.77			
Max.	26.76			
Mean± SD	15.26± 16.25			
T.T Singh				
128	TTS244	9.61	10 µg/L	10 µg/L
129	TTS245	9.08	10 µg/L	10 µg/L
Min.	9.08			
Max.	9.61			
Mean± SD	9.34± 0.37			

Jhang				
130	JHG246	8.93	10 µg/L	10 µg/L
131	JHG247	6.16	10 µg/L	10 µg/L
Min.	6.16			
Max.	8.93			
Mean± SD	7.54± 1.95			
Faisalabad				
132	FSD248	12.35	10 µg/L	10 µg/L
133	FSD 249	5.78	10 µg/L	10 µg/L
134	FSD 250	12.35	10 µg/L	10 µg/L
135	FSD 251	9.12	10 µg/L	10 µg/L
136	FSD 252	13.09	10 µg/L	10 µg/L
137	FSD 253	20.13	10 µg/L	10 µg/L
138	FSD 254	18.31	10 µg/L	10 µg/L
139	FSD 256	28.82	10 µg/L	10 µg/L
140	FSD 257T	10.73	10 µg/L	10 µg/L
141	FSD 257TK	8.16	10 µg/L	10 µg/L
Min.	5.78			
Max.	28.82			
Mean± SD	13.88± 6.81			
Layyah				
142	LYH258	16.37	10 µg/L	10 µg/L
Min.	16.37			
Max.	16.37			
Mean± SD	16.37± 0			
D.G khan				
143	DGK259	37.76	10 µg/L	10 µg/L
144	DGK260	14.28	10 µg/L	10 µg/L
Min.	14.28			
Max.	37.76			
Mean± SD	26.02±16.60			
Rahim Yar Khan				
145	RYK261	8.18	10 µg/L	10 µg/L
146	RYK262	21.16	10 µg/L	10 µg/L
Min.	8.18			
Max.	21.16			
Mean± SD	14.67±9.17			
Bahawalpur				
147	BHW263	19.23	10 µg/L	10 µg/L
148	BHW264	33.4	10 µg/L	10 µg/L
149	BHW265T	31.21	10 µg/L	10 µg/L
150	BHW265TK	BDL	10 µg/L	10 µg/L
Min.	0			
Max.	33.4			
Mean± SD	17.86± 13.95			

The table 4.4 shows the concentration of arsenic found in 144 samples. 6 samples had the concentration below the detection limit. The permissible limit set by WHO for presence of As in drinking water is 10µg/L. Majority of the samples exceeded the permissible limit.

4.5 Fecal Coliform and E.coli presence in water samples

Findings from the analysis of numerous drinking water samples are shown in table 4.5.

Table 4.5 Results of microbiological contamination in samples

Sr #	Sample code	Colonies of E.coli	Colonies of Fecal Coliform	Sr #	Sample code	Colonies of E.coli	Colonies of Fecal Coliform
Sahiwal				33	PKP31	6	18
				34	PKP32	25	16
1	SWL 1	7	Uncountable	35	PKP33	No colonies	No colonies
2	SWL2	12	10	36	PKP34	1	12
3	SWL3	17	5	37	PKP35	19	16
4	SWL4T	3	8	38	PKP36	21	4
5	SWL4TK	27	No colonies	**Okara**			
6	SWL5	6	25	39	OKC37	30	9
7	SWL6	8	7	40	OKC38	No colonies	3
8	SWL7	14	32	41	OKC39	No colonies	No colonies
9	SWL8	15	4	42	OKC40T	8	40
10	SWL9	No colonies	No colonies	43	OKC40TK	29	26
11	SWL10	23	14	44	OKC41	22	3
12	SWL11	1	Uncountable	45	OKC42	5	14
13	SWL12T	21	10	46	OKC43	20	15
14	SWL12TK	13	8	47	OKC44	12	Uncountable
15	SWL13	5	6	48	OKC45	32	6
16	SWL14	22	5	49	OKC46T	20	12
17	SWL15	No colonies	No colonies	50	OKC46S	3	13
18	SWL16	No colonies	12	**Chichawatni**			
19	SWL17	3	13	51	CWI47	11	23
20	SWL18	18	No colonies	52	CWI48	No colonies	No colonies
21	SWL19	21	4	53	CWI49	5	7
22	SWL20	15	11	54	CWI50	Uncountable	16
23	SWL21	No colonies	18	55	CWI51	8	27
24	SWL22	35	9	56	CWI52	7	10
25	SWL23	ND	16	57	CWI53	No colonies	No colonies
26	SWL24	4	10	58	CWI54	6	14
27	SWL25	42	7	59	CWI55	5	No colonies
28	SWL26	9	20	60	CWI56	14	12

Pakpattan				**Sargodha**			
29	PKP27	19	14	61	SGD57	18	33
30	PKP28	7	22	62	SGD58	28	No colonies
31	PKP29	2	Uncountable	63	SGD59	11	5
32	PKP30	10	3	64	SGD60	16	10
65	SGD61	4	3	**Chakwal**			
66	SGD62	No colonies	13	101	CKW91	9	16
67	SGD63	23	2	102	CKW92	No colonies	No colonies
68	SGD64T	27	15	103	CKW93	20	6
69	SGD64TK	No colonies	No colonies	104	CKW94	Uncountable	No colonies
70	SGD65	20	6	105	CKW95	20	14
Mianwali				90	KHB82T	10	106
71	MW66	3	2	107	CKW97	No colonies	37
72	MW67	7	9	108	CKW98	2	18
73	MW 68	12	10	109	CKW99	22	Uncountable
74	MW69	3	5	110	CKW100	10	5
75	MW70T	3	5	**Rajanpur**			
76	MW70TK	2	18	111	RJP101	1	6
77	MW71	Uncountable	4	112	RJP102	No colonies	3
78	MW72T	3	7	**Muzzafargarh**			
79	MW72TK	1	1	113	MZJ103	6	11
80	MW73	No colonies	No colonies	114	MZJ104	2	10
81	MW74	4	12	**Attock**			
82	MW75	5	19	115	ATC105	6	38
Khushab				116	ATC106	22	13
83	KHB76	2	12	117	ATC107	No colonies	12
84	KHB77	19	24	118	ATC108	30	6
85	KHB78	8	12	119	ATC109	11	7
86	KHB 79	4	2	120	ATC110	30	17
87	KHB80T	11	Uncountable	121	ATC111T	12	3
88	KHB80TK	No colonies	11	122	ATC111TK	25	No colonies
89	KHB81	1	18	123	ATC112	14	22
90	KHB82T	10	6	124	ATC113	2	35
91	KHB82TK	No colonies	20	**Jhelum**			
92	KHB83	10	14	125	JHE114	7	6
Bhakkar				145	RWP131	5	126
93	BKR84	19	29	127	JHE116	4	No colonies
94	BKR85T	1	6	128	JHE117	10	21
95	BKR85TK	14	No colonies	129	JHE118T	No colonies	No colonies

96	BKR 86	3	1	130	JHE118TK	4	10
97	BKR87	4	11	131	JHE119	9	14
98	BKR88	14	No colonies	132	JHE120	24	8
99	BKR89	8	No colonies	133	JHE121	13	15
100	BKR90	No colonies	21	134	JHE122T	12	14
135	JHE122TK	5	21	171	KWL152T	Uncountable	4
136	JHE123	16	10	172	KWL152TK	No colonies	No colonies
137	JHE124	Uncountable	3	173	KWL153	12	20
Lodhran				157	RWP141	14	174
138	LDH125	2	16	175	KWL155T	22	5
139	LDH126	13	4	176	KWL155TK	3	14
140	LDH127T	No colonies	34	177	KWL156	No colonies	No colonies
141	LDH127TK	No colonies	32	178	KWL157	32	5
142	LDH128	8	15	179	KWL158	18	12
Rawalpindi				180	KWL159	4	10
143	RWP129	No colonies	2	**Vehari**			
144	RWP 130	1	4	181	VHR160	21	1
145	RWP131	5	7	182	VHR161	2	29
146	RWP132T	12	31	183	VHR162	No colonies	31
147	RWP132TK	10	7	184	VHR163	17	22
148	RWP133T	No colonies	No colonies	185	VHR164	7	42
149	RWP133TK	2	28	186	VHR165	2	23
150	RWP 134	5	31	187	VHR166	14	31
151	RWP135	17	40	188	VHR167	10	21
152	RWP136	3	19	189	VHR168	3	19
153	RWP137	2	9	190	VHR169	26	2
154	RWP138	12	2	191	VHR170	20	8
155	RWP139	2	17	**Multan**			
156	RWP140	1	11	192	MUL171T	2	12
157	RWP141	14	32	193	MUL171TK	17	44
158	RWP142T	6	13	194	MUL172	8	18
159	RWP142TK	No colonies	43	195	MUL173	14	6
160	RWP143	27	2	196	MUL174	No colonies	10
161	RWP 144	1	12	197	MUL175	No colonies	16
162	RWP145T	14	No colonies	198	MUL176	11	13
163	RWP145TK	24	6	199	MUL177	26	7
Khanewal				200	MUL178	28	25
164	KWL146	10	58	201	MUL179	21	No colonies
165	KWL147	13	5	202	MUL180	14	23

166	KWL148	No colonies	No colonies	203	MUL181	No colonies	No colonies
167	KWL149	2	23	204	MUL182	2	11
168	KWL150T	4	15	205	MUL183	Uncountable	2
169	KWL150TK	7	11	206	MUL184	10	21
170	KWL151	4	2	207	MUL185T	1	6
208	MUL185TK	6	23	244	LHE218	12	8
209	MUL186	11	15	245	LHE219	45	4
210	MUL187	21	10	246	LHE220	6	2
211	MUL188	No colonies	No colonies	247	LHE221	No colonies	8
Nankanasahib				**Kasur**			
212	NNS189	12	Uncountable	248	KSR222	11	4
213	NNS190T	10	36	249	KSR223	18	1
214	NNS190S	11	5	250	KSR224	Uncountable	No colonies
215	NNS191	21	10	251	KSR225	No colonies	10
216	NNS192	19	11	**MandiBahauddin**			
Sheikhupura				252	MBD226	20	24
217	SKP193	No colonies	No colonies	253	MBD227	13	31
218	SKP194	11	4	**Hafizabad**			
219	SKP195T	3	5	254	HFD228	2	Uncountable
220	SKP195TK	20	No colonies	255	HFD229	No colonies	No colonies
221	SKP196	9	18	**Narowal**			
Lahore				256	NRW230	4	11
222	LHE197	18	2	257	NRW231T	19	7
223	LHE198	No colonies	No colonies	258	NRW231TK	No colonies	16
224	LHE199	8	3	**Sialkot**			
225	LHE200	12	8	259	SKT232	14	4
226	LHE201	No colonies	Uncountable	260	SKT233	5	22
227	LHE 202	No colonies	22	261	SKT234	9	No colonies
228	LHE203	28	9	262	SKT235T	10	30
229	LHE204	10	7	263	SKT235TK	No colonies	No colonies
230	LHE205	12	4	**Gujrat**			
231	LHE206	34	10	264	GRT236	22	4
232	LHE207T	10	16	**Gujranwala**			
233	LHE207TK	No colonies	No colonies	265	GRW237	15	6
234	LHE208	5	11	266	GRW238	14	12
235	LHE209	10	6	267	GRW239	5	28
236	LHE210	2	13	268	GRW240	No colonies	15
237	LHE211	5	10	269	GRW241	No colonies	No colonies
238	LHE212	12	1	**Chiniot**			

239	LHE213	No colonies	No colonies	270	CHT242	No colonies	No colonies
240	LHE214	7	2	271	CHT243	7	5
241	LHE215	1	1	**T.T Singh**			
242	LHE216	14	No colonies	272	TTS244	30	12
243	LHE217	19	5	273	TTS245	5	8
Jhang				294	BHW265	2	2
274	JHG246	10	2	295	BHW266	28	2
275	JHG247	35	6	296	BHW267	No colonies	No colonies
Faisalabad				**Bahawalnagar**			
276	FSD248	7	11	297	BWL268	No colonies	No colonies
277	FSD249	16	2	298	BWL269	7	5
278	FSD250	No colonies	No colonies	299	BWL270	30	12
279	FSD251	4	13	300	BWL271	5	8
280	FSD252	1	9				
281	FSD253	10	3				
282	FSD254	30	20				
283	FSD255	11	7				
284	FSD256	12	3				
285	FSD 257T	14	20				
286	FSD257TK	20	11				
Layyah							
287	LYH258	20	22				
D.G Khan							
288	DGK259	1	4				
289	DGK260	5	9				
Rahim Yar Khan							
290	RYK 261	No colonies	No colonies				
291	RYK 262	17	21				
Bahawalpur							
292	BHW263	4	2				
293	BHW264	9	7				
WHO and NDWQS		**Must not be detectable in any 100 ml sample**					

The table 4.5 shows the presence of fecal coliform and E.coli in the drinking water samples. According to the guidelines of WHO and NDWQS, bacterial contamination must not be detectable in any 100 ml sample. Some of the samples had uncountable colonies formed in them.The samples were taken from tank and taps and both sources had bacterial contamination in them.

4.6: Health Risk Assessment for Arsenic

Table 4.6: Health risk assessment for Arsenic

Sr #	Sample Code	Exposure dose of Arsenic (mg/l)	Daily Arsenic Consumption (DAC)	Carcinogenic Risk
Sahiwal				
1	SWL 1	0.00945	0.49	0.7399
2	SWL 2	0.01254	0.655	0.989
3	SWL 3	0.00621	0.324	0.489
4	SWL 4T	0.00861	0.499	0.6779
5	SWL 4 TK	0.00536	0.28	0.4228
6	SWL 5	0.01905	0.995	1.502
7	SWL 6	0.0048	0.25	0.3095
8	SWL 7	0.00655	0.339	0.6024
9	SWL 8	0.0142	0.742	1.12042
10	SWL9	BDL	BDL	BDL
11	SWL 10	0	0	0
12	SWL 25	0.00865	0.512	0.7731
Pakpattan				
13	PKP26	0.00796	0.415	0.6266
14	PKP27	0.00731	0.381	0.5753
15	PKP32	0.00311	0.1625	0.1863
16	PKP35	0.01187	0.6202	0.9365
17	PKP36	0.02382	1.2446	1.87
Okara				
18	OKC40T	0.04507	2.3551	3.85
19	OKC40TK	0.02765	1.444	2.18
20	OKC43	0.00265	0.13	0.1963
21	OKC46T	0.00315	0.164	0.247
22	OKC46TK	0.00623	0.325	0.49
Chichawatni				
23	CWI48	0.01012	0.528	0.797
24	CWI50	0.00717	0.374	0.564
25	CWI52	0.001772	0.0925	0.1396
26	CWI56	0.00955	0.499	0.753
Sargodha				

27	SGD57	0.0225	1.175	1.351
28	SGD59	0.01966	1.027	1.55077
29	SGD61	0.00634	0.3312	0.5
30	SGD64T	0.01023	0.5345	0.807
31	SGD64TK	0.00843	0.4405	0.665
Mianwali				
32	MW72T	0.01123	0.586	0.884
33	MW 72TK	0.0111	0.58	0.8758
34	MW74	0.01567	0.8188	1.23
35	MW75	0.01097	0.5732	0.8655
Khushaab				
36	KHB76	0.01576	0.8235	1.24
37	KHB80T	0.04622	2.415	3.646
38	KHB80TK	0.03523	1.8409	2.779
Bhakkar				
39	BKR84	0.05032	2.629	3.969
40	BKR 86	0.01243	0.6495	0.9807
41	BKR87	0.01243	0.6495	0.9807
42	BKR88	0.00721	0.377	0.5702
43	BKR 89	0.01034	0.54	0.8154
44	BKR90T	0.01844	0.963	1.4541
45	BKR90TK	0.02012	1.051	1.587
Chakwal				
46	CKW93	0.01089	0.569	0.8591
47	CKW95	0.02345	1.225	1.8497
48	CKW98	0.03412	1.789	2.7013
49	CKW100	0.02567	1.341	2.0249
Rajanpur				
50	RJP101	0.01441	0.752	1.1355
Muzzafargarh				
51	MZJ103	0.03311	1.73	2.6123
52	MZJ104	BDL	BDL	BDL
Attock				
53	ATC105	0.02002	1.046	1.579
54	ATC106	0.01814	0.947	1.4299
55	ATC107	0.02738	1.43	2.1593
56	ATC109	0.02083	1.088	1.6428
57	ATC111T	0.03341	1.745	2.6349
58	ATC111TK	0.03277	1.712	2.5851
Jhelum				
59	JHE114T	0.0199	1.039	1.5688

60	JHE114TK	0.01321	0.69	1.0419
61	JHE117	0.02274	1.188	1.7938
62	JHE119	0.02052	1.072	1.6187
63	JHE121T	0.0052	0.271	0.4092
64	JHE121TK	0.02937	1.534	2.3163
Lodhran				
65	LDH127	0.02611	1.364	2.0596
66	LDHS128	0.01586	0.828	1.2502
Rawalpindi				
67	RWP130T	0.01259	0.657	0.992
68	RWP131TK	0.01586	0.828	1.2502
69	RWP133	0.01068	0.55	0.8305
70	RWP136T	0.02573	1.344	2.0294
71	RWP136TK	0.0446	2.33	3.518
72	RWP137T	0.0188	0.982	1.482
73	RWP137TK	0.04001	2.09	3.1559
74	RWP138	0.04391	2.29	3.4579
75	RWP140	BDL	BDL	BDL
76	RWP143	0.0138	0.721	1.0887
Khanewal				
77	KWL151	0.01813	0.947	1.429
78	KWL153	0.02112	1.103	1.665
79	KWL154T	0.01243	0.649	0.979
80	KWL154TK	0.0721	3.767	5.688
81	KWL155	0.01034	0.54	0.8154
82	KWL157	0.01844	0.963	1.454
83	KWL158	0.02012	1.051	1.587
84	KWL159	0.01714	0.89	1.343
Vehari				
85	VHR164	0.01022	0.534	0.8063
86	VHR166	0.0987	5.157	7.787
87	VHR168	0.04426	2.31	3.488
88	VHR170	0.06721	3.51	5.3
Multan				
89	MUL173	0.05512	2.88	4.34
90	MUL174	0.02862	1.49	2.249
91	MUL176	0.05084	2.656	4.01
92	MUL178	0.06231	3.25	4.9075
93	MUL180	0.03521	1.83	2.763
94	MUL182	0.0913	4.77	7.202
95	MUL184	0.03193	1.66	2.506

96	MUL186	0.01324	0.69	1.0419
97	MUL188	0.0232	1.21	1.827
Sheikhupura				
98	SKP193	0.01001	0.52	0.785
99	SKP195T	0.01612	0.84	1.268
100	SKP195TK	0.0842	4.39	6.6289
Lahore				
101	LHE196	0.02512	1.31	1.982
102	LHE197	0.01652	0.86	1.3034
103	LHE198	0.02809	1.46	2.2164
104	LHE201	0.01898	0.99	1.4959
105	LHE204	0.03283	1.71	2.9041
106	LHE207	0.02216	1.15	1.7485
107	LHE209	0.01907	0.99	1.5046
108	LHE210	0.02575	1.34	2.0317
109	LHE211T	0.03824	1.99	3.0172
110	LHE211TK	0.02497	1.3	1.9702
111	LHE212	0.0189	0.98	1.4912
Kasur				
112	KSR222	0.0943	4.92	7.4406
Mandibahauddin				
113	MBD226	0.0811	4.23	6.3991
Narowal				
114	NRW230	0.0834	4.35	6.5805
115	NRW231T	0.01709	0.89	1.3484
116	NRW231TK	0.01367	0.71	1.0786
Sialkot				
117	SKT232	0.0831	4.34	6.5569
118	SKT233	0.01176	0.61	0.9279
119	SKT235T	0.0598	3.12	4.7184
120	SKT235TK	0.01561	0.81	1.2316
Gujranwala				
121	GRW237	0.01311	0.68	1.0344
122	GRW238	0.0433	2.26	3.1416
123	GRW239T	0.01821	0.95	1.4368
124	GRW239TK	0.0714	3.73	5.6337
125	GRW241	0.03143	1.64	2.4799
Chiniot				
126	CHT242	0.02676	1.39	2.1114

127	CHT243	0.0377	1.96	2.9746
T.T Singh				
128	TTS244	0.0961	5.02	7.5826
129	TTS245	0.0961	5.02	7.5826
Jhang				
130	JHG246	0.0893	4.66	7.0461
131	JHG247	0.0616	3.21	4.8604
Faisalabad				
132	FSD248	0.01235	0.64	0.9744
133	FSD 249	0.0578	3.02	4.5606
134	FSD 250	0.01235	0.64	0.9744
135	FSD 251	0.0912	4.76	7.196
136	FSD 252	0.01309	0.68	1.032
137	FSD 253	0.02013	1.05	1.5883
138	FSD 254	0.01831	0.95	1.4447
139	FSD 256	0.02882	1.5	2.274
140	FSD 257T	0.01073	0.56	0.8466
141	FSD 257TK	0.0816	4.26	6.4385
Layyah				
142	LYH258	0.01637	0.85	1.2916
D.G khan				
143	DGK259	0.03776	1.97	2.979
144	DGK260	0.01428	0.74	1.1267
Rahim Yar Khan				
145	RYK261	0.0818	4.27	6.4543
146	RYK262	0.02116	1.1	1.6696
Bahawalpur				
147	BHW263	0.01923	1	1.5173
148	BHW264	0.0334	1.74	2.6353
149	BHW265T	0.03121	1.63	2.4625
150	BHW265TK	BDL	BDL	BDL

Among the 150 samples, As was detected in 144 samples and therefore health risk assessment was carried out to calculate the carcinogenic effect of arsenic on the children of those schools. The table shows the values for exposure dose,average daily dose and values for carcinogenic risks.

4.7 Water Quality Index with respect to physicochemical parameters

The water quality index of the samples has been mentioned in the table 4.7

Table 4.7: WQI of the drinking water samples

Sr #.	Sample code	WQI	Status	Sr #.	Sample code	WQI	Status
Sahiwal				26	SWL24	62	Fair
1	SWL 1	151	Very poor	27	SWL25	99	Poor
2	SWL2	138	Very poor	28	SWL26	51	Fair
3	SWL3	149	Very poor	**Pakpattan**			
4	SWL4T	148	Very poor	29	PKP27	58	Fair
5	SWL4TK	122	Very poor	30	PKP28	64.8	Fair
6	SWL5	223	Unfit for drinking	31	PKP29	60	Fair
7	SWL6	99	Poor	32	PKP30	60	Fair
8	SWL7	53	Fair	33	PKP31	51.2	Fair
9	SWL8	89	Poor	34	PKP32	56	Fair
10	SWL9	73	Fair	35	PKP33	55	Fair
11	SWL10	85	Poor	36	PKP34	54	Fair
12	SWL11	100.1	Very poor	37	PKP35	49	Good
13	SWL12T	93	Poor	38	PKP36	79	Poor
14	SWL12TK	84.56	Poor	**Okara**			
15	SWL13	75.46	Poor	39	OKC37	58	Fair
16	SWL14	72.58	Poor	40	OKC38	45	Good
17	SWL15	66.24	Fair	41	OKC39	107	Very poor
18	SWL16	69.82	Fair	42	OKC40T	48	Good
19	SWL17	44.34	Good	43	OKC40TK	151	Unfit for drinking
20	SWL18	65.53	Fair	44	OKC41	138	Very poor
21	SWL19	77.33	Poor	45	OKC42	119	Very poor
22	SWL20	69.36	Fair	46	OKC43	168	Unfit for drinking
23	SWL21	51.49	Fair	47	OKC44	122	Very poor
24	SWL22	64.61	Fair	48	OKC45	223	Unfit for drinking
25	SWL23	54.9	Fair	49	OKC46T	59	Fair
50	OKC46TK	87.9	Poor	77	MW71	79.73	Poor

Chichawatni				78	MW72T	81.73	Poor
51	CWI47	93.2	Poor	79	MW72TK	74.68	Poor
52	CWI48	62.2	Fair	80	MW73	52.39	Fair
53	CWI49	46.6	Good	81	MW74	68.93	Fair
54	CWI50	45.3	Good	82	MW75	84.56	Poor
55	CWI51	154	Unfit for drinking	**Khushab**			
56	CWI52	141.33	Very poor	83	KHB76	72.58	Fair
57	CWI53	131.83	Very poor	84	KHB77	66.24	Fair
58	CWI54	44.1	Good	85	KHB78	69.82	Fair
59	CWI55	29.37	Good	86	KHB79	44.34	Good
60	CWI56	37.59	Good	87	KHB80T	65.53	Fair
Sargodha				88	KHB80TK	77.33	Poor
61	SGD57	42.93	Good	89	KHB81	69.36	Fair
62	SGD58	40.58	Good	90	KHB82T	51.49	Fair
63	SGD59	65.43	Fair	91	KHB82TK	64.61	Fair
64	SGD60	31.64	Good	92	KHB83	44.5	Good
65	SGD61	34.65	Good	**Bhakkar**			
66	SGD62	40.73	Good	93	BKR84	32.16	Good
67	SGD63	57.89	Fair	94	BKR85T	42.64	Good
68	SGD64T	52.32	Fair	95	BKR85TK	37.8	Good
69	SGD64TK	53.57	Fair	96	BKR86	34.18	Good
70	SGD65	53.78	Fair	97	BKR87	45.8	Good
Mianwali				98	BKR88	31.84	Good
71	MW66	68.37	Fair	99	BKR89	31.37	Good
72	MW67	55.3	Fair	100	BKR90	36.59	Good
73	MW68	54.4	Fair	**Chakwal**			
74	MW69	43.4	Good	101	CKW91	40.54	Good
75	MW70T	0.67	Excellent	102	CKW92	44.94	Good
76	MW70TK	65.53	Fair	103	CKW93	30.53	Good
				104	CKW94	46.03	Good
				105	CKW95	45.63	Good
106	CKW96	54.79	Fair	132	JHE120	60.1	Fair

107	CKW97	35.23	Good	133	JHE121	70.3	Fair
108	CKW98	43.83	Good	134	JHE122T	70.2	Fair
109	CKW99	45.58	Good	135	JHE122TK	66.3	Fair
110	CKW100	108.78	Very poor	136	JHE123	61.2	Fair
Rajanpur				137	JHE124	95.6	Poor
111	RJP101	112.7	Very poor	**Lodhran**			
112	RJP 102	138	Very poor	138	LDH125	50.1	Good
Muzzafargarh				139	LDH126	52.3	Fair
113	MZJ103	168	Unfit for drinking	140	LDH127T	74	Fair
114	MZJ104	122	Very Poor	141	LDH127TK	55.5	Fair
Attock				142	LDH128	118	Very Poor
115	ATC105	74.3	Fair	**Rawalpindi**			
116	ATC106	83.6	Poor	143	RWP129	103.1	Very Poor
117	ATC107	115.3	Very Poor	144	RWP130	143.2	Very Poor
118	ATC108	133.2	Very Poor	145	RWP131	112.1	Very Poor
119	ATC109	127.6	Very Poor	146	RWP132T	124.1	Very Poor
120	ATC110	90.3	Poor	147	RWP132TK	150.3	Very Poor
121	ATC111T	130.2	Very Poor	148	RWP133T	124.3	Very Poor
122	ATC111TK	95.6	Poor	149	RWP133TK	124.7	Very Poor
123	ATC112	57.8	Fair	150	RWP134	76.4	Poor
124	ATC113	50.1	Good	151	RWP135	86.6	Poor
Jhelum				152	RWP136	76.4	Poor
125	JHE114	64	Fair	153	RWP137	75.4	Fair
126	JHE115	55.5	Fair	154	RWP138	66.3	Fair
127	JHE116	118	Very Poor	155	RWP139	49.1	Good
128	JHE117	122	Very Poor	156	RWP140	65.4	Fair
129	JHE118T	51.2	Fair	157	RWP141	74.3	Fair
130	JHE118S	49.8	Good	158	RWP142T	122.32	Very Poor
131	JHE119	95.4	Poor	159	RWP142S	141.1	Very Poor
				160	RWP143	1.45	Excellent
				161	RWP144	1.57	Excellent
162	RWP145T	134.1	Very Poor	190	VHR169	92.3	Poor

163	RWP145TK	97.7	Poor	191	VHR170	95.3	Poor
Khanewal				**Multan**			
164	KWL146	51.02	Fair	192	MUL171T	93	Poor
165	KWL147	53.53	Fair	193	MUL171TK	101	Very Poor
166	KWL148	66.29	Fair	194	MUL172	94	Poor
167	KWL149	55.86	Fair	195	MUL173	84	Poor
168	KWL150T	72.04	Fair	196	MUL174	69.57	Fair
169	KWL150TK	65.09	Fair	197	MUL175	52.16	Fair
170	KWL151	53.83	Fair	198	MUL176	39.52	Good
171	KWL152T	50.27	Good	199	MUL177	48.75	Good
172	KWL152TK	49.51	Good	200	MUL178	42.12	Good
173	KWL153	49.05	Good	201	MUL179	42.76	Good
174	KWL154	54.49	Fair	202	MUL180	35.39	Good
175	KWL155T	43.23	Good	203	MUL181	53.06	Fair
176	KWL155TK	70.33	Fair	204	MUL182	44.64	Good
177	KWL156	59.49	Fair	205	MUL183	47.44	Good
178	KWL157	59.73	Fair	206	MUL184	37.44	Good
179	KWL158	68.57	Fair	207	MUL185T	32.26	Good
180	KWL159	86.03	Poor	208	MUL185TK	36.13	Good
Vehari				209	MUL186	49.56	Good
181	VHR160	58.72	Fair	210	MUL187	34.81	Good
182	VHR161	56.64	Fair	211	MUL188	42.31	Good
183	VHR162	64	Fair	**Nankanasahib**			
184	VHR163	132	Very Poor	212	NNS189	56.45	Fair
185	VHR164	101	Poor	213	NNS190T	38.28	Good
186	VHR165	143	Very Poor	214	NNS190TK	35.37	Good
187	VHR166	113	Very Poor	215	NNS191	41.33	Good
188	VHR167	113.2	Very Poor	216	NNS192	31.83	Good
189	VHR168	99.4	Poor	**Sheikhupura**			
				217	SKP193	37.59	Good
				218	SKP194	45.08	Good
219	SKP195T	42.93	Good	245	LHE219	44.07	Good

220	SKP195TK	40.58	Good	246	LHE220	46.57	Good
221	SKP196	76.24	Poor	247	LHE221	62.28	Fair
219	SKP195T	42.93	Good	**Kasur**			
220	SKP195TK	40.58	Good	248	KSR222	52.76	Fair
221	SKP196	76.24	Poor	249	KSR223	64.02	Fair
Lahore				250	KSR224	42.3	Good
222	LHE197	79.73	Poor	251	KSR225	94	Poor
223	LHE198	81.73	Poor	**MandiBahauddin**			
224	LHE199	74.68	Fair	252	MBD226	47	Good
225	LHE200	52.39	Fair	253	MBD227	68	Fair
226	LHE201	68.93	Fair	**Hafizabad**			
227	LHE202	84.56	Poor	254	HFD228	72.1	Fair
228	LHE203	75.46	Fair	255	HFD229	61	Fair
229	LHE204	72.58	Fair	**Narowal**			
230	LHE205	66.24	Fair	256	NRW230	88	Poor
231	LHE206	69.82	Fair	257	NRW231T	72.4	Fair
232	LHE207T	44.34	Excellent	258	NRW231TK	94.5	Poor
233	LHE207S	65.53	Fair	**Sialkot**			
234	LHE208	77.33	Poor	259	SKT232	112	Very Poor
235	LHE209	69.36	Fair	260	SKT233	59.54	Fair
236	LHE210	51.49	Fair	261	SKT234	51.16	Fair
237	LHE211	64.61	Fair	262	SKT235T	37.95	Good
238	LHE212	44.5	Good	263	SKT235TK	35.97	Good
239	LHE213	79.51	Poor	**Gujrat**			
240	LHE214	59.53	Fair	264	GRT236	65.4	Fair
241	LHE215	63.92	Fair	**Gujranwala**			
242	LHE216	50.04	Good	265	GRW237	32.72	Good
243	LHE217	72.77	Fair	266	GRW238	53.53	Fair
244	LHE218	30.88	Good	267	GRW239	56.73	Fair
				268	GRW240	54.92	Fair
				269	GRW241	53.2	Fair
Chiniot				289	DGK259	52.51	Fair

270	CHT242	84.6	Poor	**Rahim Yar Khan**			
271	CHT243	88.8	Poor	290	RYK261	28.1	Good
T.T Singh				291	RYK262	33.8	Good
272	TTS244	32.72	Good	**Bahawalpur**			
273	TTS245	53.53	Fair	292	BHW263	78.1	Poor
Jhang				293	BHW264	56.9	Fair
274	JHG246	54.92	Fair	294	BHW265	65.4	Fair
275	JHG247	53.2	Fair	295	BHW266	77.3	Poor
Faisalabad				296	BHW267	50.8	Good
276	FSD248	84.6	Poor	**Bahawalnagar**			
277	FSD249	88.8	Poor	297	BWL268	66.1	Fair
278	FSD250	32	Good	298	BWL269	55.8	Fair
279	FSD251	100.3	Poor	299	BWL270	53.6	Fair
280	FSD252	83.2	Poor	300	BWL271	34.12	Good
281	FSD253	74.1	Fair				
282	FSD254	90.5	Poor				
283	FSD255	95.5	Poor				
284	FSD256	55.8	Fair				
285	FSD257T	57.73	Fair				
286	FSD 257TK	48.4	Good				
Layyah							
287	LYH258	75.7	Fair				
D.g Khan							
288	DGK259	88.4	Poor				

The results of table 4.7 show about the quality of drinking water at public primary schools of Urban Punjab. The quality of water was categorized according to the values of WHO. Samples having values between 0-25 were considered as excellent however, samples having values above 150 were considered unsuitable for drinking.

4.8 Graphical Representation of the data:

4.8.1: Results of Physicochemical parameters:

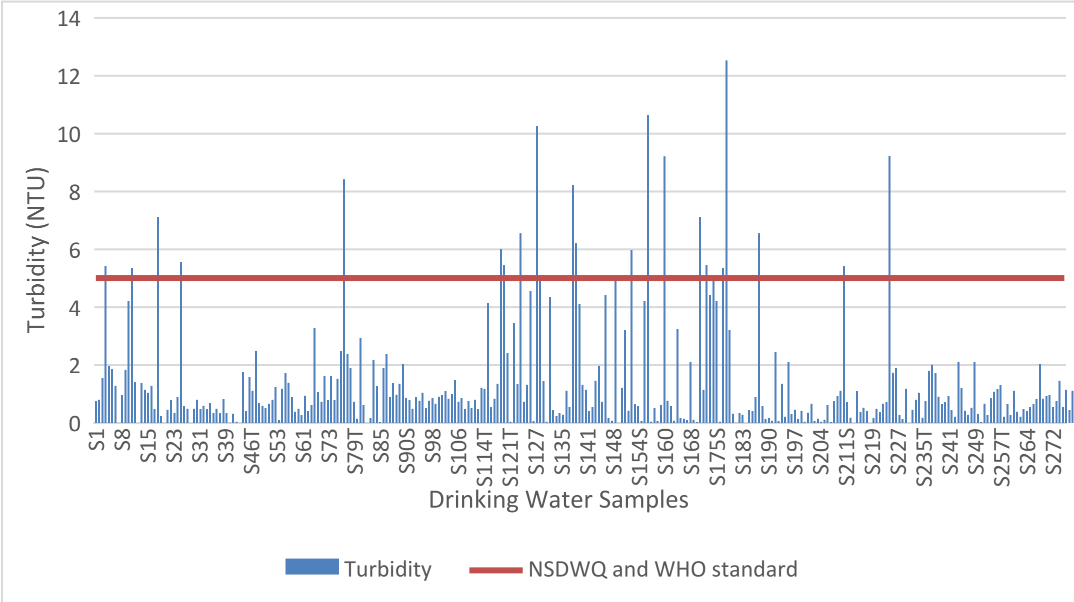

Fig 4.1: Comparison of drinking water samples with NDWQS and WHO for turbidity

According to figure 4.1, the measured turbidity levels of all collected samples with maximum value is 12.52 NTU. 7.3% of the samples exceeded the permissible limit.

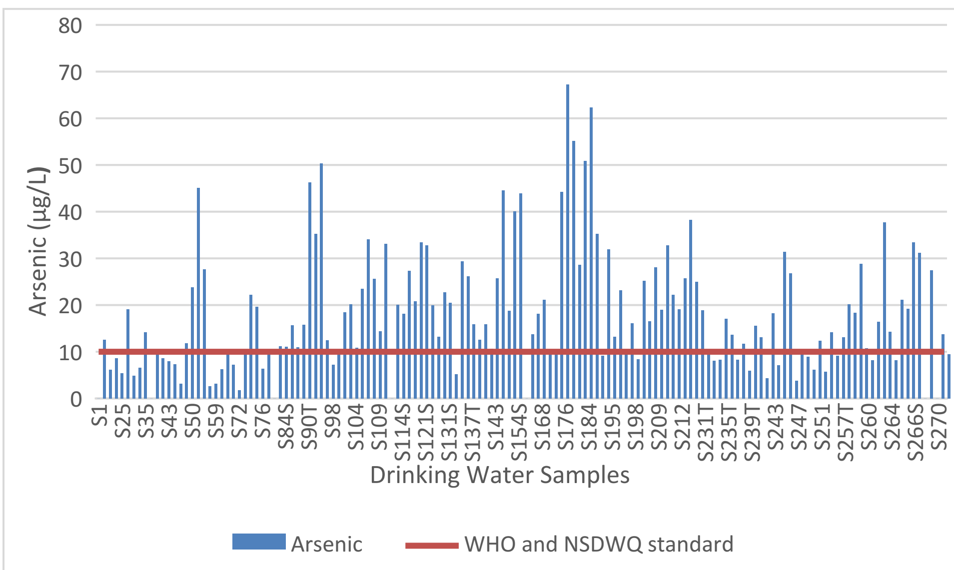

Fig 4.2: Comparison of drinking water samples with NDWQS and WHO for arsenic

According to the figure 4.2, the highest detected concentration for As was 67.21 µg/l. 55 % of the samples exceeded the permissible limit which is 10ug/l.

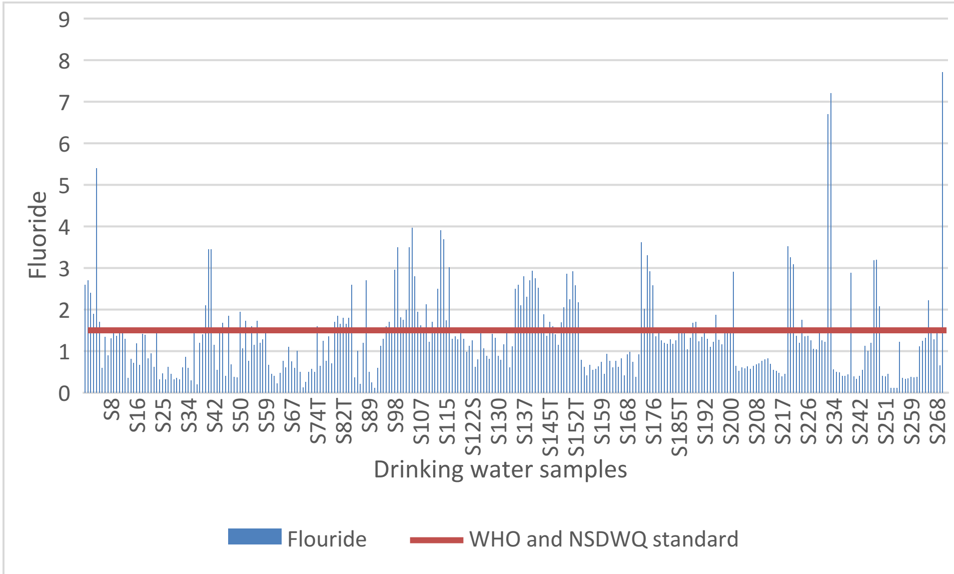

Fig 4.3: Comparison of drinking water samples with NDWQS and WHO for fluoride

According to the figure 4.3, the highest value of F^- was 7.2 mg/L.Majority of the samples were within the permissible limit while only 21% of the samples were exceeding the limit set by WHO and NDWQS.

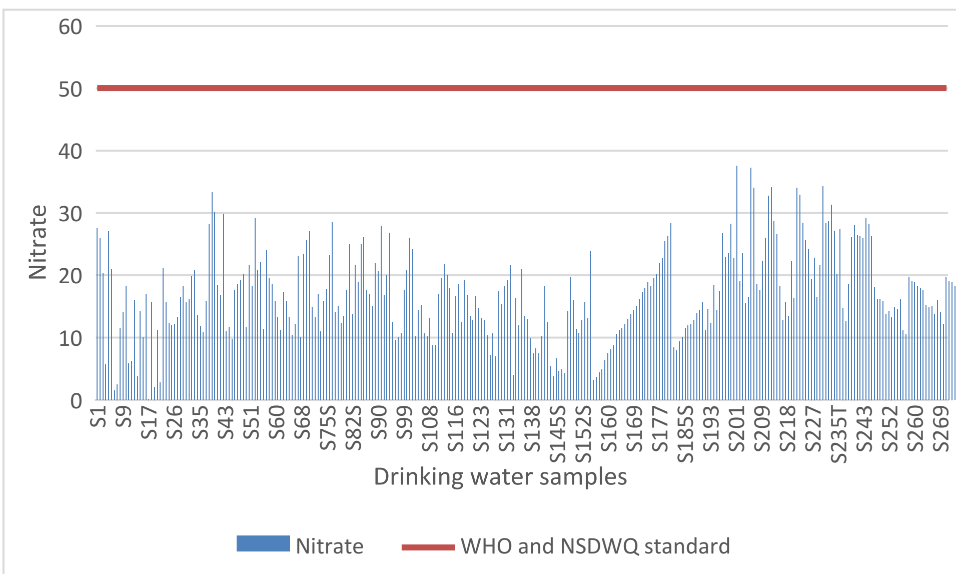

Fig 4.4: Comparison of drinking water samples with NDWQS and WHO for nitrate

Figure 4.4 shows that the permissible limit by the WHO and NDWQS for nitrates is 50 mg/L and all the samples were within the permissible limits.

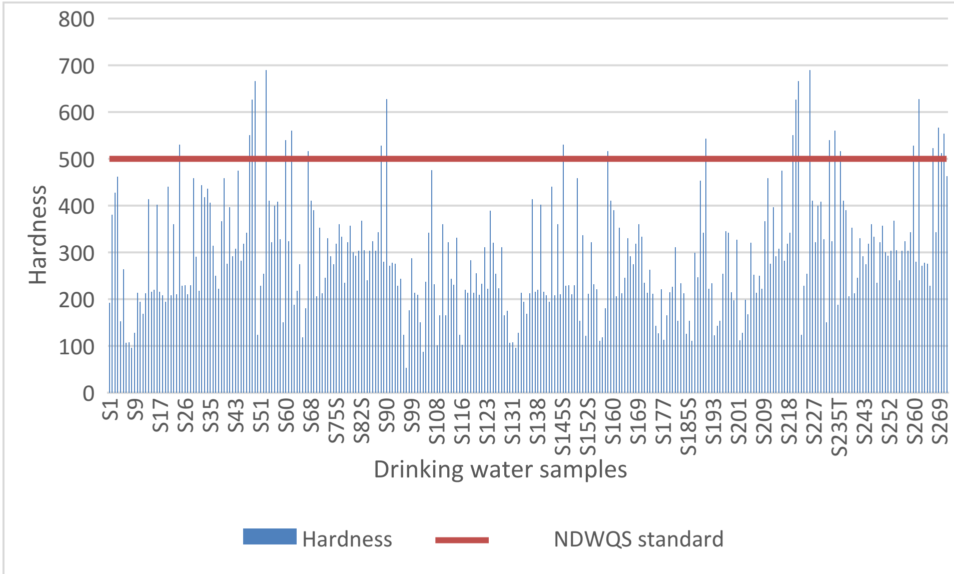

Fig 4.5: Comparison of drinking water samples with NDWQS for hardness

According to the figure 4.5, the permissible limit for hardness is 500 mg/L and 8% percent of the samples were beyond the limit.

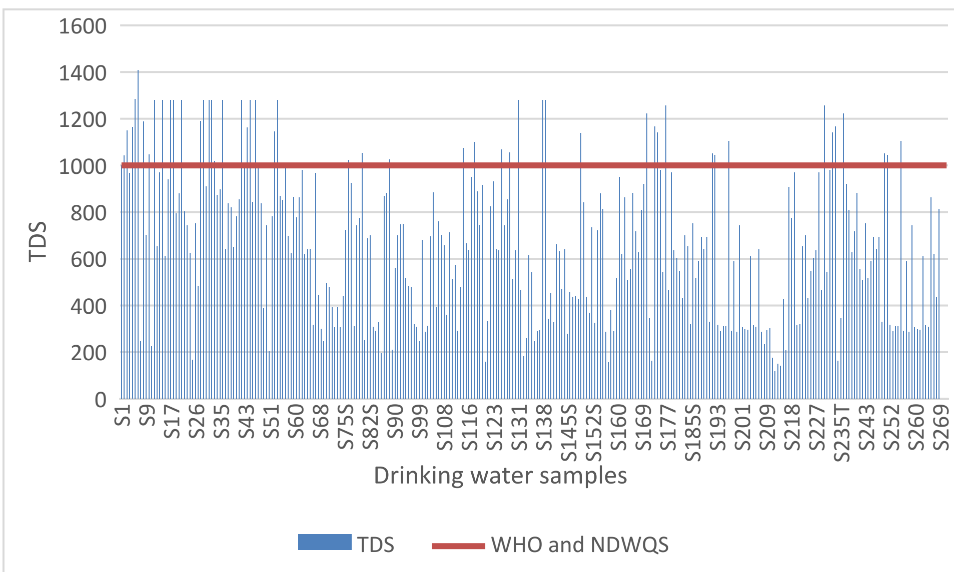

Fig 4.6: Comparison of drinking water samples with NDWQS for TDS

The figure 4.6 shows that among the 300 samples, 15.6 % of the samples exceeded the limit of 1000 mg/L.

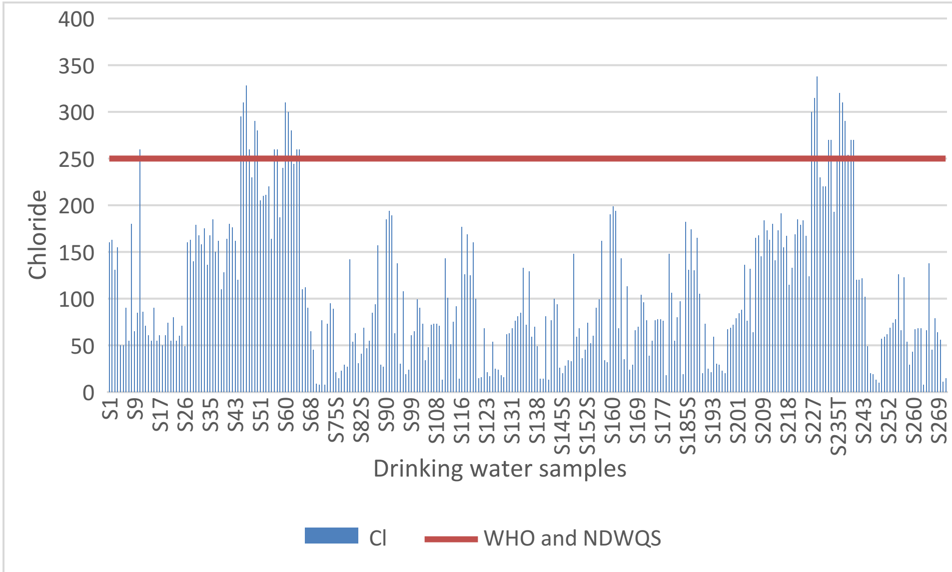

Fig 4.7: Comparison of drinking water samples with NDWQS for Cl^-

The figure 4.7 shows that the permissible limit of Cl^- according to WHO and NDWQS is 250 mg/L. 9.3% of the samples exceeded the permissible limit.The highest value is 338 mg/L.

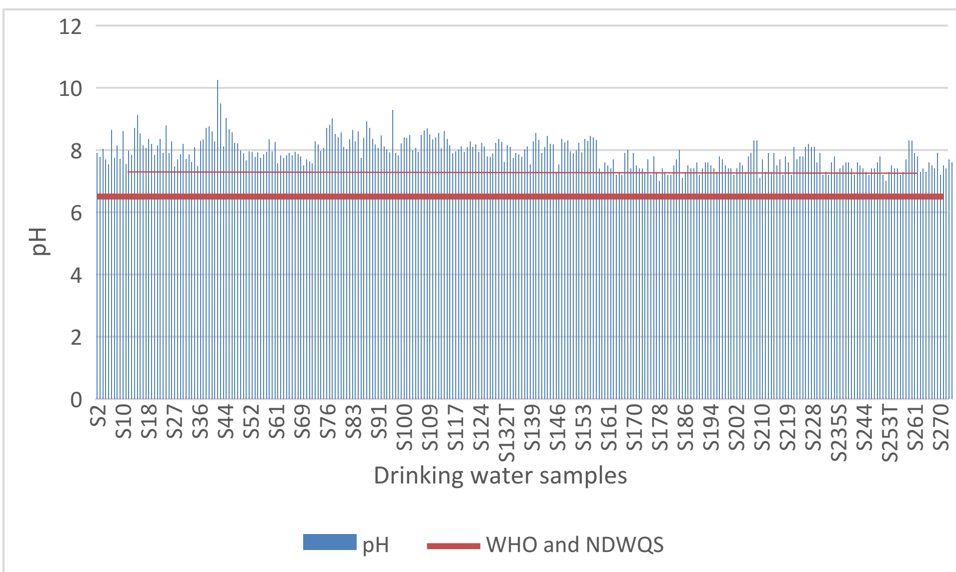

Fig 4.8: Comparison of drinking water samples with NDWQS for pH

For the pH, the permissible limit by WHO and NDWQS is 6.5-8.5. The measured pH for water samples ranged from 7 to 10. Majority of the samples had pH within the limit.

4.8.2: Results of responses of questionnaire survey:

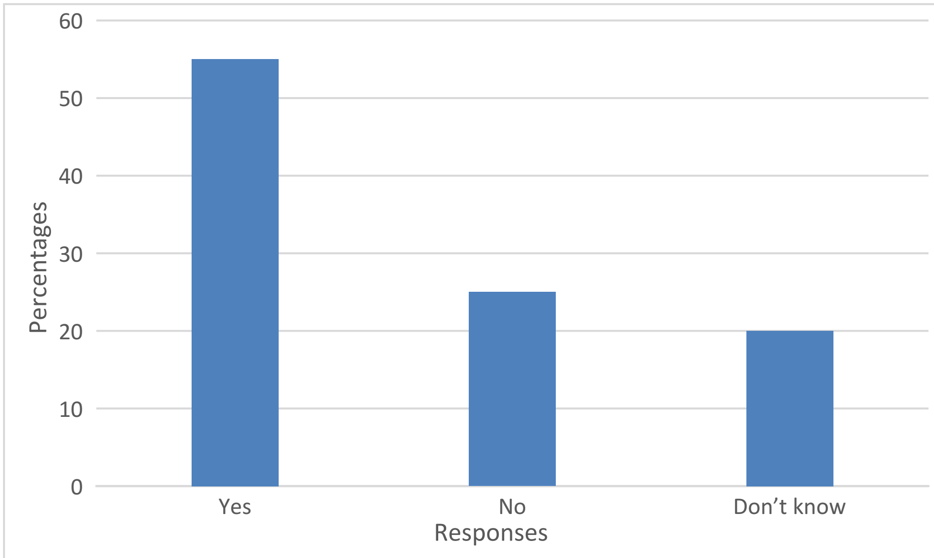

Fig 4.9: Presence of water filters in schools

The figure 4.9 shows response of the students about the presence of water filters in their schools. Among the 300 schools the water filters were present in 55% of the schools, while 25% of the school didn’t have a water filtration system. Rest of the respondents had no idea about the presence of water filters in schools.

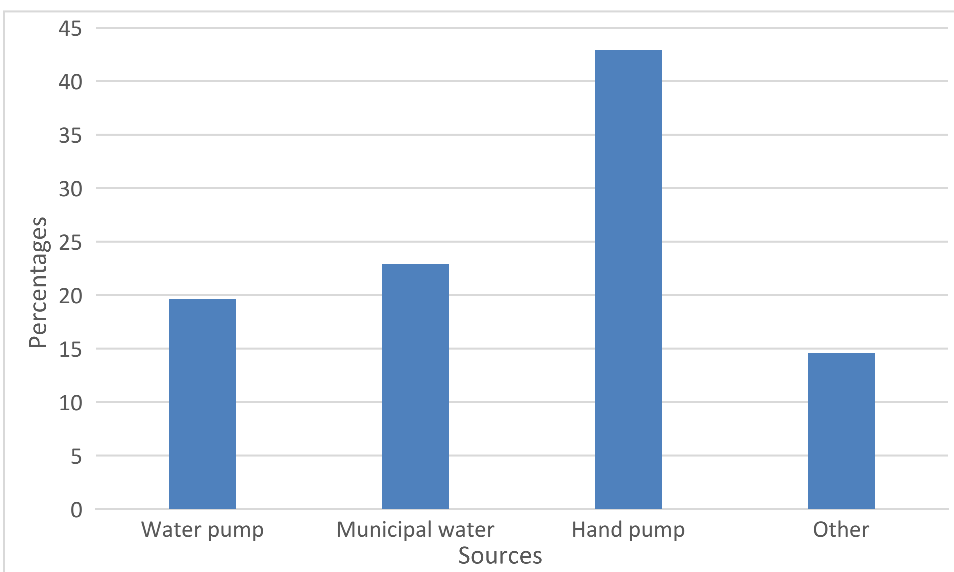

Fig 4.10: Primary source of drinking water in schools

The figure 4.10 shows that the primary source of drinking water in 42.85% of the schools was hand pumps, 22.9% municipal, 19.6% water pumps and 14.5% other sources.

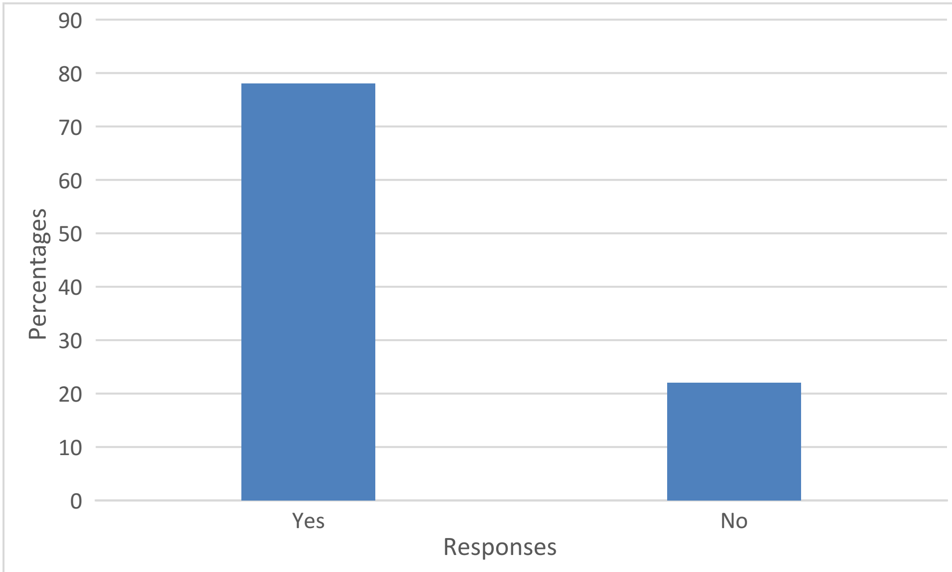

Fig 4.11: Satisfaction with the quality of water at school.

The figure 4.11 above shows the satisfaction level of parents with the quality of water consumed by their kids at schools. 78 % of the parents were satisfied with the quality of water while 22 % of the parents were not satisfied with quality of water.

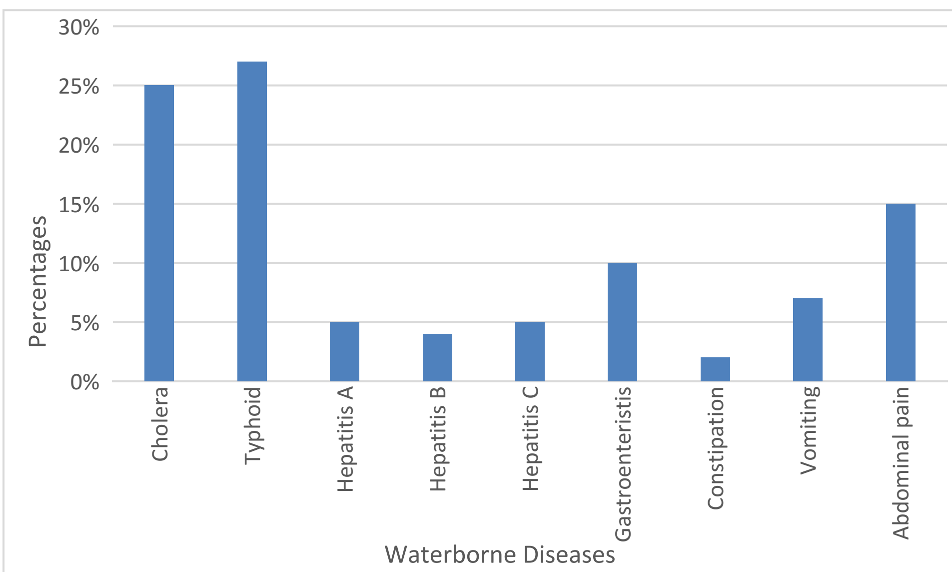

Fig 4.12: Percentages of students suffering from different waterborne diseases

The figure 4.12 shows the percentage of the waterborne diseases which the students may have contracted after the consumption of water at school. 3 % had suffered from the constipation, 4 %

had suffered from Hepatitis B, 5% from Hepatitis A and C, 7 % suffered from vomiting, 10 % of the children had the issue of gastroenteristis, 15 % had abdominal pain, 25% had cholera while 27 % of the children had suffered from the typhoid.

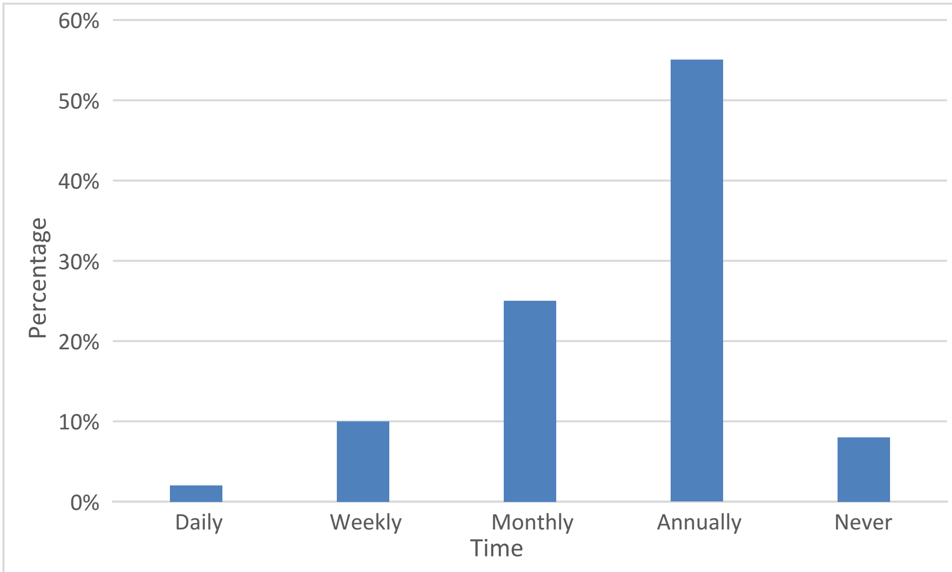

Fig 4.13: Percentages of drinking water quality testing at schools

The figure 4.13 shows the frequency of water quality testing at schools. According to the data, 55% of the schools tested quality of drinking water annually, 25% tested monthly, 10 % tested weekly, 2 % tested daily however, 8 % of the schools never tested their water quality.

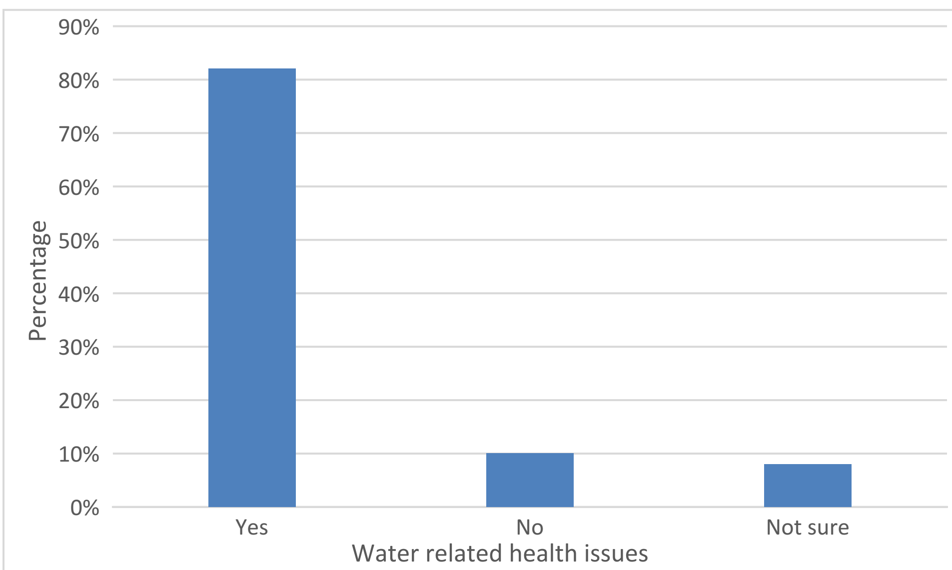

Fig 4.14: Percentages of water related health issues among students or staff

The figure 4.14 shows that 80% of the students and staff had suffered from water related health issues, 10 % of the respondents didn't suffer from the water related health issues while the rest of the respondents didn't suffer from any health issues.

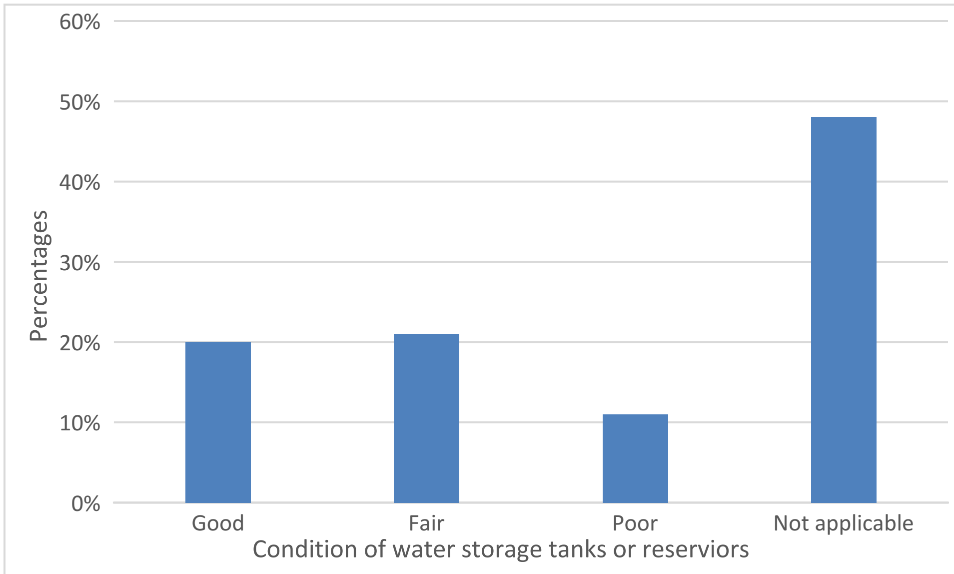

Fig 4.15: Percentages of condition of water storage tanks or reservoirs

The figure 4.15 shows the condition of the water storage tanks/reservoirs at the government primary schools in urban areas of Punjab. 20 % of the storage tanks were in good condition, 11 % had poor condition.

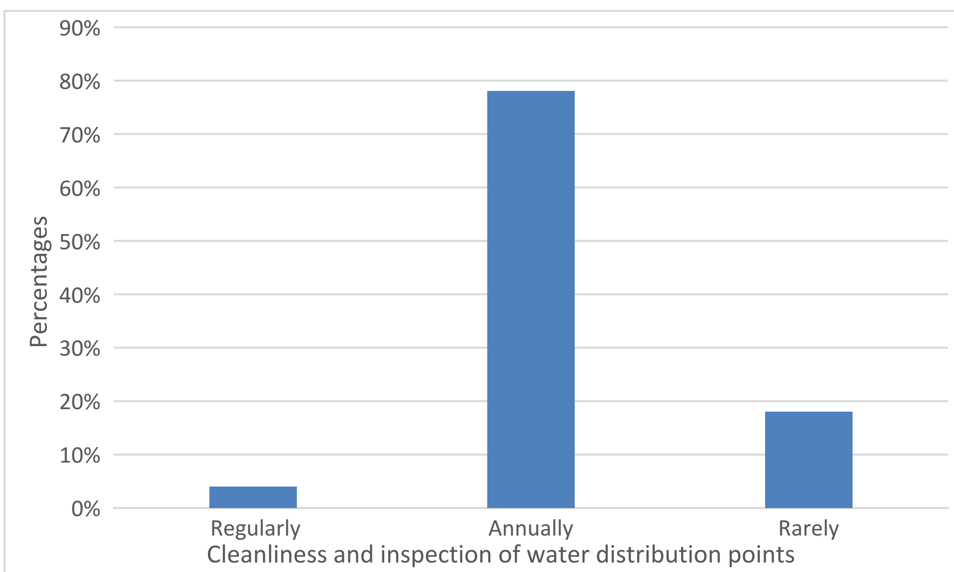

Fig 4.16: Percentages of cleanliness and inspection of water distribution points

The figure 4.16 shows the percentage of cleanliness and inspection of distribution points of drinking water. 79% of the schools cleaned and inspected the points annually, 19% of the schools rarely cleaned and inspected while 3% did it regularly.

4.8.3: Geospatial Mapping:

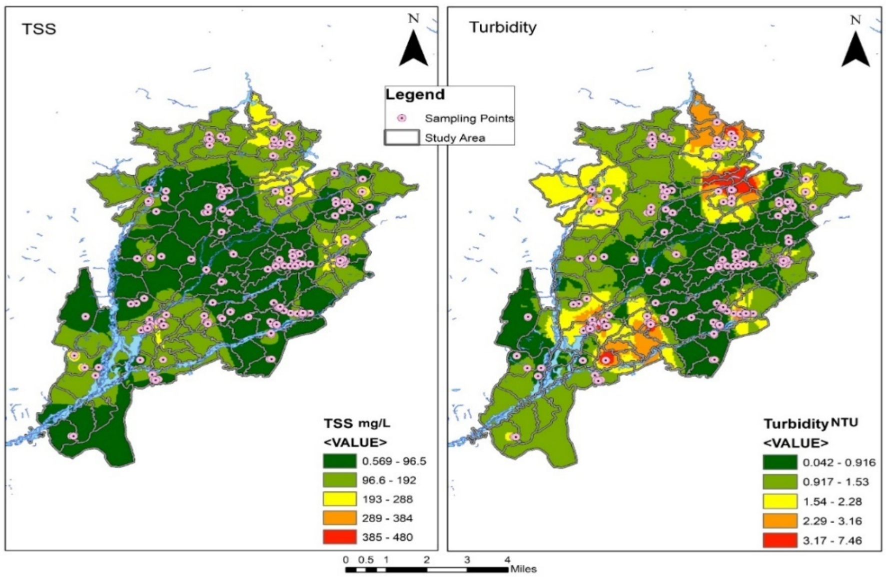

Fig 4.17: Map showing presence of TSS and Turbidity in samples

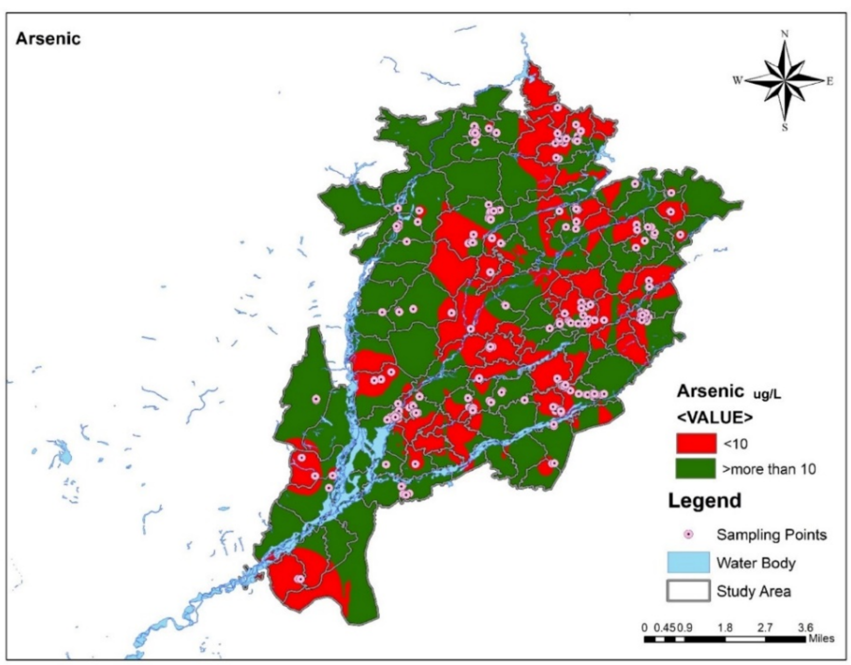

Fig 4.18: Map showing Arsenic concentration in schools

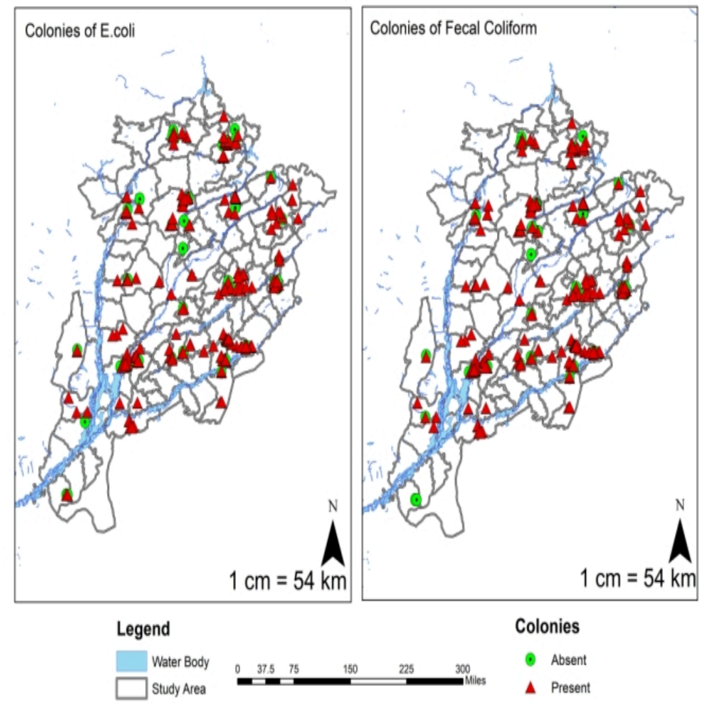

Fig: 4.19: Map showing bacteriological contamination in samples

Description of MAPS

The figure 4.17,4.18 and 4.19 presents a visual representation of the distribution of TSS (Total Suspended Solids), Turbidity, arsenic levels (exceeding 10 mg/L marked in red), and fecal coliform levels across the province of Punjab. The red shading in the arsenic map highlights concentrations notably surpassing the standard, with levels above 10 mg/L predominantly observed in central Punjab. This heightened concentration of arsenic poses significant concerns for water quality in the region.

In contrast, the condition regarding TSS and Turbidity showcases favorable ratings—classified as excellent and good, respectively—in central Punjab. However, certain areas in northern Punjab exhibit comparatively poorer conditions in terms of TSS and Turbidity, indicating potential water quality challenges in those regions. Additionally, the distribution of fecal coliform levels, though not highlighted, may further contribute to the overall assessment of water quality across the province.

4.9 Correlation between the physicochemical parameters

Table 4.9 shows the correlation between the physicochemical parameters.

Correlations

		pH	DO	TDS	EC	Hardness	Cl	Nitrate	Fluoride	Arsenic
pH		1	-.019	.145*	.143*	.026	-.075	-.118*	.097	0.63
DO		-.019	1	-.064	-.064	.014	-.010	.016	-.061	-.010
TDS		.145*	-.064	1	.984**	.052	.134*	-.049	.152**	.134*
EC		.143*	-.064	.984**	1	.044	.137*	-.034	.143*	.0.129*
Hardness		.026	.014	.052	.044	1	.206**	.163**	-.060	0.45
Cl		-.075	-.010	.134*	.137*	.206**	1	.221**	-.009	-.010
Nitrate		-.118*	.016	-.049	-.034	.163**	.221**	1	-.016	0.032
Flouride		.097	-.061	.152**	.143*	-.060	-.009	-.016	1	0.021
Arsenic		0.63	-.010	.134*	.0.129*	0.45	-.010	0.032	0.021	1

*. Correlation is significant at the 0.05 level (2-tailed).

CHAPTER V

DISCUSSION

Access to safe drinking water is undeniably a fundamental human right as it is the basic necessity for sustaining life and ensuring good health. However, this aspect is even more crucial for learners at schools to avoid contact with infectious diseases. Ground and surface water are considered as the primary sources of water in almost all parts of the world [60]. However, the quality of these water sources is often affected by various anthropogenic activities. When assessing the quality of drinking water, several physical and chemical parameters are taken into account to ensure the regulatory standards. Table 4.1 explicates the detailed analysis of physical parameters of all the collected samples of drinking water. The table shows the temperature values, color, odor, taste, turbidity levels, and values for total suspended solids found in the collected samples. 300 drinking water samples from primary schools in urban areas were collected across 36 different districts of Punjab.The collected water samples were analyzed to assess the quality of drinking water.

As per WHO 75% of the diseases in developing countries are primarily associated with contaminated drinking water. The quality of drinking water is determined by various physical, chemical, and biological parameters, therefore, they need to be addressed. The quantitative results of chemical parameters for water samples are shown in Table 4.3. The table explicates detected pH values, DO, EC, TDS, measured water hardness and concentrations of Cl, NO_3, and F^-.

The permissible limit for pH given by the WHO for drinking water is between 6.5 to 8.5. The measured pH for water samples ranged from 7 to 10. The observed pH ranged from moderate to high. The measured pH of majority of the samples were within the permissible limit, whereas, some values were observed to be higher than the permissible limit given by WHO. The water samples with higher detected pH values were mostly collected from the medical district and agricultural areas of Okara. Specifically, samples OKC41, OKC42, and OKC44 had pH values of 10.25, 9.49, 9.03. Neutral pH of drinking water ensures normal enzyme functions within the human body, therefore, quality control measures are important [61]. Similarly, for healthy metabolic processes, the amount of oxygen dissolved in water is another important parameter considered while assessing its quality. Oxygen concentration up to 100 mg/l is considered ideal in drinking water, whereas, if the concentration exceeds 100 mg/l, the water quality becomes relatively poor [62]. As shown in table 4.2, the observed DO levels of all the collected drinking water samples varied from 0.35 mg/l to 5.88 mg/l.

Electrical conductivity is defined as the measure of water's ability to conduct electricity, which is due the presence of dissolved salts and minerals in the water. The measured EC ranged from 187 μ/S to 2200 μ/S, showing noticeable variation. Higher EC values indicates higher concentration of dissolved ions.

Total dissolved solids indicate the amount of salts, minerals, organic material and metals dissolved in water. Water with TDS levels less than 100 mg/l is considered safe for drinking purposes. TDS values ranged from 119.68mg/l to 1408 mg/l, as shown in Table 4.3. The permissible limit set by WHO and NDWQS is 1000 mg/l. The majority of the measured TDS values were below the permissible limit, whereas 15.6 % of the samples exceeded the limit of 1000 mg/L.

Hardness of water refers to the total concentration of minerals, primarily calcium and magnesium, dissolved in water. Calcium and magnesium provide various benefits, but only if taken in right amounts, i.e., within the permissible limits [63]. Table 4.3 presents the measured water hardness values for all the collected samples and with ranging from a minimum detected value of 53 mg/l to a maximum of 690 mg/l. The majority of detected values were less than 500 mg/l, which is the permissible limit set by NDWQS.

Furthermore, the levels of NO_3 have also increased in our water resources due to the widespread use of inorganic fertilizers and the application of animal manure in agricultural areas. Nitrates in drinking water supplies can pose numerous health risks for both children and adults. The elevated levels of nitrates in drinking water can cause diseases such as blue baby, cancer, and bleeding of the spleen [64]. Table 4.3 also present the measured concentrations of chlorine, nitrates, and fluoride separately in the collected drinking water samples. The measured values ranged from 0.1 mg/l to 37.5 mg/l. All the values were below the limit set by WHO and NDWQS which is 50 mg/l.

Similarly, Cl and F^- also have a significant impact on the water quality index. Cl is normally used as a disinfectant and it is added to drinking water as chlorine gas, or sodium hypochlorite. However, their concentration in drinking water should not exceed 250 mg/l, as per the guidelines provided by the WHO and NDWQS. The measured concentration values for chlorine in drinking water samples ranged from 8 to 338 mg/l, which is within the permissible limit.

Furthermore, F^- plays a crucial role in growth and development of teeth and bone in body. Excess or less consumption of fluoride can have negative impacts on our bodies. Excess fluoride accumulation in body can cause bone fractures, tooth decay, and kidney damage. Therefore, it is advised to consume F^- at optimal level to avoid the adverse effects, which neither too less nor too much [65]. The measured concentration levels of fluoride in drinking water samples ranged from 0.1 mg/l to 7.2 mg/l, showing noticeable variation. The majority of the observed values were within the permissible limit set by the WHO and NDWQS, which is 1.5 mg/l. The highest levels of F^- concentration were detected in the water samples collected from residential and agricultural areas of Sialkot (SKT234, SKT235T - 6.7mg/l and 7.2 mg/l). Similarly, high levels of fluoride were observed in the water samples collected from Sahiwal, Attock, Jhelum, Okara, Multan, Lahore, Kasur and Faisalabad because these schools were located near the hospitals and industries. In Okara, most of the schools in urban area were close to the agricultural land.

Excessive amount of F^- in pregnant women can form a lipid soluble complex that can damage the fetal brain by crossing the blood barrier and can accumulate in the brain tissues of the new born. Therefore, it can affect the intelligence levels and reflexes of a newborn. Developmental disorders in the uterus of the pregnant women were also observed. Moreover, recent studies have reported that high intake of F^- for long term can also damage the central nervous system of children and adults both. In 2021, a study was conducted in Palu city to assess the influence of fluoride in drinking water, it's link with fluorosis, and how it affects the intelligence of children. For the analysis, 100 students aged between 6 to 12 years were observed from two different areas with varying levels of fluoride in their drinking water. As a result, 40 students were identified as suffering from fluorosis of these, 38 were from the area with high F^- in their drinking water, while 2 students were from the area with low F^- in their drinking water. Furthermore, 17 students residing in the areas with high fluoride in their drinking water were exhibited with low IQ levels. However, no student from the low F^- areas was found to have low a

IQ level. Among the students who didn't suffer from fluorosis, 96.6% of them had high IQ levels [66].

Table 4.1 shows the measured physical parameters of all the collected drinking water samples. The observed temperature values were between 18.5°C to 28.5°C. Temperature is one of the physio chemical factors used to determine the drinking water quality. Higher temperature values increase the demand for disinfectants and microbial activity, making it less favorable [67].

Turbidity is defined as the reduction in water clarity due to the presence of suspended matter absorbing or scattering the light, hence, plays a crucial role in the assessment of drinking water quality. According to the given guidelines by WHO and NDWQS, the ideal turbidity level for drinking water should be less than 5 NTU. Table 4.1 shows the measured turbidity levels of all collected samples with maximum value 12.52 NTU. Noticeable variation was observed in the turbidity levels of the collected samples from tap as compared to the samples collected from source directly. The samples exhibiting elevated levels of turbidity showed to have a significant effect on the color and taste of the water as well. As the water sample with 12.52 NTU turbidity was yellow in color whereas majority other samples were colorless, as per the basic property of safe drinking water. Whereas, some water samples were in pale yellow and light yellow color with muddy smell with turbidity levels between 8.22 NTU and 10.25 NTU, respectively. Spillage of sewage matter into the water resources increases the turbidity, which in turn raises the risk of pathogenic organisms that may escape the effect of added disinfectants [68].

Water distribution systems are responsible for delivering clean and safe drinking water to the consumers. However, having safe drinking water at the source doesn't guarantee the purity of the water at consumption points. Water can come in contact with various harmful pathogens or chemical between the source and the point where it is being consumed. In 2020, a study was conducted in a district area in Hanoi, Veitnam to assess the drinking water quality in schools. For analysis, 2 bottles of drinking water samples were collected from 154 schools and each water samples was analyzed for physiochemical and microbial parameters. Among physiochemical parameters, only one sample was found to have high turbidity level, i.e. 4.33 NTU. High levels of turbidity give water a cloudy appearance and reduce its palatability. Moreover, water with high turbidity levels become challenging to disinfect because microorganisms (bacteria, viruses, and protozoa) in turbid water tend to resist the added disinfectants as they effortlessly get attached to the particulates, thus indicating a greater chlorine demand [69].

Total suspended solids refers to the amount of solid particles present in water that do not dissolve in water. High levels of TSS in drinking water significantly affect the quality i.e. taste, color and odor of drinking water making it unsafe and unhygienic. Table 4.1 displays the measured TSS in collected water samples. Noticeable concentration of suspended solids were observed in majority of the water samples with the maximum TSS value in the samples collected from Vehari (670 mg/l), thus, reducing the palatability of the water.

The presence of suspended soluble matter in water can decrease the suitability of drinking water. High TSS values in water indicate high levels of carbonates and bicarbonates in water resulting in a cloudy appearance and increased salinity. In 2021 a study was conducted in the Swat, Mardan, Kohat and Peshawar districts of Khyber Pakhtunkhwa to assess the drinking water quality of the available water sources. Among all the provinces, Khyber Pakhtunkhwa is considered one of the most flood affected, distant and highly poverty stricken areas. These areas have remained least maintained and neglected areas in terms of the drinking water quality index. For analysis, a total of 50 water samples were collected from 4 different sources i.e., bore, bottle, wells, and taps from each province. Therefore, as a result, significant high TSS levels i.e. 9 ± 2.70 mg/Lwere observed in well water of Kohat. Whereas, in Peshawar for bottle water, the least TSS level was 2.2 ± 0.58 mg/L. Moreover, a high high trend of TSS level i.e. >7mg/L was observed in the samples collected from the well water of all the districts. Higher TSS values in well water in all the districts indicated that the well water is being exposed to contaminated sources. The study concluded that wells near the sewage areas, canals, and factory areas had higher concentration for total suspended solids in the samples compared to those in other areas [70]. Similarly, the TSS levels in this study were found to be highest in the samples collected from Vehari as the schools were in the commercial area and there were hospitals, schools and factories nearby.

Coliform bacteria are a group of bacteria that are usually found in the feces of warm blooded animals and humans. They are often used as indicators of water quality as their presence in water can signal potential fecal contamination which may also contain numerous harmful pathogens. Detection of coliform bacteria in drinking water supplies can be a serious health concern, as their presence can indicate conditions that might lead to waterborne diseases. Coliform bacteria include various species, however, Escherichia coli (E. Coli) is used as the primary indicator for monitoring of drinking water [71]. Table 4.5 explicates the attained results of microbiological contamination in the collected samples. Colonies of E. Coli and fecal coliform were detected in majority of the samples. Moreover, in some samples collected from Sahiwal, Pakpattan, Okara, Chichawatni, Mianwali, Khushab, Chakwal, Bhakkar, Lodhran, Khushaab, Khanewal, Nankanasahib, Kasur, Lahore, and Hafizabad, were severely contaminated with uncountable colonies of E. Coli and colonies of fecal coliform, i.e. SWL1, SWL11, SWL26, PKP29, OKC44, CWI50, MW71, KHB76, CKW94, BKR84 CKW99, LDH128, KWL152TK, KHB80T, MW80T, MUL183, NNS189, LHE201, KSR224, and HFD228. Presence of fecal coliform in drinking water signifies compromised water treatment system's efficiency. As per the WHO and NDWQS guidelines they should be absent (should be undetectable in any 100 ml sample) from the well treated plant effluents. Coliform bacteria are not considered as pathogens, as they are unlikely to cause severe illness. However, their presence in drinking water indicates the presence of infectious agents within the water system [72].

Samina khalid *al.* Conducted a study in in urban areas of Vehari, Mailisi, and Burewala to assess the assess the quality of drinking water. 41 samples were collected 35 from water pump and 6 from Tehsil Municipal Administration. As a result the presence of E coli. and colonies of coliform were detected in the 5 samples collected from the Tehsil Municipal Administration in three blocks as the ground water in these blocks was found to be contaminated pathogenic microbes and feces. Moreover, a survey was conducted in the selected Tehsils and as a results 48.6% of the respondents were not satisfied with their drinking water quality and 45.8% reported greater high disease development [73].

The quality of drinking water gets highly affected by the presence of these harmful organisms. In 2020, a study was conducted in Kabul to assess the drinking water quality in one of their most populated district. For analysis, the water samples were collected from 4 different sources, i.e., qanat, open well, tap water, and a hand pump. Bacteriological analysis indicated a high number of colonies for total coliforms and fecal coliforms. In the qanat water source samples, 55-189 colonies of TCF/100mL were observed. In the open well samples, 10-135 colonies of TCF/100mL were observed. In the tap water samples, 3-88 colonies of TCF/100mL were observed. Lastly, for the hand pump, the colonies ranged from 0-130 colonies of TCF/100mL. Similarly, noticeable contamination of fecal coliforms was also observed in all the collected

drinking water samples. The values ranged between 7 - 147 FCF/100 mL. In tap water samples, the range of 0 - 67 colonies of FCF/100 mL was detected, in open well samples, the values ranged between 7 - 20 colonies of FCF/100 mL. Furthermore, the results for hand pump water samples ranged between 0 - 122 colonies of FCF/100 mL. Major contamination was observed in warm season. Furthermore, improper waste disposal and expire corroded pipes were also contributing in deteriorating the quality of drinking water [74].
Leakage or discharge from septic tanks and improper solid waste disposal systems emerge as the primary factors contributing to the contamination of water resources. Water contaminated with even the slightest concentration of human or animal waste can cause diseases, such as typhoid, cholera, dysentery, hepatitis, and other illness intestinal infections [75].

In urban areas, the intensive extraction process and inefficient sewage disposal has deteriorated the ground water quality with detectable concentrations of contaminants, i.e. As, B, Ba, Cu, Fe, Li, Mn, Zn, Sr followed by high concentrations of oxides of Sulphur and magnesium ions. Exposure to these contaminants cause direct damage to the DNA in the human body, as proven and discussed in various studies [76].

Table 4.4 explicates the detected concentrations of As, in drinking water samples. Out of 150 samples, noticeable concentrations of arsenic were observed in 144 samples, with only 6 samples, collected from i.e., Sahiwal (SWL9, SWL10), Muzzafargarh (MZJ104), Rawalpindi (RWP140), Bahawalpur (BHW265S, BHW266), were free from arsenic. Among all the samples, the highest detected concentration for As was 67.21 µ/l, which is significantly higher than the guidelines provided by WHO and NDWQS, which is 10ug/l. Furthermore, during sample collection some water samples were collected from the municipal water supply at different schools, i.e. specifically from taps, whereas, majority of the other samples were collected directly from the tank. Hence, the analyzed results showed noticeable variations among the sample categories. Higher concentrations of As were detected from the samples that were specifically collected from the taps, while relatively lower values were detected in the samples collected directly from the source. Therefore, it seems that the water distribution system or the pipelines through which the water travels are not truly cleaned, ultimately leading to arsenic contamination.

Arsenic can enter groundwater through various routes, primarily through the natural route, where rock water interactions results in exchange of minerals that contain arsenic. Anthropogenic activities, including mining activities and the release of untreated industrial wastewater, can also contribute to the leaching of arsenic into groundwater [77]. Therefore, potentially toxic elements including As and Pb in water can be a leading cause of chronic obstructive pulmonary disease, peripheral neuropathy, myocardial infarction and stroke due to their long term exposure [78]. Moreover, the findings of recent studies elucidate miscarriages, still births and infant mortality in women with long term exposure to water contaminated with high concentrations of arsenic [79].

Table 4.6 presents data on exposure dose of arsenic, daily arsenic consumption, hazard quotient value and carcinogenic risk extent associated with exposure to water contaminated with arsenic. For cancer risk extent, the CR values ranged from 0.1863 to 7.787 across 36 districts of Punjab, which included 150 drinking water samples, respectively. The calculated CR values were significantly higher than the permissible limit of 6 to 10 set by USEPA. Therefore, the children being exposed to arsenic contaminated water are at risk of developing cancer [80].

In 2022, a study was conducted in Multan to assess the rising trend of arsenic in drinking water supply.The highest detected value of As was 75 µ/l, in Northern Bypass and Chungi no.8 and lowest observed value was 25 µ/l in Mumtazabad, which was still beyond the acceptable limit. The reason for high concentration of As in the mentioned areas was due the the presence of high amount of As in ground water. Moreover, the areas were surrounded major industries. Moreover, due to high amount of As in drinking water, stomach problems, skin issues and eye infections were observed in each house of these areas [81].

Arsenic in drinking water remains a public health concern as it's long term exposure is linked with numerous life threatening diseases. Recently, Daniela Nuvolone *et al.* conducted a study in Italy to study the effects of long term exposure to low level of arsenic in drinking water. For a comprehensive analysis, data from the past 5 years was collected from Mt. Amiata. The results concluded endocrine disorders, cardiovascular, respiratory diseases, heart failure, hypertension and cerebrovascular diseases among both men and women being exposed to long term arsenic concentrations in the range 5–10 µg/l. Furthermore cases of ischemic heart disease and prostate cancer have been shown to be associated with arsenic exposure through drinking water. However, it was concluded that there is high uncertainty due to the low number of cases. The survey further linked chronic exposure to moderate arsenic concentration with vascular inflammation, carotid plaques and endothelial dysfunction. Women exposed to arsenic, even below the standard limits, showed a higher risk of chronic obstructive pulmonary disease than men. In this study, various factors were thoroghly examined based on individuals' lifestyles and consistently found a strong association between arsenic exposure and all the outcomes [82].

In this research, wide range of physical, chemical and biological parameters were considered to determine the water quality. The obtained results were evaluated based on the standard limits. However,assessing the quality of drinking water and approving it for human consumption is not really an easy task. Therefore, the most effective way to analyze the water quality is the water quality index (WQI). In 1965, Horton invented the first ever water quality index to test the quality of drinking water, the system was further improved by several scientists. The water quality index (WQI) binds all the essential water quality data into a single quantitative number in a comprehensive manner. Over time, several water quality indexes have been developed to assess the quality of surface and subsurface water sources. Such as Nation Sanitation Foundation Water Quality Index (NSFWQI), the Canadian Council of Ministers of the Environment Water Quality Index (CCMEWQI), Weighted Athematic Water Quality Index (WAWQI) and much more [82].

Water Quality Index was calculated to assess the the quality of drinking water collected from various samples. The study includes physiochemical parameters of drinking water with varied results, while most being within the permissible standard limits. WQI results ranged from excellent to very poor. The calculated values of WQI were categorized into 4 categories as shown in Table 4.7. The calculated values ranging from 0-25 were classified excellent, values between 25-50 were considered good, values between 51-75 were considered fair, values between 76-100 were considered poor, values between 101-150 were considered very poor and values surpassing the 150, were deemed unsuitable for drinking. The results concluded that the WQI of majority samples ranged from excellent to and good. However, some WQI values varied between 101 to 200 indicating unsuitable for drinking. Most of these samples were collected from residential, agricultural areas and recreational spots. Moreover, samples Sahiwal (SWL5. SWL2, SWL3, SWL4TK, SWL4T, SWL5, SWL11), Okara (OKC41, OKC42, OKC43 OKC44, OKC45), Chichawatni (CWI51, CWI52, CWI53), Chakwal (CKW100), Rajanpur (RJP101), Muzzafargarh (MZJ103, MZJ104), Attock (ATC107 - ATC109), Lodhran (LDH128), Rawalpindi (RWP129- RWP133) were classified as having very poor water quality and unfit for drinking with unreasonably high WQI values.

To study the prevelance and exposure to different waterborne illnesses among the school going children of the study areas, a questionnaire survey was also conducted among all the schools from which the drinking water samples were collected. A total of 2800 questionnaire were filled out by the parents of on-going students of all schools. Two different types of questionnaires were used. The questionnaire A was filled out by students and their parents of grade 1 to 5, whereas, the questionnaire B was filled out by school management. The questionnaire A included a variety of questions based on the students' intake of drinking water from school, quality of water, presence of water filters in schools, and the health conditions linked to water consumption. Whereas, the questionnaire B was based on the school information, primary sources of water, cleanliness of tanks or reservoirs and water treatment systems.

The results collected from the respondents indicated that the water filters were present in 55% of the schools, while 25% of the studied campuses did not have a water filtration system. 20% of the respondents were unsure about the presence of water filters in their child's school. The primary source of drinking water in 42.85% of the schools was hand pumps, 22.9% municipal supply, 19.6% had water pumps and 14.5% other sources, that were not specified, as shown in figure 4.10. Therefore, 78% of the parents were satisfied with the quality of water their children consume, while 22% parents weren't satisfied with the drinking water quality being consumed in schools, as shown in figure 4.11.

Two questions were added to the questionnaire regarding the health of students who consume drinking water within the school premises. The question was designed to determine if they have ever gotten sick from consuming water from the school and the second question was aimed to identify the types of waterborne diseases they may have contracted. Therefore, the results concluded, as shown in figure 4.12, that 25% of the students who regularly consumed water from the school had suffered from cholera, 27% had suffered from Typhoid, 5% suffered from hepatitis A, 4% from hepatitis B and 5% from hepatitis C. The results further concluded, 10% of students had suffered from gastroenteritis. Additionally, 7% of students were found vomiting after consuming the water from school, while, 15% of students experienced from abdominal pain. In conclusion, as shown in figure 4.14, 80% of the students and staff members were found to have water related issues, while 10% of the students and staff members were not found to have any prominent water related health issues. Additionally, 10% were unsure if any of their health condition was linked to water quality.

The next question was structured to assess how frequently the water quality was being tested at the selected primary schools in Punjab. The results from the respondents concluded, as shown in the figure 4.13, that 55% of the schools were found to annually test their drinking water quality. Additionally, 25% of schools were found to monthly test their drinking water quality. While, 10% of schools got their water quality tested weekly, while, only 2% of schools get their drinking water quality tested on a daily basis. However, 8% of schools never get their drinking water quality tested.

Furthermore, in order to conduct a comprehensive analysis, the next question was designed to assess the condition of water storage tanks or reservoirs. As shown in figure 4.15, The condition of water storage tanks or reservoirs in 20% of the schools was good or fair. While 11% of the schools had poor sanitary conditions for their water storage tanks or reservoirs. However, alarmingly, the condition of water storage tanks or reservoirs in 48% of the schools was not acceptable. Similarly, the next question was designed to assess the cleanliness and inspection of water distribution points. The results, as shown in figure 4.16, concluded that in 79% of the schools, water distribution points were inspected and thoroughly cleaned on an annual basis. Whereas, it was found that 19% of the schools rarely check and clean their water distribution points and only 3% schools were found to have their water distribution points inspected and cleaned on a regularly.

The correlation table 4.9 provides a comprehensive insight into the interrelationships among various water quality parameters. pH demonstrates a moderate positive correlation with Total Dissolved Solids (TDS) (0.145*) and Electrical Conductivity (EC) (0.143*), suggesting a tendency for pH levels to moderately increase as TDS and EC rise. However, these correlations, while statistically significant, indicate a relationship of moderate strength. Dissolved Oxygen (DO) exhibits negligible correlations with other factors, signifying its relative independence from the measured variables. Notably, the exceptionally high positive correlation between TDS and EC (0.984**) underscores their strong association and mutual dependence in water quality assessments. The interplay between Total Dissolved Solids (TDS), Electrical Conductivity (EC), and pH in water quality assessments presents a complex relationship, often influenced by the mineral content and dissolved substances within water bodies. Studies, including one conducted in Dhaka in 2017, have shown positive correlations between TDS, conductivity, and pH levels in water samples. Elevated TDS levels, indicative of increased mineral content, tend to correspond with higher conductivity due to the greater presence of dissolved ions. This heightened conductivity often coincides with higher pH values, leading to more alkaline water conditions. However, it's crucial to note that while TDS can impact pH, the relationship is not universally consistent. Various factors beyond TDS, such as the presence of specific ions or organic matter, can also influence pH levels independently. These nuances highlight the multifaceted nature of water quality dynamics. Regions characterized by high groundwater mineralization often exhibit these correlated patterns among TDS, EC, and pH. Understanding these relationships is crucial for effective water quality monitoring and management, providing valuable insights into the overall health and composition of water sources [83].Hardness displays moderate positive correlations with Chlorine (Cl) (0.206**) and Nitrate (0.163**), suggesting a simultaneous increase tendency alongside these parameters. Chlorine and Nitrate also exhibit a notable positive correlation (0.221**), indicating their concurrent rise in water samples. The correlation table provides a comprehensive insight into the interrelationships among various water quality parameters. pH demonstrates a moderate positive correlation with Total Dissolved Solids (TDS) (0.145*) and Electrical Conductivity (EC) (0.143*), suggesting a tendency for pH levels to moderately increase as TDS and EC rise. However, these correlations, while statistically significant, indicate a relationship of moderate strength. Dissolved Oxygen (DO) exhibits negligible correlations with other factors, signifying its relative independence from the measured variables. Notably, the exceptionally high positive correlation between TDS and EC (0.984**) underscores their strong association and mutual dependence in water quality assessments. The interplay between Total Dissolved Solids (TDS), Electrical Conductivity (EC), and pH in water quality assessments presents a complex relationship, often influenced by the mineral content and dissolved substances within water bodies.

The analysis, referenced in Figures 4.17, vividly delineates the variegated water quality profiles prevailing across Punjab's regions. Figures 4.17 unmistakably portray stark differences in Total Suspended Solids (TSS) and Total Dissolved Solids (TDS), evidencing higher concentrations in the northern and southern territories in contrast to the relatively lower levels observed in central Punjab. This divergence likely stems from a combination of geological disparities, distinct land use practices such as intensive agriculture or industrial activities, and differential water management strategies among these regions.

Moreover, the maps detailing arsenic distribution in figure 4.18 accentuate elevated arsenic content predominantly within the northern and southern areas, albeit with sporadic hotspots in central Punjab. These discrepancies could be attributed to specific geological formations, industrial discharges, or agricultural practices contributing to arsenic mobilization. The visual representations serve as a compelling call for region-specific interventions, underscoring the urgency to address the heightened TSS, TDS, and arsenic levels in the northern and southern sectors. Tailored remedial actions aimed at mitigating these water quality concerns are imperative to ensure equitable access to safe drinking water and to foster sustainable environmental practices across Punjab's diverse landscape.

CONCLUSION

The study aimed to assess the drinking water quality in primary schools of Punjab, by looking at physical, chemical and bacteriological parameters of drinking water. The drinking water samples were collected from the water supply sources of all the selected schools. The findings revealed that majority of the water quality parameters were within the permissible limits of WHO and NDWQS. The observed pH, EC, TDS, hardness, NO3, Cl and F^- are among them. Turbidity levels ranged between 8.22 NTU and 10.25 NTU. High TSS were also observed in majority of the water samples with the maximum TSS value, 670 mg/l. In addition, colonies of E. Coli and fecal coliform were detected in majority of the samples. Moreover, in some samples colonies of E. Coli and colonies of fecal coliform were uncountable, i.e. SWL1, SWL11, SWL26, PKP29, OKC44, CWI50, MW71, KHB76, CKW94, BKR84 CKW99, LDH128, KWL152S, KHB80T, MW80T, MUL183, NNS189, LHE201, KSR224, and HFD228. Similarly, out of 150 samples, noticeable concentrations of arsenic were observed in 144 samples, with only 6 samples, collected from i.e., Sahiwal (SWL9, SWL10), Muzzafargarh (MZJ104), Rawalpindi (RWP140), Bahawalpur (BHW265TK, BHW266), were free from arsenic. Higher concentrations of arsenic were detected from the samples that were specifically collected from the taps. Therefore, it seems that the water distribution system or the pipelines through which the water travels are not truly cleaned. For cancer risk extent, the CR values ranged from 0.1863 µ/l, to 7.787 µ/l, across 36 districts of Punjab. The calculated CR values were significantly higher than the permissible limit of 6-10 set by USEPA. Moreover, the results of the questionnaire survey also indicated that 52% of the students were suffering from cholera and typhoid while, 46% were suffering from other waterborne diseases. To conclude, it was found that over 90% of schools were negligent in inspecting and maintaining cleanliness of their water distribution points. This negligence is probably the root cause of the water contamination in the collected samples. Hence, regular monitoring of water distribution points is essential.

RECOMMENDATIONS

- Schools, should conduct a comprehensive survey, to determine whether to install filters at point of entry (to treat all water entering the building) or point of use (to treat water coming out from a specific location), based on their specific requirements.
- All schools should effectively adopt the water filtration systems based on the specific water quality concern, for example, activated carbon filters are used to target different types of chemicals.
- Regular monitoring of water quality should be conducted and inspection of water storage tanks must be done monthly.
- Government and non-government agencies should step forward with water supply projects by delivering safe drinking water to all the schools.

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ANNEXURE I

Questionnaire A

Water quality assessment and evaluation of human health risk of drinking water in children of urban primary schools

Section 1

Name: ______________________

Gender

1.Male

2. Female

Age (in years)

1. 1-5

2. 5-10

3. 11-16

Level of education

1. Grade 1

2. Grade 2

3. Grade 3

4. Grade 4

5. Grade 5

Weight (in kg)

20-30

30-40

40-50

Section 2:

Are the drinking water access points that are available to students clean and operating properly?

1. Yes

2. No

What is your child's average daily intake of water?

1. ½ litre

2. 1 litre

3. 1 ½ litre

4. 2 litre

5. More than 2 litre

Are there water filters in your child's school?

1. Yes

2. No

3. Don't know

Are you satisfied with the quality of water your kid consumes at school?

1. Yes

2. No

Do you think your child can get sick from the water they drink at school?

1.Yes

2. No

Which of the following diseases has your child experienced? (You can choose more than one)

1. Cholera

2. Typhoid

3. Hepatitis A

4. Hepatits B

5. Hepatitis C

6. Gastroenteristis

7. Constipation

8. Vomiting

9. Abdominal pain

How often does your child get sick?

a) Once a week

b) Once a month

c) twice a month

Table 4.8 shows response of parents whose children study at government primary schools.

	Variable	Frequency
Gender	Male Female	1592 1208
Age (In years)	1-5 5-10 11-16	800 1360 640

Level of Education	Grade 1 Grade 2 Grade 3 Grade 4 Grade 5	250 340 923 750 537
What is the primary source of drinking water in your kid's school?	Water pump Municipal water Hand pump Other	550 642 1200 408
Are the drinking water access points that are available to students clean and operating properly?	Yes No	1543 1257
What is your child's average daily intake of water?	½ litre 1 litre 1 ½ litre 2 litre More than 2 litre	45 2490 166 90 9
Are there water filters in your child's school?	Yes No Don't know	1540 700 560
Are you satisfied with the quality of water your kid consumes at school?	Yes No	2184 616
Do you think your child can get sick from the water they drink at school?	Yes	2348 452

	No	
Which of the following diseases has your child experienced?	Cholera Typhoid Hepatitis A Hepatits B Hepatitis C Gastroenteristis Constipation Vomiting Abdominal pain	700 750 138 109 133 275 79 196 420
How often does your child get sick?	Once a week Once a month Twice a month	675 1085 1040

Questionnaire B

School Information:

School Name:____________________________________

School
Address:____
____
____

School Contact Information (Phone, Email):

1.What is the Primary source of drinking water?

Municipal supply

Waterpump

Handpump

Other (please specify): ________

2.Is the water supplied regularly without interruptions?

Yes

No

Sometimes (please specify any issues):

3.Does the school store water in tanks or reservoirs?

Yes

No

4.How often are the tanks or reservoirs cleaned and maintained?

Regularly

Annually

Rarely

Not sure

5.Are there any water treatment systems in place?

Yes

No

6. How often is the drinking water quality tested at the school?

Daily

Weekly

Monthly

Annually

Never

7.Have there been any reports of water-related health issues among students or staff?

Yes

No

Not sure

8.Describe the condition of the water storage tanks or reservoirs:

Good

Fair

Poor

Not applicable

9.How often are the drinking water distribution points cleaned and inspected?

Regularly

Annually

Rarely

10.Are there any visible signs of water quality issues?

Yes

No

Table 4.9 shows the response of headmasters of government primary schools

	Variable	Frequency
What is the Primary source of drinking water?	Water pump Municipal water Hand pump Other	45 72 92 91
Is the water supplied regularly without interruptions?	Yes No Sometimes	212 88 0
Does the school store water in tanks or reservoirs?	Yes No	154 146
How often are the tanks or reservoirs cleaned and inspected?	Regularly Annually Rarely	9 234 57
How often is the drinking water quality tested at the school?	Daily Weekly Monthly Annually Never	6 30 52 137 21
Have there been any reports of water-related health issues among students or staff?	Yes No Not sure	240 30 30
Are there any water treatment systems in place?	Yes No	300 0
Describe the condition of the water storage tanks or reservoirs?	Good Fair Poor Not applicable	60 66 33 141
Are there any visible signs of water quality issues?	Yes No	6 294

ANNEXURE II

Sampling locations of selected area

Table 3.1: Geographical coordinates and sampling locations of Selected Areas

Sr #	Sample code	Source	Longitude	Latitude	Site description	School name	City
1	SWL 1	Tap	E 73°06'51"	N 30°39'36"	Residential Area	GPS FAIZA E AAM SAHIWAL	Sahiwal
2	SWL2	Tap	E 73°06'25"	N 30°39'03"	Commercial Area	GPS SHARQIA RIZVIA	Sahiwal
3	SWL3	Tap	E 73°06'42"	N 30°40'16"	Commercial Area	GPS MC FATEH SHER	Sahiwal
4	SWL4T	Tap	E 73°06'19"	N 30°37'26"	Transportation Hub	GPS MC BRANCH J SAHIWAL	Sahiwal
5	SWL4TK	Tank	E 73°06'30"	N 30°39' 25"	Residential Area		Sahiwal
6	SWL5	Tap	E 73°05'32"	N 30°39'48"	Recreational Spot	GPS MC CAPT. JAIL ROAD	Sahiwal
7	SWL6	Tap	E 73°06'45"	N 30 °39'54"	Commercial Area	GPS MC BRANCH D SAHIWAL	Sahiwal
8	SWL7	Tap	E 73°06'35"	N 30°40'04"	Administrative centre	GPS MC BRANCH A SAHIWAL	Sahiwal
9	SWL8	Tap	E 73°04'46"	N 30°40'42"	Government offices	GPS MC BRANCH R SAHIWAL	Sahiwal
10	SWL9	Tap	E 73°06'31"	N 30 °39'51"	Commercial Area	GPS MC BRANCH B SAHIWAL	Sahiwal
11	SWL10	Tap	E 73°06'14"	N 30°41'12"	Shrines complex	GPS JAMIA RASHIDIA NO.2	Sahiwal
12	SWL11	Tap	E 73°06'34"	N 30°40'57"	Residential Area	GPS KOT ALLAH DIN NO.1	Sahiwal
13	SWL12T	Tap	E 73°07'23"	N 30°40'18"	Residential Area	GPS MILLAT SAHIWAL	Sahiwal
14	SWL12TK	Tank	E73 °07'15"	N 30 °40'11"	Residential Area		Sahiwal
15	SWL13	Tap	E73 °07'23"	N 30 °39'55"	Medical district	GPS NOOR UN-NABI	Sahiwal
16	SWL14	Tap	E 73°07'01"	N 30°39'30"	Residential Area	GGPS GARDEN TOWN SAHIWAL	Sahiwal
17	SWL15	Tap	E73 °00'46"	N 30°41'43"	Commercial Area	GGPS CHOWK YADGAR	Sahiwal

						SAHIWAL CITY	
18	SWL16	Tap	E 73°07'41	N 30°40'03"	Residential Area	GGPS MC NO.15	Sahiwal
19	SWL17	Tap	E 73°03'48"	N 30°44'11"	Commercial Area	GGPS MC NO.13 MOHALLA RAJPUR	Sahiwal
20	SWL18	Tap	E 73°05'48"	N 30°39'32"	Recreational Spot	GGPS MC NO.11	Sahiwal
21	SWL19	Tap	E 73°06'52"	N 30°39'57"	Commercial Area	GGPS MC NO.10 CHAMAN ZAR	Sahiwal
22	SWL20	Tap	E 73°06'04"	N 30°39'21"	Medical district	GGPS MC NO.6 SAHIWAL	Sahiwal
23	SWL21	Tap	E 73°06'19"	N 30°39'33	Commercial Area	GGPS MC NO.5	Sahiwal
24	SWL22	Tap	E 72°55'33"	N 30°43'56"	Residential Area	GGPS ALLWAL COLONY	Sahiwal
25	SWL23	Tap	E 73°06'31"	N 30°40'46"	Religious zone	GGPS MAO PUBLIC SWL	Sahiwal
26	SWL24	Tap	E 73°07'08"	N 30 °40'56"	Recreational Spot	GGPS KOT ALLAH DIN NO.2	Sahiwal
27	SWL25	Tap	E73 °05"58	N 30°41'21"	Cattle farm	GGPS KOT KHADIM ALI	Sahiwal
28	SWL26	Tap	E 72°54'31"	N 30°42'01"	Agricultural area	GGPS AGRI FARM	Sahiwal
29	PKP27	Tap	E 73°22'18"	N 30°21'19"	Commercial Area	GPS AZIZ ABAD BASTI	Pakpattan
30	PKP28	Tap	E 73°22'45"	N 30°22'03"	Residential Area	GPS BASTI ASLAM NOI PAKPATTAN	Pakpattan
31	PKP29	Tap	E 73°17'33"	N30°20'50"	Commercial Area	GPS MADAY SHAH	Pakpattan
32	PKP30	Tap	E 73°23'45"	N 30°21'29"	Shrine complex	GPS Fareed Nagar	Pakpattan
33	PKP31	Tap	E 73°16'23"	N 30°25'19"	Medical district	GGPS ADDA MALKA HANS	Pakpattan
34	PKP32	Tap	E 73°14'38"	N 30°25'33"	Commercial Area	GGPS MOHALLAH FAREED NAGAR	Pakpattan
35	PKP33	Tap	E73°23'59"	N 30°20'39"	Commercial Area	GGPS MC NO. 3 PIR KOT PAKPATTAN	Pakpattan
36	PKP34	Tap	E 73°23'37"	N 30°20'04"	Civil lines	GGPS MC NO. 2 SOFIA ABAD	Pakpattan
37	PKP35	Tap	E 73°24'21"	N 30°18'06"	Industrial area	GGPS BASTI GIRJA GHAR	Pakpattan
38	PKP36	Tap	E 73°23'09"	N 30°20'15"	Residential Area	GPS PIR KOT PAKPATTAN	Pakpattan
39	OKC37	Tap	E 73°19'37"	N 30°58'40"	Agricultural area	GPS THATHA SYEDAN	Okara
40	OKC38	Tap	E 73°27'20"	N 30°47'46"	Commercial Area	GPS SIDDIQUE NAGAR	Okara
41	OKC39	Tap	E 73°25'55"	N 30°48'49"	Agricultural area	GPS SABRI COLONY	Okara
42	OKC40T	Tap	E73°24'44"	N30°51'04"	Government	GPS AZEEM ABAD , OKARA	Okara

					offices		
43	OKC40TK	Tank	E 73°25'17"	N 30°49'20"	Government offices		Okara
44	OKC41	Tap	E 73°10'50"	N 31°17'00"	Medical district	GPS TELEEM-UL-ISLAM	Okara
45	OKC42	Tap	E 73°32'51"	N 31°02'59"	Agricultural area	GGPS SHER KAY BALA	Okara
46	OKC43	Tap	E 73°26'56	N 30°49'09"	Residential Area	GGPS MODEL TOWN	Okara
47	OKC44	Tap	E 73°26'55"	N30°49'13"	Residential Area	GGPS GHAFOOR COLONY OKARA	Okara
48	OKC45	Tap	E 73°26'49"	N 30°49'01"	Recreational Spot	GGPS FATEH NOOR TOWN	Okara
49	OKC46T	Tap	E 73°27'44"	N 30°49'29"	Commercial Area	GGPS FAISAL MEHMOOD COLONY	Okara
50	OKC46TK	Tank	E 73°29'00"	N 30°51'02"	Residential Area		Okara
51	CWI47	Tap	E 72°41'00"	N 30°31'36"	Cattle market	GPS MALL MANDI CCI	Chichawatni
52	CWI48	Tap	E 72°42'06"	N 30°31'31"	Commercial Area	GPS BASTI BOSAN	Chichawatni
53	CWI49	Tap	E 72°41'12"	N 30°31'21"	Residential Area	GPS HOUSING COLONY	Chichawatni
54	CWI50	Tap	E72°40'44"	N 30°31'28"	Residential Area	GPS EK MINAR BLOCK NO.18	Chichawatni
55	CWI51	Tap	E 72°41'10"	N 30°31'51"	Administrative centre	GPS MC NO. 2 BLOCK NO.2	Chichawatni
56	CWI52	Tap	E 72°41'18"	N 30°31'49"	Recreational Spot	GPS MC NO. 4 CHICHAWATNI	Chichawatni
57	CWI53	Tap	E 72°41'45"	N 30°31'59"	Judicial Complex	GPS MC NO. 3 CHICHAWATNI	Chichawatni
58	CWI54	Tap	E 72°40'59"	N 30°31'43"	Religious zone	GPS MC NO. 5 CHICHAWATNI	Chichawatni
59	CWI55	Tap	E 72°40'22"	N 30°32'41"	Grain market	GPS MC NO.1 CWI	Chichawatni
60	CWI56	Tap	E72°42'12"	N 30°30'59"	Agricultural area	GGPS HAYAT ABAD CHICHAWATNI	Chichawatni
61	SGD57	Tap	E 72°39'49"	N 32°06'11"	Industrial area	GPS NOON SUGAR MILL SHAH TOWN	Sargodha
62	SGD58	Tap	E 72°54'59"	N 32°16'10"	Industrial area	GPS MADRISA TUL ISLAMIA AL-FAZAL TOWN	Sargodha
63	SGD59	Tap	E 72°53'47"	N 32°16'05"	Residential Area	GPS SANROORIA BHALWAL IJAZ COLONY	Sargodha
64	SGD60	Tap	E 72°40'49"	N 32°05'15"	Railway Station	GPS MC OLD CIVIL LINE SARGODHA	Sargodha

65	SGD61	Tap	E 72°39'12"	N 32°04'54"	Commercial Area	GPS MC BLOCK NO.5 SARGODHA	Sargodha
66	SGD62	Tap	E 72°43'25"	N 32°02'24"	Recreational Spot	GPS MC CITY GROUND SARGODHA	Sargodha
67	SGD63	Tap	E 72°39'31"	N 32°06'16"	Residential Area	GPS MC MUHAMMADIA COLONY	Sargodha
68	SGD64T	Tap	E 72°41'24"	N 32°05'35"	Industrial area	GPS MC NO. 11 FACTORY AREA	Sargodha
69	SGD64TK	Tank	E 72°41'17"	N 32°04'53"	Residential Area		Sargodha
70	SGD65	Tap	E 72°41'08"	N 32°04'41"	Residential Area	GPS IQBAL KOT FARID	Sargodha
71	MW66	Tap	E 71°32'30"	N 32°57'54"	Residential Area	GPS KAREEM ABAD KALABAGH	Mianwali
72	MW67	Tap	E 71°33'15"	N 32°57'51"	Commercial Area	GPS NO. 1 KALA BAGH	Mianwali
73	MW68	Tap	E 71°31'22"	N 32°34'35"	Religious zone	GPS MC MUSLIM BAZAR	Mianwali
74	MW69	Tap	E 71°31'07"	N 32°34'19"	Residential Area	GPS MC MOHALLAH MIANA	Mianwali
75	MW70T	Tap	E 71° 31'58"	N 32°34'42"	DHQ	GPS MC GAU SHALA	Mianwali
76	MW70TK	Tank	E 71°31'55"	N 32°34'38"	Residential Area		Mianwali
77	MW71	Tap	E 71°34'46"	N 32°38'06"	Residential Area	GPS MC WANDHI WALI MOHAMMAD KHAN	Mianwali
78	MW72T	Tap	E 71°32'09"	N 32°36'04"	Commercial Area	GPS MC GALI BANK	Mianwali
79	MW72S	Tank	E 71°34'00"	N 32°35'49"	Commercial Area		Mianwali
80	MW73	Tap	E 71° 31'57"	N 32°35'43"	Central Jail	GPS MC CENTRAL JAIL	Mianwali
81	MW74T	Tap	E 71°32'12"	N 32°33'54"	Recreational Spot	GGPS WATTA KHEL NO.1	Mianwali
82	MW75TK	Tank	E 71°31'52"	N 32°36'58"	Residential Area		Mianwali
83	KHB76	Tap	E 72°15'51"	N 32°16'44"	Residential Area	GPS RAMZAN COLONY JOUHARABAD	Khushab
84	KHB77	Tap	E 72°21'12"	N 32°17'56"	Agricultural area	GPS ALKOSAR TAJPURA	Khushab
85	KHB78	Tap	E 72°20'01"	N 32°18'20"	Commercial Area	GPS BADLI WALA	Khushab
86	KHB79	Tap	E 72°20'34"	N 32°17'43"	Residential Area	GPS ISLAM PURA KUSHAB	Khushab
87	KHB80T	Tap	E 72°21'30"	N 32°17'50"	Residential Area	GPS JAMIA NOOR UL ISLAM	Khushab
88	KHB80TK	Tank	E 72°19'51"	N32°18' 24"	Residential Area		Khushab
89	KHB81	Tap	E 72°20'56"	N 32°17'45"	Medical district	GGPS DHOK BALAL KHB	Khushab

90	KHB82T	Tap	E 72°21'07"	N 32°17'02"	Shrines complex	GGPS DILDAR HUSSAIN BALOUCH	Khushab
91	KHB82TK	Tank	E 72°20'59"	N 32°17'33"	Residential Area		Khushab
92	KHB83	Tap	E 72°21'48"	N 32°26'56"	Government offices	GPS PEERHA KALWAL	Khushab
93	BKR84	Tap	E 71°09'59"	N 31°35'11"	Residential Area	GPS MOHALLA MALKAN WALA	Bhakkar
94	BKR85T	Tap	E 71°03'42"	N 31°37'58"	Commercial Area	GPS BHAKKAR NO 1	Bhakkar
95	BKR85TK	Tank	E 71°03'36"	N 31°38'14"	Commercial Area		Bhakkar
96	BKR86T	Tap	E 71°03'44"	N 31°37'06"	Railway Station	GPS BHAKKAR RAILWAY STATION	Bhakkar
97	BKR87TK	Tank	E 71°03'48"	N 31°37'00"	Recreational Spot		Bhakkar
98	BKR88	Tap	E 71°05'11"	N 31°39'06"	Commercial Area	GGPS DHANDHLA BHAKKAR	Bhakkar
99	BKR89	Tap	E 71°01'48"	N 31°36'11"	Medical Complex	GGPS CHRISTIAN COLONY	Bhakkar
100	BKR90	Tap	E 71°03'48"	N 31°36'17"	Commercial Area	GGPS ALAM ABAD NO.2	Bhakkar
101	CKW91	Tap	E 72°52'03"	N 32°56'52"	Agricultural area	GPS ASHRAF TOWN 3-MARLA SCHEME	Chakwal
102	CKW92	Tap	E 72°51'21"	N 32°55'36"	Residential Area	GGPS MC NO. 3 CHAKWAL	Chakwal
103	CKW93	Tap	E 72°51'02"	N 32°56'22"	Railway Station	GGPS MC NO.1 CHAKWAL	Chakwal
104	CKW94	Tap	E 72°48'54"	N 32°54'44"	Commercial Area	GGPS MC NO.5 CHAKWAL	Chakwal
105	CKW95	Tap	E 72°50'50"	N 32°55'40"	Recreational Spot	GGPS MC NO. 2 COMMITTEE BAGH	Chakwal
106	CKW96	Tap	E 71°58'11"	N 32°54'58"	Agricultural area	GPS LAWA WEST	Chakwal
107	CKW97	Tap	E 71°56'04"	N 32°41'53"	Residential Area	GPS LAWA EAST	Chakwal
108	CKW98	Tap	E 73°02'20"	N 32°53'09"	Residential Area	GPS KUND MIAN MUHAMMAD	Chakwal
109	CKW99	Tap	E 72°52'04"	N 32°55'47"	Residential Area	GGPS EID GAH LAWA NO.3	Chakwal
110	CKW100	Tap	E 72°45'14"	N 32°54'18"	Residential Area	GGPS MOHALLA FAROOQI CHAKWAL	Chakwal
111	RJP101	Tap	E 70°36'33"	N 29°44'55"	Commercial Area	GGPS QASAI WALA	Rajanpur
112	RJP102	Tap	E 70°20'07"	N 29°06'59"	Transportation Hub	GGPS RAILWAY COLONY RAJANPUR	Rajanpur

113	MZJ103	Tap	E 70°52'49"	N 29°30'07"	Residential Area	GPS NO. 2 JATOI	Muzafargarh
114	MZJ104	Tap	E 70°57'00"	N 29°45'10"	Residential Area	GGPS CANAL COLONY	Muzafargarh
115	ATC105	Tap	E 72°25'33"	N 33°42'08"	Residential Area	GPS DHOK FATEH SARWALA	Attock
116	ATC106	Tap	E 72°23'06"	N 33°51'22"	Agricultural area	GPS AMF KAMRA	Attock
117	ATC107	Tap	E 72°21'06"	N 33°46'09"	Commercial Area	GPS (MC) ATTOCK NO.6	Attock
118	ATC108	Tap	E 72°22'49"	N 33°53'43"	Agricultural area	GPS (MC) CHOI WEST ATTOCK CITY	Attock
119	ATC109	Tap	E 72°21'07"	N 33°46'10"	Residential Area	GPS (MC) ATTOCK NO.3	Attock
120	ATC110	Tap	E 72°21'25"	N 33°46'18"	Hockey stadium	GGPS APWA	Attock
121	ATC111T	Tap	E 72°21'34"	N 33°46'03"	Recreational Spot	GGPS (MC) R BLOCK	Attock
122	ATC111TK	Tank	E 72°20'28"	N 33°45'54"	Residential Area		Attock
123	ATC112	Tap	E 72°23'44"	N 33°45'43"	Residential Area	GPS FATEH JANG NO.2	Attock
124	ATC113	Tap	E 72°23'34"	N 33°34'31"	Commercial Area	GPS MIAN NOOR FATEH JANG	Attock
125	JHE114	Tap	E 73°43'28"	N 32°56'10"	Residential Area	GPS MC NO.2 MACHINE MOHALLAH	JHElum
126	JHE115	Tap	E 73°43'49"	N 32°56'32"	Residential Area	GPS MC NO.3 MACHINE MOHALLAH	JHElum
127	JHE116	Tap	E 73°43'41"	N 32°56'27"	Agricultural area	GPS MC BOARDING MOHALLAH JHELUM	JHElum
128	JHE117	Tap	E 73°44'04"	N 32°55'52"	Commercial Area	GGPS NO. 1 JHELUM	JHElum
129	JHE118T	Tap	E 73°43'22"	N 32°57'45"	Commercial Area	GGPS KARIM PUR	JHElum
130	JHE118TK	Tap	E 73°43'30"	N 32°57'41"	Medical district		JHElum
131	JHE119	Tap	E 73°41'43"	N 32°58'35"	Commercial Area	GGHS NO. 2 KALA GUJRAN	JHElum
132	JHE120	Tap	E 73°43'50"	N 32°56'31"	Commercial Area	GGPS NO. 3 JEHLUM	JHElum
133	JHE121	Tap	E 73°43'55"	N 32°55'31"	Agricultural area	GGPS NO. 2 JHELUM	JHElum
134	JHE122T	Tap	E 73°41'43"	N 33°55'13"	Residential Area	GGPS MC IQBAL ROAD JHELUM	JHElum
135	JHE122TK	Tank	E 73°43'45"	N 32°55'24"	Recreational Spot		JHElum
136	JHE123	Tap	E 73°43'25"	N 32°56'12"	Residential Area	GPS KHAWAS PUR	JHElum
137	JHE124	Tap	E 73°41'56"	N 32°56'50"	Residential Area	GGPS MOHALLAH QUDRAT ABAD, CHOTALA	JHElum
138	LDH125	Tap	E 71°38'01"	N 29°32'38"	Commercial Area	GPS NO.3 LODHRAN	Lodhran

139	LDH126	Tap	E 71°37'56"	N 29°32'42"	Commercial Area	GPS MODEL NO. 1 LODHRAN WAR NO. 9	Lodhran
140	LDH127T	Tap	E 71°38'30"	N 29°31'58"	Agricultural area	GPS NO.2 LODHRAN	Lodhran
141	LDH127TK	Tank	E 71°38'44"	N 29°32'08"	Government offices	GGPS RAO COLONY	Lodhran
142	LDH128	Tap	E 71°37'34"	N29°32'22"	Agricultural area	GGPS BHAKHOO WALA STATION MUJAHID ABAD	Lodhran
143	RWP129	Tap	E 73°27'52"	N 33°33'35"	Residential Area	GPS KAHUTA - A	Rawalpindi
144	RWP130	Tap	E 73°23'27"	N33°35'59"	Residential Area	GGPS MUHALLAH RAJGAN KAHUTA	Rawalpindi
145	RWP131	Tap	E 73°17'23"	N 33°33'16"	Commercial Area	GPS AMAR PURA	Rawalpindi
146	RWP132T	Tap	E 73°04'32"	N33°41'36"	Cattle market	GPS BAKRA MANDI	Rawalpindi
147	RWP132TK	Tank	E 73°02'12"	N 33°37'55"	Residential Area		Rawalpindi
148	RWP133T	Tap	E 73°02'40"	N 33°38'15"	Government offices	GPS STANDARD MUSLIM KHAYABAN-E-SIR SYED	Rawalpindi
149	RWP133TK	Tank	E 73°02'56"	N33°38'25"	Religious zone		Rawalpindi
150	RWP134	Tap	E 73°04'04"	N 33°36'03"	Recreational Spot	GGPS MC CHAMAN ZAR COLONY RWP	Rawalpindi
151	RWP135	Tap	E 73°04'01"	N 33°36'26"	Residential Area	GGPS MC ARIYA MOHALLAH RWP	Rawalpindi
152	RWP136	Tap	E 73°02'22"	N 33°38'07"	Residential Area	GGPS MC BANGASH COLONY RWP	Rawalpindi
153	RWP137	Tap	E 73°03'00"	N 33°38'06"	Administrative centre	GGPS NEW PAGWARI RWP	Rawalpindi
154	RWP138	Tap	E 73°04'28"	N 33°35'58"	Commercial Area	GGPS MC WARD NO. 28	Rawalpindi
155	RWP139	Tap	E 72°48'34"	N 33°45'43"	Railway Station	GPS TAXILA	Rawalpindi
156	RWP140	Tap	E 72°39'50"	N 33°50'51"	Residential Area	GPS JAMILABAD	Rawalpindi
157	RWP141	Tap	E73°04'07"	N 33°47'49"	Commercial Area	GPS KHAN ABAD	Rawalpindi
158	RWP142T	Tap	E 73°19'18"	N 33°15'20"	Commercial Area	GGPS MC JUNIOR PUBLIC NO. 2 GUJAR KHAN	Rawalpindi
159	RWP142TK	Tank	E 73°21'21"	N 33°15'23"	Residential Area	GPS GUJAR KHAN NO. 2	Rawalpindi
160	RWP143	Tap	E 73°18'12"	N 33°16'15"	Residential Area	GGPS NO. 3 GUJAR KHAN	Rawalpindi

161	RWP144	Tap	E 73°18'16"	N 33°16'06"	Medical district	GGPS KARULI GUJAR KHAN	Rawalpindi
162	RWP145T	Tap	E 73°19'08"	N 33°04'48"	Commercial Area	GPS MUGHAL ABAD	Rawalpindi
163	RWP145TK	Tank	E 73°19'09"	N 33°07'48"	Commercial Area		Rawalpindi
164	KWL146	Tap	E 71°52'00"	N 30°24'29"	Grain market	GPS QASIM KABIRWALA, KABIRWALA	Khanewal
165	KWL147	Tap	E 71°46'54"	N 30°24'32"	Residential Area	GPS CHANAN WALA MOUZA KOREY WALA KABIRWALA	Khanewal
166	KWL148	Tap	E 71°58'49"	N 30°37'02"	Residential Area	GPS SARAI SIDHU SHARQI, SARAI SIDHU	Khanewal
167	KWL149	Tap	E 72°08'14"	N 30°33'02"	Commercial Area	GPS FAIZ UL ALOOM, ABDUL HAKIM	Khanewal
168	KWL150T	Tap	E 71°50'58"	N 30°27'55"	Cattle market	GGPS EID GHAH, KABIRWALA	Khanewal
169	KWL150TK	Tank	E 71°51'02"	N 30°26'10"	Government offices		Khanewal
170	KWL151	Tap	E 71°51'54"	N 30°17'56"	Residential Area	GPS KHURRAM PURA, MADINA COLONY, KHANEWAL	Khanewal
171	KWL152T	Tap	E 71°56'15"	N 30°18'23"	Residential Area	GGPS NIZAM ABAD, KHANEWAL	Khanewal
172	KWL152TK	Tank	E 71°56'38"	N 30°18'30"	Medical district		Khanewal
173	KWL153	Tap	E 71°55'16"	N 30°18'11"	Government offices	GGPS PEOPLES COLONY, KHANEWAL	Khanewal
174	KWL154	Tap	E 71°54'35"	N 30°19'24"	Agricultural area	GGPS 51/10-R COLONY NO. 2, KHANEWAL	Khanewal
175	KWL155T	Tap	E 71°53'34"	N 30°18'50"	Agricultural area	GGPS COLONY NO.3 KHANEWAL	Khanewal
176	KWL155TK	Tank	E 71°54'33"	N 30°17'59"	Residential Area		Khanewal
177	KWL156	Tap	E 71°56'45"	N 30°18'07"	Commercial Area	GGPS MC 7-G, P/O ISLAM PURA, KHANEWAL	Khanewal
178	KWL157	Tap	E 71°55'06"	N 30°17'54"	Grain market	GGPS MC 5-G, OLD MANDI, KHANEWAL	Khanewal
179	KWL158	Tap	E 71°56'39"	N 30°18'15"	Commercial Area	GGPS MC 8-G, JAMIA ABAD KHANEWAL	Khanewal

180	KWL159	Tap	E 71°54'53"	N 30°18'18"	Recreational Spot	GGPS TARIQ ABAD, KHANEWAL	Khanewal
181	VHR160	Tap	E 72°16'30"	N 30°02'05"	Residential Area	GPS AZIZ ABAD	Vehari
182	VHR161	Tap	E 72°43'07"	N 30°09'54"	Commercial Area	GPS AHYA ALOOM BUREWALA	Vehari
183	VHR162	Tap	E 72°19'43"	N 30°02'03"	Residential Area	GGPS MC E-BLOCK	Vehari
184	VHR163	Tap	E 72°15'10"	N 30°03'56"	Religious zone	GGPS MC H-BLOCK	Vehari
185	VHR164	Tap	E 72°40'52"	N 30°09'41"	Medical district	GGPS MC AZIM ABAD	Vehari
186	VHR165	Tap	E 72°20'38"	N 30°02'39"	Commercial Area	GGPS MC G-BLOCK	Vehari
187	VHR166	Tap	E 72°41'27"	N 30°09'55"	Residential Area	GGPS MUJAHID COLONY	Vehari
188	VHR167	Tap	E 71°53'06"	N 29°58'36"	Religious zone	GGPS WARD NO 7 TIBBA SULTAN PUR	Vehari
189	VHR168	Tap	E 72°21'21"	N 30°02'40"	Commercial Area	GPS MC D-BLOCK	Vehari
190	VHR169	Tap	E 72°20'08"	N 30°02'11"	Commercial Area	GGPS MARKET COMMITTEE	Vehari
191	VHR170	Tap	E 71°24'41"	N 30°13'28"	Religious zone	GPS BAKHSH WALA SURAJ MIANI MULTAN	MULtan
192	MUL171T	Tap	E71°28'20"	N30°14'54"	Agricultural area	GPS BRING WALA MOZA NEEL KOT	MULtan
193	MUL171TK	Tank	E71°30'00"	N30°14'52"	Agricultural area		MULtan
194	MUL172	Tap	E71°29'14"	N30°15'08"	Commercial Area	GPS MEHMOOD KOT BOSAN ROAD MULTAN	MULtan
195	MUL173	Tap	E68°40'31"	N25°27'03"	Agricultural area	GPS HAJI PUR MOZA DURANA LANGANA P/O RASHIDABAD	MULtan
196	MUL174	Tap	E71°19'32"	N29°57'09"	Agricultural area	GPS TIBI WALA MOZA DURANA LINGANA	MULtan
197	MUL175	Tap	E71°33'31"	N30°29'26"	Agricultural area	GPS JAHANGIR ABAD NEAR KHANEWAL ROAD	MULtan
198	MUL176	Tap	E71°33'22"	N30°12'21"	Commercial Area	GPS POWER STATION PIRRAN GHAIB PIRAN GHAIB	MULtan
199	MUL177	Tap	E71°33'29"	N30°11'48"	Commercial Area	GPS RAILWAY STATION PIRAN GHAIB	MULtan
200	MUL178	Tap	E71°23'27"	N30°10'30"	Residential Area	GPS BASTI LANGRIAL MULTAN CANTT	MULtan

201	MUL179	Tap	E71°28'20"	N30°14'55"	Residential Area	GPS CHOWK KUMHARAN WALA	MULtan
202	MUL180	Tap	E 71°20'51"	N30°10'40"	Commercial Area	GPS NISHTAR COLONY MULTAN	MULtan
203	MUL181	Tap	E71°43'36"	N32°18'49"	Agricultural area	GPS SHOR KOT MULTAN MOZA DURANA LANGANA	MULtan
204	MUL182	Tap	E 71°34'51"	N 30°20'35"	Agricultural area	GPS AHMED ABAD	MULtan
205	MUL183	Tap	E71°27'59"	30°12'14"	Commercial Area	GGPS PURANA BARAF KHANA	MULtan
206	MUL184	Tap	E71°33'57"	N30°14'47"	Residential Area	GGPS BASTI BHIR MULTAN CENTER BOHDALA TOWN	MULtan
207	MUL185T	Tap	E71°31'59"	N30°13'33"	Agricultural area	GGPS BOOAA PUR MULTAN	MULtan
208	MUL185TK	Tank	E 71°29'56"	N 30°12'54"	Religious zone		MULtan
209	MUL186	Tap	E 71°30'44"	N 30°13'30"	Residential Area	GGPS CHAH MAYER WALA NO. 2	MULtan
210	MUL187	Tap	E 71°30'24"	N30°13'29"	Recreational Spot	GGPS AHMAD ABAD	MULtan
211	MUL188	Tap	E71°25'29"	N30°06'59"	Residential Area	GGPS FAKHIR-ABAD MULTAN	MULtan
212	NNS189	Tap	E73°28'59"	N31°34'27"	Residential Area	GPS NO. 2 SHAHKOT	Nankansahib
213	NNS190T	Tap	E76°07'15"	N30°57'03"	Agricultural area	GGPS MC NO. 2 NANKANA SAHIB	Nankansahib
214	NNS190TK	Tank	E76 °09'12"	N30°55'28"	Agricultural area		Nankansahib
215	NNS191	Tap	E 73°28'14"	N 31°34'05"	Commercial Area	GGPS SHAH KOT NO.1	Nankansahib
216	NNS192	Tap	E 73°49'51"	N31°32'36"	Residential Area	GPS RAILWAY COLONY WARBURTON	Nankansahib
217	SKP193	Tap	E 73°47'49"	N 31°47'35"	Residential Area	GPS MC ROSHAN PURA	Sheikhupura
218	SKP194	Tap	E 73°53'30"	N 31°42'52"	Industrial area	GGPS HIGHWAY COLONY	Sheikhupura
219	SKP195T	Tap	E 73°58'49"	N31°45'40"	Agricultural area	GGPS SHAFIQ NAGAR	Sheikhupura
220	SKP195TK	Tank	E73°58'22"	N 31°44'57"	Residential Area		Sheikhupura
221	SKP196	Tap	E 73°47'53"	N 31°40'53"	Residential Area	GGPS MC REHMAT COLONY	Sheikhupura
222	LHE197	Tap	E74°26'15"	N31°30'18"	Residential Area	GPS SEHJPALL	Lahore
223	LHE198	Tap	E 74°23'40"	N31°35'29"	Commercial Area	GPS QADRIA SHALIMAR TOWN	Lahore
224	LHE199	Tap	74°16'00"	31°28'10"	Residential Area	GGPS NAWAN PIND H-II	Lahore

						JOHAR TOWN	
225	LHE200	Tap	E74°16'14"	N31°27'09"	Residential Area	GPS PAK WELFARE SOCIETY FAZAL PURA	Lahore
226	LHE201	Tap	E74°22'27"	N31°35'27"	Residential Area	GPS AUQAF PILOT MADHU LAL HUSSAIN	Lahore
227	LHE202	Tap	E74°23'23"	N31°34'43"	Commercial Area	GPS KHALID MODEL KOTLI PIR ABDUL	Lahore
228	LHE203	Tap	E74°23'02"	N31°35'12"	Commercial Area	GPS ASLAM BAGHBAN PURA LHE	Lahore
229	LHE204	Tap	E74°22'27"	N31°35'27"	Commercial Area	GPS ZARYAB BAGHBANPURA LAHORE	Lahore
230	LHE205	Tap	E74°17'21"	N31°36'31"	Residential Area	GGPS MALIK PARK SHAHDARA	Lahore
231	LHE206	Tap	E74°18'33"	N31°34'40"	Residential Area	GPS MUHALLAH JALOTION BHATI GATE LAHORE	Lahore
232	LHE207T	Tap	E 74°24'33"	N31°25'37"	Agricultural area	GPS GURUMANGET	Lahore
233	LHE207TK	Tank	E 74°18'21"	N 31°26'32"	Residential Area		Lahore
234	LHE208	Tap	E 74°18'12"	N31°27'21"	Recreational Spot	GPS ASLAM JUNIOR MODEL B -II TOWNSHIP	Lahore
235	LHE209	Tap	E 74°21'27"	N31°28'37"	Commercial Area	GPS NA REHMAN PURA	Lahore
236	LHE210	Tap	E 74°17'50"	N 31°31'52"	Residential Area	GPS IQBAL MODEL SAMANABAD	Lahore
237	LHE211	Tap	E 74°18'54"	N31°27'42"	Commercial Area	GPS BLOCK NO. 5 SECTOR B-I TOWNSHIP	Lahore
238	LHE212	Tap	E74°17'35"	N31°31'07"	Residential Area	GPS SULEMAN JUNIOR MODEL SAMAN ABAD	Lahore
239	LHE213	Tap	E 74°17'14"	N31°32'58"	Commercial Area	GPS FIRDOUS CO-OPRETIVE GULSHAN-E-RAVI	Lahore
240	LHE214	Tap	E 74°20'26"	N 31°29'02"	Medical district	GPS GULAB DEVI HOSPITAL	Lahore
241	LHE215	Tap	E 74°21'42"	N31°29'00"	Residential Area	GPS RAILWAY COLONY WALTON	Lahore
242	LHE216	Tap	E 74°19'58"	N31°32'21"	Medical district	GPS SERVICES HOSPITAL LHE	Lahore
243	LHE217	Tap	E 74°21'39"	N 31°32'15"	Residential Area	GPS GHOUSIA MIAN MEER	Lahore

						COLONY	
244	LHE218	Tap	E 74°21'31"	N31°31'51"	Workshops	GGPS QURBAN LINE	Lahore
245	LHE219	Tap	E 74°18'23"	N 31°26'38"	Commercial Area	GGPS CDG SECTOR A-II TOWNSHIP	Lahore
246	LHE220	Tap	E 74°23'18"	N31°34'08"	Commercial Area	GGPS MODEL SHAHRA-I-AIWAN-E-TIJARAT	Lahore
247	LHE221	Tap	E 74°19'13"	N 31°32'55"	Residential Area	GGPS APWA MODEL WARIS ROAD LAHORE	Lahore
248	KSR222	Tap	E74°26'27"	N31°06'49"	Residential Area	GPS MC KOT GHULAM MUHAMMAD KASUR	Kasur
249	KSR223	Tap	E74°26'59"	N31°07'23"	Residential Area	GPS MC SABZI MANDI	kasur
250	KSR224	Tap	E74°26'54"	N31°07'29"	Residential Area	GGPS MC BASTI CHIRAGH SHAH	Kasur
251	KSR225	Tap	E74°27'02"	N31°06'55"	Residential Area	GGPS MC KOT FATEH DIN KHAN	Kasur
252	MBD226	Tap	E 73°29'56"	N32°35'36"	Agricultural area	GPS FAIZ ABAD	Mandi Bahauddin
253	MBD227	Tap	E 73°29'43"	N 32°35'54"	Residential Area	GGPS TARIQ ABAD	Mandi Bahauddin
254	HFD228	Tap	E73°41'09"	N32°04'18"	Residential Area	GPS MC NO.7 HAFIZABAD	Hafizabad
255	HFD229	Tap	E73°41'31"	N32°03'31"	Residential Area	GGPS MC NO. 2 HAFIZABAD	Hafizabad
256	NRW230	Tap	E74°51'56"	N32°05'37"	Commercial Area	GPS AMIN COLONY MOHALLA	Narowal
257	NRW231T	Tap	E74°52'17"	N32°05'30"	Agricultural area	GGPS ALAMA IQBAL MOHALLAH USMANIA	Narowal
258	NRW231TK	Tank	E74°52'07"	N32°07'53"	Residential Area		Narowal
259	SKT232	Tap	E74°21'08"	N32°19'50"	Residential Area	GGPS MC DASKA KALAN	Sialkot
260	SKT233	Tap	E74°32'36"	N32°25'55"	Agricultural area	GGPS PASRUR NO.2	Sialkot
261	SKT234	Tap	E74°33'03"	N32°28'57"	Residential Area	GGPS MISSION NAIKA PURA	Sialkot
262	SKT235	Tap	E74°29'10"	N32°35'58"	Agricultural area	GPS SHER PUR	Sialkot
263	SKT236	Tap	E74°25'18"	N32°35'48"	Residential Area		Sialkot
264	GRT236	Tap	E74°12'17"	N32°38'32"	Residential Area	GGPS NAI ABADI J.P.Jattan	Gujrat
265	GRW237	Tap	E74°12'06"	N32°03'21"	Agricultural area	GGPS DEWANAN NO.1	Gujranwala

						(EMINABAD)	
266	GRW238	Tap	E74°06'33"	N32°26'46"	Residential Area	GGPS MC NO.01 WAZIRABAD	Gujranwala
267	GRW239	Tap	E74°11'40"	N32°11'16"	Residential Area	GPS FAISAL TOWN (VIRAK TOWN)	Gujranwala
268	GRW240	Tap	E74°10'55"	N32°08'58"	Residential Area	GGPS FAZAL BIBI GALLA MEHAR NOOR WALA	Gujranwala
269	GRW241	Tap	E74°10'34"	N32°08'59"	Residential Area	GPS PEERU SHAHEED	Gujranwala
270	CHT242	Tap	E72°58'21"	N31°44'53"	Residential Area	GPS MC LAHORI GATE	Chiniot
271	CHT243	Tap	E72°59'17"	N31°43'54"	Residential Area	GGPS AHMED PURA	Chiniot
272	TTS244	Tap	E72°41'14"	N31°08'26"	Residential Area	GPS ASHRAF COLONY GOJRA WARD NO. 13	T.T Singh
273	TTS245	Tap	E72°28'11"	N30°58'07"	Residential Area	GPS NO.4 AWAMI BASTI T.T.SINGH	T.T Singh
274	JHG246	Tap	E72°18'25"	N31°16'38"	Residential Area	GPS BARKAT UL ISLAM	Jhang
275	JHG247	Tap	E72°18'40"	N31°16'47"	Agricultural area	GGPS BAST GHOGHAY WALI	Jhang
276	FSD248	Tap	E73°05'41"	N31°22'33"	Residential Area	GPS NASIR TOWN	Faisalabad
277	FSD249	Tap	E73°02'21"	N31°24'42"	Residential Area	GPS SHAIKH COLONY FSD	Faisalabad
278	FSD250	Tap	E73°07'41"	N31°26'42"	Commercial Area	GPS AMIN PARK FSD	Faisalabad
279	FSD251	Tap	E73°05'58"	N31°27'09"	Residential Area	GPS ASHRAF ABAD FSD	Faisalabad
280	FSD252	Tap	E73°03'35"	N31°24'31"	Residential Area	GPS AYUB COLONY FSD	Faisalabad
281	FSD253	Tap	E73°03'53"	N31°23'20"	Agricultural area	GGPS ISLAMIA MODEL SAMANABAD	Faisalabad
282	FSD254	Tap	E73°04'04"	N31°22'49"	Residential Area		Faisalabad
283	FSD255	Tap	E73°02'24"	N31°22'26"	Residential Area	GGPS SITARA COLONY	Faisalabad
284	FSD256	Tap	E73°05'14"	N31°22'55"	Residential Area	GGPS MC ALLAMA IQBAL COLONY FSD	Faisalabad
285	FSD257	Tap	E73°06'03"	N31°26'43"	Residential Area	GGPS MC GHOUSHALA	Faisalabad
286	LYH257	Tap	E 71°13'59"	N30°57'36"	Residential Area	GGPS 128 TDA WARD NO. 6 CHOWK AZAM	Layyah
287	LYH258	Tap	E71°00'54"	N 30°56'17"	Residential Area	GGPS MC NO. 2 LAYYAH	Layyah
288	DGK259	Tap	E 70°37'46"	N30°03'32"	Commercial Area	GPS CITY NO. 13	D.G Khan
289	DGK260	Tap	E 70°37'48"	N 30°03'46"	Recreational Spot	GPS CITY NO. 14	D.G Khan

290	RYK261	Tap	E70°16'52"	N28°24'32"	Residential Area	GGPS MASTAN SHAH	Rahim Yar Khan
291	RYK262	Tap	E70°19'04"	N28°24'13"	Residential Area	GGPS MC FACTORY AREA	Rahim Yar Khan
292	BHW263	Tap	E71°40'42"	N29°22'31"	Residential Area	GPS MC HALQA NO.1 BAHAWALPUR	Bahawalpur
293	BHW264	Tap	E71°39'35"	N29°23'41"	Residential Area	GPS MC HALQA NO.2 BAHAWALPUR	Bahawalpur
294	BHW265	Tap	E71°45'03"	N29°23'54"	Residential Area	GPS MC SHAHDARA BAHAWALPUR	Bahawalpur
295	BHW266	Tap	E71°46'05"	N29°24'22"	Commercial Area	GGPS BADAR SHAIR NO.2	Bahawalpur
296	BHW267	Tap	E71°42'06"	N29°22'32"	Residential Area	GGPS BASTI HANSRA	Bahawalpur
297	BWL268	Tap	E73°13'33"	N29°59'01"	Commercial Area	GPS GAOSHALA	Bahawalnagar
298	BWL269	Tap	E73°16'22"	N29°59'41"	Residential Area	GPS MADINA MASJID	Bahawalnagar
299	BWL270	Tap	E73°15'49"	N30°00'27"	Residential Area	GGPS REVENUE COLONY	Bahawalnagar
300	BWL271	Tap	E73°15'44"	N30°00'49"	Residential Area	GGPS NAZIR COLONY	Bahawalnagar

*T= Tap,*TK= Tank

Table 3.3:WHO standard values (Vs) and unit weights (Wn) of their corresponding parameters

Column1	Sn	1/Sn	Σ 1/Sn	k=1/Σ 1/Sn	Wi=k/Sn	ideal Value	Vn	Vn/Sn	Vn/Sn*100	Qn
pH	8.5	0.117647	1.126314	0.887852094	0.10445319	7	7.71	1.87	187	19.5327461
TDS	500	0.002			0.0017757	0	1000	2	200	0.35514084
EC	300	0.003333			0.00295951	0	1563	5.21	521	1.54190314
Hardness	300	0.003333			0.00295951	0	192	0.64	64	0.18940845
Cl	75	0.013333			0.01183803	0	160	2.133333	213.3333333	2.52544596
Nitrate	50	0.02			0.01775704	0	27.5	0.55	55	0.9766373
Flouride	1.5	0.666667			0.5919014	0	1.5	1	100	59.1901396
Arsenic	10	0.1			0.08878521	0	9.28	0.928	92.8	8.23926743
		1.126314			1					151.812414

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