

**DRINKING WATER QUALITY ASSESSMENT OF PUBLIC PRIMARY  
SCHOOLS OF RURAL PUNJAB, PAKISTAN**

**MPHIL ENVIRONMENTAL SCIENCES**



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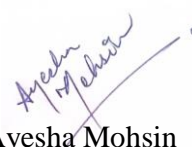
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## ABSTRACT

The compromised drinking water quality in primary schools can lead to various health issues, particularly among children, as they are more vulnerable to the harmful effects of contaminants. It can also impact their attendance, concentration, and overall well-being. Thus, the present study was conducted to assess the physiochemical and microbial drinking water quality, using standard methods, among 274 primary schools of rural Punjab, Pakistan. A total number of 18 cities were selected for sampling purpose and results were compared with World Health Organization (WHO) standards. Results showed that EC (14.60%), TDS (10.95%), DO Total hardness (16.06%), Cl (29.56%), F (12.04%), Nitrate (16.42%), Cr (7.30%), Ni (8.39%), and As (10.95%) exceeded WHO recommended range. MPN method was used to test microbiological contamination in drinking water samples. Results showed that 36% of samples were bacteriologically contaminated with Total coliforms. Drinking Water Quality Index (DWQI) revealed, 38%, 41%, 16%, 4% and 1% of the water samples to be categorized as good water, fair water, poor water, very poor and unsuitable for drinking respectively, thus making overall water quality not suitable for drinking purposes. Health risk assessment of suggests HQ indices for Pb and Ni in all the samples was  $<1$ , which imparting no potential adverse health effect to the study population. Some samples had shown  $HQ > 1$  for Cr, As and F. All the samples of Pb had cancer risk  $< E-04$ , however, in some samples Cr, Ni and As cancer risk was  $> E-04$ . Pearson correlation matrix showed statistically significant relationships ( $p < 0.01$ ) between various physiochemical parameters. Health risk survey from parents found that majority of the respondents had knowledge about water borne diseases and were suffering from Hepatitis A (12.7%), Kidney problems (13%), Diarrhoea/Vomiting (26%), Abdominal pain (25%), tiredness (33.3) and Dysentery (4.8) etc. Contingent valuation method (CVM) was used for determining Willingness to pay (WTP) for drinking water quality which was found to be PKR. 974.69, This amounts can make a difference in water quality. ANOVA, Chi square, Cramm's V and linear regression test, with a p-value  $< 0.05$ , revealed that income and education level significantly affected the willingness to pay for improved drinking water. Hence, authorities should regularly monitor the drinking water quality in public primary schools to ensure a safe and healthy learning environment for the students and staff.

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## LIST OF ABBREVIATION

ADD	Average Daily Dose
As	Arsenic
Cr	Chromium
CR	Cancer Risk
CSF	Cancer Slope Factor
CVM	Contingent Valuation Method
DWQI	Drinking Water Quality Index
DO	Dissolved Oxygen
EC	Electrical Conductivity
F	Fluoride
GIS	Geographical Information System
HQ	Hazard Quotient
HMs	Heavy metals
JMP	Joint Monitoring Programme
Ni	Nickel
Pb	Lead
SMDW	Safely managed drinking water services
UNICEF	United Nations Children's Fund
TDS	Total Dissolved Solids
TSS	Total Suspended Solids
WHO	World Health Organization

# CHAPTER I

## INTRODUCTION

The value of adequate availability of drinking water is inevitable for healthy living standards. Report of United Nations quotes approximately 884 million humans globally with no access to clean or safe drinking water. In context of water contamination and population explosion, the availability of clean drinking water in developing countries has emerged as a global challenge [1]. Human health and environment are facing visible consequences of water contamination. Majority of the population from under developed countries faces lethal condition every year due to water borne diseases [2].

The worsening and negative impact on the quality of drinking water is a result of the addition of toxic chemicals in water supply systems and natural water bodies via anthropogenic and natural activities. Natural water contamination is the result of different chemicals entering the system through geological process, whereas anthropogenic contamination is a result of herbicides and pesticides use in agriculture, discharge of hazardous toxins, coal mining, septic tank, petroleum refining, water disposal and other such sources [3,4]. Death of young children resulting from preventable diseases is one of the causes of destabilization in families as they do not have access to safe drinking water [5]. Consequently, deteriorated health history in childhood followed by load of repeated sickness afterwards in life lends minimal chances of success in future for such children [6]. World Health Organisation report of 2021 has declared water pollution responsible for causing 80 % of diseases 50% of child deaths in poor countries worldwide [7].

Various forms of cancers have also been linked to polluted water consumption, specifically with heavy metals. Bacterial or fungal contamination of water in any region is primary threat to local citizens health and demands immediate steps to control it. The key source of microbial contamination of water bodies is either bacteria or fungi from animal plus humans excreta via leakage from sewage system, contaminated landfills, stations of waste water treatment, or contaminated groundwater, subsequently resulting in major health based issues. More than one third population has lost its life due to microbial contaminated water intake in poor countries [8]. 4 billion diarrhea patients are admitted every year; 2.2 million of which are subjected to death with main victims being the children under 5 years of age. Almost 90% of disease ratio

is in poor countries. Each spell of diarrhea continually compromises the immune system as a result of which millions of people are killed each year [9].

The Sustainable Development Goals (SDGs) set high global standards for access to clean water, hygiene and sanitation. Use of safely managed drinking water services (SMDW) is SDG target 6.1. The term "SMDW services" refers to enhanced sources of drinking water (protected groundwater sources, piped water, rainwater collection and packaged water) that are available on premises, accessible when needed, and uncontaminated [10]. The WHO/UNICEF Joint Monitoring Programme (JMP) for Water Supply, Sanitation, and Hygiene indeed plays a crucial role in assessing global access to safe drinking water and sanitation. The JMP primarily emphasizes indicators related to microbial (coliform bacteria) and chemical contamination (arsenic and fluoride). The WHO's Guidelines for Drinking Water Quality provide the framework that supports national standards in many countries and cover a much broader range of water quality criteria [11]. According to the most recent JMP estimates, 2 billion people lack SMDW, with the majority living in Sub-Saharan Africa (747 million) and Central and South Asia (768 million). This finding shows that drinking water contamination is the limiting factor for SMDW [12].

In Punjab, Pakistan, since many communities are characterised by restricted access to portable water, so understanding the drinking water quality and how it affects school children's health is important. It is requested to establish the importance of water quality parameters, such as pH, Total Dissolved Solids (TDS), Electrical Conductivity (EC), total hardness, sodium (Na), potassium (K), fluoride (F), chloride (Cl), heavy metals like arsenic (As), chromium (Cr), nickel (Ni), and lead (Pb), and organic compounds such as phenolic compounds [13]. Investigation of the origins or source of these pollutants and any potential health concern of children attending rural primary schools needs to be studied. The overall taste and general quality of water can be impacted inappropriate pH level, which can also have negative health effects. Hardness of water affects how minerals are absorbed in the digestive system. Although  $\text{Ca}^{+2}$  and  $\text{Mg}^{+2}$  are important nutrients, drinking a lot of hard water can prevent your body from absorbing other vital minerals. Since high  $\text{Na}^{+2}$  levels are linked to hypertension, they are particularly concerning.  $\text{Cl}^-$  concentrations impact the taste of water. Water sources can get contaminated with toxic metals including Cr, Ni, Pb, and As through industrial processes or natural geological sources [14]. Their consumption can have detrimental effects on children health, ranging from organ damage to developmental problems. Due to industrial

discharges, inappropriate waste management and agricultural runoff, phenolic compounds can enter the water sources. They can be harmful to your health, and can even be carcinogenic [15].

In rural Punjab, poor water treatment facilities and contamination from agricultural activities and nearby industries have a substantial impact on water quality. Consumption of contaminated water can have negative implications, especially for young children attending primary schools. Contaminated water causes skin issues, gastrointestinal syndromes, delayed cognitive development, skeletal and dental issues and other chronic health illnesses. The importance of improving water quality in primary schools is heightened by the sensitivity of children to these health issues. In order to guarantee that the next generation has access to clean and safe drinking water, addressing these water quality issues requires a multifaceted strategy comprising infrastructure improvements, effective sanitation procedures, and community awareness [13, 16]

In Pakistan, only twenty percent of entire population has access to clean drinking water. Contribution to water pollution are primarily fertilizers, industrial waste, unavailability of proper sewage system and pesticides [17]. In Pakistan, up gradation of sewage framework is required and local bodies (government) failed to provide it, resulting in alarming risk for spread of pollutants to the population [18]. Pollutants can be added in network of water distribution when either service is unavailable completely or during low pressure times. Moreover, community centers such as shops, building or construction sites and schools mostly don't have on site storage reservoirs of water and are mainly dependent on alternatives such as private water vendors, springs and stored rainwater. There is no proper system for water quality monitoring and suppliers providing water locally are most of the times unregistered. Secondary and cross contamination of safe drinking water is most likely to occur as a result of its unhygienic handling [19]. Twenty to forty percent hospitals in Pakistan are occupied with waterborne sickness, as reported by UNICEF in 2018. A number of diseases such as guinea worm infections, hepatitis, cholera, giardiasis, typhoid, cryptosporidiosis and dysentery represent almost eighty percent (including the diseases caused by sanitation issues) of all the diseases and are responsible for 33% of the deaths globally. About 50% population of Pakistan do not have access to adequate sanitation facilities, affecting both rural and urban communities [20].

Contaminated water supplies, particularly those containing faeces, are the main route by which infectious diseases are spread. Water-borne disease outbreaks continue to happen throughout

the world, but they are particularly dangerous in developing nations. Shigella species, Salmonella species, campylobacter species, Escherichia coli, Cholera, Vibrio, Yersinia enterocolitica and various viruses like Rota Virus, Hepatitis E, A and parasites like Giardia species and Entamoeba histolytica are just a few of the human pathogens that pose a serious risk of disease through drinking water [21]. Monitoring drinking water for every conceivable microbial pathogen is impractical. Hence, common gut microbes act as a faecal pollution indicator, which include the entire coliform category of organisms [22]. The mixing of human and animal excreta and the absence of an effective sewage and solid waste disposal infrastructure cause bacterial contamination of drinking water. This, in turn, can result in a number of waterborne illnesses that affect people, including cholera, hepatitis, dysentery, intestinal infections, and typhoid fever. Due to urbanisation, overpopulation, and the inappropriate use of water in the industrial and agricultural sectors, the freshwater resources that are already accessible are under a lot of stress. Due to inadequate administration and financial constraints, the situation is particularly bad in developing nations [23].

In Pakistan only 52 % schools have access to better systems of sanitation ; moreover nearly 32% of washrooms are routinely maintained and operational. The polluted water along with poor sanitation implies a burden to economy of Pakistan of about \$5.7 billion (USD), parallel to about four percent of its Gross Domestic Products (GDP). Students learning needs along with health outcomes are considered to be key factors for achieving optimal learning in school settings. Health and Demographic Survey (2017 to 2018) conducted recently in Pakistan revealed substandard school performance factors (such as dropout, enrolment, absenteeism, illness etc) with high ratio of waterborne diseases that include diarrhoea being the major one [24].

17.6 million students are registered in Pakistan's public primary schools, where enrolment is open to children between the ages of 5 and 9. According to data given by the Ministry of Federal Education's Institute for Education Planning and Management, there were 34,890 government primary schools without access to potable water nationwide in 2009. By 2014, the problem got worse as additional schools were added to the list. There are currently 75,631 primary schools in Pakistan that have access to clean drinking water out of 197,900 [25]. Despite being Pakistan's most rich state, Punjab's educational system paints a different picture when it comes to the education of young children. Punjab, a province with a population of more than 100 million, has over 22 million children between the ages of 5-16 years. According to school education department Punjab, there are almost 36,321 public primary schools out of

which 88.5% are rural and 11.5% are urban. The infrastructure of the current public elementary schools is insufficient to create a productive learning environment [26]. Public schools lack the most basic amenities and are housed in outdated, frequently unsafe premises. Lack of access to safe drinking water is a major factor in low enrollment, high dropout rates and a growing dependency on the facilities of private educational institutions, which are generally better [27].

To ensure appropriate water quality assessment, identification of key health impacts of pollutants that are present in safe drinking water is of utmost importance. For that purpose HHRA (human health risk assessment) along with DWQI (drinking water quality index) serve as key beneficial tools for quantifying major health issues by different contaminants. Human health risk assessment is basically the analysis, characterization and identification of major negative health impacts of different contaminants in human bodies. In order to help policymakers manage and mitigate risks, HHRA systematically assesses the potential health concerns connected to specific contaminants. WQI, on the other hand, offers a single numerical value that represents the overall water quality and enables direct comparison between the quality of various sources as well as the identification of potential health hazards associated with certain contaminants. Authorities can efficiently prioritise activities and put policies into place to protect the public health and maintain the quality of safe drinking water by incorporating the results from HHRA and WQI [28].

## **1.1 Study Area**

Punjab is the central eastern, the most populous and revenue generating province of Pakistan, at 31.1704° N, 72.7097° E. It is the second largest in terms of area covered, around 205,344 square kilometres. Its total population is 120 million. It is bordered by the Indian states of Punjab and Rajasthan to the east, Khyber Pakhtunkhwa province to the northwest, Sindh province to the south, and Baluchistan province to the southwest.

Punjab experiences a semi-arid to sub-humid climate with distinct seasonal variations. The summers are hot and dry (40°C), while the winters are relatively cooler (5°C). Monsoon rains occur from July to September, contributing significantly to the recharge of groundwater aquifers.

The province is divided into North, Central and Southern regions. It consists of 36 districts, 145 tehsils and 58 cities. There are approximately 22 million children between the age group of 5 to 16 out of over 120 million population of Punjab province. Almost 15 % of these children are not attending the schools. According to the figures stated by school Education Department

of Punjab out of approximately 53,000 schools operating in Punjab, 36,000 schools are of primary level [26].

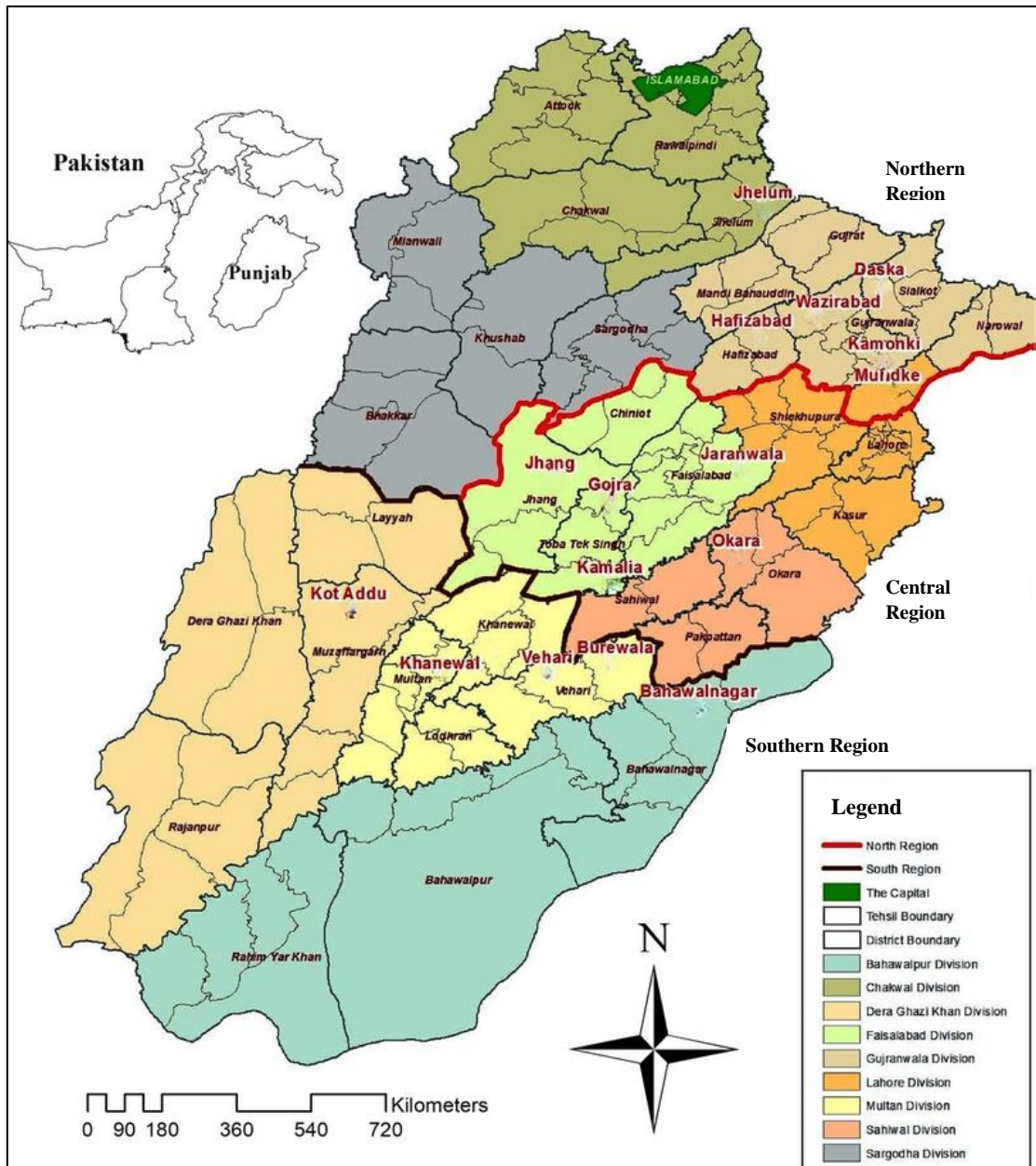


Figure 1.1: Map of the Study Area: Punjab, Pakistan

## **RATIONALE**

Safe drinking water availability is inevitable for human health. Contaminants present in ground and surface water are of significant threat to human existence most importantly to children as they are more likely to be exposed to diseases caused by the pollutants in the form of metals or otherwise. Schools are the most important part of life where children spend maximum part of their day and consume their intake of daily water from sources available in school boundaries. In Punjab water quality issues are getting attention but the main focus put on the quantity provided to water users and water distributors. The guidelines set by World Health Organisation for quality of drinking water is not met by any rural water distribution network. People living in the rural areas are mostly uneducated and ignorant towards the sickness caused by consuming water not safe for human health. Rural areas don't have any proper system to monitor the water quality. In addition to this students and management of primary schools lack adequate knowledge regarding water quality used for drinking purposes. So a study to monitor the bacteriological and physio chemical parameters of drinking was the need of hour (in primary schools of rural Punjab) for assessing major risks of consuming compromised quality drinking water on health of children. Although the quality of drinking water at households has been widely investigated, there is limited research on drinking water quality at schools of Punjab. Thus this study aimed to systematically analyze quality of drinking water available in the primary schools of Punjab, Pakistan.

## **OBJECTIVES**

The objectives of this study were to:

- Assess the concentration of selected parameters (physiochemical and biological) in drinking water samples of rural primary schools of Punjab, Pakistan.
- Determine the water quality index and health risk index for the contamination level of pollutants in drinking water samples.
- Conduct economic valuation of clean drinking water in the study area using CVM (Contingent Valuation Method).

## CHAPTER II

### LITERATURE REVIEW

Contaminated drinking water is a worldwide health problem that causes illness and death, particularly in under developed and developing countries. This is a significant concern as children are more susceptible to waterborne diseases caused by contaminated water. In developing countries, such as Pakistan, many primary school children lack access to safe drinking water, which might lead to a rise in the number of water-related illnesses and poor academic performance.

#### 3.1 Physiochemical and Microbial Quality of Drinking Water

The studies conducted across different regions in Pakistan reveal a concerning pattern of deteriorating water quality and its impact on human health. In Sindh, drinking water quality in 425 public primary schools was assessed via physiochemical parameters using a simple random sampling method. These schools primarily relied on surface water (38%) and groundwater (62%) sources. Comparison against Pak NEQS and WHO standards showed that parameters like DO, pH, and NO<sub>3</sub><sup>-</sup> met standards, but TDS (33%), EC (46%), turbidity (27%), hardness (11%), and chloride (34%) exceeded limits. Dissolved salts showed correlations with TDS/EC concentration. The Water Quality Index (WQI) revealed 26% of schools had poor-quality water, while 74% had excellent quality. South Sindh schools had the highest poor water quality (33%) compared to North (15%) and Central zones (25%). The study emphasized implementing robust water quality management programs in primary schools to prevent water-related diseases among students [29]. Similar research in Bahawalpur, Pakistan, compared groundwater quality against WHO standards across three sampling sites: Islamic Colony, Shahdrah, and Satellite Town, collecting two samples from each. Data collection involved questionnaires and lab analysis, focusing on parameters like pH, EC, TDS, Alkalinity, and hardness. Results indicated deteriorating groundwater quality, especially severe in Islamic Colony, with 41% reporting a slight smell, 48% diluted water, and 55% brackish water. Lab analysis confirmed significant contamination, pH, hardness, TDS, EC and other parameters were found higher than the tolerable limits set by the WHO. This poor water quality correlated with increased water-related illnesses; 36% of Islamic Colony residents reported serious diseases like cholera and diarrhoea. To protect the community's health, the research

recommends regular water quality monitoring and increased water filtration plant installations by the local government [30].

In Charsadda, KPK, contamination in handpump and well water samples surpassed permissible limits for nitrate, sulphate, heavy metals, and coliform bacteria. Findings revealed nitrate (10.3–14.84 mg/L) in 13 samples exceeded USEPA's 10 mg/L limit, while sulphate (505–555 mg/L) in 9 samples surpassed WHO's 500 mg/L limit. Lead, cadmium, nickel, and iron levels also exceeded permissible limits in some sites. Contamination sources were linked to improper sewage disposal, aging piping networks, agrochemical use, and transportation. Waterborne diseases like dysentery and gastroenteritis were reported, indicating bacterial contamination impact. The study recommends discontinuing contaminated water sources, ensuring clean water supply pipelines away from sewage, educating farmers on chemical use, and conducting water management awareness programs for sustainable drinking water practices [31]. Furthermore, the study in Lahore highlighted the alarming presence of arsenic and coliform bacteria in water samples. Concentrations of coliform bacteria and arsenic exceeded WHO standards, with arsenic levels ranging from 24.92–32.72 µg/L. Two samples exhibited bacterial contamination exceeding WHO standards of 0 MPN/100mL. The study concluded that high arsenic concentration rendered the drinking water unfit for human consumption, highlighting the urgent need for precautionary measures and stringent monitoring to prevent contamination and ensure safe drinking water in the area [32].

Similarly, in Swat district, water quality in educational institutions were assessed in 80 schools and colleges of Mingora city. Parameters such as temperature (25.83°C), pH (6.3), TDS (410.7mg/l), and nitrate (44.52mg/l) were within standards set by APHA and WHO. However, findings showed critical contamination with fecal coliform and *Escherichia coli*, linked to waterborne illnesses like diarrhea, gastroenteritis, dysentery, and reported cases of viral hepatitis among local residents. The study emphasizes the need for stringent monitoring and interventions to address water contamination issues in the region [33].

Access to safe water is a fundamental right for all living beings, yet many school children in developing countries suffer from water-related illnesses. So, Brazil's Santarem region, reliant on the Alter do Cho aquifer, investigated drinking water quality and its impact on school children's health. Analysis of water samples from city and rural schools revealed contamination with *E.coli* and total coliform, posing risks of abdominal illnesses. Though most parameters met Brazilian standards, schools relying on shallower wells exhibited elevated Al and NO<sub>3</sub>-

levels, highlighting the need for ongoing monitoring and further epidemiological studies to prevent health hazards, emphasizing the importance of considering water acidity, microbial contamination, and pollutants to safeguard children's health [34]. Moving to Bangladesh, Patuakhali and Magura districts revealed alarming findings regarding water quality in schools. A Research in Patuakhali district assessed drinking water quality at elementary schools from tube wells (TWs). 65 samples were analyzed for physiochemical parameters, showing most within national standards except for elevated Fe and As levels in 11% of samples. Microbial analysis indicated 40% free from total coliforms and 60% from fecal coliforms. However, As in 26% of TWs posed noncarcinogenic risks for children, with 6.15% samples indicating potential cancer risks for children if consumed long-term, highlighting the concerning health implications of water contamination in these areas [35]. Magura District assessed primary school children's drinking water sources, using APHA methods to analyze physiochemical parameters and metals like manganese, arsenic, and iron. Samples from 20 tube wells showed values beyond recommended ranges: EC (400–2340  $\mu\text{S}/\text{cm}$ ), hardness (200–535 mg/L), TDS (208–1216 mg/L), chloride (10–640 mg/L), and pH (7.05–9.03). Metal concentration in the samples, manganese (10–370  $\mu\text{g}/\text{L}$ ), iron (40–9890  $\mu\text{g}/\text{L}$ ), and arsenic (1–55  $\mu\text{g}/\text{L}$ ), exceeded WHO and Bangladesh drinking water quality standards, indicating the inadequacy of water quality in the Magura district for ensuring safe potable water for schoolchildren [36].

Similarly, at Atarra tehsil of India, where drinking water samples were collected from 6 hand pump located in the primary schools. Quality of drinking water was analyzed. Lab tests were conducted to analyze parameters such as pH, Cl, hardness, alkalinity, and TDS. The results were compared against the WHO drinking water quality standards. Study revealed that few of the drinking water samples were not suitable for the human consumption. EC was found to be greater than the tolerable limit at all stations. Total hardness ( $\text{Ca}^{+2}$  and  $\text{Mg}^{+2}$ ) were also greater than the acceptable level, except for S6 (Nijaminagar) and S2 (Awashti Ashram)). Turbidity at S3 (Nagwara) exceeded the WHO standard.  $\text{NO}_3^-$  exceeded the limit at S5 (Badausa area) and fluoride levels were found to be high at S6 (Nijaminagar). It is essential to note that without access to safe and clean water, positive health and well-being cannot be achieved. In order to emphasise the significance of water quality management in the area, this study set out to evaluate the quality of groundwater in and around the Atarra tehsil [37].

The presence of bacteria in drinking water used for human consumption can pose risks to community health, as these microbes may carry plasmids that can be transferred to other bacteria. In Shanghai, similar research focused on elementary and middle school drinking water

quality due to the health risks associated with bacteria in water. Out of 183 schools sampled, residual chlorine, CFU, COD, and turbidity were analyzed. Findings showed varied parameters: residual chlorine (<LOD-0.670 mg/l), CFU (<LOD->300), COD (0.090–2.710 mg/l), and turbidity (0.100–2.050 NTU) in direct-drinking water. CFU levels were higher at 25-60 °C but decreased at 60–100 °C, lower in middle schools, influenced by water treatment systems and faucet type. Additionally, the study suggested measures like keeping water at room temperature, away from toilets, or heating it to 60°C or higher to improve drinking water quality, emphasizing differences observed between urban and rural areas and various water treatment technologies [38]. In Brazil's Morrinhos, investigation faecal coliforms in drinking water and on drinking source surfaces, examining bacterial conjugation, plasmid stability, antibiotic resistance, and plasmid presence in 110 public schools was conducted. Surface microorganisms were identified through biochemical tests and culture media. Antibiotic resistance was tested using ampicillin, tetracycline, and ciprofloxacin. Results showed 51% positive for coliforms and 31% for *Salmonella* spp. Among coliform-positive samples, 27 displayed persistent, conjugation-capable plasmids, indicating potential risks associated with bacterial contamination and transmission of resistance traits in the studied area [39].

Similar research in 8 public schools in Cebu City, Philippines analyzed water samples from Water Vending Machines (WVMs) due to health concerns. Microbial tests using CFU method revealed a total coliform count of 2.6 CFU/ml in all 8 samples, with *E. coli* values between 1.1-2.6 CFU/ml. These values exceeded national and international permitted levels for drinking water, except in two schools that passed physicochemical analysis but failed microbiological tests due to *E. coli* presence. The study strongly advises students against drinking water from WVMs and recommends regular cleaning, maintenance, and checks of these machines in schools and institutions to prevent coliform and *E. coli* contamination [40]. Similarly, in Ankara's primary schools, 31 drinking water samples were analyzed for physical, chemical, and biological aspects within 24 hours of collection. 93.5% of schools used communal water supply, with physicochemical parameters meeting permissible ranges except for Cd and Pb levels. Buildings older than 30 years (24.1% of all) had significantly higher average lead levels (0.0160.013 mg/l) compared to newer buildings (0.0060.01 mg/l). No *Cryptosporidium* or *Giardia* parasites were found, but microbial reproduction wasn't determined. The study suggests treating lead-contaminated plumbing in older buildings and implementing ongoing drinking water quality monitoring in schools [41]. Likewise study in Hanoi City, Vietnam, aimed to evaluate tap water quality in kindergartens and elementary schools for primary

prevention of water-borne illnesses, particularly in children. From August to October 2019, a cross-sectional study collected water samples from 154 schools, examining microbiological and physical-chemical factors against domestic water quality standards and WHO guidelines. All schools used the community water system, with most physicochemical parameters meeting standards. However, a few samples deviated in pH (3.9%), Turbidity (0.6%), Nitrite (3.2%), Permanganate (6.5%), and Ammonium (5.8%) levels from national standards. Additionally, microbiological data showed municipal water system samples contaminated with Coliform (9.7%) and/or *E. coli* (7.8%), suggesting a portion of low-quality water in the system [42].

In Chattogram city, Bangladesh, evaluation of microbial quality in drinking water of 50 elementary schools found bacteria, impacting students' health. Total viable count (TVC), total coliform (TCC), and fecal coliform were assessed using pour plate and MPN methods. Results showed 52% of samples contained coliform, 28% had fecal coliform, and 46% exceeded WHO guidelines (>500 CFU/ml) for TVC. Schools from Chattogram city corporation exhibited the highest TCC (83%) and TVC (67%) levels. Bacteria like *Salmonella*, *E. coli*, *Yersinia*, *Enterobacter*, *Klebsiella*, and *Citrobacter* were found, suggesting water reservoir contamination across many schools, indicating impurity [43].

Likewise, in the Garhwal region of Uttarakhand, schools obtain drinking water directly from natural sources. Investigation of drinking water quality found that the metal concentration and physiochemical parameters of the water met British standards and were fit for human consumption. However, some sampling spots showed total coliform ranged between 6 to 18 MPN/100 ml [44]. Another study investigated the drinking water quality in academic institutions in Tamluk, the state of west bengal, India. A significant concentration of faecal coliform (2400/100ml) was identified in the drinking water, revealing contamination of poor drinking water supply system. The investigation revealed that the current water supply infrastructure was insufficient and drinking water was not suitable for human consumption and required appropriate treatment [45]. Similar study conducted in Rajshahi City Corporation to assess the quality of groundwater samples from various educational institutions for drinking purposes. The pH, total solids, suspended solids, dissolved solids, total alkalinity, total acidity, manganese, iron, chloride, arsenic, COD, BOD, DO, turbidity, hardness, fecal coliform and total coliform was examined. The results showed that except for total acidity and pH, all parameters in drinking water samples collected from all sites were within permissible limits. However, the water supply system of these academic institution's had higher concentrations of EC, COD, DO, fecal and total coliform which can be harmful to human health [46].

### 3.2 Water Sanitation and Hygiene (WASH)

The Sustainable Development Goals by the United Nations aims at the target of providing access to WASH (Water and Sanitation Hygiene) for everyone, but very few researches have analyzed comprehensively Water and sanitation hygiene services in schools of Pakistan. A study conducted in Pakistani primary schools aimed to identify WASH practices and their impact on academic performance. In Sindh province, a representative cross-sectional study evaluated WASH conditions using structured analysis and interviews in 425 schools. The study focused on compliance with national WASH policies, coverage, and WASH-related performance concerns. Findings revealed low provision of basic WASH facilities, inconsistency in functionality, accessibility, and availability. The study highlighted a significant association ( $P < 0.001$ ) between school performance and WASH policy/interventions but found no connection between current interventions/policies and overall drinking water quality. Discrepancies included high fecal and heavy metal contamination, suggesting the need for adopting the National WASH policy and adequately funding evidence-based WASH interventions for improved educational outcomes in primary schools [47].

Many interventions to improve water, sanitation, and hygiene in schools have focused on reducing diarrheal diseases. So, a study in Uganda and Mozambique assessed rural school drinking water quality using WASH indicators and *Escherichia coli* tests in 374 schools. Results showed 83% and 71% of schools had low-risk water quality, while 13% and 7% respectively had unfit water quality. Schools with improved water sources had reduced *E. coli* risk by 0.22 (Uganda) and 0.12 (Mozambique), and factors like quick access to water sources and availability of soap correlated with decreased *E. coli* levels. Implementing actionable WASH services is recommended to improve school water quality, potentially benefiting children's health, cognitive growth, and learning environments. [48].

Hygiene and water treatment programs implemented in schools have been shown to reduce absenteeism, increase students' knowledge, and improve hygiene practices. So Kenya assessed the impact of a "safe water and hand hygiene" program in 42 schools, introducing water filtration and hygiene practices. After implementation, improvements in handwashing techniques were noted, and a decrease in acute respiratory diseases among students was observed. However, no reduction in diarrhea was found. The program participants showed sustained hygiene knowledge improvement and a reduced risk of respiratory infections, indicating the positive effects of the school-based intervention on student health and hygiene

practices. [49]. While the Kenyan intervention showcased sustained hygiene knowledge improvement and reduced risk of respiratory infections, the Nepalese findings underscored the urgent need for WASH improvements at various levels. In Ramechhap and Dolakha districts of Nepal, a study assessed WASH conditions for 562 households and 708 school children. Water quality analysis of 634 samples from community sources, selected schools, and homes revealed contamination in 39.5% of community water sources, 27.4% of household point-of-use samples, and 75.0% of school drinking water sources with thermotolerant bacteria. Although pH, mean Pb, total residual chlorine, and mean As concentrations met national criteria, contamination was linked to roaming domestic animals in households. The findings emphasize the necessity to improve WASH conditions across households, schools, and communities. [50].

Phenols in drinking water are a concern as they can originate from industrial discharges, pesticides, and disinfectants. In Lahore, a study investigated phenols in water and soil from a furniture market using High Performance Liquid Chromatography (HPLC). Three priority phenols (phenol, p-cresol, and catechol) were analyzed, revealing phenol and p-cresol in most water samples but no detectable catechol. Phenol concentrations ranged from 1.86-1.91 ppm in drain and tap water samples, with p-cresol at 2.13-2.17 ppm in several water samples and one soil sample. Alarmingly, all detected phenol levels exceeded EU Directive limits, indicating potential environmental contamination. [51] Likewise research on Pakistani apple juice assessed its physiochemical parameters and nutrient content. The juice displayed TDS, conductivity, and pH within specific ranges. Iron content ranged from 1.076 to 1.688 mg/1000mL, while Vitamin C varied from 8.79 to 45.56 mg/1000ml. Additionally, total phenolic content ranged between 40.8 and 59.8 mg/1000 mL, indicating potentially higher levels of essential nutrients in Pakistani apple juice compared to reported data. [52].

Similar study in Bangladesh, aimed to evaluate the antibacterial properties, antioxidant activity and polyphenol content in different tea varieties including green tea, red dust, broken orange pekoe and flowery broken orange pekoe.. The results indicated that green tea had significantly higher levels of total phenolic and flavonoid contents ( $P < 0.05$ ) compared to the other black tea varieties. Additionally, compared to the other tea varieties examined, green tea had higher free radical scavenging and antioxidant properties ( $P < 0.05$ ). Overall this research suggests that Bangladeshi tea, particularly green tea, holds promise as a natural antioxidant and effective antibacterial agent, potentially contributing to enhanced human health. [53].

### 3.3 Health Risk Assessment of Heavy Metals

Drinking water quality is crucial for the well-being of all individuals, including teenagers. With this in mind, a study in Multan, Pakistan assessed arsenic (As) levels in high school drinking water and associated health risks. Water samples from four tehsils showed As content between 3.25-184  $\mu\text{g/L}$ , with 99% exceeding the WHO's safe limit of 10  $\mu\text{g/L}$ . Hazard quotient (HQ) and Hazard index (HI) in Multan surpassed safe levels ( $>1$ ) set by USEPA, indicating potential health risks. Carcinogenic risk (CR) and carcinogenic indices (CI) for dermal and oral exposure exceeded USEPA standards ( $10^{-6}$ ), suggesting extreme cancer risks. These findings emphasize the urgent need for action by educational authorities and water suppliers to provide safe drinking water, highlighting significant health hazards from arsenic contamination in Multan's water sources [54]. Similarly, An assessment of groundwater quality in 150 government schools in flooded regions of southern Punjab, Pakistan, revealed concerning findings. 49% of samples were contaminated with total coliform, 37% with faecal coliform bacteria, and various chemical constituents exceeded WHO limits (Ca-43%, Mg-11%, K-37%, Na-39%,  $\text{SO}_4^{2-}$ -31%, Hardness-15%, Cl-35%, TDS-39%). Elevated levels of fluoride (15%), iron (60%), and arsenic (58%) were present. The mean chronic daily intake values for arsenic and iron were 0.012 and 0.011 mg/kg/day, respectively. The arsenic health risk index (HRI) indicated potential health hazards ( $>1$ ) for 58% (adults) and 88% (children) of samples, emphasizing the immediate need for addressing water quality issues to ensure access to safe drinking water in Southern Punjab [55].

Water quality assessments in Pakistan revealed widespread contamination issues in different regions. In Sindh province, Pakistan, a study assessed Fe, Mn, Cd, and Pb concentrations in drinking water across 425 public primary schools. Results showed that in 67% of schools, Pb levels exceeded the WHO permissible limits, while Cd levels exceeded the limits in 17% of schools, and Fe levels in 15% of schools. The cumulative lifetime cancer risk (ILCR) for Pb was higher than acceptable levels, which is concerning as Pb can negatively affect children's long-term health, school performance, growth and development [56]. Similarly in Punjab's Mailsi district, a study assessed drinking water quality, particularly As levels and health impacts. 44 groundwater samples from Mailsi and Sargana underwent analysis for As and other cations using atomic absorption spectrophotometry, while anions were identified via titration or spectrophotometry. Water chemistry indicated dominance of  $\text{Ca}^{+2}$  cation and  $\text{Cl}/\text{HCO}_3^-$  anions, displaying a Ca-Mg- $\text{HCO}_3^-$  type. As concentrations ranged from 11-828  $\mu\text{g L}^{-1}$ , surpassing WHO limits, and higher levels of  $\text{SO}_4^{2-}$  (247-1053 mg/L) were also noted. Health

Risk Index (HRI) at Sargana site indicated inappropriateness for consumption due to elevated levels of HQ, ADD and CR of As, emphasizing the urgent need for arsenic testing in wells to prevent potential adverse health effects. [57]. Another research in Kahrora, Punjab, Pakistan, assessed As concentration in drinking water in urban and rural areas. Water samples showed As levels ranging from 1.62 – 35.28 µg/L (rural) and 3.23 – 45.62 µg/L (urban), indicating contamination likely from agricultural and human activities. Health risk assessment revealed chronic health risks, with hazard quotient values exceeding 1 and cancer risk surpassing USEPA limits ( $1 \times 10^{-4}$  to  $1 \times 10^6$ ). Statistical analyses linked As contamination in drinking water to both anthropogenic and geogenic factors, suggesting potential future cancer-related issues in the area due to As-contaminated water consumption [58].

The issue of the presence of As in drinking water of Pakistan has not been taken seriously in the past. A study sought to conduct a more comprehensive analysis on the presence of arsenic in groundwater samples from Hyderabad, Lahore and Muzaffarabad, where insufficient information on the As had previously been reported. Results showed Lahore had the highest samples exceeding WHO limits ( $>10$  µg/L), especially in areas like Yuhana, Dograiy Kallan, and Nishtar Colony ( $>50$  µg/L). Arsenic concentrations correlated with mean ADD, HQ, and CR values, with Lahore being most affected, followed by Hyderabad and Muzaffarabad. Children faced a higher risk than adults. Besides arsenic, the study explored physicochemical parameters, concluding that Lahore had the most significant arsenic impact, while Muzaffarabad was comparatively less affected. [59].

The degree of As contamination in drinking water and any potential health impacts were examined in the Shikhpura District of Pakistan, finding concentrations ranging from 2 to 900 µg L<sup>-1</sup>, surpassing the 10 µg L<sup>-1</sup> acceptable limit. Health risk assessment using indicators like ADD, HI, HQ, CR, and CI for dermal and oral exposure showed elevated values ( $1.03 \times 10^{-5}$ – $9.69 \times 10^{-6}$ ,  $1.07 \times 10^{-2}$ – $9.85 \times 10^{-4}$ ) exceeding toxic risk index values. Both HI and CI surpassed WHO standards, indicating increased cancer and disorder risks due to As exposure in the studied population. [60].

The toxicity and non-degradable nature of heavy metals cause significant public health and environmental concern globally. So, a study conducted in Satkhira district, Bangladesh, drinking water supplies of 240 primary schools were examined to ensure arsenic-free water. Findings showed 49% of tube wells exceeded WHO's arsenic limit (10 µg/L), reaching a maximum of 167.9 µg/L; iron and chloride levels also surpassed Bangladesh's drinking water

quality standards. Arsenic concentrations in the water failed to meet both Bangladesh and WHO standards, posing potential cancer risks ( $HQ > 1$ ) across all 7 Upazilas, highlighting health hazards from arsenic exposure in the drinking water supply. [61]. Similarly in Mashhad, Iran, a study evaluated health risks from heavy metals (Cr, Ni, Pb, Hg, As) in 140 treated drinking water samples for both children and adults through dermal and oral exposure. Hazard assessments (CR, HI, HQ) indicated HQ values for adults were within safety standards ( $< 1$ ), but some stations showed higher HI for kids. Chromium (Cr) contributed significantly to the HI for both populations (55% to 71.2%). Total Carcinogenic Risk (TCR) for adults and children was  $7.38 \times 10^{-5}$  and  $1.33 \times 10^{-4}$ , respectively, with CR<sub>total</sub> values indicating potential cancer risk, urging the implementation of effective purification programs to safeguard urban dwellers' health. [62].

Likewise in Bangladesh, a study focused on Fe and As levels in drinking water from primary schools, assessing potential health risks for students. Among 58 samples, the average As concentration exceeded WHO's limit (0.044 mg/L vs. 0.01 mg/L), with 18.97% surpassing Bangladeshi standards (0.05 mg/L) and 55.17% above 0.01 mg/L. Fe levels averaged 2.84 mg/L, surpassing Bangladeshi limits (1 mg/L) in 75.66% of samples. Boys had lower vulnerability than girls to As-related health risks. However, both groups faced noncarcinogenic hazards from As intake (HQs: boys 6.01-17.85, girls 7.41-22.03) and combined As and Fe ingestion might pose health risks ( $HI > 1$ ). Average CR values (boys: 0.0027-0.008, girls: 0.0033-0.0099) indicated an increased cancer risk beyond acceptable thresholds. [63]. In another study in Bangladesh, 20 drinking water samples from primary school level were collected for examination at the Magura district. Health risk assessment found As and Fe didn't meet UEPA standards ( $HQ > 1$  and  $CR > 10^{-6}$ ). The study suggests exploring alternative safe drinking water options in schools to prevent potential health hazards linked to As contamination [64].

### **3.4 Willingness to Pay (WTP) and Health Risk Associated with Water Borne Diseases**

A significant proportion of the population in South Asia lives in rural areas where water-borne diseases are prevalent and people may not be aware of the risks associated with them. To determine the WTP for improved drinking water facilities in the rural settlement of Aamsani Khui, Lahore. A questionnaire survey was conducted. This study aims to investigate the relationship between influencing factors and WTP by using multiple regression and chi-square analyses. It revealed high rates of diarrhea cases among adults (50%) and children (31.9%) in

the area, with 48.6% having completed middle school and monthly incomes ranging from 5000-30,000 Rupees. The research highlighted a strong association between poor health status and WTP, while educational and income levels showed a weaker correlation. The average WTP ratio was 1.835, indicating an average willingness to pay between Rs. 1 to 5. These findings suggest that various factors such as educational level, health status, and income are crucial determining factors of WTP for better quality of drinking water facilities [65].

Water scarcity is a growing concern in developing nations due to the increasing population. In addition, the declining quality of water supply infrastructure leads to the mixing of clean water with sewage, resultantly causing water-related diseases. Another research, conducted in Lahore, Pakistan, aimed to determine the WTP from 200 respondents for better quality of water using the contingent valuation method. Socioeconomic factors like income, household type, and occupation were studied, revealing income as the most influential factor for WTP. The mean WTP was 0.70 USD, and respondents reported dissatisfaction with water quality, experiencing daily water inaccessibility for 1 to 2 hours. The research suggests the need for larger-scale studies to comprehensively understand Lahore's water supply situation and preferences, urging further investigation with increased participant numbers [66].

Another questionnaire-based study focused on rural community awareness, disease occurrence, and the cost of water-borne illnesses among 50 households was conducted. Approximately 40% of respondents had limited knowledge about water-borne diseases beyond typhoid and diarrhea. Stomach ailments were prevalent, and those below the poverty line incurred daily costs of \$0.6 to 1.2 (Rs. 50 to 100), while those with lower to average incomes faced direct costs of \$2.3 (Rs. 200). Indirect disease costs increased with higher incomes, reaching \$2.3 to 4.7 (Rs. 200 to 400) daily. People with higher incomes demonstrated a higher willingness to pay (WTP) for improved sewage and water systems, with WTPs of \$3.6 or Rs. 300 and \$1.2 or Rs. 100 per month, respectively. The ability to pay correlated significantly with income ( $r = 0.319, 0.307; p < 0.05$ ) and demonstrated a significant influence on WTP for better water supply and sewerage systems ( $r = 0.805, 0.797; p < 0.05$ ). The study advocates for health interventions such as improved drinking water and hygiene facilities to enhance rural health and curb waterborne diseases [67].

Providing clean water and sanitation remains a significant challenge for developing countries such as Bangladesh, particularly in southern cities with a shortage of clean, safer water for sanitation drinking purposes. To resolve this issue, a study was carried out to investigate the

potential revenue for the water supply authority in Khulna city and demand for improving water supply services. Factors like household income, education years, and time spent collecting water significantly influenced willingness to pay (WTP) using the single-bounded dichotomous choice contingent valuation technique. On average, households were willing to pay \$5.05 monthly, potentially generating yearly revenues of \$4.26 million, surpassing the current revenue by 2.5 times. The water supply agency currently faces an annual loss of about \$2.14 million, which could be offset by upgrading water supply services. The study suggests leveraging potential revenue and addressing structural barriers to mitigate urban water scarcity effectively [68]. Similarly, in Owo, Nigeria, a study on improved water facility WTP surveyed 256 households across 11 political wards. Logit regression and descriptive statistics analyzed the data. Findings indicated 18.8% used boreholes, 20.3% wells, and 43% public utilities for water sources, with 70.3% dissatisfied with unreliable services. Residents expressed a willingness to pay an average of \$4.5 monthly for better water supply. Factors influencing WTP included income, gender, water quality, frequency, education, household size, and connection fees. [69]. Likewise, a study focused on estimating the WTP to strengthen Benin's rural water supply system. Results found that rural households in Benin expressed their willingness to pay more than the existing amount to strengthen their water supply facilities. Education, wealth and characteristics of new and current water system was influenced by WTP [70].

In Sebeta, Ethiopia, rapid urban growth from proximity to Addis Ababa caused water shortages. This study aimed to determine household willingness to pay (WTP) for better water facilities and analyze influencing factors. Using a contingent valuation method with 250 respondents, 66% were willing to pay an average of 20 ETB, exceeding the current 161 ETB monthly water tariff. The binary logistic model revealed significant correlations between WTP and gender, age, education, marital status, income, and years lived in Sebeta [71]. After attending a camp in June 2015 a public health lab investigated reports of students showing gastroenteritis symptoms. Using a standardized questionnaire and microbiological techniques, the study aimed to link illnesses with camp exposures. Among 188 students experiencing abdominal pain, nausea, and diarrhea, the investigation suggested a likely connection between the outbreak and camp drinking water use. Microbiological analysis detected various *Escherichia coli* strains in both drinking water and student stool samples, highlighting issues with the water supply system, such as pipeline defects and inappropriate water purifier filters. [72].

## **CHAPTER III**

### **MATERIALS AND METHODS**

Following the research objectives outlined in the previous chapter, this section explains the systematic approach employed to collect, analyze, and interpret the data.

#### **3.1 Site Selection**

Rural areas from Punjab i.e. north, central and south were selected for sampling purpose. These rural subhubs were Lahore, Sheikhpura, Kasur, Okara, Pakpattan, Sahiwal, Lodhran, Faisalabad, Nankana Sahib, Narowal, Sialkot, Gujranwala, Hafizabad, Jhang, Vehari, Multan, Khanewal and Bhawalnagar.

#### **3.2 Collection of Data**

Secondary data was collected by using internet and library to gain access to published articles, journals, books, reports, case studies and thesis. While primary data was collected through reconnaissance survey and field visits of the selected areas.

#### **3.3 Collection of Samples**

A total number of 274 drinking water samples of primary schools were taken from rural Punjab through simple random sampling. 49 samples were taken from subhubs of Lahore, 15 each from Sheikhpura and Kasur, 5 each from Okara and Pakpattan, 18 from Sahiwal, 4 from Lodhran, 20 from Faisalabad, 10 from Nankana Sahib, 10 from Narowal, 50 from Sialkot, 28 from Gujranwala, 10 from, Hafizabad, 35 samples were taken from subhubs of Jhang (n=10), Multan (n=5), Vehari (n=8), Khanewal (n=8) and Bhawalnagar (n=4).

Prior to sampling, each sampling source was pumped for 5 minutes to clear the pipe line. Bottle cover was taken off. The bottle was filled with drinking water. To avoid leaks, bottles were completely filled and screwed tightly with cap. Water samples were collected in properly labeled polyethylene (PET) bottles of 600 ml capacity each for laboratory analysis.

Before sampling, the bottles were washed with dilute acid, rinsed thoroughly and finally washed properly with deionized water, several times. Bottles were filled within one to two inches of the top after three thorough rinses with sample water. After the collection, these

samples were placed in cooler with ice. The samples were then transported to the laboratory within 24 to 48 hours and stored at 4 °C.

**Table 3.1 The codes of water samples samples according to cities**

Sample Code	Cities	Longitude	Latitudes	Schools	Water source	Remarks
<b>Primary Schools of Northern Rural Punjab, Pakistan</b>						
NRW-1	Narowal	74.8099262	32.28215	GPS Dhaipur	Water Pump	Nearby Agricultural area
NRW-2		74.6475211	31.95709	GGPS Heera Jhun	Water Pump	Nearby Agricultural area
NRW-3		74.7854969	32.07136	GGPS Poong	Water Pump	Nearby Agricultural area
NRW-4		74.8038637	32.22014	GGPS Ghass	Water Pump	Nearby Agricultural area
NRW-5		74.8686653	32.18015	GGPS Bhalia Pind	Water Pump	Nearby Agricultural area
NRW-6		74.961092	32.30206	GPS Pindi Amlak	Water Pump	Nearby Agricultural area
NRW-7		75.1146711	32.3629	GGPS Samsial	Water Pump	Nearby Agricultural area
NRW-8		75.1086543	32.32975	GGPS Bhaloopur	Water Pump	Nearby Agricultural area
NRW-9		74.7810513	32.18757	GGPS Lodhi Khangora	Water Pump	Nearby Industry &Agricultural area
NRW-10		74.7823367	32.20643	GGMPS Sahobillo	Water Pump	Nearby Agricultural area
GRW1	Gujranwala	74.2045794	32.37615	GPS Harrian Wala Khurid	Water Pump	Nearby Agricultural area
GRW2		73.8129602	32.34255	GGPS Rukh Singh Pura	Water Pump	Nearby Agricultural area
GRW3		74.1887643	32.46693	GPS Sohdra No.1	Water Pump	Nearby Industry &Agricultural area
GRW4		74.1034022	32.43954	GPS Bhatte ke wzirabad	Water Pump	Nearby Agricultural area
GRW5		73.7966764	32.24939	GPS Chah Isher Wala	Water Pump	Nearby Agricultural area
GRW6		74.0090752	32.33843	GGPS Kakka	Water Pump	Nearby Industry &Agricultural area
GRW7		74.0206919	32.36376	GMPS Kheway Wali	Water Pump	Nearby Agricultural area
GRW8		74.1232619	31.79428	GMPS Jhattan Wali	Water Pump	Nearby Agricultural area
GRW9		73.9817025	32.35918	GMPS Jewany Wali	Water Pump	Nearby Agricultural area
GRW10		74.0204643	32.38008	GGPS Kathore Khurd	Water Pump	Nearby Industry &Agricultural area
GRW11		73.9466363	32.31635	GMPS Dilawar Khurd	Water Pump	Nearby Agricultural area
GRW12		74.0052353	32.22319	GGPS Kot Jahangir	Hand Pump	Nearby Industry &Agricultural area
GRW13		74.1255514	32.29985	GPS Kot Noora	Water Pump	Nearby Agricultural area
GRW14		73.8779251	32.29946	GGPS Dera Jamujam Wala	Hand Pump	Nearby Agricultural area

GRW15		74.1643652	32.34618	GMPS Dodan Wali	Water Pump	Nearby Agricultural area
GRW16		74.172438	32.30787	GMPS Iban Wali	Water Pump	Nearby Industry & Agricultural area
GRW17		73.9946396	31.93727	GPS Supray	Water Pump	Nearby Agricultural area
GRW18		74.0934365	32.0417	GGPS Ratta Goraya	Water Pump	Nearby Agricultural area
GRW19		74.3291397	32.1264	GPS Islam Pura	Water Pump	Nearby Agricultural area
GRW20		73.9912933	32.31244	GPS Ahmad Nagar	Water Pump	Nearby Agricultural area
GRW21		73.9785952	32.12263	GPS Chak Jaid	Water Pump	Nearby Industry & Agricultural area
GRW22		74.1368908	32.16483	GMPS Kot Isaish	Water Pump	Nearby Agricultural area
GRW23		74.2726347	32.06342	GGPS Kot Karam Chand	Water Pump	Nearby Agricultural area
GRW24		74.1553972	32.4906	GPS lawairi wala	Hand Pump	Nearby Agricultural area
GRW25		74.2435719	32.1433	GGPS Kotli Bal Gobind	Water Pump	Nearby Agricultural area
GRW26		73.9770021	31.963	GMPS Lunj Kalan	Water Pump	Nearby Agricultural area
GRW27		74.298621	32.31014	GMPS Burj Chemma	Water Pump	Nearby Agricultural area
GRW28		73.8647984	32.33703	GPS Mandiala Chatha	Water Pump	Nearby Agricultural area
HFD-1	Hafizabad	73.7111724	31.96019	GGPS Hanjran Wala	Hand Pump	Nearby Agricultural area
HFD-2		72.9285122	31.77169	GPS Kotli Amir Singh	Water Pump	Nearby Agricultural area
HFD-3		73.6349529	32.2718	GMPS Kot Mian Khan	Hand Pump	Nearby Agricultural area
HFD-4		73.506402	31.86022	GGPS Haji Pura	Water Pump	Nearby Agricultural area
HFD-5		73.7205707	32.11455	GPS Thatha Kalian	Water Pump	Nearby Agricultural area
HFD-6		73.4552196	31.86482	GGPS Dubbar	Hand Pump	Nearby Agricultural area
HFD-7		73.4415901	31.8696	GGPS Walgan Saqian	Water Pump	Nearby Agricultural area
HFD-8		73.5358049	31.86928	GGPS Walgan Raja	Water Pump	Nearby Agricultural area
HFD-9		73.5041941	31.83156	GMPS Mochi Wala	Hand Pump	Nearby Agricultural area
HFD-10		73.7079729	32.04364	GMPS Bhoon Khurd	Water Pump	Nearby Agricultural area
SKT-1	Sialkot	74.7890845	32.40357	GGPS Chobarah	Water Pump	Nearby Agricultural area
SKT-2		74.6212752	32.08629	GPS Ghataliyan	Water Pump	Nearby Agricultural area
SKT-3		74.9077237	32.42746	GPS Naju Chak	Water Pump	Nearby Agricultural area
SKT-4		74.5589669	32.10881	GGPS Kot Agha	Water Pump	Nearby Agricultural area
SKT-5		74.6224897	32.15024	GGPS Eiso Gega	Hand Pump	Nearby Agricultural area
SKT-6		74.5778163	32.13564	GPS Hunjra	Water Pump	Nearby Agricultural area
SKT-7		74.4910273	32.41491	GGPS Haran Wali	Water Pump	Nearby Industry & Agricultural area
SKT-8		74.5853625	32.08138	GGPS Gakhar Wali	Water Pump	Nearby Agricultural area

SKT-9	74.5903052	32.43666	GGPS Guna Khurd	Water Pump	Nearby Agricultural area
SKT-10	74.1875826	32.50226	GGPS Tahli Wala	Water Pump	Nearby Agricultural area
SKT-11	74.322943	32.50986	GGPS Hadokay	Water Pump	Nearby Agricultural area
SKT-12	74.3079144	32.33661	GGPS Kot Jandu	Water Pump	Nearby Industry &Agricultural area
SKT-13	74.5640918	32.13347	GPS Hussa Jajja	Water Pump	Nearby Agricultural area
SKT-14	74.3286867	32.52032	GGPS Kolokay	Water Pump	Nearby Agricultural area
SKT-15	74.8791178	32.41167	GGPS Sanghey	Water Pump	Nearby Industry &Agricultural area
SKT-16	74.5282254	32.55377	GPS Propi Arian	Water Pump	Nearby Industry &Agricultural area
SKT-17	74.3163523	32.44452	GGPS Chak Basao	Water Pump	Nearby Industry &Agricultural area
SKT-18	74.5715779	32.42938	GMPS Prag Pur	Water Pump	Nearby Industry &Agricultural area
SKT-19	74.8627705	32.45385	GMPS Gogial	Water Pump	Nearby Agricultural area
SKT-20	74.6289389	32.42433	GMPS Vinjay	Water Pump	Nearby Agricultural area
SKT-21	74.8083983	32.09135	GGPS Dhari Wal	Hand Pump	Nearby Agricultural area
SKT-22	74.6065024	32.41485	GGPS Pakar Pur	Water Pump	Nearby Agricultural area
SKT-23	74.5066974	32.66263	GMPS Pindi Panjoran	Water Pump	Nearby Industry &Agricultural area
SKT-24	74.4848832	32.51263	GGPS Sleem Pur	Water Pump	Nearby Agricultural area
SKT-25	74.8377124	32.43809	GGPS Jhambian	Water Pump	Nearby Agricultural area
SKT-26	74.8660641	32.43412	GMPS Lalyal	Hand Pump	Nearby Agricultural area
SKT-27	74.3855883	32.30985	GGPS Kallan Khurd	Water Pump	Nearby Agricultural area
SKT-28	74.8537845	32.41094	GMPS Sangrial	Water Pump	Nearby Agricultural area
SKT-29	74.5067771	32.17871	GPS Kot Mokhal	Water Pump	Nearby Industry &Agricultural area
SKT-30	74.5968528	32.08674	GPS Data Zaidka	Water Pump	Nearby Agricultural area
SKT-31	74.6796012	32.17579	GGPS Thatha Sarkari	Water Pump	Nearby Agricultural area
SKT-32	74.3436697	32.53227	GMPS Chak Khana	Water Pump	Nearby Industry/Agricultural area
SKT-33	74.4420904	32.4964	GGPS Oulakh Awana	Hand Pump	Nearby Agricultural area
SKT-34	74.5661	32.35833	GMPS Tong	Water Pump	Nearby Agricultural area
SKT-35	74.5706331	32.66378	GMPS Ahmel Pur	Hand Pump	Nearby Agricultural area
SKT-36	74.4359919	32.30688	GMPS Janduky Goraya	Water Pump	Nearby Agricultural area
SKT-37	74.4741772	32.52046	GMPS Fateh Bhinder	Water Pump	Nearby Industry &Agricultural area

SKT-38		74.5430641	32.57651	GGPS Malekay	Water Pump	Nearby Agricultural area
SKT-39		74.4745438	32.26323	GGPS Kotli Basakha Singh	Water Pump	Nearby Agricultural area
SKT-40		74.2696506	32.52073	GPS Malian Wala	Water Pump	Nearby Agricultural area
SKT-41		74.5856985	32.40987	GGPS Badi Pur	Water Pump	Nearby Agricultural area
SKT-42		74.6305276	32.6011	GGPS Rang Pur Jattan	Water Pump	Nearby Agricultural area
SKT-43		74.357948	32.37894	GGPS Nai Abadi Najwal	Hand Pump	Nearby Agricultural area
SKT-44		74.4657513	32.17912	GPS Siran Wali	Water Pump	Nearby Agricultural area
SKT-45		74.6067363	32.51017	GGPS Tibbi Aarian	Dispenser	Nearby Agricultural area
SKT-46		74.2949556	32.29517	GMPS Burj Arrian	Water Pump	Nearby Agricultural area
SKT-47		74.6869637	32.33798	GPS Chawinda	Water Pump	Nearby Agricultural area
SKT-48		74.2987881	32.30965	GMPS CM Burj Cheema	Water Pump	Nearby Agricultural area
SKT-49		74.3316201	32.58963	GMPS Khasa	Water Pump	Nearby Industry & Agricultural area
SKT-50		74.5285964	32.3193	GPS Ferozkay Nagra	Water Pump	Nearby Agricultural area

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NNS-1	Nankana-Sahib	73.452839	31.58106	GPS Chak 51 RB	Hand Pump	Nearby Industry & Agricultural area
NNS-2		73.6648737	31.29909	GPS Kot Amir	Water Pump	Nearby Agricultural area
NNS-3		73.3867229	31.79809	GGPS Sadkana Chak 110	Water Pump	Nearby Agricultural area
NNS-4		73.4572933	31.72112	GGPS Dheer Chak 29/RB	Water Pump	Nearby Agricultural area
NNS-5		73.7580998	31.47049	GGPS Model Laddoana Fatah Thatha	Water Pump	Nearby Agricultural area
NNS-6		73.7014218	31.56781	GPS Kairan Wala	Water Pump	Nearby Agricultural area
NNS-7		73.8497302	31.5674	GPS Kot Nawab Khan	Water Pump	Nearby Agricultural area
NNS-8		73.3813937	31.09401	GPS Pindi Cherry	Water Pump	Nearby Agricultural area
NNS-9		73.462163	31.17441	GGPS Jamalpur Syedwala	Water Pump	Nearby Agricultural area
NNS-10		73.7322049	31.45495	GPS Talian Village	Water Pump	Nearby Agricultural area
LYP-1	Faisalabad	73.2217885	31.45419	GPS Chak 205 RB I	Water Pump	Nearby Agricultural area
LYP-2		73.1668769	31.12292	GPS 561 GB	Hand Pump	Nearby Industry & Agricultural area
LYP-3		73.2615118	31.48178	GGPS Chak 194 RB I	Water Pump	Nearby Agricultural area
LYP-4		73.5992062	31.42696	GPS 586 GB I	Water Pump	Nearby Agricultural area
LYP-5		73.3130372	31.49137	GPS Chak 74 RB I	Hand Pump	Nearby Industry & Agricultural area
LYP-6		73.3243933	31.43654	GPS 104 RB	Water Pump	Nearby Agricultural area

LYP-7		73.4914236	31.39281	GPS Chak 625 GB IV	Hand Pump	Nearby Agricultural area
LYP-8		72.9957381	31.26428	GGPS Chak No. 257 RB	Hand Pump	Nearby Agricultural area
LYP-9		72.8833011	31.06989	GPS Chak 141 GB	Hand Pump	Nearby Industry &Agricultural area
LYP-10		73.106561	31.0754	GPS Chak 418 GB	Water Pump	Nearby Agricultural area
LYP-11		72.8892102	31.18599	GGPS Chak 273 RB II	Water Pump	Nearby Agricultural area
LYP-12		72.9215309	31.16672	GGCMS Chak 528	Hand Pump	Nearby Agricultural area
LYP-13		72.9886205	30.89879	GPS 541 GB I	Water Pump	Nearby Industry &Agricultural area
LYP-14		72.9066154	31.00158	GPS 473 GB E	Water Pump	Nearby Agricultural area
LYP-15		73.0003214	31.09239	GGCMS Chak 387 GB I	Water Pump	Nearby Agricultural area
LYP-16		73.2670091	31.60463	GPS 146 RB-II	Hand Pump	Nearby Agricultural area
LYP-17		72.8371006	30.87318	GPS 202 GB	Water Pump	Nearby Agricultural area
LYP-18		72.8854653	30.92601	GPS 484 GB	Water Pump	Nearby Agricultural area
LYP-19		73.051198	30.98353	GPS Chak 419 GB	Water Pump	Nearby Agricultural area
LYP-20		72.8680593	30.79548	GPS 555 GB	Water Pump	Nearby Agricultural area
SWN-1	Sahiwal	72.4955427	30.39498	GPS 21/14-L	Water Pump	Nearby Agricultural area
SWN-2		72.526964	30.34301	GPS 94/12-L	Water Pump	Nearby Agricultural area
SWN-3		73.0761864	30.63414	GPS 136/9-L	Water Pump	Nearby Agricultural area
SWN-4		72.5987752	30.37269	GGPS 88/12 L Kalan	Water Pump	Nearby Industry &Agricultural area
SWN-5		73.0352943	30.54987	GPS 105/9-L	Hand Pump	Nearby Agricultural area
SWN-6		72.8841191	30.56819	GPS Harapa No. 2	Water Pump	Nearby Agricultural area
SWN-7		72.5008749	30.53975	GPS 41/14-L	Water Pump	Nearby Agricultural area
SWN-8		72.7512458	30.37482	GPS 171/9-L	Water Pump	Nearby Agricultural area
SWN-9		73.0141168	30.622	GPS 132/9-L	Water Pump	Nearby Agricultural area
SWN10		72.711412	30.40606	GGCMS 27/11-L	Water Pump	Nearby Agricultural area
SWN11		73.1292957	30.77407	GGPS 55/GD	Water Pump	Nearby Agricultural area
SWN12		73.0635471	30.5271	GGCMS 114/9-L	Water Pump	Nearby Industry/Agricultural area
SWN13		72.9389425	30.44653	GGPS 120/9-L	Water Pump	Nearby Agricultural area
SWN14		73.0420606	30.46042	GPS 124/9-L	Water Pump	Nearby Agricultural area
SWN15		73.5520422	31.15143	GGPS Kot Allah din No. 1	Water Pump	Nearby Agricultural area
SWN16		73.004149	30.649	GPS 98/6R	Hand Pump	Nearby Agricultural area
SWN17		72.943312	30.68417	GGPS Nalka Farm	Water Pump	Nearby Agricultural area
SWN18		72.6975824	30.33875	GPS 168/9-L	Water Pump	Nearby Agricultural area

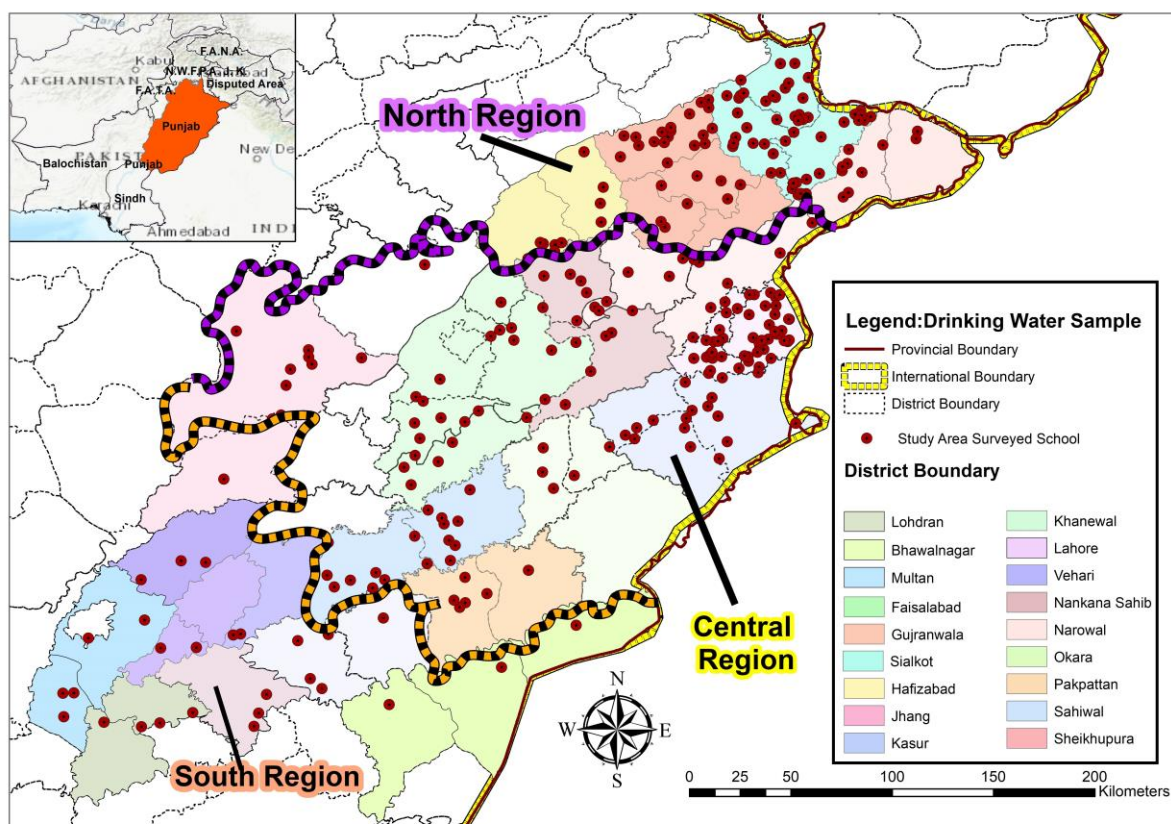
OKR-1	Okara	73.4538033	30.95938	GPS ADP Thatta Pehlwan Ka	Hand Pump	Nearby Agricultural area
OKR-2		73.4511235	30.85222	GGPS Shahmad	Water Pump	Nearby Agricultural area
OKR-3		73.4511218	30.66026	GPS Chak 23-A/4L	Hand Pump	Nearby Industry &Agricultural area
OKR-4		73.5918029	30.83729	GPS Chak 16/1L	Water Pump	Nearby Agricultural area
OKR-5		73.500061	30.77968	GPS Bagiana Okara	Water Pump	Nearby Agricultural area
JNG-1	Jhang	72.0923671	31.47696	GGPS Khan Pur Dhakli	Water Pump	Nearby Agricultural area
JNG-2		72.4279413	31.33046	GGPS Chak 264 JB	Hand Pump	Nearby Industry &Agricultural area
JNG-3		72.4130701	31.39411	GPS Safdar Abad	Hand Pump	Nearby Agricultural area
JNG-4		72.333349	31.308	GPS Goghay Wali	Water Pump	Nearby Agricultural area
JNG-5		72.2526264	31.08703	GGPS Darbar Gilmala	Water Pump	Nearby Agricultural area
JNG-6		72.2911512	31.10506	GGPS Darbar Kanwan	Water Pump	Nearby Agricultural area
JNG-7		72.3133011	31.23689	GGPS Basti Mangan	Water Pump	Nearby Agricultural area
JNG-8		72.0369907	30.82131	GMPS Basti Qazian	Hand Pump	Nearby Agricultural area
JNG-9		72.6483915	31.35818	GMPS Chak No. 250 II	Water Pump	Nearby Agricultural area
JNG-10		72.4136764	31.36228	GPS Basti Dr. Abdul Aziz	Water Pump	Nearby Agricultural area
PKP-1	Pakpattan	73.3889415	30.41667	GPS Chak 26/SP	Water Pump	Nearby Agricultural area
PKP-2		73.1088368	30.27294	GPS Chak 19 EB Hussainpur	Water Pump	Nearby Agricultural area
PKP-3		73.0833224	30.25221	GPS 73 EB P.O Chak No. 75/EB	Water Pump	Nearby Agricultural area
PKP-4		73.1068301	30.38593	GGPS 20 EB P.O 30 EB	Water Pump	Nearby Industry &Agricultural area
PKP-5		73.2042847	30.31296	GPS 3 EB P.O 7 EB	Water Pump	Nearby Agricultural area
KUS-1	Kasur	74.1080777	30.96368	GGPS Dhoobli	Water Pump	Nearby Agricultural area
KUS-2		74.1849195	31.14331	GPS Murali Ottar	Water Pump	Nearby Agricultural area
KUS-3		73.9429364	31.08168	GPS Ahlloval Theh patoki	Water Pump	Nearby Agricultural area
KUS-4		74.2032428	31.18246	GPS Bhamba Khurd	Water Pump	Nearby Agricultural area
KUS-5		74.57484	31.06795	GGPS Sheikh Pura Nau	Water Pump	Nearby Agricultural area
KUS-6		74.0810581	31.04767	GPS Sayeddan Wala	Water Pump	Nearby Agricultural area
KUS-7		74.2705774	30.98705	GGPS Basti Eid Gah	Water Pump	Nearby Agricultural area
KUS-8		73.8691048	31.04821	GPS Malan Wala No. 34	Water Pump	Nearby Agricultural area
KUS-9		73.818683	31.01573	GPS Lubana Chak No. 37	Water Pump	Nearby Agricultural area
KUS-10		74.2351848	30.91265	GPS Pial Kalan No. 2	Water Pump	Nearby Agricultural area
KUS-11		74.1145131	31.12547	GGCMS Bohar	Water Pump	Nearby Agricultural area

KUS-12		74.2294608	31.10046	GPS Haveli Ibrahim Wali	Hand Pump	Nearby Agricultural area
KUS-13		73.7485212	30.96439	GPS Tibbi Dial Singh	Water Pump	Nearby Agricultural area
KUS-14		73.8601009	31.00019	GGPS Chak No. 3	Water Pump	Nearby Agricultural area
KUS-15		74.084351	31.25055	GPS Dhari Wal	Water Pump	Nearby Industry &Agricultural area
SKP-1	Sheikhpura	73.6470723	31.6476	GPS Rasool Pur Jattan	Water Pump	Nearby Agricultural area
SKP-2		74.2721463	31.68852	GPS Rana Town	Hand Pump	Nearby Agricultural area
SKP-3		73.7357839	31.60761	GPS Dera Mitt Singh	Water Pump	Nearby Agricultural area
SKP-4		73.6832323	31.58373	GPS Chak Nahara	Water Pump	Nearby Agricultural area
SKP-5		74.2606604	31.60678	GGPS Badoo	Water Pump	Nearby Industry &Agricultural area
SKP-6		73.8309863	31.73842	GPS Dera Ali Aabas Shah	Water Pump	Nearby Agricultural area
SKP-7		74.073592	31.79878	GGPS Tary Wala	Water Pump	Nearby Agricultural area
SKP-8		74.0134633	31.71984	GGPS Malhu	Other	Nearby Agricultural area
SKP-9		74.1187032	31.44945	GPS Purani Bhaini	Water Pump	Nearby Agricultural area
SKP-10		73.5744657	31.72906	GPS Tibbi Chobkhan	Water Pump	Nearby Agricultural area
SKP-11		74.5051367	31.8231	GPS Goil Kala Kathai	Water Pump	Nearby Agricultural area
SKP-12		74.1981266	31.58108	GPS Meekhowala	Water Pump	Nearby Agricultural area
SKP-13		73.6212664	31.6996	GGPS Madiala	Hand Pump	Nearby Agricultural area
SKP-14		74.145801	31.78256	GGPS Pindi rattan singh	Water Pump	Nearby Agricultural area
SKP-15		73.6036321	31.52294	GPS Chak 6 UCC	Water Pump	Nearby Agricultural area
LHR-1	Lahore	74.4151863	31.40677	GPS Deo Kalan	Water Pump	Nearby Agricultural area
LHR-2		74.5128812	31.47901	GGPS Devsani	Water Pump	Nearby Industry &Agricultural area
LHR-3		74.4845182	31.6288	GGPS Bhani Dhilwan	Water Pump	Nearby Agricultural area
LHR-4		74.2488329	31.26971	GPS Model rakh johho dheer	Water Pump	Nearby Industry &Agricultural area
LHR-5		74.5453027	31.5295	GPS Minhala Kalan	Water Pump	Nearby Agricultural area
LHR-6		74.322344	31.31288	GPS Chah Khokran	Water Pump	Nearby Industry &Agricultural area
LHR-7		74.3652714	31.34289	GPS Kashmir Patti	Water Pump	Nearby Industry &Agricultural area
LHR-8		74.2113893	31.43077	GPS Nawazish ababd	Water Pump	Nearby Agricultural area
LHR-9		74.3629334	31.36344	GPS Kilaki	Govt. Water	Nearby Industry &Agricultural area
LHR-10		74.3469866	31.36769	GGPS Theh Panjoo	Water Pump	Nearby Industry &Agricultural area

LHR-11	74.3154701	31.577	GPS Hakiman Wala	Water Pump	Nearby Agricultural area
LHR-12	74.4869202	31.58985	GPS Rampura Jagir	Water Pump	Nearby Industry & Agricultural area
LHR-13	74.4328347	31.39652	GGPS Model thata dilwan	Water Pump	Nearby Agricultural area
LHR-14	74.4823273	31.5505	GGPS Rakh Tarah	Water Pump	Nearby Agricultural area
LHR-15	74.1887919	31.28996	GPS Bhaikot	Water Pump	Nearby Agricultural area
LHR-16	74.1788531	31.36099	GPS Maqadam singhwala	Water Pump	Nearby Industry & Agricultural area
LHR-17	74.205667	31.35706	GGPS Aasal Kundal	Water Pump	Nearby Agricultural area
LHR-18	74.4395329	31.58864	GGPS Adda Chabil	Water Pump	Nearby Agricultural area
LHR-19	74.2455779	31.36335	GGPS Haveli Janjaty	Water Pump	Nearby Agricultural area
LHR-20	74.5384447	31.43067	GGPS Jhugian Noorpur	Water Pump	Nearby Agricultural area
LHR-21	74.3673453	31.55012	GGPS Mustafabad Shahdara	Water Pump	Nearby Agricultural area
LHR-22	74.5454804	31.43752	GGPS Noorpur	Water Pump	Nearby Agricultural area
LHR-23	74.4524022	31.44106	GGPS Mota singh	Water Pump	Nearby Agricultural area
LHR-24	74.5237531	31.4343	GGPS Gaga	Water Pump	Nearby Agricultural area
LHR-25	74.3860085	31.44836	GGPS Badukke	Water Pump	Nearby Agricultural area
LHR-26	74.3900364	31.63818	GPS Qadria Shalimar	Water Pump	Nearby Agricultural area
LHR-27	74.0886586	31.09146	GPS Haveli Sohan Singh	Hand Pump	Nearby Agricultural area
LHR-28	74.4631793	31.6473	GPS Abadi Hatar Shah	Water Pump	Nearby Agricultural area
LHR-29	74.1775096	31.43632	GPS Bhatee Sultanpur	Water Pump	Nearby Agricultural area
LHR-30	74.1942694	31.3722	GPS Thatha Tharran	Water Pump	Nearby Agricultural area
LHR-31	74.4123243	31.42469	GPS Dev Khalan	Water Pump	Nearby Agricultural area
LHR-32	74.4122148	31.31782	GPS Khano Harni	Water Pump	Nearby Agricultural area
LHR-33	74.408057	31.29322	GPS Keet	Hand Pump	Nearby Agricultural area
LHR-34	74.4912181	31.46335	GPS Sangat Pura	Water Pump	Nearby Agricultural area
LHR-35	74.5435316	31.53002	GGPS Minhala Khurd	Water Pump	Nearby Agricultural area
LHR-36	74.4575788	31.50552	GGPS Jindra Dairy	Water Pump	Nearby Agricultural area
LHR-37	74.5030423	31.63791	GGPS Ganjay Sindhu	Water Pump	Nearby Agricultural area
LHR-38	74.4650188	31.35597	GGPS Lakhoky	Water Pump	Nearby Agricultural area
LHR-39	74.4047785	31.38366	GGPS Ahllo	Water Pump	Nearby Agricultural area
LHR-40	74.2517788	31.44475	GGPS Mohammad Pura	Water Pump	Nearby Agricultural area
LHR-41	74.2296582	31.43238	GGPS Qila Zulfiqar	Water Pump	Nearby Agricultural area
LHR-42	74.2364546	31.48317	GGPS Thokar Niaz Baig	Hand Pump	Nearby Agricultural area

LHR-43		74.1964978	31.30226	GGPS Bhai Kot	Water Pump	Nearby Agricultural area
LHR-44		74.3689964	31.63877	GPS Karol	Water Pump	Nearby Agricultural area
LHR-45		74.1225161	31.35607	GPS Juggian Khanake	Water Pump	Nearby Agricultural area
LHR-46		74.4813589	31.47515	GGPS Chak Dhera	Other	Nearby Agricultural area
LHR-47		74.4238733	31.43604	GGPS Harpal Key	Water Pump	Nearby Agricultural area
LHR-48		74.2034709	31.38326	GPS Fateh Singh Wala	Water Pump	Nearby Agricultural area
LHR-49		74.2673629	31.55864	GMMS Abu Tarb Shabli Town Bund-road	Well	Nearby Agricultural area
<b>Primary Schools of Southern Rural Punjab, Pakistan</b>						
WGB-1	Bhawalnagar	73.6000366	30.17322	GGPS Basti Amir	Hand Pump	Nearby Agricultural area
WGB-2		72.7706656	29.82199	GGPS Basti Gujrara	Hand Pump	Nearby Agricultural area
WGB-3		73.2693132	29.98674	GGPS Hajipur Cchuta Bhok	Hand Pump	Nearby Agricultural area
WGB-4		73.058586	30.28428	GGPS Bhatta Muhammad Pura	Water Pump	Nearby Agricultural area
LON-1	Lodhran	71.5053534	29.74295	GGPS Har Dil Wala	Water Pump	Nearby Agricultural area
LON-2		71.8991466	29.78563	GMPS Ramzan Wala	Water Pump	Nearby Agricultural area
LON-3		71.6716735	29.72328	GGPS 37/M NO.2	Water Pump	Nearby Agricultural area
LON-4		71.7531119	29.7404	GPS Chak No. 399	Water Pump	Nearby Agricultural area
MUX-1	Multan	71.3230549	29.87171	GGPS Aray Wala Shujabad	Water Pump	Nearby Agricultural area
MUX-2		71.3716197	29.87333	GGPS Chak Sardar Pur Theh. Shujabad	Water Pump	Nearby Agricultural area
MUX-3		71.3271576	29.76755	GGPS Gari Wala Shujabad	Water Pump	Nearby Industry & Agricultural area
MUX-4		71.6850145	30.1964	GPS Shak-e-Maddina	Water Pump	Nearby Agricultural area
MUX-5		71.4359743	30.11621	GGPS Siddique Wala Qasba Maral Road	Water Pump	Nearby Agricultural area
VHR-1	Vehari	72.7451817	30.2056	GPS 415 EB	Water Pump	Nearby Agricultural area
VHR-2		72.3651502	30.1048	GGPS Shabbir Abad	Water Pump	Nearby Agricultural area
VHR-3		72.4204066	29.93656	GPS Din Wah	Water Pump	Nearby Agricultural area
VHR-4		72.2263506	29.86628	GPS Cheju Deh	Water Pump	Nearby Agricultural area
VHR-5		72.472035	29.89208	GES Moza Sharf	Water Pump	Nearby Industry & Agricultural area
VHR-6		72.170586	29.72535	GPS Bahleem	Water Pump	Nearby Agricultural area
VHR-7		72.1915716	29.7837	GPS Dharam Pura	Water Pump	Nearby Agricultural area
VHR-8		72.5006202	30.132	GPS Chak No. 6/WB	Water Pump	Nearby Industry & Agricultural area
KWL-1	Khanewal	71.9564352	30.45196	GMPS Ali Pur	Water Pump	Nearby Agricultural area

KWL-2		71.9153906	30.07489	GGPS 99/10-R, Jahanian	Water Pump	Nearby Agricultural area
KWL-3		72.111252	30.13444	GMPS 74-B/15-L, P/O 79/15-L, Kacha Khuh	Water Pump	Nearby Industry & Agricultural area
KWL-4		71.9155606	30.07438	GGPS 100-10/R, Jahanian	Water Pump	Nearby Industry & Agricultural area
KWL-5		71.8473751	30.45863	GGPS Sher Khan, Kabirwala	Water Pump	Nearby Agricultural area
KWL-6		71.6698916	30.37506	GGPS Pathaney Wala, Kabirwala	Water Pump	Nearby Agricultural area
KWL-7		72.078657	30.12987	GGPS 47/10-R,	Water Pump	Nearby Agricultural area
KWL-8		71.7570623	30.07176	GMPS 143/10-R	Water Pump	Nearby Agricultural area



**Fig 3.1: Sampling points of Study Area**

### 3.4 Selection and Analysis of Parameters

The samples collected from the selected areas were then brought to the Laboratory of Environmental Sciences Department, Kinnaird College for Women for the determination of physiochemical parameters and bacteriological detection. The physiochemical parameters included colour, odour temperature, pH, Electrical Conductivity (EC), Dissolved Oxygen (DO), Sulphate (SO<sub>4</sub>), Nitrate (NO<sub>3</sub>), Total dissolved solids (TDS), Chloride (Cl), , Fluoride

(Fl), Total Hardness (TH), Calcium (Ca<sup>+</sup>), Magnesium (Mg<sup>+</sup>), Carbonate (CO<sub>3</sub>), Bicarbonate (HCO<sub>3</sub>), Sodium (Na<sup>+</sup>), Potassium (K), Chromium (Cr), Nickel (Ni), Lead (Pb) Arsenic (As) and Phenolic Compounds (As Phenols) while bacteriological detection involves the analysis of Total Coliform (TC). Table 3.1 represents that analysis of pH, EC, DO, turbidity and TDS were conducted through pH meter, EC meter, DO meter, turbidity meter and TDS meter, respectively. While the analysis of Cl<sup>-</sup>, TH, Ca<sup>+2</sup>, Mg<sup>+2</sup>, CO<sub>3</sub> and HCO<sub>3</sub> were conducted through titrimetric method, As, Cr, Ni and Pb through atomic absorption spectrophotometer, TSS through gravimetric method, SO<sub>4</sub><sup>-2</sup> and phenols through UV- Visible Spectrophotometer, Na and K through flame photometer. Fl and NO<sub>3</sub><sup>-</sup> were analysed through Ion electrode method and MPN method using incubator and autoclave was used for Total Coliforms.

**Table 3.2: Standard Procedures for the analysis of Selected Parameter [73]**

<b>Parameter</b>	<b>Instrument/Model No.</b>	<b>Method No.</b>
pH	pH Meter, Hanna Model HI 991301	HACH 8156
EC (µs/cm)	EC meter, Hanna Model HI 991301	HACH 8160
DO (mg/L)	DO meter, Hanna Model H19146-04	HACH 5C100
TDS (mg/L)	TDS Meter, Hanna Instrument Model HI 93703	APHA 2510
TSS (mg/L)	Gravimetric Method	APHA 2540 D
Chloride (mg/L)	Silver Nitrate Titration	APHA 4500-Cl B
Fluoride (ppm)	Ion-Selective Electrode Method, Model 930	APHA 4500-FI B
Nitrate (ppm)		APHA 4500-NO3 D
Turbidity (NTU)	Turbidity meter, Hanna H193703	APHA 2130 B
Total Hardness (mg/L)	EDTA Titration	APHA 2340 C
Calcium (mg/L)	Titrimetric Method	APHA 3600-Ca
Magnesium (mg/L)		APHA 3500-Mg E
Carbonate (mg/L)		APHA 2320
Bicarbonate (mg/L)		
Sodium (mg/L)	Flame photometer, Sherwood 410	APHA 3500-Na B
Potassium (mg/L)		APHA 3500-K B
Chromium (mg/L)	Atomic Absorption Spectrophotometer, 240 AA	APHA 3111 B
Nickel (mg/L)		
Lead (mg/L)		
Arsenic (mg/L)		APHA 3114 B
Total Coliforms (MPN/100ml)	Incubator, Autoclave	APHA 9221 D

## 3.5 Procedures Details

### 3.5.1 Determination of pH and Electrical Conductivity

#### Apparatus

Beaker, pH meter, Conductivity meter and Distilled water

#### Procedure

30ml of sample was taken in a beaker pre-rinsed with distilled water. In the first step pH meter and EC meter were calibrated and electrodes were properly rinsed with distilled water. For the reading, probe of each instrument was immersed in the samples and kept until the equilibrium was established between the probe and sample. Readings of pH and EC were then recorded.

### 3.5.2 Determination of TDS and TSS

#### Apparatus

Beakers, Stirrer, Glass rod, Stand, Distilled water, Filter Paper, Weighing Balance, Oven and TDS meter

#### Procedure

20ml of sample was taken in a beaker pre-rinsed with distilled water. TDS meter was calibrated and electrode was properly rinsed with distilled water. For the measurement of TDS, probe was immersed in the sample and reading was recorded. For the determination of TSS, 20ml of sample was taken in a beaker and then filtered through pre-weighted filter paper. Wet filter paper was then placed in labelled aluminum tray in drying oven at 105 °C. Filter paper was then allowed to cool at room temperature and weighted again through weighing balance. TSS were calculated using following formula:

$$TSS \left( \frac{mg}{L} \right) = \frac{W_i - W_f}{20ml} * 1000 \dots (1)$$

Where,  $W_i$  = Initial weight of filter paper and

$W_f$  = Final weight of filter paper

### 3.5.3 Determination of DO and Turbidity

#### Apparatus

Beaker, DO meter and Turbidity meter, Distilled water

## Procedure

DO meter was turned on and probe was rinsed with distilled water. For the reading, probe was immersed in the samples and Kept until the equilibrium was established between the probe and sample. Reading was then recorded with DO meter. For the determination of turbidity, 10ml of sample was taken in sample cell up to the horizontal mark. Sample cell was then placed in turbidity meter and readings were recorded.

### 3.5.4 Determination of Chlorides

#### Apparatus

Conical flask, Funnel, Beaker, Burette, Pipette, Dropper and Iron stand

#### Reagents

AgNO<sub>3</sub>, K<sub>2</sub>Cr<sub>2</sub>O<sub>4</sub>

#### Procedure

10ml of sample was pipetted out in a conical flask and 1 to 2 drops of K<sub>2</sub>Cr<sub>2</sub>O<sub>4</sub> were added as an indicator. I was titrated against the standard solution of AgNO<sub>3</sub> taken in burette. the titration continued until the colour changed to brick red. Concentration of chlorides were calculated using following formula:

$$Cl \left( \frac{mg}{L} \right) = (A - B) * N * \frac{35460}{10} \dots (2)$$

Where, A-B = Volume of AgNO<sub>3</sub> required for titration

N= Normality of AgNO<sub>3</sub>

### 3.5.5 Determination of Total Hardness

#### Apparatus

Conical flask, Funnel, Beaker, Burette, Pipette, Dropper and Iron stand

#### Reagents

1N EDTA solution, Ammonia Buffer (NH<sub>3</sub>+ NH<sub>4</sub>Cl + Distilled water) and Eriochrome Black T indicator

## Procedure

10ml of sample was pipetted out in a conical flask and 2 to 3 drops of Ammonia Buffer were added in it. Pinch of Eriochrome black T was added in the solution as an indicator. It was titrated against the standard solution of EDTA taken in burette. The titration was continued until the colour changed from wine red to blue. Titration was repeated 2 to 3 times for accurate measurements. Total Hardness was calculated using following formula:

$$\text{Total hardness as CaCO}_3 \left( \frac{\text{mg}}{\text{L}} \right) = (A - B) * N * \frac{1000}{10} \dots (3)$$

Where,

A-B = Volume of EDTA required for titration

N= Normality of EDTA

### 3.5.6 Determination of Ca<sup>+2</sup> and Mg<sup>+2</sup>

#### Apparatus

Conical flask, Funnel, Beaker, Burette, Pipette, Dropper and Iron stand

#### Reagents

Patton reader indicator, KOH, 1N EDTA Solution

#### Procedure

10ml of sample was pipetted out in a conical flask and 2 to 3 drops of KOH were added in it. Pinch of Patton reader was added in the solution, as an indicator. It is titrated against the standard solution of EDTA taken in burette. The titration was continued until the colour changed from wine red to blue. Titration was repeated 2 to 3 times for accurate measurements. Ca<sup>+2</sup> and Mg<sup>+2</sup> were calculated using following formula:

$$\text{Calcium hardness} \left( \frac{\text{mg}}{\text{L}} \right) = (A - B) * N * \frac{400.8}{10} \dots (4)$$

$$\text{Magnesium hardness} \left( \frac{\text{mg}}{\text{L}} \right) = [\text{Total Hardness} - \text{Calcium Hardness}] * 0.243 \dots (5)$$

Where, A-B = Volume of EDTA required for titration and

N= Normality of EDTA

### 3.5.6 Determination of Carbonates and Bicarbonates

#### Apparatus

Conical flask, Funnel, Beaker, Burette, Pipette, Dropper and Iron stand

#### Reagents

0.1N H<sub>2</sub>SO<sub>4</sub>, Methyl orange and phenolphthalein

#### Procedure

10ml of sample was pipetted out in a conical flask and 2 to 3 drops of phenolphthalein were added as an indicator. Solution turned pink. It is titrated against the standard solution of H<sub>2</sub>SO<sub>4</sub> taken in burette. The titration was continued until the disappearance of pink colour. Burette readings were recorded. Now in the same solution 2 to 3 drops of methyl orange was added and titrated it against H<sub>2</sub>SO<sub>4</sub> taken in burette till the yellow straw colour changed to rose red. Carbonates and bicarbonates were calculated using following formula:

$$\text{Carbonates } \left( \frac{meq}{L} \right) = 20 * A.. (6)$$

$$\text{Bicarbonate } \left( \frac{meq}{L} \right) = 10 * (B - A).. (7)$$

Where, A= Amount of H<sub>2</sub>SO<sub>4</sub> required in 1st titration

B = Amount of H<sub>2</sub>SO<sub>4</sub> required in 2nd titration

### 3.5.7 Determination of Nitrate and Fluoride

#### Apparatus

Beaker, Ion electrode meter

#### Reagents

Ammonium Nitrate and Hydrogen Fluoride

#### Procedure

For the determination of nitrate and fluoride, first of all the standard solution of 1,3,5,10,20,30,40,50 and 100 ppm for fluoride and 10,20,30,40,50,100,200 and 300 ppm for nitrate were prepared using hydrogen fluoride and ammonium nitrate. Then the ion electrode was properly calibrated for nitrate and fluoride. Electrode was properly rinsed with distilled

water. For the reading, probe was immersed in the samples and kept until the equilibrium was established between the probe and sample. Readings were then recorded with ion electrode meter for nitrate and fluoride.

### **3.5.8 Determination of Sodium and Potassium**

#### **Apparatus**

Flame photometer, Round bottom flasks, Spatula, Weighing balance and Distilled water

#### **Reagents**

Sodium hydroxide and Potassium dichromate

#### **Procedure**

For the determination of sodium and potassium, first of all the standard solution of 1,3,5,10,20,30,40,50 and 100 ppm were prepared using sodium hydroxide and potassium dichromate. These standard were run at flame photometer and absorbance values were recorded. Calibration curve of absorbance vs concentration was plotted for both sodium and potassium separately. All the samples were then run at flame photometer and their absorbance values were recorded for both sodium and potassium separately. Calibration curves were used to find the exact concentration of sodium and potassium in the unknown samples.

### **3.5.8 Determination of Heavy metals (Cr, Ni, Pb, and As)**

#### **Apparatus**

Atomic Absorption Spectrophotometer

#### **Procedure**

0, 1, 2, 5, 10, 15, 20 ml of standard solution were prepared for Cr, Ni, Pb and As. These standards were then run at Atomic Absorption Spectrophotometer, 240 AA. Calibration curves were generated and saved in the readout device/recorder of instrument. All the samples were run separately for Cr, Ni, Pb and As and final concentrations values were recorded.

### **3.5.9 Determination of Total Coliforms**

#### **Apparatus**

Capped Test tubes, Aluminum Foil, Shaker, Autoclave, Incubator, Pipette and Beakers

## Reagents

Distilled water and lauryl sulfate broth

## Procedure

35g of lauryl sulfate broth was taken and diluted to 1000ml with distilled water. The mixture was shaken well in conical flask with the help of shaker, until it became homogeneous. The broth solution was transferred from conical flask to glass bottle. Capped test tube were pre-rinsed and covered with aluminum foil. Glass bottle with lauryl sulfate broth solution, test tubes, pipette and beakers was autoclaved at 24 degrees for 2 hours. 10ml of lauryl sulfate broth solution was added in each test tube. For each sample, 0.1, 1 and 10 ml of sample was pipetted out in each test tube containing lauryl sulfate broth solution. Total number of 9 dilutions were prepared for each sample. These dilutions were kept in incubator for 24 hours at 26°C. After the incubation, samples with presence of bacteria showed milky suspension. Total coliforms were calculated using Thoma's simple equation [73]:

$$\frac{MPN}{100} mL = \frac{\text{no. of positive tubes} * 100}{\sqrt{\text{ml of sample in negative tubes} * \text{ml of sample in all tubes}}} \dots (8)$$

## 3.6 Drinking Water Quality Index (DWQI)

Intended water use depends on the quality of water which is dependent on the concentration of certain parameters in water samples. The Drinking Water Quality Index (DWQI) is a critical tool used to assess and communicate the quality of drinking water.

The significance of certain characteristics depends on how water will be used. The DWQI was assessed taking into account the following significant factors:

- (1) the parameter's significance;
- (2) the statistical link between corresponding index and parameter concentration.
- (3) Water quality classification according Horten, 1965 rating scale, (unsuitable, very poor, poor, good and excellent quality). The standards for drinking water that were used in this study are World Health Organization's (WHO) standards for drinking water quality. DWQI is mostly done to check the suitability of water for human consumption [24].

DWQI was calculated using the following equation.

$$DWQI = \sum_{n=1}^n q_n W_n / \sum_{n=1}^n q_n \dots (9)$$

Where,  $q_n$ = Quality rating and  $W_n$ = Unit Weight

### 3.6.1 Quality Rating ( $q_n$ ) Calculation

$q_n$  is the quality rating and calculated by

$$q_n = 100 (V_n - V_i) / (V_s - V_i) \dots (10)$$

Where,

$V_s$  = Standard value

$V_n$  = Sbserved value

$V_i$  = Ideal value

In most cases  $V_i = 0$  except for pH and DO. Calculation of quality rating for pH & DO:

$$q_{pH} = 100 \frac{(V_{pH} - 7.0)}{(8.5 - 1.0)} \dots (11)$$

$$q_{DO} = 100 \frac{(V_{DO} - 14.6)}{(15.0 - 14.6)} \dots (12)$$

### 3.6.2 Unit Weight Calculation ( $W_n$ )

$W_n$  is the unit weight and calculated by

$$W_n = k / S_n \dots (13)$$

Where,  $S_n$  = nth standard/permisible value of parameter

$k$  = proportionality constant.

$$K = 1 / \sum (1/S_n) \dots (14) \quad [74, 75]$$

**Table 3.3: The suitability of DWQI values for human consumption [76]**

DWQI Rating Scale	
0-25	Excellent water quality
26-50	Good water quality
51-65	Fair water quality
66-75	Poor water quality
76-100	Very poor water quality
100 and above	Unsuitable for drinking

### 3.7 Health Risk Assessment

It is the process to determine the nature and probability of adverse health effects of chemicals on human. The risk assessment process consists of several steps, including data collection, exposure assessment, toxicity assessment and risk characterization [74, 75].

#### 3.7.1 Exposure Assessment

In order to estimate the exposure of chemicals/pollutants to individuals (children), USEPA suggests the following formula to calculate the Exposure Dose/ Average Daily Dose (ADD)/ Chronic Daily Intake (CDI)

$$ADD = C * IR * ED * EF / BW * AT \dots (15)$$

Where,

ADD = Average daily dose

C = the drinking water contaminant concentration (mg/l)

IR = Intake rate (2 L/day)

ED = Exposure duration (6 years)

EF = Exposure frequency (365 days/year)

BW = Body weight (40.10 kg)

AT = Average lifetime (2,190 days)

All of the data regarding consumption, body weight, and exposure of children regarding age groups was obtained according to USEPA guidelines [77].

#### 3.7.2 Hazard Quotient/ Health Risk Index

Non-cancer risks due to non-carcinogenic effects of HMs in drinking water were determined by the non-cancer hazard quotient/ HRI, which was calculated using the following equation:

$$HRI \text{ or } HQ = ADD / RfD \dots (16)$$

Where RfD is the reference dose (mg/kg/d). Based on the values of HQ, the toxicants' health risk assessment was interpreted, HQ less than 1 (HQ < 1) means no risk but if HQ is greater than or equal to 1 then, the intake of such water is considered to be a health risk. For oral toxicity of metal; According to USEPA IRIS (Integrated Risk Information System), RfD values are following:

**Table 3.4: RfD values of heavy metals for oral toxicity [78]**

Heavy Metal	RfD (mg/kg/d)
Cr	0.003
Ni	0.02
Pb	0.0035
As	0.0003
F	0.06

### 3.7.3 Cancer Risk

A carcinogenic risk of  $10^{-4}$  poses health hazards; therefore, it is sufficiently large, poses health hazards, and need some sort of intervention and remediation. Cancer Risk (CR) would be calculated by the following formula:

$$CR = ADD * CSF \dots(17)$$

Where, CSF = cancer slope factor (mg/kg/day). [79,80,81]

**Table 3.5: CSF values for heavy metals [82,83]**

Heavy Metal	CSF (mg/kg/day)
Cr	0.5
Ni	0.91
Pb	0.0085
As	1.5

### 3.8 GIS Mapping

Spatial interpolation of Drinking Water Quality Index and Health Risk was conducted with the help of ArcGIS version 10.7. Kriging technique was used for the GIS mapping. kriging is an essential spatial analysis tool in assessing drinking water quality. It aids in generating accurate spatial predictions, identifying patterns and effectively visualizing water quality variations across geographic areas.

### 3.9 Questionnaire Survey

Two types of questionnaires, Health Risk Assessment and Economic Valuation (WTP) were designed. The questionnaires were translated into Urdu and English, both languages, to ensure ease of use. The questionnaires were pre-tested among five schools to evaluate the clarity of language, based on their culture and beliefs.

Health risk assessment survey (n=252) was designed for the primary school children to inquire about their demographic information and health risk associated with water borne diseases. This questionnaire consisted of close ended questions to assess the average amount of water intake from the schools daily. While the primary schools principals/headmasters (n=110) were interviewed (structured questionnaire) about willingness to pay for improved drinking water quality in their schools, which also provided economic valuation of the drinking water in the study area. Contingent valuation method (CVM) was used to estimate the economic value of school's combined willingness to pay (WTP) for improved drinking water quality. It is a technique used in environmental economics to estimate the economic value that individuals place on goods or services that do not have a market price [84]. The formula used to conclude the WTP was:

$$Y = \beta_0 + \beta_n X_n \dots (18)$$

Where,

Y=dependent variable (WTP);

$\beta_0$ =Constant;

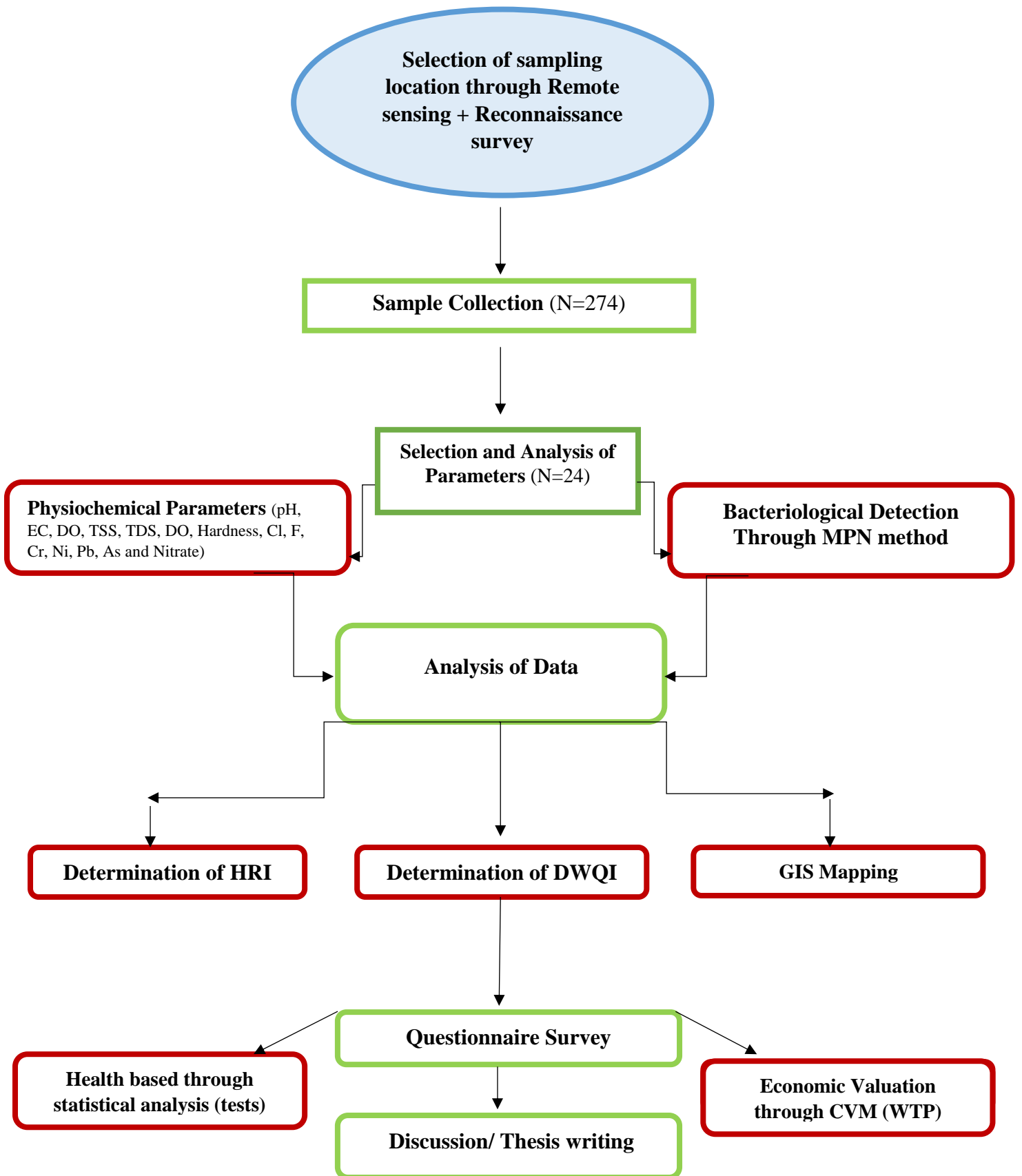
$\beta_n$  = estimated linear regression coefficients;

$X_n$  = explanatory variables

[84]

### 3.10 Statistical Analysis

The water quality monitoring results were interpreted by using IBM SPSS version 21 by running descriptive statistics (mean, median, mode, standard deviation). Pearson correlation coefficient values were used to determine the correlation between the results. The data of questionnaire was analyzed by performing statistical test including Pearson correlation, chi square, crammers V, ANOVA and linear regression. These statistical tests help in understanding the relationships between various factors (income, education and gender etc) and the willingness of individuals or groups to pay for improved water quality in schools.



**Fig 3.2: Methodology Flow Chart**

## **CHAPTER IV**

### **RESULTS**

In this chapter, the results of research are described. The experiments were performed in laboratory and data was collected. The following tables shows the results obtained for different parameters of drinking water quality of north, central and southern Schools of rural Punjab, Pakistan.

#### **4.1 Results of Drinking Water Quality of Rural Punjab**

The results of Total coliforms colour, odor, pH, Electrical conductivity (EC), Total Dissolved Solids (TDS), Total Suspended Solids (TSS), Dissolved Oxygen (DO), Turbidity, Calcium (Ca), Magnesium (Mg), Carbonate ( $\text{CO}_3^{2-}$ ), bicarbonate ( $\text{HCO}_3^-$ ), Total Hardness, Sodium ( $\text{Na}^+$ ), Potassium ( $\text{K}^+$ ), Chloride ( $\text{Cl}^-$ ), Fluoride ( $\text{F}^-$ ), Nitrate and heavy metals including chromium (Cr), Nickel (Ni), Lead (Pb) Arsenic (As) are given in the following tables.

#### **4.2 Results of Primary Schools of Rural Punjab (North)**

North Punjab consists of 4 cities (Narowal, Hafizaabad, Gujranwala and Sialkot) according to the study boundary. The results of these areas have been provided in the following table (4.1):

### 4.1 Physiochemical and Microbial Quality of North Punjab drinking water samples

Sample Code	Colour	odour	Temp	pH	EC	TSS	TDS	DO	Turbidity	Ca <sup>+2</sup>	Mg <sup>+2</sup>	CO <sub>3</sub> <sup>-</sup>	HCO <sub>3</sub> <sup>-</sup>	TH	Na <sup>+</sup>	K <sup>+</sup>	Cl <sup>-</sup>	F <sup>-</sup>	Nitrate	Cr	Ni	Pb	As	Total Coli-forms
			°C		µS/cm	mg/l						meq/l		mg/l			ppm			mg/l			MPN/100	
<b>Narowal</b>																								
NRW-1	Acceptable	Acceptable	27.6	6.92	780	138.1	393	5.29	0.27	56.11	20.38	6	4	380	BDL	0.00	141.84	0.128	60.72	BDL	BDL	BDL	BDL	0
NRW-2	Acceptable	Acceptable	28	6.98	1415	4.4	701	5.35	1.44	116.23	42.23	0	16	460	79.02	1.47	212.76	0.409	56.39	BDL	BDL	BDL	BDL	0
NRW-3	Acceptable	Acceptable	28.1	7.18	1036	37.95	513	5.38	1.53	80.16	29.12	2	7	310	102.59	4.18	177.3	0.843	45.64	BDL	0.0054	BDL	0.007	0
NRW-4	Acceptable	Acceptable	28	7.14	1006	42	502	5.17	0.66	60.12	21.84	2	8	270	106.99	4.42	177.3	0.603	44.7	BDL	0.008	BDL	BDL	0
NRW-5	Acceptable	Objectionable	28	6.9	1324	27	633	5.16	0.53	76.15	27.67	0	15	700	82.64	0.00	212.76	0.241	52.67	BDL	0.0056	BDL	0.013	30.15
NRW-6	Acceptable	Acceptable	27.9	7.19	1099	1.35	538	6.04	0.77	64.13	23.30	0	17	400	120.47	3.93	177.3	0.683	74.77	BDL	0.0048	BDL	0.0016	14.82
NRW-7	Acceptable	Acceptable	28	6.99	1251	40.4	632	5.46	0.91	88.18	32.03	0	8	580	70.21	0.00	141.84	0.942	47.9	BDL	0.0041	BDL	BDL	0
NRW-8	Acceptable	Acceptable	27.2	6.93	1354	17.4	634	6.06	0.43	56.11	20.38	4	7	550	74.09	0.00	212.76	0.897	53.7	0.0003	0.0071	0.003	BDL	0
NRW-9	Acceptable	Acceptable	28	7.38	542	1.75	274	5.24	0.64	44.09	16.02	2	7	430	37.82	0.00	141.84	0.153	32.98	0.067	0.026	BDL	0.028	0
NRW-10	Acceptable	Acceptable	38.1	6.63	364	155	380	5.89	0.56	124.25	45.14	2	4	510	90.41	2.70	354.6	0.612	39.3	BDL	BDL	BDL	BDL	0
<b>Gujranwala</b>																								
GRW-1	Acceptable	Acceptable	27.8	6.66	498	13.8	401	5.88	0.9	60.12	21.84	2	16	340	41.45	32.92	425.5	1.763	36.07	BDL	BDL	BDL	BDL	0
GRW-2	Objectionable	Acceptable	27.2	7.03	466	51.25	227	5.15	1.51	120.24	43.68	2	4	280	284.97	3.19	141.8	0.134	45.12	BDL	BDL	BDL	BDL	0
GRW-3	Acceptable	Acceptable	26.2	6.72	415	52.75	201	5.23	2.23	16.03	5.82	4	2	270	72.54	0.25	70.92	0.612	30.43	0.053	0.021	BDL	BDL	0
GRW-4	Acceptable	Acceptable	27.4	7.08	1342	30.55	631	5.09	1.09	60.12	21.84	2	5	940	54.15	4.91	177.3	0.241	52.64	0.0091	0.0076	BDL	0.031	0
GRW-5	Objectionable	Acceptable	27.5	7.36	1076	38.65	510	5.75	1.75	20.04	7.28	4	2	520	77.72	1.47	141.8	0.403	48.75	0.034	0.019	BDL	BDL	0
GRW-6	Acceptable	Acceptable	27.8	6.63	313	50.85	161	5.54	1.54	60.12	21.84	2	3	470	10.62	0.00	70.92	0.913	26.56	0.0057	0.0031	BDL	BDL	0
GRW-7	Acceptable	Acceptable	27.1	7.31	1237	1.8	599	5.19	1.19	48.10	17.47	4	8	580	141.71	0.25	319.1	0.526	68.92	BDL	BDL	BDL	0.0067	9.55
GRW-8	Acceptable	Acceptable	27.5	7.29	534	27.95	258	5.87	0.87	32.06	11.65	0	8	250	31.61	31.94	177.3	0.224	39.2	0.013	BDL	0.003	0.0006	20.7
GRW-9	Acceptable	Acceptable	27.5	6.78	1210	12	582	3.28	1.28	120.24	43.68	4	6	600	77.98	5.90	177.3	0.166	50.62	0.0047	0.0078	BDL	0.0075	0
GRW-10	Acceptable	Acceptable	27.7	6.88	486	23.95	231	5.85	0.85	20.04	7.28	2	2	300	74.09	0.00	177.3	0.517	46.27	2	0.032	BDL	BDL	0
GRW-11	Acceptable	Acceptable	27.6	7.02	465	24.5	228	6.97	0.97	28.06	10.19	10	4	250	72.28	0.49	283.6	0.417	53.64	0.0063	0.0089	BDL	BDL	9.55

GRW-12	Acceptable	Acceptable	27.4	6.88	1038	71.8	493	7.61	0.61	44.09	16.02	2	8	650	98.70	4.67	212.7	0.697	54.12	0.057	0.024	BDL	BDL	11.5
GRW-13	Acceptable	Acceptable	27.6	7.14	1097	60	526	6.11	1.11	48.10	17.47	0	6	530	108.03	1.72	248.2	0.161	46.27	0.032	BDL	BDL	BDL	0
GRW-14	Acceptable	Acceptable	27.4	7.16	681	79.5	327	8.67	0.67	24.05	8.74	0	6	470	80.83	17.20	177.3	0.707	48.9	0.021	0.0231	BDL	0.0021	0
GRW-15	Acceptable	Acceptable	27.8	7.14	455	46.35	226	6.15	1.15	60.12	21.84	0	9	350	37.05	0.00	106.3	0.997	49.83	BDL	0.0019	0.004	0.007	0
GRW-16	Acceptable	Acceptable	27.5	6.99	682	83	330	6.86	0.86	100.20	36.40	4	4	300	52.59	2.95	177.3	0.808	42.4	0.0064	0.0041	BDL	0.0067	9.55
GRW-17	Acceptable	Acceptable	27.2	7.21	881	50.85	419	7.32	1.32	56.11	20.38	2	5	570	59.59	1.47	177.3	0.642	46.6	0.018	BDL	BDL	0.016	0
GRW-18	Acceptable	Acceptable	27.4	7.14	1097	20.35	526	5.36	1.36	60.12	21.84	0	6	430	166.58	6.88	177.3	0.812	38.05	BDL	BDL	BDL	0.009	76.1
GRW-19	Acceptable	Acceptable	27.5	6.42	1397	55.65	666	5.71	1.71	80.16	29.12	2	7	500	9.07	3.69	177.3	0.764	54.49	BDL	BDL	BDL	BDL	0
GRW-20	Acceptable	Acceptable	27	6.98	919	60.15	432	5.59	1	88.18	32.03	0	2	430	57.25	0.74	531.9	1.532	48.29	BDL	0.0086	0.005	BDL	0
GRW-21	Objectionabl	Objectionable	27.3	6.14	1638	3.45	767	5.92	0.92	80.16	29.12	0	18	770	115.28	46.68	354.6	0.981	53.83	0.0059	0.0028	BDL	0.0018	27.41
GRW-22	Objectionabl	Objectionable	26.5	6.17	1662	0.15	726	5.66	8.66	80.16	29.12	0	19	700	111.66	53.07	212.7	0.829	22.55	0.032	0.0087	BDL	0.0037	0
GRW-23	Acceptable	Acceptable	26.9	6.91	1008	2.55	466	7.63	7.73	72.14	26.21	2	4	550	58.81	0.74	248.2	0.956	58.9	BDL	BDL	BDL	BDL	0
GRW-24	Acceptable	Acceptable	27.4	7.08	767	18.45	373	5.25	0.25	80.16	29.12	10	10	430	74.87	2.95	141.8	0.791	83.57	0.0036	0.0098	BDL	0.0048	9.55
GRW-25	Acceptable	Acceptable	27.6	7.3	509	0.25	261	5.02	1.02	40.08	14.56	2	5	540	39.12	1.72	141.8	0.416	38.79	BDL	0.0061	BDL	0.0016	20
GRW-26	Acceptable	Objectionable	27.3	6.79	1344	7.9	633	5.47	1.47	76.15	27.67	4	4	430	58.81	1.97	212.7	1.831	69.56	BDL	BDL	BDL	BDL	0
GRW-27	Acceptable	Acceptable	27.3	6.78	907	1.1	430	5.49	1.49	84.17	30.58	0	17	510	173.06	0.00	177.3	0.269	36.93	BDL	BDL	BDL	0.0066	0
GRW-28	Acceptable	Acceptable	27.4	6.88	1301	29.4	540	6.19	1.19	48.10	17.47	6	1	590	61.66	67.08	177.3	0.994	58.39	0.018	BDL	BDL	0.0081	0

**Hafiz-Abad**

HFD-1	Acceptable	Acceptable	26.9	6.87	860	54.9	399	6.53	0.53	40.08	14.56	4	2	370	63.73	2.70	106.38	1.72	51.92	0.00078	0.003	BDL	0.0005	10
HFD-2	Acceptable	Acceptable	27.1	7.21	688	0.25	337	6.53	0.53	44.09	16.02	2	7	340	123.83	0.49	177.3	0.633	55.21	BDL	BDL	BDL	BDL	0
HFD-3	Acceptable	Acceptable	27.2	6.91	690	0.6	339	5.83	0.83	76.15	27.67	0	5	340	56.74	0.00	177.3	0.573	48.46	0.021	0.0061	BDL	BDL	0
HFD-4	Acceptable	Acceptable	26.8	6.88	926	40.55	442	5.12	1.12	76.15	27.67	0	6	400	79.53	0.00	957.42	0.843	45.87	BDL	0.0018	BDL	BDL	14.82
HFD-5	Acceptable	Acceptable	27.4	6.83	1324	13.8	611	6.83	0.8	80.16	29.12	0	8	650	121.24	45.9	177.3	0.277	67.11	0.048	0.013	BDL	BDL	20.74
HFD-6	Acceptable	Acceptable	27.4	7.08	466	39	215	5.79	0.46	48.10	17.47	2	4	430	43.26	1.47	70.92	0.121	39.57	BDL	BDL	BDL	BDL	25.89
HFD-7	Acceptable	Acceptable	27.5	6.86	895	4.35	442	5.81	0.67	64.13	23.30	2	12	580	70.47	0.25	212.76	0.473	33.83	0.034	BDL	BDL	BDL	0
HFD-8	Acceptable	Acceptable	27.4	7.04	674	0.75	326	6.95	0.42	56.11	20.38	2	8	360	84.97	0.00	177.3	0.413	45.64	BDL	0.0034	BDL	BDL	0
HFD-9	Acceptable	Acceptable	27.5	6.92	775	4.6	381	7.61	0.6	68.14	24.75	2	4	380	95.85	0.25	177.3	0.895	40.68	BDL	0.0087	BDL	BDL	0
HFD-10	Acceptable	Acceptable	27.5	6.93	1338	14.5	635	5.57	0.68	92.18	33.49	4	2	530	133.16	0.00	141.84	0.751	38.22	0.001	BDL	BDL	BDL	4

**Sialkot**

SKT-1	Acceptable	Acceptable	29.6	7.08	1182	60	572	6.46	1.11	108.22	39.31	4	6	230	39.12	0.98	177.3	0.683	31.33	BDL	BDL	BDL	BDL	19.92
SKT-2	Acceptable	Acceptable	29.2	6.89	1122	46.2	527	5.18	0.93	48.10	17.47	10	3	380	103.11	7.86	106.3	1.612	34.54	BDL	0.0003	BDL	0.0067	0
SKT-3	Acceptable	Acceptable	29.2	7.5	1251	84.8	570	6.4	1.1	200.40	72.80	0	13	400	82.64	4.18	106.3	0.951	21.64	0.028	0.018	BDL	BDL	0
SKT-4	Acceptable	Acceptable	29.2	6.99	1571	108.1	728	5.71	0	128.26	46.59	0	11	410	99.22	8.11	177.3	0.14	18.96	0.0013	0.0153	0.006	BDL	0
SKT-5	Acceptable	Acceptable	29.1	7.14	1493	5.25	678	5.83	1.13	44.09	16.02	6	7	480	86.53	0.00	212.7	0.245	21.2	0.0033	0.0053	BDL	0.00208	14.83
SKT-6	Acceptable	Objectionable	29.3	6.55	259	14.3	119	5.48	0.37	68.14	24.75	4	5	540	76.42	0.00	106.3	0.185	18.46	0.0017	0.0016	0.003	0.0055	0
SKT-7	Acceptable	Objectionable	29.3	5.55	604	2.25	296	5.64	1.63	120.24	43.68	2	7	570	10.88	0.00	106.3	0.889	15.826	0.056	0.023	0.005	BDL	0
SKT-8	Acceptable	Objectionable	29.3	6.63	876	6.7	394	5.13	0.56	72.14	26.21	6	2	590	7.51	11.06	106.3	0.98	14.97	0.0048	0.0208	BDL	BDL	0
SKT-9	Acceptable	Acceptable	29.3	6.54	1519	11.2	650	6.31	0	48.10	17.47	364	138	640	44.04	0.00	177.3	0.838	25.08	0.039	0.016	0.006	0.0007	0
SKT-10	Acceptable	Acceptable	29.4	6.71	385	26.15	194	5.37	0.21	76.15	27.67	2	12	530	47.67	0.00	141.8	0.994	32.91	0.0078	0.0072	0.005	0.0048	25.89
SKT-11	Acceptable	Acceptable	29.4	6.72	814	6.95	351	5.57	0.89	84.17	30.58	14	2	180	128.24	0.00	212.7	0.584	26.36	0.0063	BDL	BDL	0.00502	0
SKT-12	Acceptable	Acceptable	29.2	7.88	618	32.25	310	5.21	0	120.24	43.68	6	4	485	28.76	62.65	106.3	0.997	20.34	0.0068	0.0033	BDL	BDL	0
SKT-13	Acceptable	Acceptable	29	7.06	1209	31.15	529	5.74	0.5	60.12	21.84	16	3	410	25.13	55.04	177.3	0.759	16.83	0.0073	BDL	BDL	BDL	0
SKT-14	Acceptable	Acceptable	29.2	6.73	626	6.05	311	5.58	0	84.17	30.58	10	4	850	BDL	91.89	141.8	0.397	10.74	0.015	BDL	0.006	BDL	115.7
SKT-15	Acceptable	Acceptable	29.2	6.71	786	53.7	394	5.62	0.13	128.26	46.59	2	5	440	35.23	2.95	106.3	0.175	21.54	0.074	BDL	BDL	0.00624	0
SKT-16	Acceptable	Acceptable	29.2	6.98	1273	12.85	471	5.91	0	96.19	34.95	4	10	300	68.39	4.18	177.3	0.081	43.29	0.008	0.0036	BDL	0.00528	0
SKT-17	Acceptable	Acceptable	29.3	6.79	636	19.15	307	5.87	0.14	104.21	37.86	4	16	650	92.49	9.34	106.3	0.221	29.47	0.0051	0.0078	BDL	0.00674	0
SKT-18	Acceptable	Objectionable	28.9	6.98	663	22.4	329	5.99	0	68.14	24.75	4	4	260	63.73	2.70	70.92	0.761	23.63	0.0061	0.013	0.006	BDL	19.9
SKT-19	Acceptable	Acceptable	29	6.86	384	6.9	195	5.28	0.5	68.14	24.75	4	5	320	83.16	6.39	177.3	0.245	22.15	0.0093	0.022	0.005	BDL	115.7
SKT-20	Acceptable	Objectionable	29	6.71	987	69.1	484	5.76	0.47	92.18	33.49	4	1	270	53.63	2.46	177.3	0.342	29.88	BDL	0.0069	BDL	BDL	3.59
SKT-21	Acceptable	Acceptable	29	7.2	851	69.7	409	5.75	0.33	92.18	33.49	14	-3	500	92.23	38.82	106.3	1.081	20.649	BDL	BDL	BDL	0.006	25.89
SKT-22	Acceptable	Acceptable	29.1	7.39	244	75.75	125	5.39	0	68.14	24.75	6	6	200	94.30	3.44	70.92	1.156	19.836	0.0018	0.0088	0.006	0.0048	0
SKT-23	Acceptable	Acceptable	29.1	7.11	2000	76.1	1267	6.87	1.5	44.09	16.02	16	-5	210	6.48	2.95	354.6	1.737	18.717	0.003	0.002	0.008	BDL	0
SKT-24	Acceptable	Acceptable	29.2	7.38	1356	64	665	5.27	1.02	216.43	78.63	4	6	490	167.36	3.44	177.3	0.696	21.49	BDL	BDL	BDL	BDL	0
SKT-25	Acceptable	Acceptable	29.2	7.3	314	49.5	148	5.89	2.15	56.11	20.38	2	10	600	126.68	3.44	177.3	1.454	28.06	BDL	BDL	BDL	0.0052	0
SKT-26	Objectionabl	objectionable	29.2	7.41	412	12.85	471	5.33	0.58	44.09	16.02	0	10	210	27.98	0.00	70.92	1.393	26.26	0.064	BDL	0.001	BDL	0
SKT-27	Acceptable	Acceptable	29.3	7.01	1311	24.4	678	5.45	0.81	52.10	18.93	10	4	440	83.68	1.72	283.6	0.922	21.514	BDL	BDL	0.004	BDL	25.89
SKT-28	Acceptable	Acceptable	29.3	6.85	1356	2.1	619	5.17	0.75	92.18	33.49	6	7	600	0.00	0.00	283.6	0.224	29.88	0.0065	0.019	0.009	BDL	116.1
SKT-29	Acceptable	Acceptable	29.2	6.66	819	34.55	398	5.07	0.04	76.15	27.67	6	4	270	134.72	72.73	248.2	1.374	41.73	0.0052	0.016	BDL	0.00528	30.15
SKT-30	Acceptable	Acceptable	29.3	6.76	829	13.4	406	5.36	0.37	64.13	23.30	16	0	380	37.05	56.76	248.2	1.467	49.7	0.0019	0.0018	BDL	BDL	0
SKT-31	Acceptable	Acceptable	29.4	6.9	1173	34.95	571	2.86	1.45	116.23	42.23	2	4	490	70.73	6.39	283.6	1.473	20.76	0.0048	BDL	BDL	BDL	19.9

SKT-32	Acceptable	Acceptable	29.4	7.04	763	70.75	364	5.63	1.61	64.13	23.30	4	10	320	108.55	8.11	70.92	1.176	41.62	0.00051	0.0023	0.007	BDL	94.92
SKT-33	Acceptable	Acceptable	29.4	6.69	791	46.3	383	5.29	1.58	52.10	18.93	6	4	290	45.60	5.16	141.8	2.111	42.34	BDL	BDL	BDL	0.0055	0
SKT-34	Acceptable	Acceptable	29.4	6.89	1918	60.3	940	6.23	1.63	64.13	23.30	0	6	500	56.74	8.60	354.6	1.011	37.01	BDL	BDL	0.009	0.0007	0
SKT-35	Acceptable	Acceptable	29.3	6.88	349	29.35	155	5.11	1.28	152.30	55.33	0	9	300	160.36	53.81	141.8	0.622	18.76	0.0063	BDL	0.001	0.0048	76.1
SKT-36	Acceptable	Acceptable	29.2	7.04	489	50	194	5.34	1.02	56.11	20.38	48	15	300	8.81	5.90	177.3	0.263	28.63	BDL	BDL	BDL	0.0063	20
SKT-37	Objectionabl	Acceptable	29.1	6.82	968	39.85	482	5.59	0.32	72.14	26.21	4	3	500	19.17	1.23	177.3	0.377	13.91	0.053	0.028	0.008	BDL	0
SKT-38	Acceptable	Acceptable	29.3	7.19	2000	44.55	1172	7.4	0.16	96.19	34.95	10	5	800	9.59	2.70	638.2	0.046	18.42	BDL	BDL	BDL	BDL	94.94
SKT-39	Acceptable	Acceptable	29.3	6.91	1409	28.3	679	5.83	0.34	148.30	53.87	0	40	150	149.48	137.1	248.2	0.109	19.204	BDL	BDL	BDL	0.0016	30.15
SKT-40	Acceptable	Objectionable	29.4	6.88	578	82.55	502	5.3	0.61	120.24	43.68	742	120	530	105.18	34.89	248.2	0.113	30.22	BDL	BDL	0.003	0.0062	0
SKT-41	Acceptable	Acceptable	29.5	6.83	807	82.4	214	3.28	0.59	60.12	21.84	0	18	420	56.99	5.90	141.8	0.245	22.56	0.0006	0.0036	0.009	BDL	19.9
SKT-42	Acceptable	Acceptable	29.4	7.08	1481	61.85	728	5.06	0.18	72.14	26.21	14	8	580	27.72	0.00	141.8	0.185	33.21	0.0077	0.0098	0.006	BDL	0
SKT-43	Acceptable	Acceptable	29.4	6.86	1853	63.15	867	5.69	0.09	76.15	27.67	2	4	420	90.41	0.00	354.6	0.464	14.29	BDL	BDL	BDL	0.0053	30.15
SKT-44	Acceptable	Acceptable	29.3	7.04	1014	88.15	502	5.55	0.39	76.15	27.67	4	11	550	174.61	23.34	709.2	1.075	35.35	BDL	BDL	BDL	BDjL	0
SKT-45	Acceptable	Acceptable	29.3	6.92	412	85.1	203	5.76	0.67	64.13	23.30	4	4	420	82.12	0.00	141.8	0.791	37.83	0.00234	0.00765	0.006	BDL	0
SKT-46	Acceptable	Acceptable	29.3	6.93	717	78.9	334	5.78	0.31	28.06	10.19	2	10	780	8.81	0.00	212.7	0.118	25.43	BDL	BDL	BDL	0.0048	0
SKT-47	Acceptable	Objectionable	29.5	7.14	1102	50.85	542	5.07	0	48.10	17.47	2	9	300	91.45	5.65	141.8	0.102	20.86	BDL	BDL	BDL	BDL	9.55
SKT-48	Acceptable	Objectionable	29.5	6.33	510	50.65	260	5.97	0.36	64.13	23.30	4	3	320	23.06	24.57	212.7	0.185	26.24	0.0048	BDL	BDL	0.0055	0
SKT-49	Acceptable	Acceptable	29.5	7.89	491	24.7	226	5.73	0.9	100.20	36.40	2	25	280	50.52	4.91	141.8	0.882	39.57	0.058	0.021	BDL	0.00528	10
SKT-50	Acceptable	Acceptable	29.4	8.23	730	21.35	362	6.88	0.2	36.07	13.10	6	10	460	15.03	0.00	141.8	0.817	48.01	BDL	BDL	BDL	BDL	25.89
WHO guidelines [85]	Acceptable	Acceptable	-	6.5-8.5	<1500	-	1000	5	5	-	-	-	-	500	-	-	250	1.5	50	0.05	0.02	0.01	0.01	0/100 ml
NEQS	Acceptable	Acceptable	-	6.5-8.5	<1500	-	1000	5	5	-	-	-	-	500	-	-	250	1.5	50	0.05	0.02	0.01	0.05	0/100 ml

**BDL= Below Detection Limit**

### 4.3 Results of Primary Schools of Rural Punjab (Central)

Central Punjab consists of 9 cities (Faisalabad, Sahiwal, Okara, Jhang, Pakpattan, Nankana Sahib, Sheikhpra, Kasur and Lahore) according to study boundary. Results of these areas have been given in the following table (4.2):

#### 4.2: Physiochemical and Microbial Quality of Central Punjab drinking water samples

Sample Code	Colour	odour	Temp	pH	EC	TSS	TDS	DO	Turbidity	Ca <sup>2+</sup>	Mg <sup>2+</sup>	CO <sub>3</sub> <sup>-</sup>	HCO <sub>3</sub> <sup>-</sup>	TH	Na <sup>+</sup>	K <sup>+</sup>	Cl <sup>-</sup>	F <sup>-</sup>	Nitrate	Cr	Ni	Pb	As	Total Coli-forms
			°C		µS/cm	mg/l						meq/l		mg/l			ppm			mg/l			MPN/100 ml	
<b>Nankana Sahib</b>																								
NNS-1	Acceptable	Acceptable	28.9	7.04	533	110	389	6.51	1.19	36.07	13.10	4	0	378	542.00	7.86	70.92	0.743	45.87	0.059	0.036	BDL	0.032	0
NNS-2	Acceptable	Acceptable	27.9	6.92	764	73.85	380	5.16	0.26	32.06	11.65	8	2	310	52.85	2.21	354.6	0.495	63.29	BDL6	0.0001	BDL	0.0012	0
NNS-3	Acceptable	Acceptable	28.1	7.24	1219	107.6	611	5.12	0.3	32.06	11.65	2	11	330	113.47	8.60	141.84	0.595	49.29	BDL	0.0058	BDL	0.003	0
NNS-4	Acceptable	Acceptable	28.1	6.8	522	6.4	251	5.17	0.31	136.27	49.51	2	11	340	27.72	4.18	531.9	0.58	45.33	BDL	BDL	BDL	BDL	4
NNS-5	Acceptable	Acceptable	28.2	6.81	1200	115.7	597	6.17	0.15	128.26	46.59	4	10	420	66.84	0.00	177.3	0.733	43.19	BDL	0.006	BDL	0.009	0
NNS-6	Acceptable	Acceptable	28	7.34	418	83.9	241	6.02	0.48	36.07	13.10	0	11	200	61.40	0.00	496.44	0.87	49.81	BDL	0.0009	BDL	0.0014	0
NNS-7	Acceptable	Acceptable	27.8	7.26	279	66.05	147	5.53	0.69	52.10	18.93	2	8	200	10.36	0.00	177.3	0.51	25.43	BDL	0.0015	BDL	0.008	9.56
NNS-8	Acceptable	Acceptable	27.6	7.31	662	97	337	5.14	0.33	64.13	23.30	4	8	380	49.22	5.65	531.9	0.842	57.19	BDL	BDL	BDL	BDL	0
NNS-9	Acceptable	Acceptable	28.1	6.95	378	126.5	190	5.61	0.38	40.08	14.56	-2	6	280	15.54	0.00	248.22	0.997	49.88	BDL	BDL	BDL	0.017	30.15
NNS-10	Acceptable	Acceptable	28	7.46	823	40	424	5.01	0.51	68.14	24.75	4	4	400	74.87	0.00	496.44	0.149	68.61	BDL	0.008	BDL	0.009	14.82
<b>Faisalabad</b>																								
LYP-1	Acceptable	Acceptable	27.8	7.38	736	4.1	373	7.37	0.93	68.14	24.75	6	8	350	44.04	2.46	141.84	2.805	57.51	BDL	BDL	BDL	BDL	0
LYP-2	Objectionable	Objectionable	28.1	6.41	623	9.1	256	5.34	1.12	72.14	26.21	0	9	260	20.98	0.00	496.44	0.526	38.58	0.00346	BDL	0.003	BDL	0
LYP-3	Acceptable	Acceptable	28.3	7.06	674	5.4	320	6.43	0.3	36.07	13.10	8	5	290	75.65	0.25	120.56	0.696	43.08	0.0078	0.0073	0.006	0.0037	0
LYP-4	Acceptable	Acceptable	28.2	7.02	1291	29.95	681	5.62	1.37	48.10	17.47	8	7	290	138.60	1.47	425.52	0.089	45.67	0	BDL	BDL	BDL	0
LYP-5	Acceptable	Objectionable	28.4	6.82	580	0.9	228	6.25	0.35	116.23	42.23	4	6	310	54.15	0.00	531.9	0.322	37.35	0.046	0.036	0.007	0.0134	30.15
LYP-6	Acceptable	Acceptable	28.2	7.06	667	10	327	6.12	1.02	68.14	24.75	10	3	290	73.58	0.98	248.22	0.702	22.04	BDL	BDL	BDL	BDL	0
LYP-7	Acceptable	Acceptable	28.7	6.73	531	44.55	266	5.41	0.9	60.12	21.84	12	0	290	45.08	0.00	460.98	3.241	39.2	BDL	BDL	0.006	0.0073	10
LYP-8	Acceptable	Acceptable	28.2	6.71	533	3.65	267	5.53	0.85	64.13	23.30	0	15	170	47.93	0.00	177.3	0.447	38.67	0.0456	0.0089	BDL	0.004	0
LYP-9	Acceptable	Acceptable	28.3	6.98	1396	5.65	633	5.21	0.51	52.10	18.93	184	64	380	177.20	1.97	460.98	0.63	34.49	0.0568	0.0098	BDL	0.0063	0
LYP-10	Acceptable	Acceptable	28.2	6.79	575	83.95	303	6.52	0.93	52.10	18.93	0	10	200	56.48	0.00	425.52	0.402	37.01	0.0452	0.0161	0.002	0.0029	0

<b>LYP-11</b>	Acceptable	Acceptable	28.3	6.98	1364	44.95	584	5.78	0.75	44.09	16.02	6	14	270	174.87	3.69	141.84	0.659	43.89	BDL	BDL	BDL	BDL	0
<b>LYP-12</b>	Acceptable	Acceptable	28.2	6.86	1436	54.5	681	5.48	1.45	44.09	16.02	6	10	280	173.06	2.21	602.82	0.562	41.92	0.041	BDL	0.006	0.0091	76.1
<b>LYP-13</b>	Acceptable	Objectionabl	28.2	6.71	1394	56.1	647	5.75	0.42	52.10	18.93	8	6	310	169.69	3.44	283.68	2.433	40.09	0.0576	0.0221	0.009	BDL	14.82
<b>LYP-14</b>	Acceptable	Acceptable	28.3	7.2	675	98.85	337	5.58	0.27	40.08	14.56	0	14	240	80.31	0.00	531.9	0.704	54.72	BDL	BDL	BDL	0.008	9.54
<b>LYP-15</b>	Acceptable	Acceptable	28.1	7.39	1774	29.65	872	5.63	0.36	36.07	13.10	4	9	260	202.85	13.0	106.38	0.137	46.56	BDL	0.0032	BDL	0.037	0
<b>LYP-16</b>	Acceptable	Acceptable	28.2	7.82	2000	31.6	970	6.47	0.68	24.05	8.74	6	13	120	238.60	2.70	921.96	0.332	67.78	0.00098	BDL	0.002	BDL	0
<b>LYP-17</b>	Acceptable	Acceptable	28.2	7.04	737	38.4	300	5.99	0.53	56.11	20.38	0	13	240	70.98	0.74	460.98	1.842	45.89	BDL	BDL	BDL	0.0026	0
<b>LYP-18</b>	Acceptable	Acceptable	27.9	6.79	834	63.2	419	7.55	1.47	32.06	11.65	2	7	200	116.32	0.49	212.76	0.842	47.24	0.034	BDL	0.007	BDL	0
<b>LYP-19</b>	Acceptable	Acceptable	28.29	7.64	898	38.45	445	5.29	0.61	20.04	7.28	4	7	180	115.54	17.9	141.84	0.98	37.59	BDL	BDL	BDL	0.0093	3.59
<b>LYP-20</b>	Acceptable	Acceptable	28.9	6.71	368	45	337	5.93	1.03	16.03	5.82	0	1	200	336.00	6.88	319.14	0.842	45.55	BDL	BDL	0.002	BDL	15.1

**Sahiwal**

<b>SWN-1</b>	Acceptable	Acceptable	28.2	6.72	1134	12.2	539	6.79	0.36	80.16	29.12	2	5	460	87.05	6.63	141.84	0.816	17.27	0.029	0.0043	BDL	0.004	10
<b>SWN-2</b>	Acceptable	Acceptable	28.7	6.73	828	4.15	403	5.62	0.27	80.16	29.12	6	1	260	24.09	46.6	524.80	0.971	12.34	0.031	BDL	BDL	BDL	0
<b>SWN-3</b>	Acceptable	Acceptable	28.9	6.55	816	0.15	406	7.56	0.36	100.20	36.40	0	6	360	20.47	0.00	170.20	0.759	15.79	0.019	0.014	BDL	BDL	9.69
<b>SWN-4</b>	Acceptable	Acceptable	29	6.88	857	34.6	408	6.82	0.51	96.19	34.95	2	3	220	30.05	0.00	524.80	0.79	15.97	0.023	0.0028	BDL	BDL	3.59
<b>SWN-5</b>	Acceptable	Acceptable	28.3	6.12	407	6.15	194	7.97	0.35	40.08	14.56	0	7	230	7.77	0.25	134.74	0.709	14.64	BDL	BDL	BDL	0.006	0
<b>SWN-6</b>	Acceptable	Acceptable	29	7.24	233	5.4	113	5.14	0.38	236.47	85.91	0	3	190	0.00	0.00	354.6	0.657	29.09	BDL	BDL	0.006	BDL	0
<b>SWN-7</b>	Acceptable	Acceptable	28.9	6.5	231	4.8	108	5.16	0.17	36.07	13.10	4	0	210	3.11	5.90	106.38	0.587	28.07	0.007	0.0174	0.007	0.008	19.9
<b>SWN-8</b>	Objectionable	Acceptable	29	6.18	372	12.9	191	7.22	0.61	44.09	16.02	0	3	250	6.22	0.00	531.9	0.786	35.26	BDL	0.0142	BDL	BDL	0
<b>SWN-9</b>	Acceptable	Acceptable	28.9	7.17	214	28.6	104	6.5	0.86	40.08	14.56	6	1	210	3.89	0.00	319.14	0.354	30.78	0.037	BDL	BDL	BDL	0
<b>SWN-10</b>	Acceptable	Acceptable	28.3	6.48	1196	30.5	183	5.84	1.03	80.16	29.12	0	12	250	66.58	67.0	496.44	1.348	29.47	0.0388	0.0023	BDL	BDL	0
<b>SWN-11</b>	Acceptable	Acceptable	28.9	6.62	608	57.2	317	7.34	1.04	80.16	29.12	0	6	570	17.88	34.6	460.98	0.61	33.83	BDL	0.0193	BDL	BDL	0
<b>SWN-12</b>	Acceptable	Acceptable	28.3	6.87	1113	20.85	529	5.79	0.42	88.18	32.03	6	1	330	93.52	0.00	141.84	0.651	36.59	0.076	0.062	0.022	BDL	76.1
<b>SWN-13</b>	Acceptable	Acceptable	29	6.5	2000	8.7	2112	5.55	0.69	212.42	77.17	0	8	490	262.95	8.11	567.36	1.569	38.58	BDL	0.0132	BDL	BDL	19.9
<b>SWN-14</b>	Acceptable	Acceptable	28.9	6.76	665	9.65	320	7.5	0.14	80.16	29.12	0	14	250	63.47	0.00	567.36	0.984	36.67	BDL	0.0145	BDL	0.006	0
<b>SWN-15</b>	Acceptable	Acceptable	28.9	6.9	684	9.55	341	7.74	0.47	64.13	23.30	0	7	250	62.44	0.49	177.3	0.875	53.28	BDL	BDL	BDL	BDL	0
<b>SWN-16</b>	Acceptable	Acceptable	29	7.04	368	21.05	184	5.1	1.08	56.11	20.38	0	13	230	8.03	0.00	212.76	0.909	52.64	0.0436	0.00327	BDL	0.023	0
<b>SWN-17</b>	Acceptable	Acceptable	27.7	6.69	518	42.65	264	7.43	0.24	276.55	100.47	0	8	270	44.04	0.00	70.92	0.915	25.96	0.009	0.0087	0.009	0.009	0
<b>SWN-18</b>	Acceptable	Acceptable	28.9	6.89	968	9.75	495	6.97	0.56	108.22	39.31	2	5	240	73.58	14.5	354.6	0.145	51.36	BDL	0.0032	BDL	BDL	0

Okara																								
<b>OKR-1</b>	Acceptable	Acceptable	28.9	6.87	2000	50.45	1600	6.88	0.32	104.21	37.86	8	4	240	391.71	11.0	567.36	0.88	48.57	BDL	0.001	BDL	BDL	9.55
<b>OKR-2</b>	Acceptable	Acceptable	29	7.68	1913	7.45	785	5.62	0.56	80.16	29.12	2	5	310	184.46	2.95	319.14	1.86	35.43	0.023	0.012	BDL	BDL	0
<b>OKR-3</b>	Acceptable	Objectionabl	28.8	6.81	2000	36.55	1488	5.4	0.64	96.19	34.95	0	5	390	267.62	7.13	354.6	0.96	16.61	0.056	0.029	0.006	BDL	0
<b>OKR-4</b>	Acceptable	Acceptable	27.9	7.06	2000	43.7	1747	7.62	0.43	20.04	7.28	2	11	450	2820.7	11.3	460.98	2.66	24.06	0.019	0.0068	BDL	BDL	19.9
<b>OKR-5</b>	Acceptable	Acceptable	28.9	7.53	2000	13.25	1410	5.71	0.91	40.08	14.56	8	4	190	310.36	13.5	283.68	0.073	41.34	BDL	BDL	BDL	BDL	0
Jhang																								
<b>JNG-1</b>	Acceptable	Acceptable	27.3	6.89	1481	1.4	676	8.17	0.25	72.14	26.21	2	7	1720	104.40	0.00	212.76	1.917	45.96	BDL	BDL	BDL	BDL	0
<b>JNG-2</b>	Acceptable	Acceptable	27.2	7.2	1172	9.4	536	5.57	0.6	104.21	37.86	2	5	3580	75.91	5.65	177.3	0.678	33.52	0.031	0.0232	0.002	0.0069	0
<b>JNG-3</b>	Acceptable	Acceptable	27.3	7.26	1092	21.5	524	7.08	0	96.19	34.95	0	6	400	134.46	5.41	283.68	0.829	35.42	0.0097	0.019	BDL	0.0053	0
<b>JNG-4</b>	Acceptable	Acceptable	27.5	6.92	1432	16.2	695	6.54	1.7	48.10	17.47	0	9	640	115.54	57.9	248.22	0.229	42.59	BDL	BDL	BDL	0.025	9.55
<b>JNG-5</b>	Acceptable	Acceptable	27.4	7.11	1170	6.95	55	5.68	0.83	40.08	14.56	6	11	320	151.81	7.86	248.22	0.879	66.67	0.0042	0.008	BDL	BDL	0
<b>JNG-6</b>	Acceptable	Acceptable	27.4	7.22	844	2.05	414	5.12	0	48.10	17.47	2	8	300	58.29	0.00	283.68	0.263	27.69	BDL	0.0089	BDL	BDL	27.4
<b>JNG-7</b>	Acceptable	Acceptable	27.4	7.04	963	5.45	476	6.89	0.73	44.09	16.02	0	6	400	116.06	0.00	177.3	2.81	50.33	0.013	0.0122	BDL	0.002	9.55
<b>JNG-8</b>	Acceptable	Acceptable	27.6	6.58	516	6	264	5.81	0.24	32.06	11.65	2	3	330	64.51	8.85	177.3	0.482	35.1	BDL	BDL	0.008	0.021	11.05
<b>JNG-9</b>	Acceptable	Acceptable	27.7	7.24	944	53.25	474	5.32	0	76.15	27.67	0	9	270	107.77	0.00	248.22	0.827	97.46	0.002	0.0196	BDL	0.0054	0
<b>JNG10</b>	Acceptable	Acceptable	27.4	6.36	1447	14.4	694	6.16	6.64	40.08	14.56	2	7	220	207.51	0.00	248.22	0.582	87.77	0.0064	0.0113	0.003	BDL	0
Pakpattan																								
<b>PKP-1</b>	Acceptable	Acceptable	27.9	6.74	2000	38.05	1988	5.35	0.77	212.42	77.17	8	2	760	283.16	11.3	1099.2	0.986	28.25	0.0031	0.0029	BDL	BDL	0
<b>PKP-2</b>	Acceptable	Acceptable	28.2	7.19	2000	3.45	1046	6.96	0.66	84.17	30.58	2	8	350	187.31	8.85	248.22	0.166	24.54	BDL	BDL	BDL	BDL	0
<b>PKP-3</b>	Acceptable	Acceptable	28.8	6.98	1207	52.45	584	5.36	0.53	124.25	45.14	0	8	430	61.14	7.13	531.9	0.099	25.55	BDL	BDL	BDL	0.0019	115.7
<b>PKP-4</b>	Acceptable	Acceptable	28.2	7.22	1008	40.45	483	6.64	0.55	60.12	21.84	4	4	370	101.30	0.00	177.3	2.393	38.49	0.038	0.012	0.008	BDL	0
<b>PKP-5</b>	Acceptable	Acceptable	28.8	6.79	1438	8.95	693	5.36	0.68	120.24	43.68	0	9	420	94.04	13.0	496.44	0.817	29.88	0.009	BDL	0.009	BDL	0
Kasur																								
<b>KUS-1</b>	Acceptable	Acceptable	29	6.92	1693	4.2	1354	7.98	0.51	100.20	36.40	2	6	260	185.75	3.44	531.9	0.294	29.31	BDL	BDL	BDL	0.0009	0
<b>KUS-2</b>	Acceptable	Acceptable	29	6.98	1223	18	978	5.66	0.85	48.10	17.47	6	6	360	118.65	9.58	283.6	0.897	27.24	0.0096	BDL	0.009	BDL	0
<b>KUS-3</b>	Acceptable	Acceptable	28.8	7.18	1104	13.35	883	6.97	0.71	80.16	29.12	16	1	300	113.47	7.86	496.4	0.156	30.73	0.0063	BDL	0.006	0.013	19.8

<b>KUS-4</b>	Acceptable	Acceptable	28.7	7.14	2000	8.15	1600	5.96	0.89	96.19	34.95	2	6	310	170.21	138.3	882.9	0.662	46.19	0.034	0.018	BDL	BDL	0
<b>KUS-5</b>	Acceptable	Acceptable	28.3	6.9	1987	4.85	1589	5.18	0.6	60.12	21.84	0	9	380	172.80	129.2	166.6	0.953	26.3	0.041	BDL	0.003	0.017	0
<b>KUS-6</b>	Acceptable	Acceptable	29	7.19	2000	1.3	1600	5.12	0.93	116.23	42.23	2	11	350	181.61	121.1	404.2	0.51	25.43	0.0063	0.0048	BDL	0.008	0
<b>KUS-7</b>	Acceptable	Acceptable	28.9	6.99	2000	13.1	1600	5.37	1.19	80.16	29.12	0	20	480	207.77	111.0	212.7	0.966	30.64	BDL	BDL	BDL	0.0025	76.1
<b>KUS-8</b>	Acceptable	Acceptable	28.3	6.93	2000	9.15	1600	5.34	1.16	48.10	17.47	4	13	420	0.52	9.09	390.0	1.74	54.96	BDL	BDL	BDL	0.028	14.82
<b>KUS-9</b>	Acceptable	Acceptable	28.9	7.38	1267	18.75	1013	5.43	0.04	128.26	46.59	4	9	280	138.34	9.58	425.5	0.59	63.15	0.008	BDL	0.008	0.0071	30.15
<b>KUS-10</b>	Acceptable	Acceptable	28.3	7.68	1790	18.85	1432	5.62	0.64	44.09	16.02	0	15	320	178.76	90.17	567.3	0.54	25.08	BDL	BDL	BDL	0.0098	0
<b>KUS-11</b>	Acceptable	Acceptable	29	6.81	2000	1.5	1600	5.25	0.75	60.12	21.84	2	8	410	254.15	6.63	248.2	0.277	19.6	0.0071	BDL	0.007	BDL	0
<b>KUS-12</b>	Acceptable	Acceptable	28.9	6.18	553	5.7	442	5.12	0.35	20.04	7.28	2	3	230	93.52	1.23	460.9	2.16	55.29	BDL	0.0089	BDL	BDL	9.55
<b>KUS-13</b>	Acceptable	Acceptable	28.9	7.17	510	2.25	408	5.41	0.57	60.12	21.84	0	9	160	86.53	0.74	177.3	0.438	37.44	0.006	BDL	0.006	BDL	19.96
<b>KUS-14</b>	Acceptable	Acceptable	29	6.48	2000	51.9	1600	7.53	0.95	40.08	14.56	10	1	230	216.84	105.6	496.4	0.607	32.38	BDL	BDL	BDL	0.009	0
<b>KUS-15</b>	Acceptable	Acceptable	27.7	6.62	1176	53.9	940	6.21	0.52	40.08	14.56	4	2	220	128.24	31.94	531.9	0.871	33.68	0.078	0.043	0.009	0.014	0

**Sheikhpura**

<b>SKP-1</b>	Acceptable	Acceptable	28	6.18	1376	62.9	1100	6.98	2.14	236.47	85.91	2	7	300	153.37	13.02	673.7	1.664	40.69	0.0052	BDL	BDL	BDL	0
<b>SKP-2</b>	Acceptable	Acceptable	28.8	7.17	1921	1.5	1536	5.22	1.44	68.14	24.75	2	15	350	190.41	29.24	212.7	0.572	87.98	0.03124	BDL	BDL	0.0091	20.74
<b>SKP-3</b>	Acceptable	Acceptable	28.4	6.48	535	4.55	428	6.23	1.3	56.11	20.38	4	9	400	202.33	27.03	496.4	0.441	33.26	BDL	0.0032	BDL	BDL	11.5
<b>SKP-4</b>	Acceptable	Acceptable	29.1	6.62	1962	16.4	1569	5.02	1.08	64.13	23.30	2	10	350	207.77	27.03	106.3	0.202	32.02	BDL	BDL	BDL	BDL	10
<b>SKP-5</b>	Acceptable	Acceptable	28.9	6.87	1739	25.85	1391	5.66	0.73	148.30	53.87	4	5	350	191.19	2.21	354.6	1.573	32.91	0.063	0.034	BDL	0.0338	11
<b>SKP-6</b>	Acceptable	Acceptable	29.1	6.5	379	15.25	303	6.23	0.14	60.12	21.84	2	4	250	126.17	0.49	354.6	1.264	53.91	0.056	0.018	BDL	0.0061	0
<b>SKP-7</b>	Acceptable	Acceptable	28.9	6.76	582	1.3	465	5.99	1.06	100.20	36.40	0	5	200	40.41	0.00	531.9	0.443	30.71	BDL	BDL	BDL	BDL	0
<b>SKP-8</b>	Acceptable	Acceptable	29	6.9	876	14.3	700	5.63	1.53	60.12	21.84	6	4	310	93.26	0.00	358.1	0.738	25.12	BDL	BDL	BDL	0.0018	0
<b>SKP-9</b>	Acceptable	Acceptable	28.9	7.04	2000	3.85	1600	6.65	1.11	60.12	21.84	4	6	200	271.50	14.00	354.6	0.711	42.99	BDL	BDL	BDL	BDL	94.92
<b>SKP-10</b>	Acceptable	Acceptable	28	6.81	2000	1.5	1600	5.36	0.9	32.06	11.65	4	9	140	252.07	15.48	351.0	1.284	56.02	BDL	0.0023	BDL	0.0098	115.7
<b>SKP-11</b>	Acceptable	Acceptable	28.8	7.34	2000	10.25	1600	5.26	0.7	36.07	13.10	4	10	120	282.38	14.25	319.1	1.371	50.62	BDL	BDL	BDL	0.023	0
<b>SKP-12</b>	Acceptable	Acceptable	28.8	7.26	362	0.3	289	5.21	1.04	32.06	11.65	0	6	280	16.58	0.00	531.9	0.882	56.02	0.003	0.0067	BDL	BDL	19.9
<b>SKP-13</b>	Acceptable	Acceptable	28.9	7.31	256	7.95	204	5.21	0.53	36.07	13.10	0	4	250	8.29	0.00	42.55	0.185	20.29	BDL	BDL	BDL	BDL	0
<b>SKP-14</b>	Acceptable	Acceptable	28.9	6.95	1613	1.85	1290	6.96	1.11	24.05	8.74	2	13	250	176.94	9.09	563.8	0.835	33.91	0.0089	BDL	BDL	0.0193	0
<b>SKP-15</b>	Acceptable	Acceptable	28.9	7.46	1821	26.05	1456	5.55	0.88	40.08	14.56	2	9	390	206.22	4.18	343.9	0.342	43.99	BDL	BDL	BDL	BDL	9.55

## Lahore

LHR-1	Acceptable	Acceptable	28.7	6.73	706	0.35	336	5.75	2.16	36.07	13.10	4	6	300	81.87	0.98	177.3	1.105	41.32	BDL	BDL	BDL	0.0016	0
LHR-2	Objectionabl	Acceptable	29	6.71	636	18.25	326	5.18	2.41	56.11	20.38	4	2	340	42.75	0.49	177.3	1.53	29.12	0.0073	0.0024	BDL	0.0048	0
LHR-3	Acceptable	Acceptable	28	6.98	891	26.85	455	5.28	2.11	60.12	21.84	8	0	330	89.90	1.72	177.3	1.227	29.53	BDL	BDL	BDL	0.0055	0
LHR-4	Acceptable	Acceptable	28.8	6.79	556	37.1	278	6.05	1.54	40.08	14.56	4	1	400	52.33	0.00	212.7	1.113	24.91	0.065	0.031	BDL	0.037	14.82
LHR-5	Objectionabl	Objectionable	28.4	6.98	551	6.05	271	5.34	2.47	60.12	21.84	4	6	300	47.67	0.74	177.3	0.612	16.6	0.00125	0.0068	BDL	0.00621	0
LHR-6	Acceptable	Acceptable	29.1	6.86	640	1.5	313	6.33	1.31	72.14	26.21	4	2	310	65.80	0.74	212.7	0.902	20.15	0.053	0.021	BDL	0.0048	0
LHR-7	Acceptable	Acceptable	28.9	6.71	711	1.1	347	5.36	2.53	48.10	17.47	2	5	260	79.02	1.23	212.7	0.045	15.1	0.0076	0.0041	BDL	0.0007	0
LHR-8	Acceptable	Acceptable	29.1	7.2	883	0.7	605	6.76	1.22	40.08	14.56	2	6	400	150.78	3.93	141.8	1.065	28.53	0.009	0.0013	BDL	0.00063	30.15
LHR-9	Acceptable	Acceptable	28.9	7.39	1226	26.4	270	6.41	1.12	48.10	17.47	4	1	200	77.20	0.98	460.9	0.924	24.73	0.098	0.065	BDL	0.0093	94.92
LHR-10	Acceptable	Objectionable	29	7.82	686	54.6	329	5.92	1.17	48.10	17.47	0	4	300	59.59	1.72	177.3	0.378	15.5	0.0063	0.0046	BDL	0.028	3.54
LHR-11	Acceptable	Acceptable	28.9	7.04	1348	5.6	664	6.33	1.23	132.26	48.05	4	3	220	175.65	3.93	70.92	1.166	21.34	BDL	BDL	BDL	0.0041	0
LHR-12	Acceptable	Objectionable	28	6.79	486	5	235	5.49	1.62	68.14	24.75	2	4	300	32.38	1.23	212.7	1.515	25.84	0.0056	0.0023	BDL	0.0048	0
LHR-13	Acceptable	Objectionable	28.8	7.64	1443	17.55	728	7.85	1.21	76.15	27.67	4	4	300	60.62	2.70	248.2	0.808	20.34	BDL	BDL	BDL	0.0098	0
LHR-14	Objectionabl	Objectionable	28.8	6.71	494	25.2	249	5.26	1.36	80.16	29.12	0	14	180	31.87	0.98	212.7	0.773	18.82	BDL	BDL	BDL	0.0067	0
LHR-15	Acceptable	Acceptable	28.9	7.04	566	3.05	240	5.45	0.98	140.28	50.96	0	3	400	50.26	0.74	141.8	0.653	62.42	BDL	0.0093	BDL	0.0007	115.7
LHR-16	Acceptable	Acceptable	28.9	6.92	778	2.45	329	6.22	1.02	48.10	17.47	2	4	200	97.15	1.47	212.7	0.983	13.68	0.078	0.029	BDL	0.002	25.89
LHR-17	Acceptable	Acceptable	28.9	7.24	1109	9.75	541	7.88	1.67	48.10	17.47	4	6	200	148.19	2.46	106.3	0.352	19.98	BDL	BDL	BDL	0.0087	0
LHR-18	Acceptable	Acceptable	29	6.8	631	6.65	312	5.07	1.39	56.11	20.38	2	5	300	71.76	0.74	248.2	0.378	25.78	0.0025	BDL	BDL	0.0091	0
LHR-19	Acceptable	Acceptable	29	6.81	481	21.2	239	6.35	1.36	76.15	27.67	8	0	300	38.86	0.49	177.3	0.546	16.86	BDL	BDL	BDL	0.0058	0
LHR-20	Acceptable	Acceptable	28.8	7.34	639	55.25	298	7.16	1.38	44.09	16.02	0	7	200	55.44	3.19	177.3	0.983	15.6	BDL	0.00123	BDL	0.0217	0
LHR-21	Acceptable	Acceptable	28.7	7.26	543	5.2	263	5.33	1.39	160.32	58.24	2	3	300	49.48	0.25	177.3	1.109	17.51	0.00125	0.0098	BDL	0.0062	0
LHR-22	Acceptable	Acceptable	28.3	7.31	486	2.5	243	5.83	1.51	108.22	39.31	4	3	200	40.93	1.23	177.3	0.602	14.5	BDL	0.0253	BDL	0.0016	0
LHR-23	Acceptable	Objectionable	28	6.95	521	13.45	254	7.98	1.52	144.29	52.42	2	5	220	51.04	0.98	177.3	0.801	12.68	BDL	0.0023	BDL	0.0032	20.7
LHR-24	Acceptable	Acceptable	28.7	7.46	529	13.55	263	5.93	1.58	40.08	14.56	4	2	210	48.96	0.49	212.7	0.297	16.97	0.00138	0.0013	BDL	0.0043	14.82
LHR-25	Acceptable	Objectionable	28.6	6.92	655	17.8	325	6.58	1.09	80.16	29.12	2	4	170	73.58	0.74	248.2	0.603	20.8	0.0094	BDL	BDL	0.00674	0
LHR-26	Acceptable	Objectionable	28.8	6.98	402	28.6	232	6.76	1.59	120.24	43.68	2	2	430	32.64	1.72	212.7	0.889	58.18	BDL	BDL	BDL	0.0006	0
LHR-27	Acceptable	Acceptable	28.9	7.18	1403	8.65	692	5.21	1.6	64.13	23.30	0	9	270	191.71	4.18	177.3	1.301	22.68	BDL	BDL	BDL	0.0141	0
LHR-28	Acceptable	Acceptable	29.1	7.14	716	18.85	345	5.23	0.8	120.24	43.68	4	4	230	83.94	0.74	354.6	1.974	20.068	0.012	BDL	BDL	0.0064	0
LHR-29	Acceptable	Acceptable	29	6.9	584	10.55	284	5.75	0.72	288.58	104.84	4	5	220	60.62	0.00	177.3	1.631	19.24	BDL	BDL	BDL	0.0012	9.55

LHR-30	Acceptable	Acceptable	29	7.19	514	0.9	259	5.07	0.68	148.30	53.87	0	1	150	59.59	0.74	248.2	0.578	16.105	BDL	BDL	BDL	0.0055	0
LHR-31	Acceptable	Acceptable	28.9	6.99	646	5.65	320	5.37	1.03	444.89	161.62	0	8	200	69.95	0.74	141.8	1.739	22.09	BDL	0.0013	BDL	0.0023	19.99
LHR-32	Acceptable	Objectionable	28.9	6.93	524	10.3	259	3.55	1.05	72.14	26.21	0	3	250	51.55	0.00	141.8	1.156	27.83	BDL	0.019	BDL	0.0053	0
LHR-33	Acceptable	Objectionable	28.7	7.38	579	10.3	283	5.35	1	136.27	49.51	0	8	350	59.84	0.74	177.3	0.847	16.61	BDL	0.0234	BDL	0.0032	0
LHR-34	Acceptable	Objectionable	28.9	7.68	737	7.85	364	5.38	1	180.36	65.52	0	5	400	73.32	6.88	283.6	1.764	19.68	0.0068	BDL	BDL	0.0048	20
LHR-35	Acceptable	Objectionable	28.9	6.81	495	6.45	245	7.91	1.44	180.36	65.52	0	5	300	48.45	0.49	212.7	0.603	24.94	0.0073	BDL	BDL	0.0078	94.92
LHR-36	Acceptable	Acceptable	28.9	7.06	635	10.3	307	5.27	0.96	60.12	21.84	2	1	300	56.74	0.74	248.2	1.166	19.216	BDL	BDL	BDL	0.0052	20.72
LHR-37	Acceptable	Acceptable	28.9	7.53	659	62.25	319	5.39	1	108.22	39.31	0	7	200	99.22	0.25	354.6	1.379	20.313	BDL	BDL	BDL	0.0250	14.82
LHR-38	Acceptable	Acceptable	29	6.74	1254	28.6	464	5.03	0.77	92.18	33.49	2	9	100	190.67	2.95	177.3	2.173	22.94	BDL	BDL	BDL	0.0034	0
LHR-39	Acceptable	Acceptable	28.9	7.19	566	19.65	278	5.38	0.94	152.30	55.33	2	3	350	75.13	0.25	248.2	1.307	53.73	BDL	BDL	BDL	0.00164	0
LHR-40	Acceptable	Acceptable	29	6.98	1348	39.15	651	5.83	0.68	120.24	43.68	8	1	250	193.78	2.70	177.3	0.805	24.48	BDL	BDL	BDL	0.0049	4
LHR-41	Acceptable	Acceptable	28.9	7.22	1367	0.9	619	5.36	0.21	76.15	27.67	0	15	300	211.92	2.95	177.3	1.02	21.34	BDL	BDL	BDL	0.0078	0
LHR-42	Acceptable	Objectionable	29	6.79	512	19.75	267	5.22	1.18	188.38	68.43	4	1	250	50.26	0.00	212.7	0.546	25.78	BDL	BDL	BDL	0.0029	0
LHR-43	Acceptable	Acceptable	29	6.72	656	3	190	5.83	0.17	48.10	17.47	4	2	250	85.49	0.74	248.2	0.171	20.48	BDL	BDL	BDL	0.018	0
LHR-44	Acceptable	Acceptable	29.1	6.73	1328	4.75	623	5.57	1	48.10	17.47	10	4	700	166.58	3.19	354.6	1.471	18.766	0.0056	BDL	BDL	0.006	0
LHR-45	Acceptable	Acceptable	29.1	6.55	1400	2.3	727	5.48	1.13	40.08	14.56	4	5	240	191.19	3.69	177.3	1.817	22.84	BDL	BDL	BDL	0.0067	0
LHR-46	Acceptable	Acceptable	29.1	6.88	532	12.25	268	5.94	1.01	44.09	16.02	0	5	200	41.45	0.74	177.3	1.185	27.28	BDL	BDL	BDL	0.0016	0
LHR-47	Acceptable	Acceptable	29	6.12	558	11.8	278	5.34	0.75	64.13	23.30	0	9	260	44.82	0.49	354.6	0.457	24.58	0.0048	0.0009	BDL	0.0048	94.92
LHR-48	Acceptable	Acceptable	29.9	7.24	1330	2.5	629	5.95	0.26	184.37	66.98	2	9	600	176.17	3.93	177.3	1.461	21.49	0.00164	BDL	BDL	0.0067	0
LHR-49	Acceptable	Acceptable	29.1	6.5	581	5.1	289	5.52	0.51	36.07	13.10	6	3	150	67.10	0.00	630	1.31	27.28	BDL	BDL	BDL	0.0084	0
WHO Guidline [85]	Acceptable	Acceptable	-	6.5- 8.5	<1500	-	1000	5	5	-	-	-	-	500	-	-	250	1.5	50	0.05	0.02	0.01	0.01	0/100 ml
NEQS	Acceptable	Acceptable	-	6.5- 8.5	<1500	-	1000	5	5	-	-	-	-	500	-	-	250	1.5	50	0.05	0.02	0.01	0.05	0/100 ml

**BDL= Below detection limit**

#### 4.4 Results of Primary Schools of Rural Punjab (South)

Southern Punjab consists of 5 cities (Lodhran, Multan, Khanewal, Vehari and Bhawalnagar) as per study boundary. Results of these areas have been given in the following table (4.3).

### 4.3: Physiochemical and Microbial Quality of South Punjab drinking water samples

Sample Code	Colour	odour	Temp	pH	EC	TSS	TDS	DO	Turbidity	Ca <sup>2+</sup>	Mg <sup>2+</sup>	CO <sub>3</sub> <sup>-</sup>	HCO <sub>3</sub> <sup>-</sup>	TH	Na <sup>+</sup>	K <sup>+</sup>	Cl <sup>-</sup>	F <sup>-</sup>	Nitrate	Cr	Ni	Pb	As	Total Coli-forms
			°C		µS/cm	mg/l						meq/l		mg/l			ppm		mg/l			MPN/100 ml		
<b>Bhawalnagar</b>																								
WGB-1	Acceptable	Acceptable	27.8	7.01	723	1.3	324	5.13	0.68	52.10	18.93	0	2	250	88.08	0.00	141.84	0.568	41.43	BDL	BDL	BDL	0.006	0
WGB-2	Acceptable	Acceptable	27.1	6.85	442	3.95	237	7.28	0.19	28.06	10.19	0	10	250	103.11	0.00	212.76	1.875	44.09	BDL	BDL	BDL	BDL	0
WGB-3	Acceptable	Acceptable	27.6	6.66	1236	14.7	537	5.68	0.23	112.22	40.77	0	8	600	91.71	0.00	248.22	0.035	32.43	BDL	BDL	BDL	BDL	25.89
WGB-4	Acceptable	Acceptable	27.7	6.76	467	41.3	233	5.94	0.48	40.08	14.56	0	3	320	97.67	0.00	177.3	0.425	52.38	BDL	BDL	BDL	0.008	0
<b>Lodhran</b>																								
LON-1	Acceptable	Acceptable	29	6.88	996	1.5	799	5.97	0.22	72.14	26.21	8	1	300	52.85	32.6	141.84	0.118	44.4	0.007	0.0098	BDL	0.0034	20.74
LON-2	Acceptable	Acceptable	29	7.04	617	23.6	276	5.96	0.41	60.12	21.84	2	6	250	0.52	1.72	70.92	0.196	41.09	BDL	BDL	BDL	0.0091	0
LON-3	Acceptable	Objectionable	29	6.82	1137	5.3	583	5.18	0.09	80.16	29.12	2	8	260	113.21	4.18	460.98	1.515	52.61	0.0087	0.0067	BDL	0.0021	0
LON-4	Acceptable	Acceptable	28.6	7.19	751	23.6	373	5.12	1.09	68.14	24.75	6	1	420	42.75	0.00	35.46	0.989	66.57	0.0098	0.0076	BDL	0.037	0
<b>Multan</b>																								
MUX-1	Acceptable	Acceptable	28	7.24	443	38.4	235	6.06	0.19	72.14	26.21	4	10	280	44.04	0.00	177.3	0.321	42.91	BDL	BDL	BDL	BDL	0
MUX-2	Acceptable	Acceptable	27.7	7.39	557	11	280	7.83	0.3	40.08	14.56	2	5	550	37.31	0.00	141.84	1.475	32.68	0.0094	BDL	BDL	0.0051	11
MUX-3	Acceptable	Acceptable	27.6	7.4	944	49	466	5.81	0.69	40.08	14.56	2	3	350	116.06	0.00	283.68	0.29	76.45	0.053	0.021	BDL	BDL	0
MUX-4	Acceptable	Acceptable	27.4	7.16	834	2	412	6.17	0.25	56.11	20.38	2	4	560	53.37	1.47	319.14	0.067	33.83	BDL	0.0018	BDL	0.022	0
MUX-5	Acceptable	Acceptable	27.8	7.14	747	1.95	377	7.04	0.19	64.13	23.30	0	2	360	50.78	0.98	177.3	0.321	32.16	BDL	BDL	BDL	0.019	0
<b>Vehari</b>																								
VHR-1	Acceptable	Acceptable	27.7	7.11	816	0.95	395	5.91	0.3	48.10	17.47	2	5	430	55.96	0.98	177.3	1.294	28.93	BDL	BDL	BDL	BDL	0
VHR-2	Acceptable	Acceptable	27.7	6.49	688	1.6	264	6.02	0.61	40.08	14.56	0	0	200	96.63	0.00	177.3	1.411	23.18	0.0071	0.019	BDL	0.0065	27.4
VHR-3	Objectionab	Objectionable	27.5	6.97	2000	0.15	1232	6.29	0.97	120.24	43.68	2	5	300	BDL	0.00	177.3	2.505	64.92	BDL	BDL	0.001	BDL	0
VHR-4	Acceptable	Acceptable	27.8	6.72	1315	0.4	643	6.33	0.61	120.24	43.68	0	11	380	233.94	0.00	354.6	3.378	27.12	0.0097	BDL	0.001	0.018	9.55

VHR-5	Acceptable	Acceptable	27.6	7.52	1297	1.05	624	7.14	0.87	72.14	26.21	4	6	910	105.18	0.00	177.3	2.616	39.62	0.067	0.035	BDL	BDL	0
VHR-6	Acceptable	Acceptable	27.7	7.26	1075	2.85	506	5.02	0.59	160.32	58.24	2	1	350	81.87	1.23	177.3	1.379	47.9	0.0081	0.0023	0.001	BDL	0
VHR-7	Acceptable	Acceptable	27.7	7.33	416	0.35	188	6.86	1.63	92.18	33.49	18	8	260	42.75	0.00	177.3	1.895	49.13	BDL	BDL	0.012	0.0093	20.75
VHR-8	Acceptable	Acceptable	27.7	7.48	540	6.95	264	5.56	0.23	64.13	23.30	4	7	310	89.90	0.00	212.76	1.364	56.02	0.066	0.025	0.001	0.024	0
<b>Bhawalnagar</b>																								
KWL-1	Acceptable	Acceptable	27.6	7.32	693	0.65	334	5.47	0.78	128.26	46.59	2	11	480	73.32	0.00	212.76	1.369	54.03	BDL	BDL	BDL	BDL	0
KWL-2	Acceptable	Acceptable	26.7	6.86	1278	25.3	611	7.83	0.63	80.16	29.12	0	14	420	139.90	0.00	177.3	0.043	25.75	0.0046	0.007	BDL	BDL	0
KWL-3	Acceptable	Acceptable	27.6	6.97	459	26.7	281	5.31	0.66	72.14	26.21	0	3	280	68.13	0.00	106.38	0.131	45.33	0.0087	0.0028	BDL	BDL	9.55
KWL-4	Acceptable	Acceptable	27.7	6.81	1746	5.5	781	7.06	0.59	128.26	46.59	656	319	520	74.09	4.18	354.6	0.527	42.01	0.0075	0.0023	BDL	0.026	11.05
KWL-5	Acceptable	Acceptable	27.6	7.11	1932	26.2	902	5.23	0.58	44.09	16.02	22	8	340	81.09	9.83	496.44	2.105	67.6	BDL	0.0022	BDL	BDL	0
KWL-6	Acceptable	Acceptable	27.7	7.38	915	7.8	443	7.48	1.14	80.16	29.12	0	5	370	131.09	0.00	177.3	0.54	41.43	0.036	0.018	BDL	BDL	0
KWL-7	Acceptable	Acceptable	27.9	7.3	1061	0.25	487	5.62	0.93	84.17	30.58	4	3	460	240.93	4.42	141.84	0.153	36.67	0.041	0.019	BDL	0.034	20.74
KWL-8	Objection	Acceptable	27.8	7.41	1076	9.7	523	5.73	0.63	72.14	26.21	6	1	410	72.54	0.00	177.3	0.794	38.14	BDL	BDL	BDL	0.001	0
WHO Guideline [85]	Acceptable	Acceptable	-	6.5- 8.5	<1500	-	1000	5	5	-	-	-	-	500	-	-	250	1.5	50	0.05	0.02	0.01	0.01	0/100 ml
NEQS	Acceptable	Acceptable	-	6.5- 8.5	<1500	-	1000	5	5	-	-	-	-	500	-	-	250	1.5	50	0.05	0.02	0.01	0.05	0/100 ml

**BDL= Below detection limit**

## 4.5 Statistical Analysis

Statistical analysis (mean, maximum, minimum) aid in the description and comprehension of data. Finding patterns and relationships in data is made easier with the help of correlation analysis, which explains how changes in one variable relate to changes in another. Results of these descriptive stats and correlation, using IBM SPSS version 2.0, are given in the table 4.4 and 4.5:

#### 4.4: Descriptive statistics of Northern and Southern Punjab Data

Parameter		Narowal	Gujranwala	Hafizaabad	Sialkot	Bhawal-nagar	Lodhran	Multan	Vehari	Khanewal	WHO Standard [85]
<b>pH</b>	Mean ± S.D	7.02±0.21	6.92 ±0.31	6.953±0.12	6.97±0.40	6.82±0.15	6.98±0.17	7.26±0.12	7.11±0.35	7.14±0.24	<b>6.5-8.5</b>
	Maximum	7.38	7.36	7.21	8.23	7.01	7.19	7.4	7.52	7.41	
	Minimum	6.63	6.14	6.83	5.55	6.66	6.82	7.14	6.49	6.81	
<b>EC (uS/cm)</b>	Mean ± S.D	1017 ±355.34	908.04 ±392.6	863.6±279.84	946.10±470.4	717±368.57	875.25±234.68	705±203.76	1018±517	1145±498.26	<b>&lt;1500</b>
	Maximum	1415.00	1662.00	1338	2000	1236	1137	944	2000	1932	
	Minimum	364.00	313.00	466.00	244	442	617	443	416	459	
<b>TSS (mg/l)</b>	Mean ± S.D	46.54 ±55.11	32.82 ±25.58	17.33±20.05	42.84±28.02	15.31±18.27	13.5±11.77	20.47±21.84	1.78±2.25	12.76±11.47	<b>-</b>
	Maximum	155.00	83.00	54.9	108.1	41.3	23.6	49	6.95	26.7	
	Minimum	1.35	0.15	0.25	2.1	1.3	1.5	235	0.15	0.25	
<b>TDS (mg/l)</b>	Mean ± S.D	520.00 ±136.63	434.64 ±172.43	412.7 ±128.85	465.50 ±248	332.75 ±142.49	507.75±232.63	354±94.96	514.5±335.8	545.25 ±212.45	<b>&lt;1000</b>
	Maximum	701	767.00	635	1267	537	799	466	1232	902	
	Minimum	274	161.00	215	119	233	276	235	188	281	
<b>DO (mg/l)</b>	Mean ± S.D	5.43 ± 0.75	5.61±1.97	6.04±1.59	5.53±1.13	5.25±0.29	5.80±0.42	5.18±0.71	5.74±0.42	4.71±0.39	<b>&gt;5</b>
	Maximum	6.06	8.67	7.61	7.31	5.94	5.97	6.17	6.86	5.73	
	Minimum	5.16	5.28	5.12	5.86	4.28	5.12	3.83	4.1	3.06	
<b>Turbidity (NTU)</b>	Mean ± S.D	0.77 ± 0.41	1.67 ±1.89	0.664±0.21	0.62±0.56	0.39±0.23	0.45±0.44	0.324±0.20	0.72±0.44	0.74±0.19	<b>5</b>
	Maximum	1.53	8.66	1.12	2.15	0.68	1.09	0.69	1.63	1.14	
	Minimum	0.27	0.25	0.42	0	0.19	0.09	0.19	0.23	0.58	
<b>Ca<sup>+2</sup> (mg/l)</b>	Mean ± S.D	76.55 ± 26.48	60.98 ±28.26	64.529±17.15	83.85±38.59	58.11±37.38	70.14±8.34	54.50±14.33	89.67±41.42	86.17±28.74	<b>-</b>
	Maximum	124.25	120.24	92.18	216.43	112.22	80.16	72.14	160.32	128.26	

	Minimum	44.09	16.03	40.08	28.06	28.06	60.12	40.08	40.08	44.09	
<b>Mg<sup>2+</sup></b> <b>(mg/l)</b>	Mean ± S.D	27.81 ± 9.62	22.15 ±10.27	23.44±6.23	30.46±14.02	21.11±13.58	25.48±3.03	19.802±5.21	32.57±15.04	31.30±10.43	-
	Maximum	45.14	43.68	33.49	78.63	40.77	29.12	26.21	58.24	46.59	
	Minimum	16.02	5.82	14.56	10.19	10.19	21.84	14.56	14.56	16.02	
<b>CO<sub>3</sub><sup>2-</sup></b> <b>(meq/l)</b>	Mean ± S.D	1.80 ± 1.99	2.50 ±2.70	1.8±1.48	28.04±115.0	0.00±0.00	4.5±3.00	2±1.41	4±5.85	86.25±230.33	-
	Maximum	6.00	10.00	4	742	0.00	8	4	18	656	
	Minimum	0.00	0.00	0.00	0.00	0.00	2	0	0	0	
<b>HCO<sub>3</sub><sup>-</sup></b> <b>(meq/l)</b>	Mean ± S.D	9.30 ± 4.85	6.82 ±5.00	5.8±3.08	12.30±25.11	5.75±3.86	4±3.56	4.8±3.11	5.37±3.58	45.5±110.59	-
	Maximum	17	19.00	12	138	10	8	10	11	319	
	Minimum	4	1.00	2	5	2	1	2	0	1	
<b>Total Hardness</b> <b>(mg/l)</b>	Mean ± S.D	459 ± 130.00	483.93 ±164.7	438±109.73	430.90±162.41	355±166.63	307.5±78.05	420±127.08	392.5±220.7	410±78.37	<b>500</b>
	Maximum	700	940.00	650	850	600	420	560	910	520	
	Minimum	270	250.00	340	150	250	250	280	200	280	
<b>Na<sup>+</sup></b> <b>(mg/l)</b>	Mean ± S.D	76.42 ± 35.24	82.22 ±56.50	87.27±30.62	66.03±46.63	95.14±6.62	52.33±46.49	60.31±31.78	88.27±68.16	110.13±59.89	-
	Maximum	120.47	284.97	133.16	174.61	103.11	113.21	116.06	233.94	240.93	
	Minimum	0.00	9.07	43.26	0	88.08	0.52	37.31	0	68.13	
<b>K<sup>+</sup></b> <b>(mg/l)</b>	Mean ± S.D	1.67 ± 1.94	10.53 ±18.23	5.106±14.36	15.63±27.88	0.00±0.00	9.62±15.41	0.49±0.69	0.27±0.51	2.30±3.60	-
	Maximum	4.42	67.08	45.9	137.1	0.00	32.6	1.47	1.23	9.83	
	Minimum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	
<b>Cl<sup>-</sup></b> <b>(mg/l)</b>	Mean ± S.D	195.03± 63.10	207.67±100.16	237±256.28	194.29±122.68	195.03±45.78	177.3±194.22	219.8±76.87	203±62.14	230.49±129.9	<b>250</b>
	Maximum	354.6	531.90	957.42	709.2	248.22	460.98	319.14	354.6	496.44	
	Minimum	141.84	70.92	70.92	70.92	141.84	35.46	141.80	177.3	106.38	
<b>F<sup>-</sup></b>	Mean ± S.D	0.55 ± 0.30	0.59 ±0.45	0.59±0.44	0.72±0.52	0.75±0.35	0.69±2.36	0.30±2.83	2.011±1.49	0.74±0.71	<b>1.5</b>

<b>(ppm)</b>	Maximum	0.94	1.76	0.895	1.612	1.88	1.51	1.47	3.37	2.11	
	Minimum	0.13	0.13	0.12	0.05	0.035	0.19	0.067	1.29	0.04	
<b>Nitrate (ppm)</b>	Mean ± S.D	45.857± 11.73	42.80 ±13.00	46.651±9.69	26.62±9.39	42.58±8.22	51.66±20.87	43.606±18.85	42.10±14.92	41.33±30.65	<b>50</b>
	Maximum	74.77	68.92	67.11	49.7	52.38	66.57	76.45	64.92	67.6	
	Minimum	32.98	22.55	33.83	10.74	32.43	41.09	32.16	23.18	25.75	
<b>Cr (mg/l)</b>	Mean ± S.D	0.004± 0.02	0.018±0.3752	0.008±0.02	0.005±0.0471	0.00±0.00	0.0064±0.0044	0.0125±0.023	0.019±0.02	0.035±0.034	<b>0.05</b>
	Maximum	0.067	2.00	0.048	0.059	0.00	0.0098	0.053	0.067	0.041	
	Minimum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
<b>Ni (mg/l)</b>	Mean ± S.D	0.006± 0.01	0.01± 0.0124	0.0046±0.0044	0.005±0.0317	0.00±0.00	0.0060±0.0042	0.0046±0.009	0.012±0.014	0.012±0.011	<b>0.02</b>
	Maximum	0.026	0.024	0.013	0.028	0.00	0.0076	0.021	0.035	0.019	
	Minimum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0000	
<b>Pb (mg/l)</b>	Mean ± S.D	0.00 ± 0.00	0.0004 ±0.001	0.00±0.00	0.002±0.3333	0.00±0.00	0.00±0.00	0.00±0.00	0.0020±0.004	0.00±0.00	<b>0.01</b>
	Maximum	0.003	0.005	0.00	0.009	0.00	0.00	0.000	0.012	0.00	
	Minimum	0.00	0.00	0.00	0.0	0.00	0.00	0.000	0.00	0.00	
<b>As (mg/l)</b>	Mean ± S.D	0.002± 0.01	0.003±0.0069	0.0001±0.0002	0.001±0.002	0.0035±0.0041	0.0129±0.0164	0.0092±0.01	0.0070±0.0088	0.0076±0.014	<b>0.01</b>
	Maximum	0.028	0.037	0.0005	0.0067	0.0065	0.037	0.022	0.024	0.034	
	Minimum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
<b>Total Coliforms (MPN/100)</b>	Mean ± S.D	4.50 ± 10.15	6.93±15.55	7.545±9.81	18.90±33.20	6.47±12.9450	5.1850±10.37	2.20±4.91	7.2±11.06	5.16±7.83	<b>0/100ml</b>
	Maximum	30.15	76.10	25.89	116.10	25.89	20.74	11	27.40	20.74	
	Minimum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	

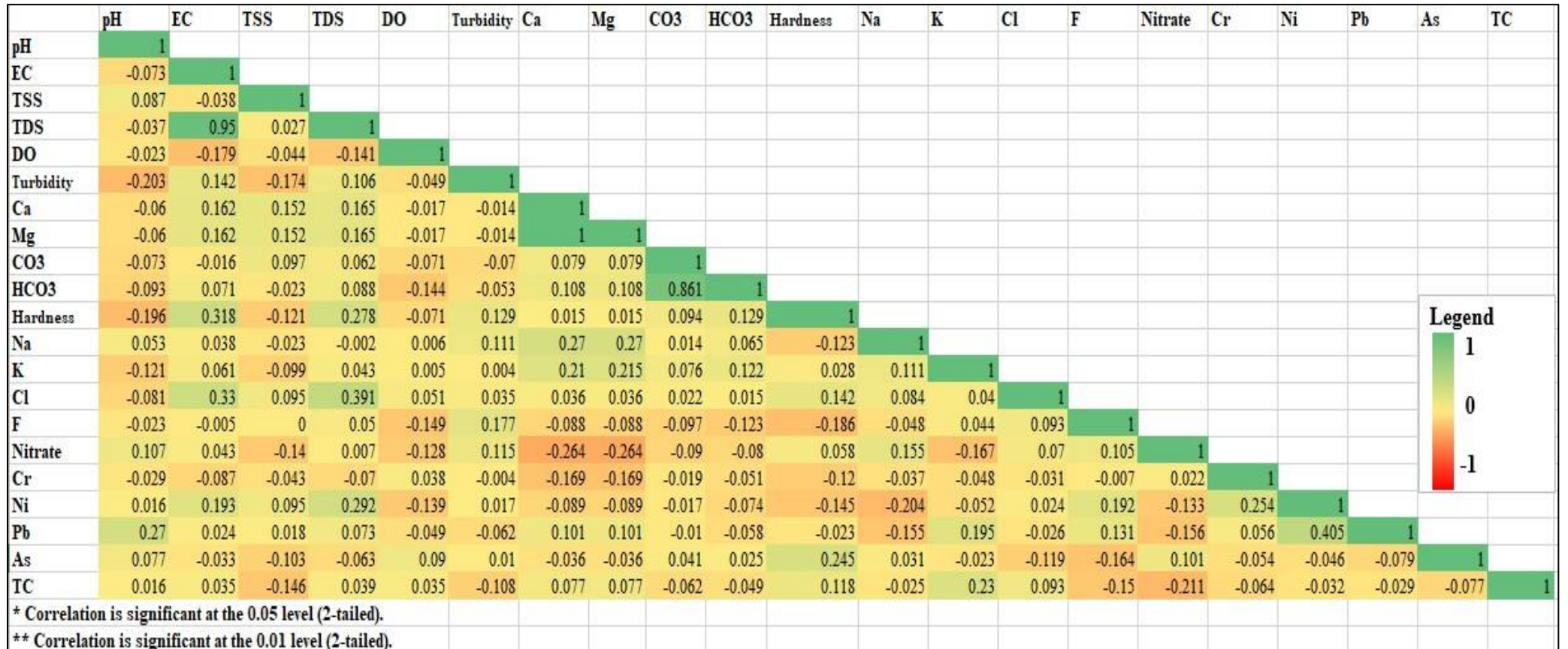
#### 4.5: Descriptive statistics of central Punjab data

Parameter		Nankana-Sahib	Faisalabad	Sahiwal	Okara	Jhang	Pakpattan	Kasur	Sheikhpura	Lahore	WHO Standard [85]
<b>pH</b>	Mean ± S.D	7.11 ±0.24	7.01±0.34	6.71±0.30	7.14±0.37	6.98±0.30	6.98±0.22	6.97±0.36	6.91±0.36	7.02±0.32	<b>6.5-8.5</b>
	Maximum	7.46	7.82	7.24	7.68	7.26	7.22	7.68	7.46	7.82	
	Minimum	6.8	6.41	6.12	6.81	6.36	6.74	6.18	6.18	6.12	
<b>EC (uS/cm)</b>	Mean ± S.D	679.80 ±325.9	954.30±465.26	734±448.62	1813.50±415.67	1106.10±304.64	1530.60±454.72	1553±540.19	1294±705.08	765±320.40	<b>&lt;1500</b>
	Maximum	1219	2000	2000	2000	1481	2000	2000	2000	1443	
	Minimum	279	368	214	968	516	1008	510	256	402	
<b>TSS (mg/l)</b>	Mean ± S.D	82.71 ±37.39	34.90±27.73	17.71±15.42	26.86±18.91	13.66±15.31	28.67±21.31	15.00±16.56	12.92±16.30	14.44±14.78	-
	Maximum	126.5	98.85	57.2	50.45	53.25	52.45	53.9	62.9	62.25	
	Minimum	6.4	0.9	0.15	7.45	1.4	3.45	1.3	0.3	0.35	
<b>TDS (mg/l)</b>	Mean ± S.D	356.70 ±158.2	462.30±218.28	390.55±457.37	1254.17±497.57	480.80±201.99	958.80±613.26	1242±432.25	1035±564.14	365.41±154.56	<b>&lt;1000</b>
	Maximum	611	970	2112	1747	695	1988	1600	1600	728	
	Minimum	147	228	104	495	55	483	408	204	190	
<b>DO (mg/l)</b>	Mean ± S.D	5.39±1.98	5.96±0.40	6.59±0.87	6.18±1.47	6.22±1.39	5.94±1.01	6.01±0.62	5.76±1.09	6.18±1.60	<b>&gt;5</b>
	Maximum	6.17	7.55	7.97	7.62	8.17	6.96	7.98	6.97	7.98	
	Minimum	5.01	5.21	5.10	5.40	5.12	5.36	5.12	5.02	5.07	
<b>Turbidity (NTU)</b>	Mean ± S.D	0.46 ±0.30	0.79±0.38	0.53±0.30	0.57±0.20	1.10±2.02	0.64±0.10	0.71±0.30	1.05±0.46	1.22±0.52	<b>5</b>
	Maximum	1.19	1.47	1.08	0.91	6.64	0.77	1.19	2.14	2.53	
	Minimum	0.15	0.27	0.14	0.32	0	0.53	0.04	0.14	0.17	
<b>Ca<sup>+2</sup> (mg/l)</b>	Mean ± S.D	62.52 ±38.96	50.10±22.35	99.98±69.55	74.82±36.53	60.12±25.35	120.24±57.94	68.14±31.05	70.27±55.72	98.56±73.91	-
	Maximum	136.27	116.23	276.55	108.22	104.21	212.42	128.26	236.47	444.89	

	Minimum	32.06	16.03	36.07	20.04	32.06	60.12	20.04	24.05	36.07	
<b>Mg<sup>2+</sup></b> <b>(mg/l)</b>	Mean ± S.D	22.71 ±14.15	18.20±8.12	36.32±25.27	27.18±13.27	21.84±9.21	43.68±21.05	24.75±11.28	25.53±20.24	35.81±26.85	-
	Maximum	49.51	42.23	100.47	39.31	37.86	77.17	46.59	85.91	161.62	
	Minimum	11.65	5.82	13.1	7.28	11.65	21.84	7.28	8.74	13.1	
<b>CO<sub>3</sub><sup>2-</sup></b> <b>(meq/l)</b>	Mean ± S.D	2.40 ±2.80	13.40±40.33	1.56±2.33	3.67±3.44	1.60±1.84	2.80±3.35	3.60±4.36	2.53±1.77	2.65±2.46	-
	Maximum	8	184	6	8	6	8	16	6	10	
	Minimum	0	0	0	0	0	0	0	0	0	
<b>HCO<sub>3</sub><sup>-</sup></b> <b>(meq/l)</b>	Mean ± S.D	7.10 ±3.98	11±13.20	5.72±4.18	5.67±2.66	7.10±2.28	6.20±3.03	7.93±5.35	7.73±3.37	4.57±3.20	-
	Maximum	11	64	14	11	11	9	20	15	15	
	Minimum	0	0	0	4	3	2	1	4	0	
<b>Total Hardness</b> <b>(mg/l)</b>	Mean ± S.D	286 ±125.54	246.50±85.12	281.67±122.15	303.33±99.93	818.00±1066.45	466.00±167.72	314±87.33	276±85.76	281.43±106.44	<b>500</b>
	Maximum	420	380	570	450	3580	760	480	400	700	
	Minimum	200	180	190	190	220	350	160	120	100	
<b>Na<sup>+</sup></b> <b>(mg/l)</b>	Mean ± S.D	101.43±157.74	120.60±80.26	48.62±61.85	674.74±1056.93	113.63±44.39	145.39±90.02	149.81±62.78	161.26±87.74	84.80±51.79	-
	Maximum	542	336	262.95	2820.7	207.51	283.16	254.15	282.38	211.92	
	Minimum	10.36	20.98	0	73.58	58.29	61.14	0.52	8.29	31.87	
<b>K<sup>+</sup></b> <b>(mg/l)</b>	Mean ± S.D	2.85 ±3.48	2.91±4.70	10.23±19.30	10.06±4.32	8.57±17.70	8.06±5.03	51.70±55.68	10.40±10.71	1.49±1.46	-
	Maximum	8.6	17.9	67	14.5	57.9	13	138.3	29.24	6.88	
	Minimum	0	0	0	2.95	0	0	0.74	0	0	
<b>Cl<sup>-</sup></b> <b>(mg/l)</b>	Mean ± S.D	322.69±180.39	360.63±209.15	325.44±182.11	390.06±105.19	230.49±41.79	510.61±362.99	418.39±187.03	373±169.88	219.80±91.63	<b>250</b>
	Maximum	531.9	921.96	567.36	567.36	283.68	1099.2	882.9	673.7	630	
	Minimum	70.92	106.38	70.92	283.68	177.3	177.3	166.6	42.55	70.92	
<b>F<sup>-</sup></b> <b>(ppm)</b>	Mean ± S.D	0.65 ±0.24	0.98±1.92	0.80±0.32	1.31±3.78	0.795±3.67	1.162±0.93	0.75±0.93	0.73±0.67	0.90±0.50	<b>1.5</b>
	Maximum	1	3.241	1.57	2.66	2.82	2.39	2.16	1.73	2.17	

	Minimum	0.15	0.4	0.15	0.15	1.83	0.1	0.16	0.19	0.05	
<b>Nitrate</b> <b>(ppm)</b>	Mean ± S.D	45.68 ±12.48	38.028±20.02	30.98±12.90	29.204±13.72	43.35±23.99	29.34±5.54	37.83±13	35.70±16.76	25.44±18.72	<b>50</b>
	Maximum	68.61	57.51	53.28	48.57	97.46	38.49	63.15	87.98	62.42	
	Minimum	25.43	37.01	12.34	16.61	27.69	24.54	19.6	20.29	12.68	
<b>Cr</b> <b>(mg/l)</b>	Mean ± S.D	0.010 ±0.82	0.0169±0.02	0.009±0.0215	0.0163±0.02	0.006±0.0029	0.021±0.0289	0.012±0.02	0.016±0.02	0.0128±0.0264	<b>0.05</b>
	Maximum	0.059	0.057	0.076	0.056	0.013	0.038	0.047	0.063	0.098	
	Minimum	0.00	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0	
<b>Ni</b> <b>(mg/l)</b>	Mean ± S.D	0.008 ±0.014	0.008±0.011	0.007±0.014	0.014±0.01	0.005±0.0064	0.004±0.0167	0.0050±0.0117	0.0065±0.01	0.0080±0.0149	<b>0.02</b>
	Maximum	0.036	0.036	0.062	0.029	0.023	0.012	0.018	0.034	0.065	
	Minimum	0.00	0.00	0.00	0.00	0.010	0.00	0.00	0.00	0.00	
<b>Pb</b> <b>(mg/l)</b>	Mean ± S.D	0.00 ±0.00	0.006±0.01	0.0024±0.0057	0.0010±0.0025	0.006±0.0122	0.0034±0.0047	0.0032±0.0038	0.00±0.00	0.00±0.00	<b>0.01</b>
	Maximum	0.00	0.009	0.022	0.006	0.008	0.009	0.008	0.00	0.00	
	Minimum	0.00	0.00	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	
<b>As</b> <b>(mg/l)</b>	Mean ± S.D	0.0093 ±0.009	0.005±0.0085	0.0031±0.0059	0.00±0.00	0.006±0.0091	0.0038±0.0085	0.0090±0.0093	0.0075±0.01	0.0098±0.0115	<b>0.01</b>
	Maximum	0.032	0.037	0.023	0.00	0.025	0.0019	0.028	0.033	0.038	
	Minimum	0.00	0.00	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	
<b>Total</b> <b>Coliforms</b> <b>(MPN/100)</b>	Mean ± S.D	5.85 ±9.96	7.96±17.89	7.73±18.33	4.90±8.27	5.75±8.96	23.14±51.74	11.35±20.46	19.55±35.78	12.23±27.80	<b>0/100ml</b>
	Maximum	30.15	76.10	76.10	19.90	27.40	115.70	76.1000	115	115.70	
	Minimum	0.00	0.00	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	

4.6: Correlational Heat Map of Northern Punjab Data



4.7: Correlational Heat Map of Central Punjab Data

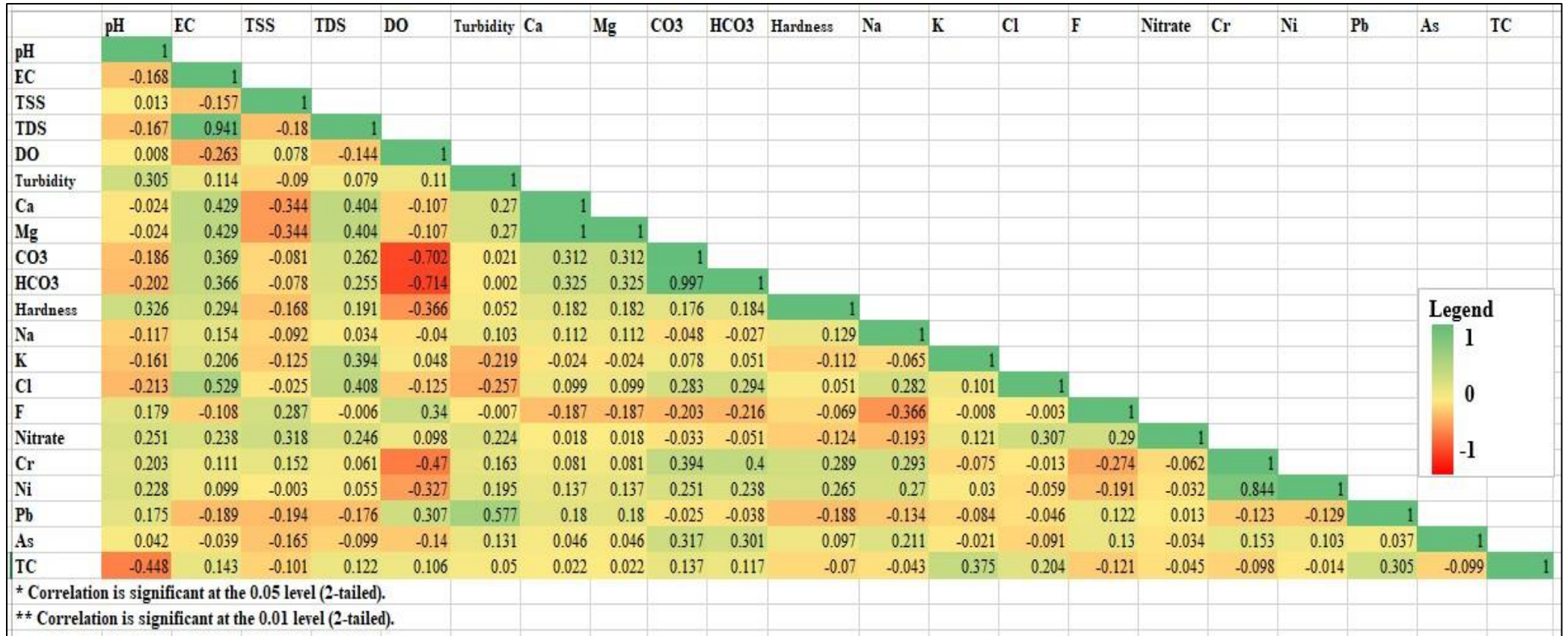
	pH	EC	TSS	TDS	DO	Turbidity	Ca	Mg	CO3	HCO3	Hardness	Na	K	Cl	F	Nitrate	Cr	Ni	Pb	As	TC	
pH	1																					
EC	0.139	1																				
TSS	0.084	-0.064	1																			
TDS	0.055	0.904	-0.065	1																		
DO	0.184	0.136	-0.048	0.028	1																	
Turbidity	-0.135	-0.011	-0.124	-0.024	-0.047	1																
Ca	-0.032	-0.05	-0.112	0.003	-0.001	-0.054	1															
Mg	-0.032	-0.05	-0.112	0.003	-0.001	-0.054	1	1														
CO3	0.004	0.096	-0.054	0.035	-0.01	-0.04	-0.067	-0.067	1													
HCO3	0.076	0.261	0.004	0.179	-0.023	-0.088	-0.074	-0.074	0.71	1												
Hardness	0.01	0.168	-0.194	0.124	0.004	-0.025	0.082	0.082	0.017	-0.002	1											
Na	0.047	0.385	0.091	0.424	0.018	-0.035	-0.111	-0.111	0.023	0.103	0.047	1										
K	-0.005	0.458	-0.053	0.486	-0.025	-0.012	-0.046	-0.046	-0.033	0.133	0.044	0.094	1									
Cl	-0.102	0.276	0.124	0.344	0.003	-0.131	0.021	0.021	0.098	0.116	-0.051	0.118	0.229	1								
F	0.046	0.19	-0.038	0.082	0.396	0.108	-0.085	-0.085	0.094	0.085	0.083	0.193	-0.087	0.031	1							
Nitrate	0.132	0.124	0.214	0.085	-0.005	0.027	-0.183	-0.18	0.089	0.214	-0.041	-0.004	-0.032	0.209	0.3	1						
Cr	0.007	-0.075	0.273	-0.043	-0.001	0.036	-0.073	-0.073	-0.006	-0.049	0.004	0.141	-0.005	-0.111	-0.039	-0.149	1					
Ni	-0.087	-0.109	0.032	-0.146	0.016	-0.019	-0.051	-0.051	-0.014	-0.155	0.151	-0.034	-0.007	-0.013	-0.007	-0.151	0.292	1				
Pb	-0.097	0.06	0.048	-0.002	-0.03	0.212	-0.047	-0.047	-0.018	0.002	0.215	-0.019	-0.075	0.127	0.237	0.24	-0.013	0.119	1			
As	0.074	0.071	0.137	0.052	-0.059	0.003	-0.105	-0.105	-0.01	0.037	-0.023	-0.015	0.084	-0.142	-0.084	-0.109	0.213	0.104	-0.146	1		
TC	-0.037	0.088	-0.047	0.094	-0.035	-0.013	0.052	0.052	-0.048	-0.007	-0.021	0.038	0.007	0.039	-0.049	0.026	-0.03	0.049	-0.005	0.04	1	

**Legend**

1  
0  
-1

\* Correlation is significant at the 0.05 level (2-tailed).  
 \*\* Correlation is significant at the 0.01 level (2-tailed).

4.8: Correlational Heat Map of Southern Punjab Data



#### 4.9: Drinking water quality status in terms of number of samples exceeding WHO limit

	Physical Parameters					Chemical Parameters									Biological parameters
	Colour	odour	Turbidity	EC	TDS	DO	TH	Cl <sup>-</sup>	F <sup>-</sup>	Nitrate	Cr	Ni	Pb	As	Total Coli forms
WHO limit	acceptable	acceptable	6.5-8.5	<1500	1000	>5	500	250	1.5	50	0.05	0.02	0.01	0.01	0/100ml
			NTU	µS/cm		mg/l			ppm		mg/L				MPN/100ml
Narowal (n=10)	0	1	0	0	0	0	4	1	0	5	1	1	0	2	2
Gujranwala (n=28)	4	4	1	1	0	1	12	5	3	11	2	2	0	2	9
Hafiza-Abad (n=10)	0	0	0	2	0	0	3	1	1	3	0	0	0	0	4
Sialkot (n=50)	2	9	0	7	3	0	13	5	2	0	4	4	0	0	22
Nankana Sahib (n=10)	0	0	0	0	0	0	0	4	0	3	1	1	0	2	4
Faisalabad (n=20)	1	3	0	2	0	0	0	11	4	3	2	2	0	2	6
Sahiwal (n=18)	1	0	0	1	1	0	1	10	1	3	1	1	1	1	6
Okara (n=5)	0	1	0	5	4	0	0	5	2	0	1	1	0	0	2
Jhang (n=10)	0	0	1	0	0	0	3	2	2	3	0	1	0	2	4
Pakpattan (n=5)	0	0	0	2	2	0	1	3	1	0	0	0	0	0	1
Kasur (n=15)	0	0	0	9	10	0	0	12	2	3	1	1	0	4	6

<b>Sheikhpura</b> (n=15)	0	0	0	8	9	0	0	12	2	3	2	1	0	3	8
<b>Lahore</b> (n=49)	2	12	0	0	0	0	2	4	6	0	3	4	0	6	15
<b>Bhawalnagar</b> (n=4)	0	0	0	0	0	0	1	0	1	1	0	0	0	0	1
<b>Lodhran</b> (n=4)	0	1	0	0	0	0	0	1	1	2	0	0	0	0	1
<b>Multan</b> (n=5)	0	0	0	0	0	0	2	2	0	1	1	1	0	2	1
<b>Vehari</b> (n=8)	1	1	0	1	1	0	1	1	4	2	1	3	1	2	3
<b>Khanewal</b> (n=8)	1	0	0	2	0	0	1	2	1	2	0	0	0	2	3
<b>Total</b> (N=274)	12	32	2	40	30	1	44	81	33	45	20	23	2	30	98
<b>Overall Percentage</b> (100%)	4.38	11.68	0.73	14.60	10.95	0.36	16.06	29.56	12.04	16.42	7.30	8.39	0.73	10.95	35.77
<b>Northern region</b> (%)	6.12	14.29	1.02	10.20	3.06	1.02	32.65	12.24	6.12	19.39	7.14	7.14	0.00	4.08	37.76
<b>Central region</b> (%)	2.72	10.88	0.68	18.37	17.69	0.00	4.76	42.86	13.61	12.24	7.48	8.16	0.68	13.61	35.37
<b>Southern region</b> (%)	6.90	6.90	0.00	10.34	3.45	0.00	17.24	20.69	24.14	27.59	6.90	13.79	3.45	20.69	31.03

#### 4.5 Drinking Water Quality Index (DWQI)

Drinking Water Quality Index is considered as the most effective method of measuring water quality. pH, EC, DO, Total Hardness, Turbidity, Cl and Nitrate have been reported in literature to be the most effective parameters in the detection of water suitability for human consumption. DWQI of northern, central and southern rural areas of Punjab have been given in the table 4.9, 4.10, 4.11:

#### 4.10: DWQI of primary schools of northern rural Punjab

Parameters	pH	EC	TDS	DO	Total Hardness	Turbidity	Cl	Nitrate
Units		μS/cm	mg/l					
<b>Northern primary schools of rural Punjab</b>								
Mean observed Value (Vn)	6.96	934.05	456.86	5.24	449.64	0.93	202.60	37.31
WHO limits (Vs/Sn)	8.5	1500	1000	5	5	500	250	50
Ideal Value (Vi)	7	0	0	14.6	0	0	0	0
Qn= [Vn-Vi]/ [Vs-Vi]*100	2.585	62.270	45.686	104.761	89.929	18.600	81.042	74.616
$\sum(1/Sn) = 0.545$								
$K=1/\sum(1/Sn) = 1.834$								
Wn=K/Sn	0.216	0.001	0.002	0.367	0.004	0.351	0.007	0.037
$\sum Wn = 1$								
QnWn	0.971	0.076	0.084	38.675	0.335	6.820	0.568	2.716
$\sum QnWn = 50.57$								
<b>DWQI = <math>\sum QnWn / \sum Wn = 50.57</math></b>								

#### 4.11: DWQI of primary schools of central rural Punjab

Parameters	pH	EC	TDS	DO	Total Hardness	Turbidity	Cl	Nitrate
Units		μS/cm	mg/l					
<b>Central primary schools of rural Punjab</b>								
Mean observed Value (Vn)	6.97	1006.59	602.38	8.78	323.74	0.90	296.35	33.52
WHO limits (Vs/Sn)	8.5	1500	1000	5	5	500	250	50
Ideal Value (Vi)	7	0	0	14.6	0	0	0	0
Qn= [Vn-Vi]/ [Vs-Vi]*100	1.909	67.106	60.238	175.68	61.748	18.124	124.578	72.887

$\sum(1/S_n) = 0.545$								
$K=1/\sum(1/S_n) = 1.834$								
<b>W<sub>n</sub>=K/S<sub>n</sub></b>	0.250	0.001	0.002	0.351	0.004	0.351	0.007	0.035
$\sum W_n = 1$								
<b>Q<sub>n</sub>W<sub>n</sub></b>	0.417	0.081	0.110	64.900	0.227	6.6410	0.931	2.650
$\sum Q_n W_n = 74.68$								
$DWQI = \sum Q_n W_n / \sum W_n = 74.68$								

#### 4.12: DWQI of primary schools of southern rural Punjab

Parameters	pH	EC	TDS	DO	Total Hardness	Turbidity	Cl <sup>-</sup>	Nitrate
<b>Units</b>		μS/cm	mg/l					
<b>Southern primary schools of rural Punjab</b>								
<b>Mean observed Value (V<sub>n</sub>)</b>	7.09	937.97	469.31	5.241	385.17	0.58	89.97	24.19
<b>WHO limits (V<sub>s</sub>/S<sub>n</sub>)</b>	8.5	1500	1000	5	5	500	250	50
<b>Ideal Value (V<sub>i</sub>)</b>	7	0	0	14.6	0	0	0	0
<b>Q<sub>n</sub> = [V<sub>n</sub>-V<sub>i</sub>]/[V<sub>s</sub>-V<sub>i</sub>]*100</b>	5.931	62.531	46.931	104.821	77.034	11.600	83.637	104.056
$\sum(1/S_n) = 0.545$								
$K=1/\sum(1/S_n) = 1.834$								
<b>W<sub>n</sub>=K/S<sub>n</sub></b>	0.250	0.001	0.002	0.351	0.004	0.351	0.007	0.035
$\sum W_n = 1$								
<b>Q<sub>n</sub>W<sub>n</sub></b>	1.280	0.076	0.086	38.444	0.283	4.254	0.613	3.816
$\sum Q_n W_n = 48.838$								
$DWQI = \sum Q_n W_n / \sum W_n = 48.838$								

According to the rating scale if DWQI is between 0 to 25 then it is excellent quality water, 26-50: good quality water and above 50 it is fair, poor, very poor and unfit for use. Results showed that, mean DWQI values of north, central and southern Punjab were 50.57, 74.67 and 48.83, fair, poor and good quality water, respectively, according to Horton, 1965 rating scale (table 3.3).

4.13: Sample wise DWQI of rural Punjab

Sample Code	DWQI	Sample Code	DWQI	Sample Code	DWQI	Sample Code	DWQI	Sample Code	DWQI	Sample Code	DWQI	Sample Code	DWQI
NRW-1	41.79	GRW10	34.64	HFD-1	65.43	SKT-10	53.53	SKT-29	50.92	SKT-48	50.46	LYP-7	31.84
NRW-2	50.61	GRW11	37.44	HFD-2	31.64	SKT-11	66.29	SKT-30	56.14	SKT-49	56.84	LYP-8	31.37
NRW-3	50.92	GRW12	37.44	HFD-3	34.65	SKT-12	55.86	SKT-31	51.74	SKT-50	47.77	LYP-9	36.59
NRW-4	43.15	GRW13	32.26	HFD-4	40.73	SKT-13	72.04	SKT-32	68.29	NNS-1	73.89	LYP-10	32.66
NRW-5	42.59	GRW14	33.13	HFD-5	57.89	SKT-14	59.3	SKT-33	67.08	NNS-2	41.53	LYP-11	40.54
NRW-6	55.34	GRW15	39.56	HFD-6	52.32	SKT-15	53.83	SKT-34	43.02	NNS-3	47.83	LYP-12	44.94
NRW-7	66.96	GRW16	34.81	HFD-7	53.57	SKT-16	50.27	SKT-35	58.46	NNS-4	40.88	LYP-13	30.53
NRW-8	55.26	GRW17	42.31	HFD-8	53.78	SKT-17	49.51	SKT-36	52.43	NNS-5	38.8	LYP-14	46.03
NRW-9	50.21	GRW18	42.04	HFD-9	52.05	SKT-18	49.05	SKT-37	47.94	NNS-6	42.43	LYP-15	45.63
NRW-10	53.49	GRW19	56.45	HFD-10	68.37	SKT-19	54.49	SKT-38	48.41	NNS-7	44.66	LYP-16	54.79
GRW1	55.74	GRW20	38.28	SKT-1	54.26	SKT-20	50.88	SKT-39	68.4	NNS-8	42.93	LYP-17	35.23
GRW2	69.57	GRW21	35.37	SKT-2	71.72	SKT-21	70.33	SKT-40	56.43	NNS-9	37.27	LYP-18	43.83
GRW3	52.16	GRW22	141.33	SKT-3	54.04	SKT-22	59.49	SKT-41	55.09	NNS-10	44.39	LYP-19	45.58
GRW4	39.52	GRW23	131.83	SKT-4	54.34	SKT-23	59.73	SKT-42	52.28	LYP-1	48.82	LYP-20	108.78
GRW5	48.75	GRW24	29.37	SKT-5	70.77	SKT-24	68.57	SKT-43	40.72	LYP-2	32.16	SWN-1	49.51
GRW6	42.12	GRW25	37.59	SKT-6	53.91	SKT-25	86.03	SKT-44	58.73	LYP-3	42.64	SWN-2	55.27
GRW7	42.76	GRW26	45.08	SKT-7	33.29	SKT-26	56.7	SKT-45	53.26	LYP-4	37.8	SWN-3	47.35
GRW8	35.39	GRW27	42.93	SKT-8	59.88	SKT-27	58.72	SKT-46	50.53	LYP-5	34.18	SWN-4	44.92
GRW9	53.06	GRW28	40.58	SKT-9	51.02	SKT-28	56.64	SKT-47	50.11	LYP-6	45.8	SWN-5	27.73

Sample Code	DWQI	Sample Code	DWQI	Sample Code	DWQI	Sample Code	DWQI	Sample Code	DWQI	Sample Code	DWQI	Sample Code	DWQI
SWN-6	54.46	JNG-5	56.56	KUS-12	39.76	LHR-4	81.73	LHR-26	44.07	LHR-48	56.73	VHR-8	55.55
SWN-7	50.58	JNG-6	56.49	KUS-13	29.61	LHR-5	74.68	LHR-27	46.57	LHR-49	54.92	KWL-1	80.91
SWN-8	41.04	JNG-7	48.99	KUS-14	32.36	LHR-6	52.39	LHR-28	62.28	WGB-1	65.41	KWL-2	52.72
SWN-9	65.21	JNG-8	71.63	KUS-15	34.45	LHR-7	68.93	LHR-29	57.19	WGB-2	46.89	KWL-3	53.5
SWN-10	69.47	JNG-9	52.72	SKP-1	58.14	LHR-8	84.56	LHR-30	52.76	WGB-3	55.15	KWL-4	55.7
SWN-11	45.92	JNG-10	79.35	SKP-2	59.5	LHR-9	75.46	LHR-31	64.02	WGB-4	73.86	KWL-5	68.88
SWN-12	44.55	PKP-1	67.36	SKP-3	60.61	LHR-10	72.58	LHR-32	30.64	LON-1	44.99	KWL-6	73.12
SWN-13	52.66	PKP-2	54.84	SKP-4	36	LHR-11	66.24	LHR-33	57.42	LON-2	46.06	KWL-7	55.07
SWN-14	34.34	PKP-3	68.01	SKP-5	53.37	LHR-12	69.82	LHR-34	58.93	LON-3	40.52	KWL-8	54.18
SWN-15	38.75	PKP-4	59.52	SKP-6	32.41	LHR-13	44.34	LHR-35	35.63	LON-4	55.55		
SWN-16	69.92	PKP-5	67.82	SKP-7	71.74	LHR-14	65.53	LHR-36	42.13	MUX-1	53.14		
SWN-17	25.22	KUS-1	40.34	SKP-8	58.09	LHR-15	77.33	LHR-37	51.71	MUX-2	52.05		
SWN-18	55.4	KUS-2	68.78	SKP-9	64.05	LHR-16	69.36	LHR-38	52.36	MUX-3	65.06		
OKR-1	39.69	KUS-3	51.22	SKP-10	56.82	LHR-17	51.49	LHR-39	59.54	MUX-4	54.16		
OKR-2	60.83	KUS-4	52.68	SKP-11	59.55	LHR-18	64.61	LHR-40	51.16	MUX-5	52.11		
OKR-3	71.72	KUS-5	41.24	SKP-12	69.13	LHR-19	44.5	LHR-41	37.95	VHR-1	52.73	<b>Horton scale</b>	
OKR-4	51.28	KUS-6	51.44	SKP-13	68.76	LHR-20	79.51	LHR-42	35.97	VHR-2	52.57	excellent	
OKR-5	70.91	KUS-7	67.43	SKP-14	51.88	LHR-21	59.53	LHR-43	52.51	VHR-3	66.42	good	
JNG-1	54.96	KUS-8	35.01	SKP-15	41.85	LHR-22	63.92	LHR-44	65.4	VHR-4	56.31	fair	
JNG-2	61.26	KUS-9	43.31	LHR-1	76.24	LHR-23	50.04	LHR-45	57.73	VHR-5	59.21	poor	
JNG-3	52.95	KUS-10	54.89	LHR-2	80.1	LHR-24	72.77	LHR-46	32.72	VHR-6	57.2	very poor	
JNG-4	69.9	KUS-11	35.34	LHR-3	79.73	LHR-25	30.88	LHR-47	53.53	VHR-7	65.46	unfit	

## 4.6 Health Risk Assessment

Examining potential pollutants in the drinking water and figuring out their potential effects on human health serves as initial steps in assessing the health concerns related to consuming water. Health risk assessment with Average Daily Dose (ADD), Hazard Quotient (HQ) and Cancer Risk (CR) of heavy metals (Cr, Ni, Pb and As) and Fluoride (F) is given in the following table (4.14):

**4.14: Health Risk Assessment of Cr, Ni, Pb, As and F**

Sample Code	Cr			Ni			Pb			As			F	
	ADD	HQ	CR	ADD	HQ	CR	ADD	HQ	CR	ADD	HQ	CR	ADD	HQ
NRW-1	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0.01	0.11
NRW-2	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0.02	0.34
NRW-3	0	0	0.00E+00	0	0.01	2.45E-04	0	0	0.00E+00	0	1.16	5.24E-04	0.04	0.7
NRW-4	0	0	0.00E+00	0	0.02	3.63E-04	0	0	0.00E+00	0	0	0.00E+00	0.03	0.5
NRW-5	0	0	0.00E+00	0	0.01	2.54E-04	0	0	0.00E+00	0.001	2.16	9.73E-04	0.01	0.2
NRW-6	0	0	0.00E+00	0	0.01	2.18E-04	0	0	0.00E+00	0	0.27	1.20E-04	0.03	0.57
NRW-7	0	0	0.00E+00	0	0.01	1.86E-04	0	0	0.00E+00	0	0	0.00E+00	0.05	0.78
NRW-8	0	0	7.48E-06	0	0.02	3.22E-04	0.0001	0.04	1.27E-06	0	0	0.00E+00	0.04	0.75
NRW-9	0.003	1.11	1.67E-03	0.001	0.06	1.18E-03	0	0	0.00E+00	0.001	4.66	2.09E-03	0.01	0.13
NRW-10	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0.03	0.51
GRW1	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0.09	1.47
GRW2	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0.01	0.11
GRW3	0.003	0.88	1.32E-03	0.001	0.05	9.53E-04	0	0	0.00E+00	0	0	0.00E+00	0.03	0.51
GRW4	0	0.15	2.27E-04	0	0.02	3.45E-04	0	0	0.00E+00	0.002	5.15	2.32E-03	0.01	0.2
GRW5	0.002	0.57	8.48E-04	0.001	0.05	8.62E-04	0	0	0.00E+00	0	0	0.00E+00	0.02	0.33
GRW6	0	0.09	1.42E-04	0	0.01	1.41E-04	0	0	0.00E+00	0	0	0.00E+00	0.05	0.76
GRW7	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	1.11	5.01E-04	0.03	0.44

GRW8	0.001	0.22	3.24E-04	0	0	0.00E+00	0.0001	0.04	1.27E-06	0	0.1	4.49E-05	0.01	0.19
GRW9	0	0.08	1.17E-04	0	0.02	3.54E-04	0	0	0.00E+00	0	1.25	5.61E-04	0.01	0.14
GRW10	0.1	33.25	4.99E-02	0.002	0.08	1.45E-03	0	0	0.00E+00	0	0	0.00E+00	0.03	0.43
GRW11	0	0.1	1.57E-04	0	0.02	4.04E-04	0	0	0.00E+00	0	0	0.00E+00	0.02	0.35
GRW12	0.003	0.95	1.42E-03	0.001	0.06	1.09E-03	0	0	0.00E+00	0	0	0.00E+00	0.03	0.58
GRW13	0.002	0.53	7.98E-04	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0.01	0.13
GRW14	0.001	0.35	5.24E-04	0.001	0.06	1.05E-03	0	0	0.00E+00	0	0.35	1.57E-04	0.04	0.59
GRW15	0	0	0.00E+00	0	0	8.62E-05	0.0002	0.06	1.70E-06	0	1.16	5.24E-04	0.05	0.83
GRW16	0	0.11	1.60E-04	0	0.01	1.86E-04	0	0	0.00E+00	0	1.11	5.01E-04	0.04	0.67
GRW17	0.001	0.3	4.49E-04	0	0	0.00E+00	0	0	0.00E+00	0.001	2.66	1.20E-03	0.03	0.53
GRW18	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	1.5	6.73E-04	0.04	0.67
GRW19	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0.04	0.64
GRW20	0	0	0.00E+00	0	0.02	3.90E-04	0.0002	0.07	2.12E-06	0	0	0.00E+00	0.08	1.27
GRW21	0	0.1	1.47E-04	0	0.01	1.27E-04	0	0	0.00E+00	0	0.3	1.35E-04	0.05	0.82
GRW22	0.002	0.53	7.98E-04	0	0.02	3.95E-04	0	0	0.00E+00	0	0.62	2.77E-04	0.04	0.69
GRW23	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0.05	0.79
GRW24	0	0.06	8.98E-05	0	0.02	4.45E-04	0	0	0.00E+00	0	0.8	3.59E-04	0.04	0.66
GRW25	0	0	0.00E+00	0	0.02	2.77E-04	0	0	0.00E+00	0	0.27	1.20E-04	0.02	0.35
GRW26	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0.09	1.52
GRW27	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	1.1	4.94E-04	0.01	0.22
GRW28	0.001	0.3	4.49E-04	0	0	0.00E+00	0	0	0.00E+00	0	1.35	6.06E-04	0.05	0.83
HFD-1	0	0.01	1.95E-05	0	0.01	1.36E-04	0	0	0.00E+00	0	0.08	3.74E-05	0.09	1.43
HFD-2	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0.03	0.53
HFD-3	0.001	0.35	5.24E-04	0	0.02	2.77E-04	0	0	0.00E+00	0	0	0.00E+00	0.03	0.48
HFD-4	0	0	0.00E+00	0	0	8.17E-05	0	0	0.00E+00	0	0	0.00E+00	0.04	0.7
HFD-5	0.002	0.8	1.20E-03	0.001	0.03	5.90E-04	0	0	0.00E+00	0	0	0.00E+00	0.01	0.23
HFD-6	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0.01	0.1
HFD-7	0.002	0.57	8.48E-04	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0.02	0.39

HFD-8	0	0	0.00E+00	0	0.01	1.54E-04	0	0	0.00E+00	0	0	0.00E+00	0.02	0.34
HFD-9	0	0	0.00E+00	0	0.02	3.95E-04	0	0	0.00E+00	0	0	0.00E+00	0.04	0.74
HFD-10	0	0.02	2.49E-05	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0.04	0.62
SKT-1	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0.03	0.57
SKT-2	0	0	0.00E+00	0	0	1.36E-05	0	0	0.00E+00	0	1.11	5.01E-04	0.08	1.34
SKT-3	0.001	0.47	6.98E-04	0.001	0.04	8.17E-04	0	0	0.00E+00	0	0	0.00E+00	0.05	0.79
SKT-4	0	0.02	3.24E-05	0.001	0.04	6.94E-04	0.0003	0.09	2.54E-06	0	0	0.00E+00	0.01	0.12
SKT-5	0	0.05	8.23E-05	0	0.01	2.41E-04	0	0	0.00E+00	0	0.35	1.56E-04	0.01	0.2
SKT-6	0	0.03	4.24E-05	0	0	7.26E-05	0.0001	0.04	1.27E-06	0	0.91	4.11E-04	0.01	0.15
SKT-7	0.003	0.93	1.40E-03	0.001	0.06	1.04E-03	0.0002	0.07	2.12E-06	0	0	0.00E+00	0.04	0.74
SKT-8	0	0.08	1.20E-04	0.001	0.05	9.44E-04	0	0	0.00E+00	0	0	0.00E+00	0.05	0.81
SKT-9	0.002	0.65	9.73E-04	0.001	0.04	7.26E-04	0.0003	0.09	2.54E-06	0	0.12	5.24E-05	0.04	0.7
SKT-10	0	0.13	1.95E-04	0	0.02	3.27E-04	0.0002	0.07	2.12E-06	0	0.8	3.59E-04	0.05	0.83
SKT-11	0	0.1	1.57E-04	0	0	0.00E+00	0	0	0.00E+00	0	0.83	3.76E-04	0.03	0.49
SKT-12	0	0.11	1.70E-04	0	0.01	1.50E-04	0	0	0.00E+00	0	0	0.00E+00	0.05	0.83
SKT-13	0	0.12	1.82E-04	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0.04	0.63
SKT-14	0.001	0.25	3.74E-04	0	0	0.00E+00	0.0003	0.09	2.54E-06	0	0	0.00E+00	0.02	0.33
SKT-15	0.004	1.23	1.85E-03	0	0	0.00E+00	0	0	0.00E+00	0	1.04	4.67E-04	0.01	0.15
SKT-16	0	0.13	2.00E-04	0	0.01	1.63E-04	0	0	0.00E+00	0	0.88	3.95E-04	0	0.07
SKT-17	0	0.08	1.27E-04	0	0.02	3.54E-04	0	0	0.00E+00	0	1.12	5.04E-04	0.01	0.18
SKT-18	0	0.1	1.52E-04	0.001	0.03	5.90E-04	0.0003	0.09	2.54E-06	0	0	0.00E+00	0.04	0.63
SKT-19	0	0.15	2.32E-04	0.001	0.05	9.99E-04	0.0002	0.07	2.12E-06	0	0	0.00E+00	0.01	0.2
SKT-20	0	0	0.00E+00	0	0.02	3.13E-04	0	0	0.00E+00	0	0	0.00E+00	0.02	0.28
SKT-21	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	1	4.49E-04	0.05	0.9
SKT-22	0	0.03	4.49E-05	0	0.02	3.99E-04	0.0003	0.09	2.54E-06	0	0.8	3.59E-04	0.06	0.96
SKT-23	0	0.05	7.48E-05	0	0	9.08E-05	0.0004	0.11	3.39E-06	0	0	0.00E+00	0.09	1.44
SKT-24	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0.03	0.58
SKT-25	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	0.86	3.89E-04	0.07	1.21

SKT-26	0.003	1.06	1.60E-03	0	0	0.00E+00	0	0.01	4.24E-07	0	0	0.00E+00	0.07	1.16
SKT-27	0	0	0.00E+00	0	0	0.00E+00	0.0002	0.06	1.70E-06	0	0	0.00E+00	0.05	0.77
SKT-28	0	0.11	1.62E-04	0.001	0.05	8.62E-04	0.0004	0.13	3.82E-06	0	0	0.00E+00	0.01	0.19
SKT-29	0	0.09	1.30E-04	0.001	0.04	7.26E-04	0	0	0.00E+00	0	0.88	3.95E-04	0.07	1.14
SKT-30	0	0.03	4.74E-05	0	0	8.17E-05	0	0	0.00E+00	0	0	0.00E+00	0.07	1.22
SKT-31	0	0.08	1.20E-04	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0.07	1.22
SKT-32	0	0.01	1.27E-05	0	0.01	1.04E-04	0.0003	0.1	2.97E-06	0	0	0.00E+00	0.06	0.98
SKT-33	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	0.91	4.11E-04	0.11	1.75
SKT-34	0	0	0.00E+00	0	0	0.00E+00	0.0004	0.13	3.82E-06	0	0.12	5.24E-05	0.05	0.84
SKT-35	0	0.1	1.57E-04	0	0	0.00E+00	0	0.01	4.24E-07	0	0.8	3.59E-04	0.03	0.52
SKT-36	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	1.05	4.71E-04	0.01	0.22
SKT-37	0.003	0.88	1.32E-03	0.001	0.07	1.27E-03	0.0004	0.11	3.39E-06	0	0	0.00E+00	0.02	0.31
SKT-38	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	0.04
SKT-39	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	0.27	1.20E-04	0.01	0.09
SKT-40	0	0	0.00E+00	0	0	0.00E+00	0.0001	0.04	1.27E-06	0	1.03	4.64E-04	0.01	0.09
SKT-41	0	0.01	1.50E-05	0	0.01	1.63E-04	0.0004	0.13	3.82E-06	0	0	0.00E+00	0.01	0.2
SKT-42	0	0.13	1.92E-04	0	0.02	4.45E-04	0.0003	0.09	2.54E-06	0	0	0.00E+00	0.01	0.15
SKT-43	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	0.88	3.97E-04	0.02	0.39
SKT-44	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0.05	0.89
SKT-45	0	0.04	5.84E-05	0	0.02	3.47E-04	0.0003	0.09	2.54E-06	0	0	0.00E+00	0.04	0.66
SKT-46	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	0.8	3.59E-04	0.01	0.1
SKT-47	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0.01	0.08
SKT-48	0	0.08	1.20E-04	0	0	0.00E+00	0	0	0.00E+00	0	0.91	4.11E-04	0.01	0.15
SKT-49	0.003	0.96	1.45E-03	0.001	0.05	9.53E-04	0	0	0.00E+00	0	0.88	3.95E-04	0.04	0.73
SKT-50	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0.04	0.68
NNS-1	0.003	0.98	1.47E-03	0.002	0.09	1.63E-03	0	0	0.00E+00	0.002	5.32	2.39E-03	0.04	0.62
NNS-2	0	0	0.00E+00	0	0	4.54E-06	0	0	0.00E+00	0	0.2	8.98E-05	0.02	0.41
NNS-3	0	0	0.00E+00	0	0.01	2.63E-04	0	0	0.00E+00	0	0.5	2.24E-04	0.03	0.49

NNS-4	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0.03	0.48
NNS-5	0	0	0.00E+00	0	0.01	2.72E-04	0	0	0.00E+00	0	1.5	6.73E-04	0.04	0.61
NNS-6	0	0	0.00E+00	0	0	4.08E-05	0	0	0.00E+00	0	0.23	1.05E-04	0.04	0.72
NNS-7	0	0	0.00E+00	0	0	6.81E-05	0	0	0.00E+00	0	1.33	5.99E-04	0.03	0.42
NNS-8	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0.04	0.7
NNS-9	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0.001	2.83	1.27E-03	0.05	0.83
NNS-10	0	0	0.00E+00	0	0.02	3.63E-04	0	0	0.00E+00	0	1.5	6.73E-04	0.01	0.12
LYP-1	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0.14	2.33
LYP-2	0	0.06	8.63E-05	0	0	0.00E+00	0.0001	0.04	1.27E-06	0	0	0.00E+00	0.03	0.44
LYP-3	0	0.13	1.95E-04	0	0.02	3.31E-04	0.0003	0.09	2.54E-06	0	0.62	2.77E-04	0.03	0.58
LYP-4	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	0.07
LYP-5	0.002	0.76	1.15E-03	0.002	0.09	1.63E-03	0.0003	0.1	2.97E-06	0.001	2.23	1.00E-03	0.02	0.27
LYP-6	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0.04	0.58
LYP-7	0	0	0.00E+00	0	0	0.00E+00	0.0003	0.09	2.54E-06	0	1.21	5.46E-04	0.16	2.69
LYP-8	0.002	0.76	1.14E-03	0	0.02	4.04E-04	0	0	0.00E+00	0	0.67	2.99E-04	0.02	0.37
LYP-9	0.003	0.94	1.42E-03	0	0.02	4.45E-04	0	0	0.00E+00	0	1.05	4.71E-04	0.03	0.52
LYP-10	0.002	0.75	1.13E-03	0.001	0.04	7.31E-04	0.0001	0.03	8.48E-07	0	0.48	2.17E-04	0.02	0.33
LYP-11	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0.03	0.55
LYP-12	0.002	0.68	1.02E-03	0	0	0.00E+00	0.0003	0.09	2.54E-06	0	1.51	6.81E-04	0.03	0.47
LYP-13	0.003	0.96	1.44E-03	0.001	0.06	1.00E-03	0.0004	0.13	3.82E-06	0	0	0.00E+00	0.12	2.02
LYP-14	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	1.33	5.99E-04	0.04	0.59
LYP-15	0	0	0.00E+00	0	0.01	1.45E-04	0	0	0.00E+00	0.002	6.15	2.77E-03	0.01	0.11
LYP-16	0	0.02	2.44E-05	0	0	0.00E+00	0.0001	0.03	8.48E-07	0	0	0.00E+00	0.02	0.28
LYP-17	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	0.43	1.95E-04	0.09	1.53
LYP-18	0.002	0.57	8.48E-04	0	0	0.00E+00	0.0003	0.1	2.97E-06	0	0	0.00E+00	0.04	0.7
LYP-19	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	1.55	6.96E-04	0.05	0.81
LYP-20	0	0	0.00E+00	0	0	0.00E+00	0.0001	0.03	8.48E-07	0	0	0.00E+00	0.04	0.7
SWN-1	0.001	0.48	7.23E-04	0	0.01	1.95E-04	0	0	0.00E+00	0	0.67	2.99E-04	0.04	0.68

SWN-2	0.002	0.52	7.73E-04	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0.05	0.81
SWN-3	0.001	0.32	4.74E-04	0.001	0.03	6.35E-04	0	0	0.00E+00	0	0	0.00E+00	0.04	0.63
SWN-4	0.001	0.38	5.74E-04	0	0.01	1.27E-04	0	0	0.00E+00	0	0	0.00E+00	0.04	0.66
SWN-5	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	1	4.49E-04	0.04	0.59
SWN-6	0	0	0.00E+00	0	0	0.00E+00	0.0003	0.09	2.54E-06	0	0	0.00E+00	0.03	0.55
SWN-7	0	0.12	1.75E-04	0.001	0.04	7.90E-04	0.0003	0.1	2.97E-06	0	1.33	5.99E-04	0.03	0.49
SWN-8	0	0	0.00E+00	0.001	0.04	6.44E-04	0	0	0.00E+00	0	0	0.00E+00	0.04	0.65
SWN-9	0.002	0.62	9.23E-04	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0.02	0.29
SWN-10	0.002	0.65	9.68E-04	0	0.01	1.04E-04	0	0	0.00E+00	0	0	0.00E+00	0.07	1.12
SWN-11	0	0	0.00E+00	0.001	0.05	8.76E-04	0	0	0.00E+00	0	0	0.00E+00	0.03	0.51
SWN-12	0.004	1.26	1.90E-03	0.003	0.15	2.81E-03	0.0011	0.31	9.33E-06	0	0	0.00E+00	0.03	0.54
SWN-13	0	0	0.00E+00	0.001	0.03	5.99E-04	0	0	0.00E+00	0	0	0.00E+00	0.08	1.3
SWN-14	0	0	0.00E+00	0.001	0.04	6.58E-04	0	0	0.00E+00	0	1	4.49E-04	0.05	0.82
SWN-15	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0.04	0.73
SWN-16	0.002	0.72	1.09E-03	0	0.01	1.48E-04	0	0	0.00E+00	0.001	3.82	1.72E-03	0.05	0.76
SWN-17	0	0.15	2.24E-04	0	0.02	3.95E-04	0.0004	0.13	3.82E-06	0	1.5	6.73E-04	0.05	0.76
SWN-18	0	0	0.00E+00	0	0.01	1.45E-04	0	0	0.00E+00	0	0	0.00E+00	0.01	0.12
OKR-1	0	0	0.00E+00	0	0	4.54E-05	0	0	0.00E+00	0	0	0.00E+00	0.04	0.73
OKR-2	0.001	0.38	5.74E-04	0.001	0.03	5.45E-04	0	0	0.00E+00	0	0	0.00E+00	0.09	1.55
OKR-3	0.003	0.93	1.40E-03	0.001	0.07	1.32E-03	0.0003	0.09	2.54E-06	0	0	0.00E+00	0.05	0.8
OKR-4	0.001	0.32	4.74E-04	0	0.02	3.09E-04	0	0	0.00E+00	0	0	0.00E+00	0.13	2.21
OKR-5	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	0.06
JNG-1	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0.1	1.59
JNG-2	0.001	0.18	2.74E-04	0.001	0.06	1.05E-03	0.0001	0.03	8.48E-07	0	1.15	5.16E-04	0.03	0.56
JNG-3	0	0.16	2.42E-04	0.001	0.05	8.62E-04	0	0	0.00E+00	0	0.88	3.97E-04	0.04	0.69
JNG-4	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0.001	4.16	1.87E-03	0.01	0.19
JNG-5	0	0.07	1.05E-04	0	0.02	3.63E-04	0	0	0.00E+00	0	0	0.00E+00	0.04	0.73
JNG-6	0	0	0.00E+00	0	0.02	4.04E-04	0	0	0.00E+00	0	0	0.00E+00	0.01	0.22

JNG-7	0.001	0.22	3.24E-04	0.001	0.03	5.54E-04	0	0	0.00E+00	0	0.33	1.50E-04	0.14	2.34
JNG-8	0	0	0.00E+00	0	0	0.00E+00	0.0004	0.11	3.39E-06	0.001	3.49	1.57E-03	0.02	0.4
JNG-9	0	0.03	4.99E-05	0.001	0.05	8.90E-04	0	0	0.00E+00	0	0.9	4.04E-04	0.04	0.69
JNG-10	0	0.11	1.60E-04	0.001	0.03	5.13E-04	0.0001	0.04	1.27E-06	0	0	0.00E+00	0.03	0.48
PKP-1	0	0.05	7.73E-05	0	0.01	1.32E-04	0	0	0.00E+00	0	0	0.00E+00	0.05	0.82
PKP-2	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0.01	0.14
PKP-3	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	0.32	1.42E-04	0	0.08
PKP-4	0.002	0.63	9.48E-04	0.001	0.03	5.45E-04	0.0004	0.11	3.39E-06	0	0	0.00E+00	0.12	1.99
PKP-5	0	0.15	2.24E-04	0	0	0.00E+00	0.0004	0.13	3.82E-06	0	0	0.00E+00	0.04	0.68
KUS-1	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	0.15	6.73E-05	0.01	0.24
KUS-2	0	0.16	2.39E-04	0	0	0.00E+00	0.0004	0.13	3.82E-06	0	0	0.00E+00	0.04	0.75
KUS-3	0	0.1	1.57E-04	0	0	0.00E+00	0.0003	0.09	2.54E-06	0.001	2.16	9.73E-04	0.01	0.13
KUS-4	0.002	0.57	8.48E-04	0.001	0.04	8.17E-04	0	0	0.00E+00	0	0	0.00E+00	0.03	0.55
KUS-5	0.002	0.63	9.48E-04	0	0	0.00E+00	0.0001	0.04	1.27E-06	0.001	2.83	1.27E-03	0.05	0.79
KUS-6	0	0.1	1.57E-04	0	0.01	2.18E-04	0	0	0.00E+00	0	1.33	5.99E-04	0.03	0.42
KUS-7	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	0.42	1.87E-04	0.05	0.8
KUS-8	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0.001	4.66	2.09E-03	0.09	1.45
KUS-9	0	0.13	2.00E-04	0	0	0.00E+00	0.0004	0.11	3.39E-06	0	1.18	5.31E-04	0.03	0.49
KUS-10	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	1.63	7.33E-04	0.03	0.45
KUS-11	0	0.12	1.77E-04	0	0	0.00E+00	0.0003	0.1	2.97E-06	0	0	0.00E+00	0.01	0.23
KUS-12	0	0	0.00E+00	0	0.02	4.04E-04	0	0	0.00E+00	0	0	0.00E+00	0.11	1.8
KUS-13	0	0.1	1.50E-04	0	0	0.00E+00	0.0003	0.09	2.54E-06	0	0	0.00E+00	0.02	0.36
KUS-14	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	1.5	6.73E-04	0.03	0.5
KUS-15	0.004	1.3	1.95E-03	0.002	0.11	1.95E-03	0.0004	0.13	3.82E-06	0.001	2.33	1.05E-03	0.04	0.72
SKP-1	0	0.09	1.30E-04	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0.08	1.38
SKP-2	0.002	0.52	7.79E-04	0	0	0.00E+00	0	0	0.00E+00	0	1.51	6.81E-04	0.03	0.48
SKP-3	0	0	0.00E+00	0	0.01	1.45E-04	0	0	0.00E+00	0	0	0.00E+00	0.02	0.37
SKP-4	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0.01	0.17

SKP-5	0.003	1.05	1.57E-03	0.002	0.08	1.54E-03	0	0	0.00E+00	0.002	5.62	2.53E-03	0.08	1.31
SKP-6	0.003	0.93	1.40E-03	0	0.02	3.63E-04	0	0	0.00E+00	0	1.01	4.56E-04	0.06	1.05
SKP-7	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0.02	0.37
SKP-8	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	0.3	1.35E-04	0.04	0.61
SKP-9	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0.04	0.59
SKP-10	0	0	0.00E+00	0	0.01	1.04E-04	0	0	0.00E+00	0	1.63	7.33E-04	0.06	1.07
SKP-11	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0.001	3.82	1.72E-03	0.07	1.14
SKP-12	0	0.05	7.48E-05	0	0.02	3.04E-04	0	0	0.00E+00	0	0	0.00E+00	0.04	0.73
SKP-13	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0.01	0.15
SKP-14	0	0.15	2.22E-04	0	0	0.00E+00	0	0	0.00E+00	0.001	3.21	1.44E-03	0.04	0.69
SKP-15	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0.02	0.28
LHR-1	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	0.27	1.20E-04	0.06	0.92
LHR-2	0	0.12	1.82E-04	0	0.01	1.09E-04	0	0	0.00E+00	0	0.8	3.59E-04	0.08	1.27
LHR-3	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	0.91	4.11E-04	0.06	1.02
LHR-4	0.003	1.08	1.62E-03	0.002	0.08	1.41E-03	0	0	0.00E+00	0.002	5.49	2.47E-03	0.06	0.93
LHR-5	0	0.02	3.12E-05	0	0.02	3.09E-04	0	0	0.00E+00	0	1.03	4.65E-04	0.03	0.51
LHR-6	0.003	0.88	1.32E-03	0.001	0.05	9.53E-04	0	0	0.00E+00	0	0.8	3.59E-04	0.04	0.75
LHR-7	0	0.13	1.90E-04	0	0.01	1.86E-04	0	0	0.00E+00	0	0.12	5.24E-05	0	0.04
LHR-8	0	0.15	2.24E-04	0	0	5.90E-05	0	0	0.00E+00	0	0.1	4.71E-05	0.05	0.89
LHR-9	0.005	1.63	2.44E-03	0.003	0.16	2.95E-03	0	0	0.00E+00	0	1.55	6.96E-04	0.05	0.77
LHR-10	0	0.1	1.57E-04	0	0.01	2.09E-04	0	0	0.00E+00	0.001	4.66	2.09E-03	0.02	0.31
LHR-11	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	0.68	3.07E-04	0.06	0.97
LHR-12	0	0.09	1.40E-04	0	0.01	1.04E-04	0	0	0.00E+00	0	0.8	3.59E-04	0.08	1.26
LHR-13	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	1.63	7.33E-04	0.04	0.67
LHR-14	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	1.11	5.01E-04	0.04	0.64
LHR-15	0	0	0.00E+00	0	0.02	4.22E-04	0	0	0.00E+00	0	0.12	5.24E-05	0.03	0.54
LHR-16	0.004	1.3	1.95E-03	0.001	0.07	1.32E-03	0	0	0.00E+00	0	0.33	1.50E-04	0.05	0.82
LHR-17	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	1.45	6.51E-04	0.02	0.29

LHR-18	0	0.04	6.23E-05	0	0	0.00E+00	0	0	0.00E+00	0	1.51	6.81E-04	0.02	0.31
LHR-19	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	0.96	4.34E-04	0.03	0.45
LHR-20	0	0	0.00E+00	0	0	5.58E-05	0	0	0.00E+00	0.001	3.61	1.62E-03	0.05	0.82
LHR-21	0	0.02	3.12E-05	0	0.02	4.45E-04	0	0	0.00E+00	0	1.03	4.64E-04	0.06	0.92
LHR-22	0	0	0.00E+00	0.001	0.06	1.15E-03	0	0	0.00E+00	0	0.27	1.20E-04	0.03	0.5
LHR-23	0	0	0.00E+00	0	0.01	1.04E-04	0	0	0.00E+00	0	0.53	2.39E-04	0.04	0.67
LHR-24	0	0.02	3.44E-05	0	0	5.90E-05	0	0	0.00E+00	0	0.71	3.22E-04	0.01	0.25
LHR-25	0	0.16	2.34E-04	0	0	0.00E+00	0	0	0.00E+00	0	1.12	5.04E-04	0.03	0.5
LHR-26	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	0.1	4.49E-05	0.04	0.74
LHR-27	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0.001	2.34	1.05E-03	0.06	1.08
LHR-28	0.001	0.2	2.99E-04	0	0	0.00E+00	0	0	0.00E+00	0	1.06	4.79E-04	0.1	1.64
LHR-29	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	0.2	8.98E-05	0.08	1.36
LHR-30	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	0.91	4.11E-04	0.03	0.48
LHR-31	0	0	0.00E+00	0	0	5.90E-05	0	0	0.00E+00	0	0.38	1.72E-04	0.09	1.45
LHR-32	0	0	0.00E+00	0.001	0.05	8.62E-04	0	0	0.00E+00	0	0.88	3.97E-04	0.06	0.96
LHR-33	0	0	0.00E+00	0.001	0.06	1.06E-03	0	0	0.00E+00	0	0.53	2.39E-04	0.04	0.7
LHR-34	0	0.11	1.70E-04	0	0	0.00E+00	0	0	0.00E+00	0	0.8	3.59E-04	0.09	1.47
LHR-35	0	0.12	1.82E-04	0	0	0.00E+00	0	0	0.00E+00	0	1.3	5.84E-04	0.03	0.5
LHR-36	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	0.86	3.89E-04	0.06	0.97
LHR-37	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0.001	4.16	1.87E-03	0.07	1.15
LHR-38	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	0.57	2.54E-04	0.11	1.81
LHR-39	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	0.27	1.23E-04	0.09	1.42
LHR-40	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	0.81	3.67E-04	0.09	1.5
LHR-41	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	1.3	5.84E-04	0.05	0.85
LHR-42	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	0.48	2.17E-04	0.03	0.45
LHR-43	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0.001	2.99	1.35E-03	0.01	0.14
LHR-44	0	0.09	1.40E-04	0	0	0.00E+00	0	0	0.00E+00	0	1	4.49E-04	0.07	1.22
LHR-45	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	1.11	5.01E-04	0.09	1.51

LHR-46	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	0.27	1.20E-04	0.06	0.99
LHR-47	0	0.08	1.20E-04	0	0	4.08E-05	0	0	0.00E+00	0	0.8	3.59E-04	0.02	0.38
LHR-48	0	0.03	4.09E-05	0	0	0.00E+00	0	0	0.00E+00	0	1.11	5.01E-04	0.07	1.21
LHR-49	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	1.4	6.28E-04	0.07	1.09
WGB-1	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	1	4.49E-04	0.03	0.47
WGB-2	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0.09	1.56
WGB-3	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	0.03
WGB-4	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	1.33	5.99E-04	0.02	0.35
LON-1	0	0.12	1.75E-04	0	0.02	4.45E-04	0	0	0.00E+00	0	0.57	2.54E-04	0.01	0.1
LON-2	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	1.51	6.81E-04	0.01	0.16
LON-3	0	0.14	2.17E-04	0	0.02	3.04E-04	0	0	0.00E+00	0	0.35	1.57E-04	0.08	1.26
LON-4	0	0.16	2.44E-04	0	0.02	3.45E-04	0	0	0.00E+00	0.002	6.15	2.77E-03	0.05	0.82
MUX-1	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0.02	0.27
MUX-2	0	0.16	2.34E-04	0	0	0.00E+00	0	0	0.00E+00	0	0.85	3.82E-04	0.07	1.23
MUX-3	0.003	0.88	1.32E-03	0.001	0.05	9.53E-04	0	0	0.00E+00	0	0	0.00E+00	0.01	0.24
MUX-4	0	0	0.00E+00	0	0	8.17E-05	0	0	0.00E+00	0.001	3.66	1.65E-03	0	0.06
MUX-5	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0.001	3.16	1.42E-03	0.02	0.27
VHR-1	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0.06	1.08
VHR-2	0	0.12	1.77E-04	0.001	0.05	8.62E-04	0	0	0.00E+00	0	1.08	4.86E-04	0.07	1.17
VHR-3	0	0	0.00E+00	0	0	0.00E+00	0	0.01	4.24E-07	0	0	0.00E+00	0.12	2.08
VHR-4	0	0.16	2.42E-04	0	0	0.00E+00	0	0.01	4.24E-07	0.001	2.99	1.35E-03	0.17	2.81
VHR-5	0.003	1.11	1.67E-03	0.002	0.09	1.59E-03	0	0	0.00E+00	0	0	0.00E+00	0.13	2.17
VHR-6	0	0.13	2.02E-04	0	0.01	1.04E-04	0	0.01	4.24E-07	0	0	0.00E+00	0.07	1.15
VHR-7	0	0	0.00E+00	0	0	0.00E+00	0.0006	0.17	5.09E-06	0	1.55	6.96E-04	0.09	1.58
VHR-8	0.003	1.1	1.65E-03	0.001	0.06	1.13E-03	0	0.01	4.24E-07	0.001	3.66	1.65E-03	0.07	1.13
KWL-1	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0.07	1.14
KWL-2	0	0.08	1.15E-04	0	0.02	3.18E-04	0	0	0.00E+00	0	0	0.00E+00	0	0.04
KWL-3	0	0.14	2.17E-04	0	0.01	1.27E-04	0	0	0.00E+00	0	0	0.00E+00	0.01	0.11

KWL-4	0	0.12	1.87E-04	0	0.01	1.04E-04	0	0	0.00E+00	0.001	4.32	1.95E-03	0.03	0.44
KWL-5	0	0	0.00E+00	0	0.01	9.99E-05	0	0	0.00E+00	0	0	0.00E+00	0.1	1.75
KWL-6	0.002	0.6	8.98E-04	0.001	0.04	8.17E-04	0	0	0.00E+00	0	0	0.00E+00	0.03	0.45
KWL-7	0.002	0.68	1.02E-03	0.001	0.05	8.62E-04	0	0	0.00E+00	0.002	5.65	2.54E-03	0.01	0.13
KWL-8	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	0.17	7.48E-05	0.04	0.66

### Legend

	High potential risk
	Moderate potential risk
	low potential risk
	No potential risk

#### 4.15: Descriptive stats of Health Risk Assessment (HRA)

	Cr			Ni			Pb			As			F	
	ADD	HQ	CR	ADD	HQ	CR	ADD	HQ	CR	ADD	HQ	CR	ADD	HQ
		<1	E-04		<1	E-04		<1	E-04		<1	E-04		<1
<b>HRA of Northern Punjab</b>														
<b>Mean</b>	0.0015	0.50	7.61E-04	0.0003±0	0.014±0.05	2.64E-04	0.0001	0.019±0.	5.80E-07	0.0001	0.48 ±3.40	2.09E-04	0.034±0.107	0.57±0.389
<b>± S.D</b>	±0.010	±3.38	±5.08E-03	.001	9	±5.40E-02	±0.00028	86	±3.88E-04	±0.011		±2.90E-02		
<b>Maximum</b>	0.1	33.25	4.99E-02	0	0.08	1.45E-03	0	0.13	3.82E-06	0	5.15	2.32E-03	0.11	1.75
<b>Minimum</b>	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	0.04
<b>HRA of Central Punjab</b>														
<b>Mean</b>	0.0006	0.186±0.4	2.80E-04	0.0003	0.0152±	2.77E-04	0.0001	0.0173	5.13E-07	0.0003±	0.977±	4.40E-04	0.0482	0.765±1.6365
<b>± S.D</b>	±0.00167	8	±1.35E-03	±0.00072	0.0347	±3.16E-02	±0.00053	±1.656	±7.45E-04	0.00028	0.08347	±7.09E-04	±0.04126	9
<b>Maximum</b>	0	1.63	2.44E-03	0	0.16	2.95E-03	0	0.31	9.33E-06	0	6.15	2.77E-03	0.16	2.69
<b>Minimum</b>	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	0.04
<b>HRA of Rural Punjab</b>														
<b>Mean</b>	0.0006	0.197	2.95E-04	0.0003	0.021	2.81E-04	0.00	0.0079	2.34E-07	0.0004	1.30 ±	5.89E-04	0.051	0.8513±2.206
<b>± S.D</b>	±0.0013	±0.452	±6.79E-04	±0.00055	±0.02718	±2.48E-02	±0.00	±0.034	±8.26E-04	±0.00019	0.03217	±2.73E-04	±0.144	
<b>Maximum</b>	0	1.11	1.67E-03	0	0.09	1.59E-03	0	0.17	2.34E-07	0	6.15	2.77E-03	0.17	2.81
<b>Minimum</b>	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	0	0.00E+00	0	0.03

## 4.8 GIS Mapping

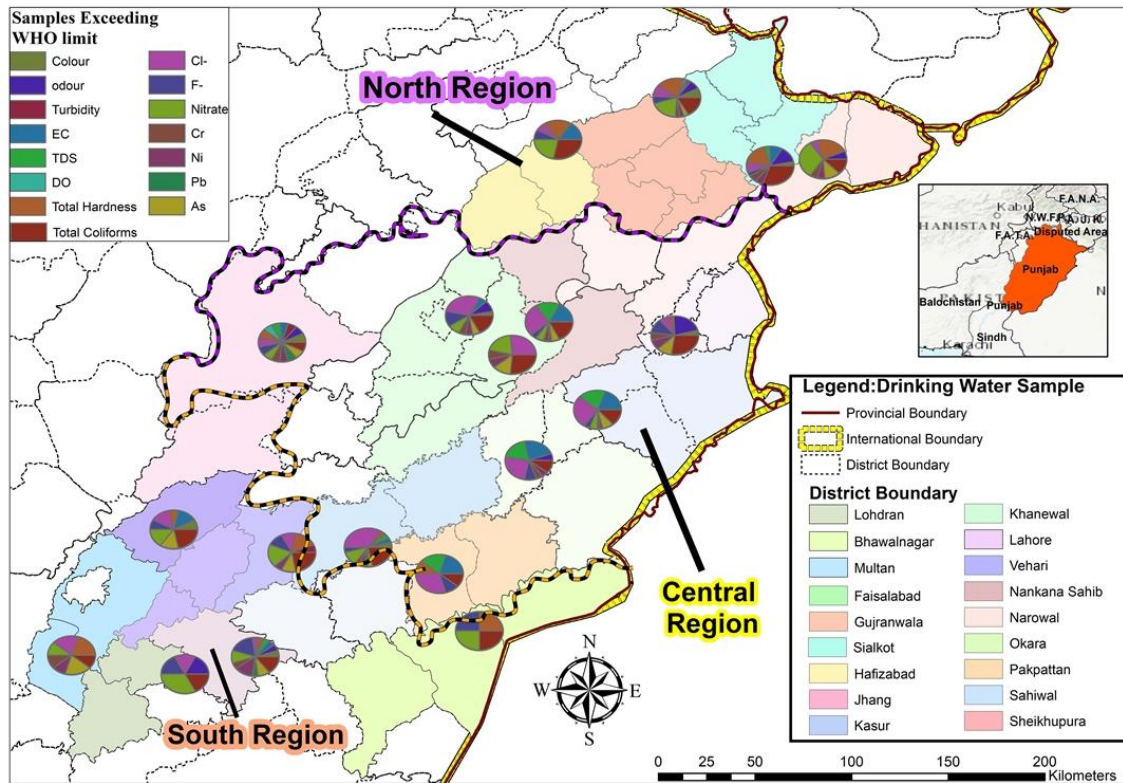


Fig 4.1 Samples exceeding WHO standards

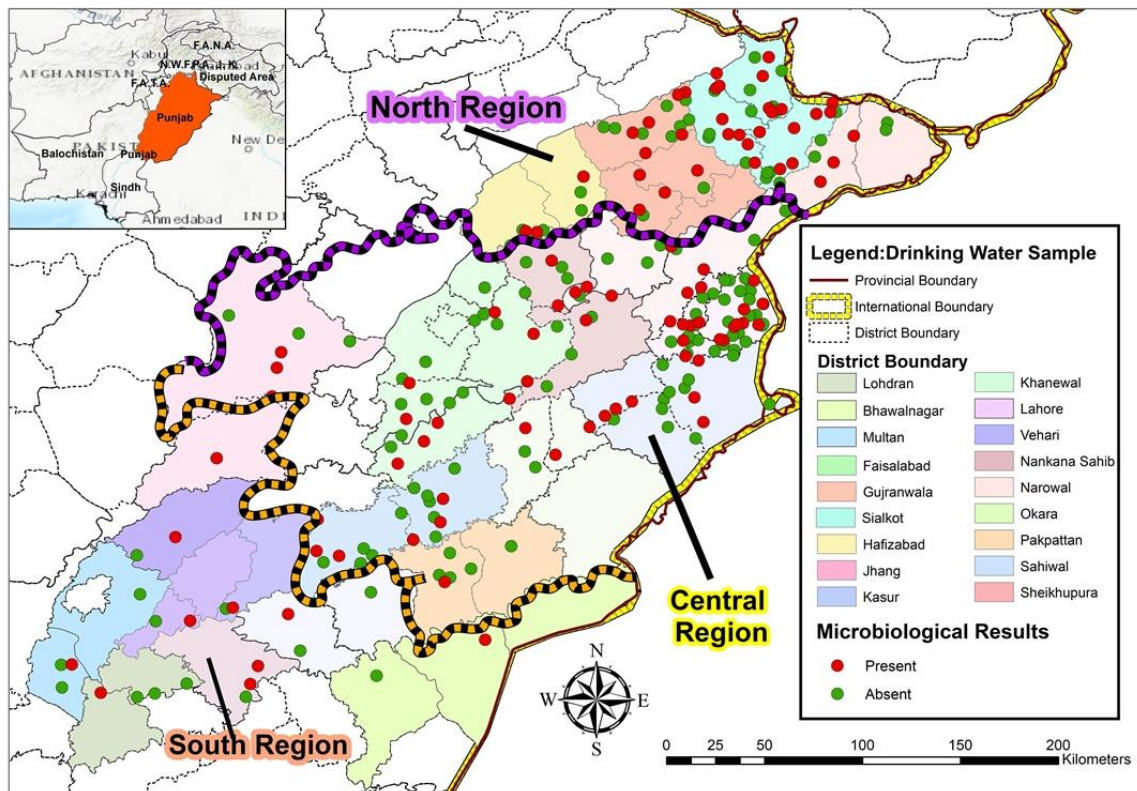
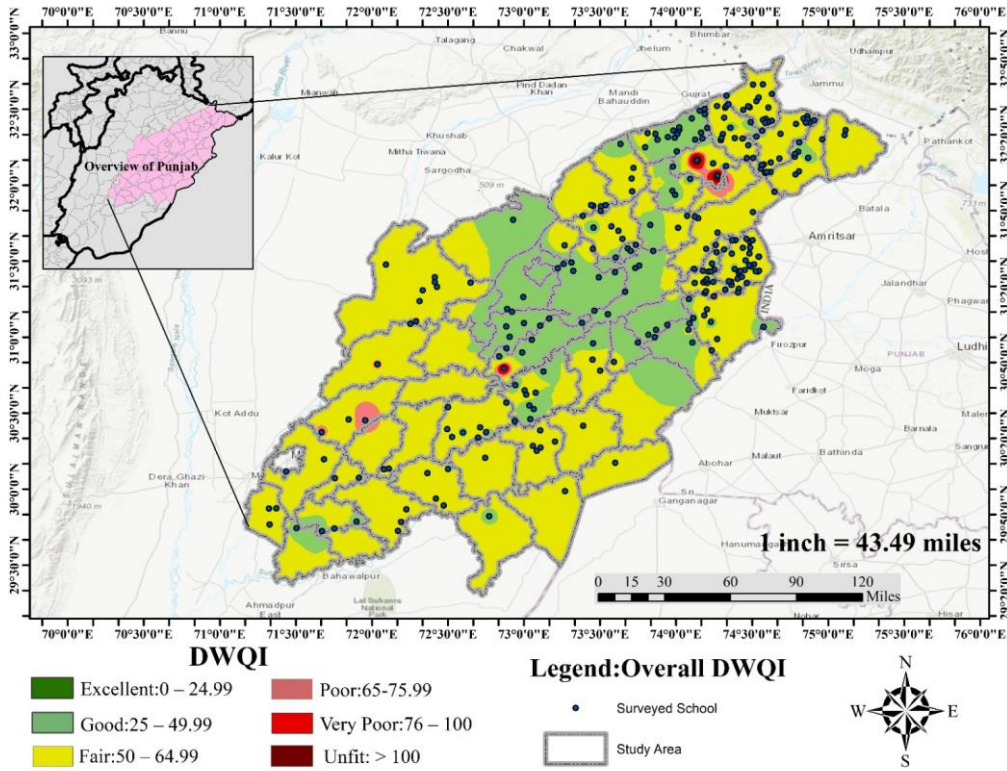
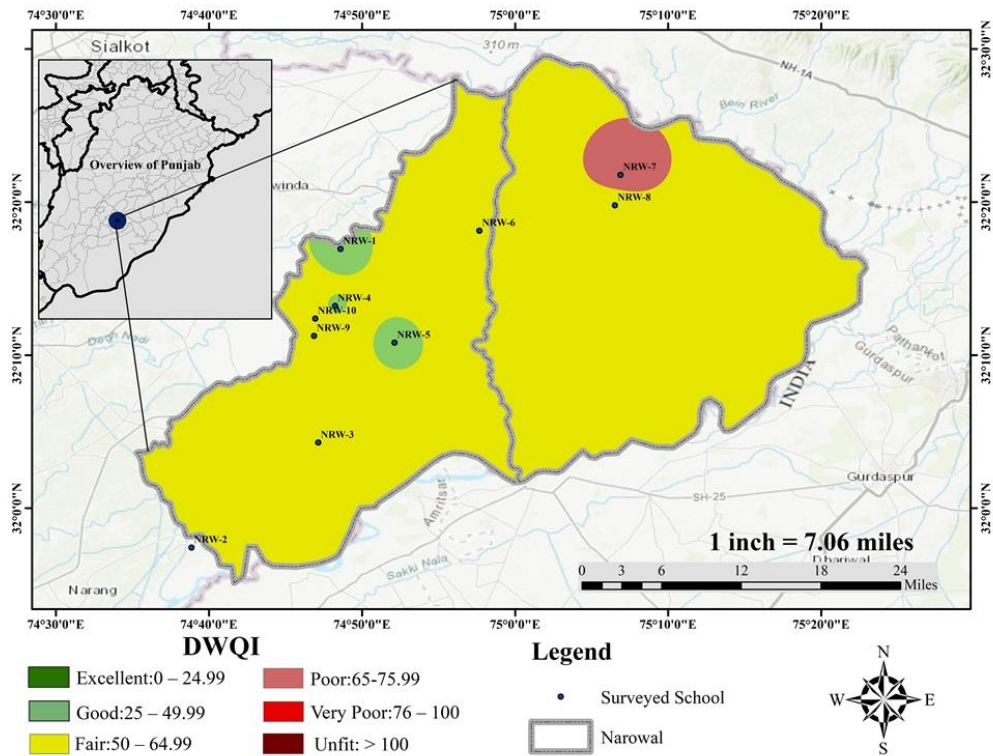


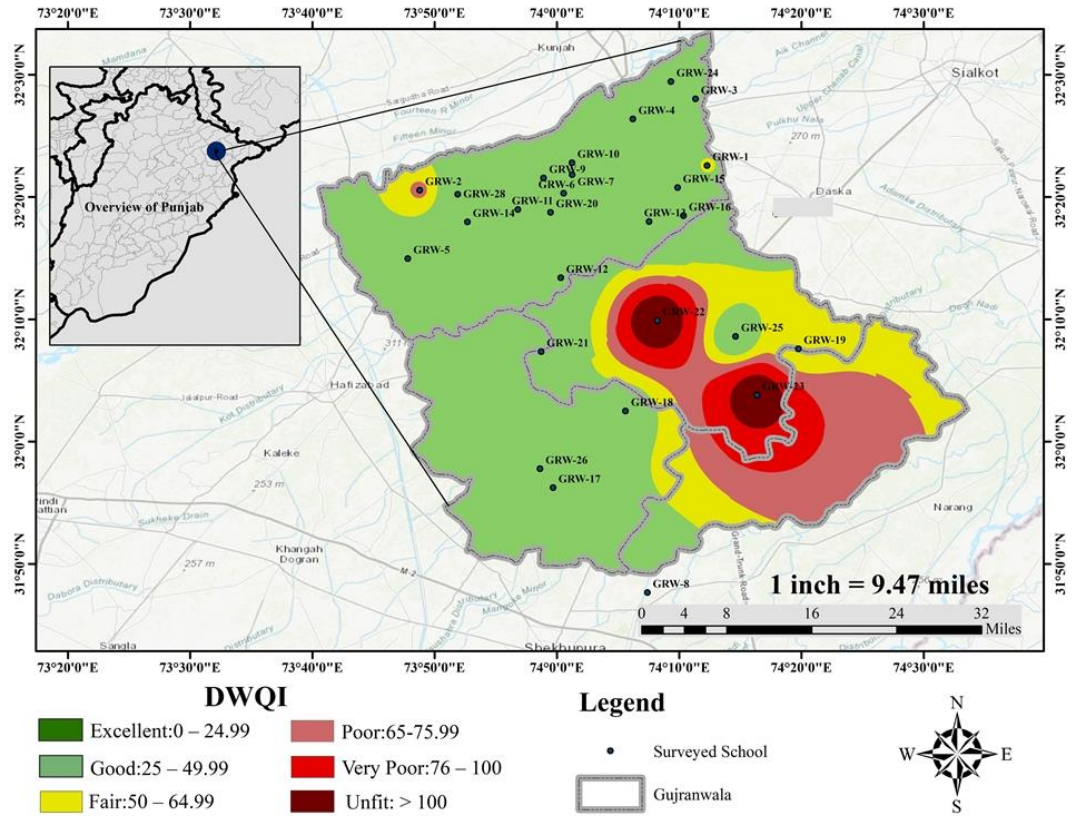
Fig 4.2 Mapping of Microbiological Results of collected samples



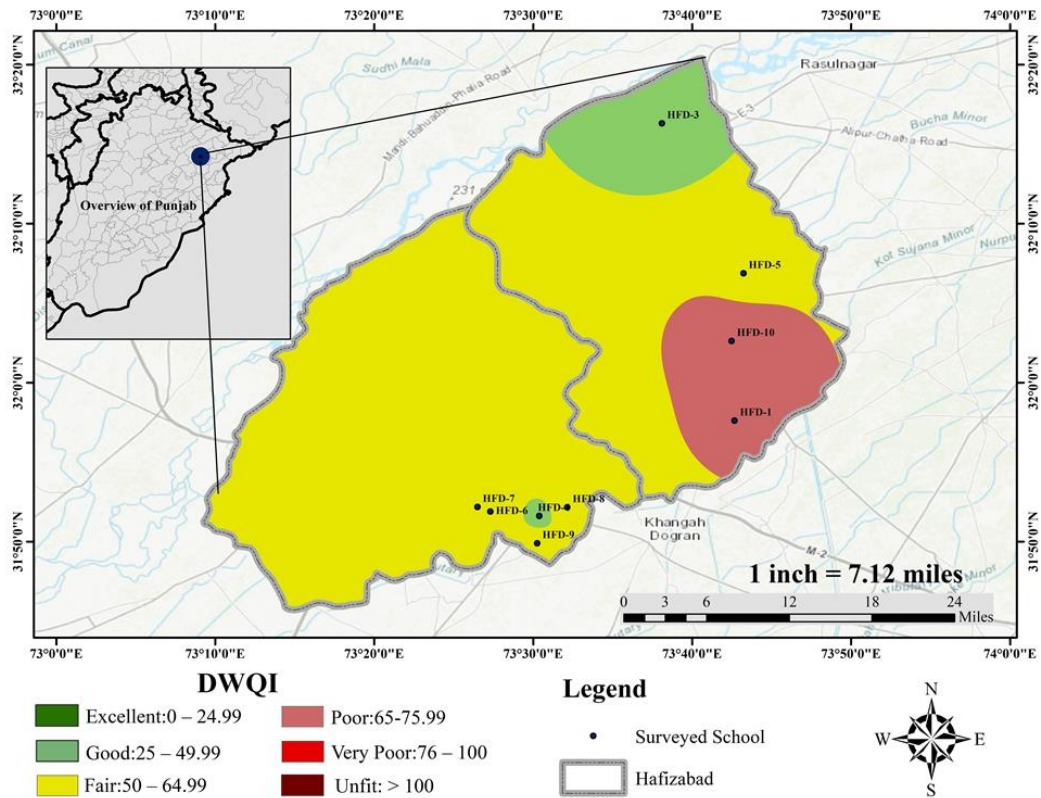
**Fig 4.3 Overall DWQI of selected cities of rural Punjab**



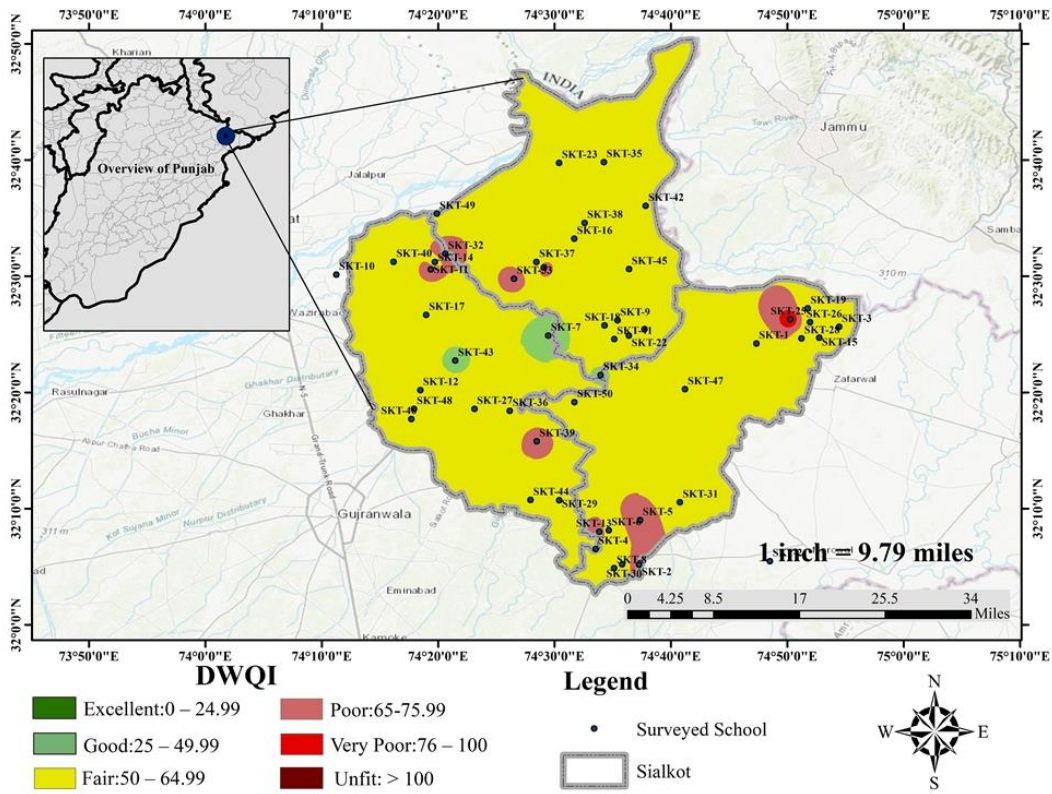
**Fig 4.4 DWQI of Narowal**



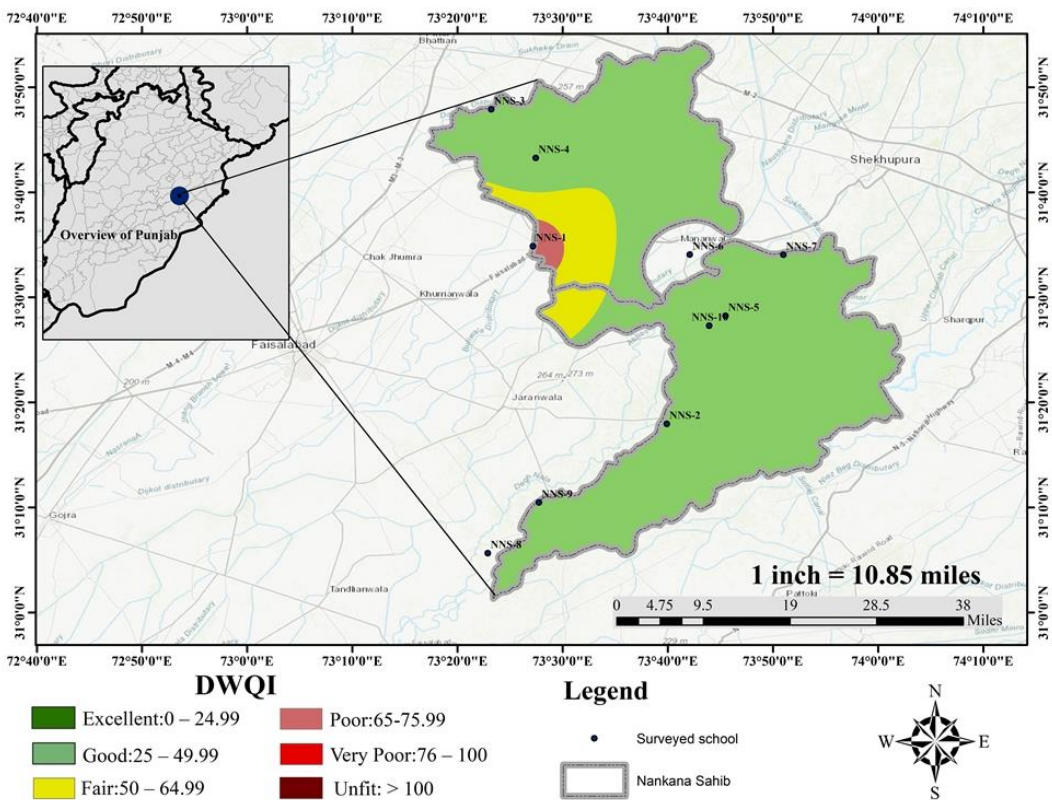
**Fig 4.5 DWQI of Gujranwala**



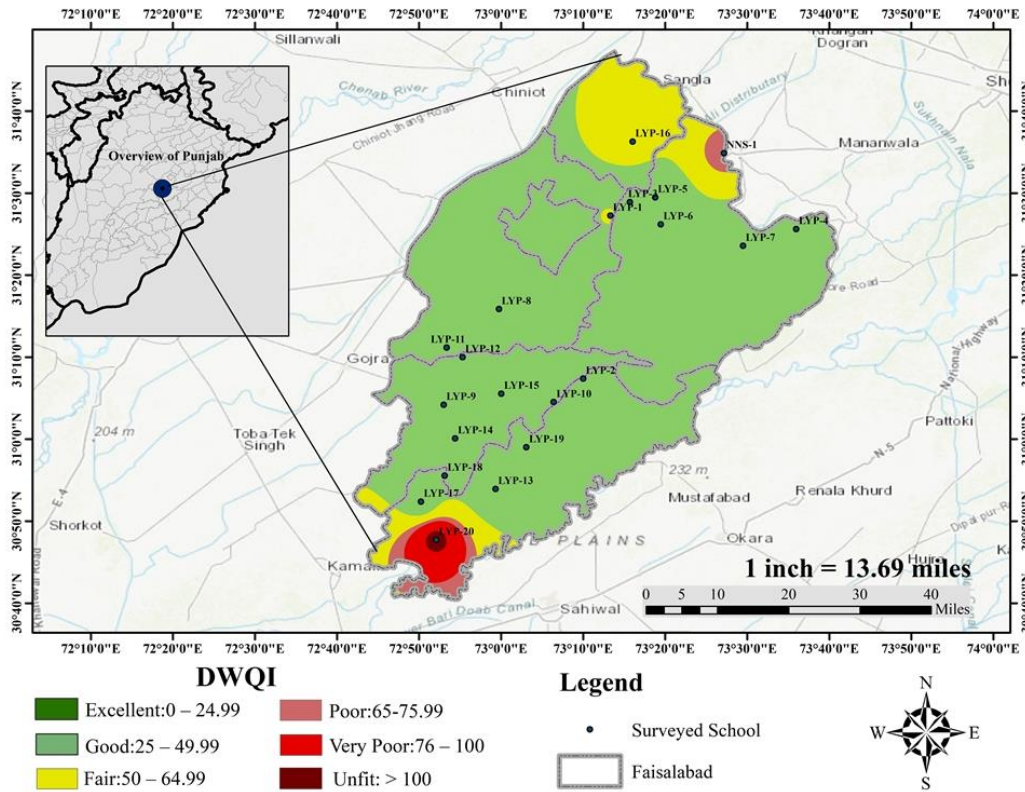
**Fig 4.6 DWQI of Hafizabad**



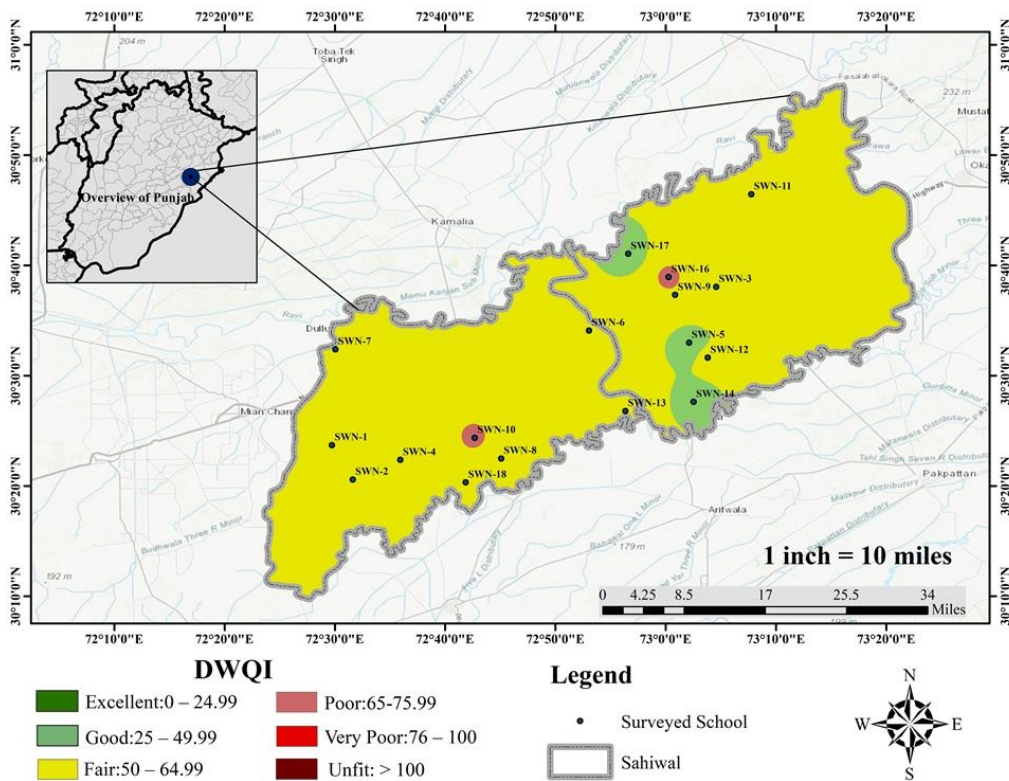
**Fig 4.7 DWQI of Sialkot**



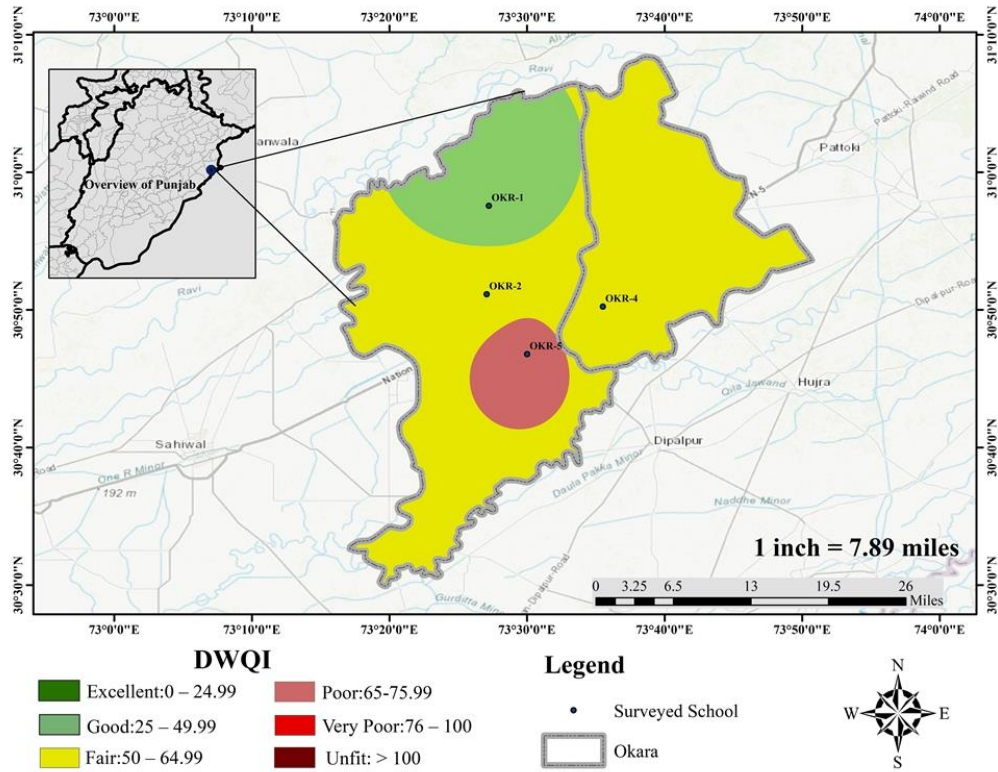
**Fig 4.8 DWQI of Nankana Sahib**



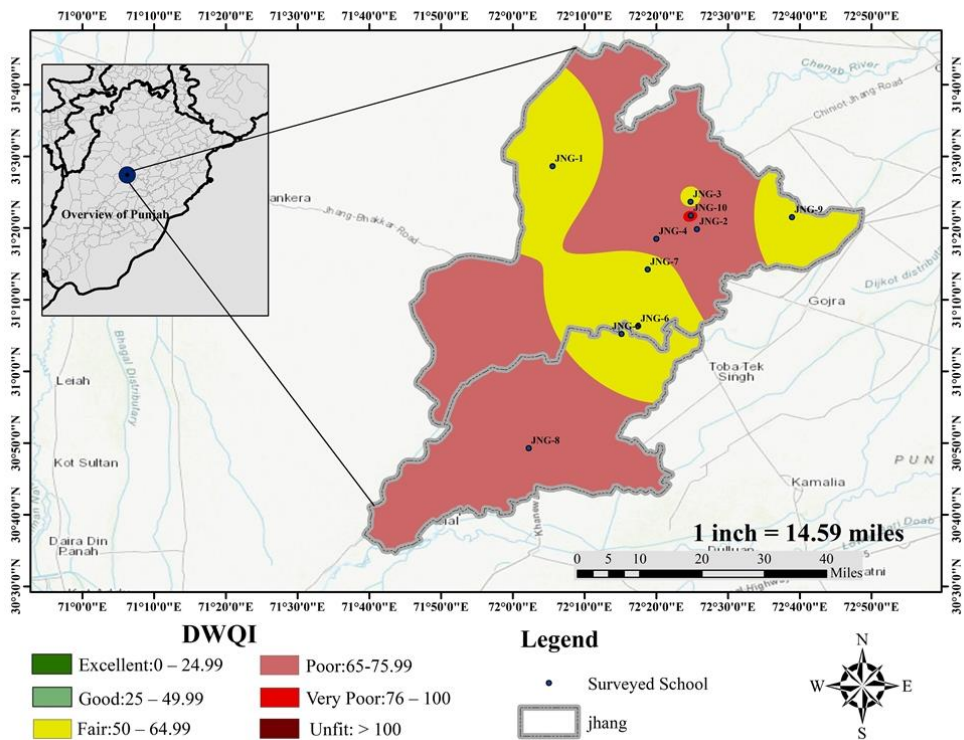
**Fig 4.9 DWQI of Faisalabad**



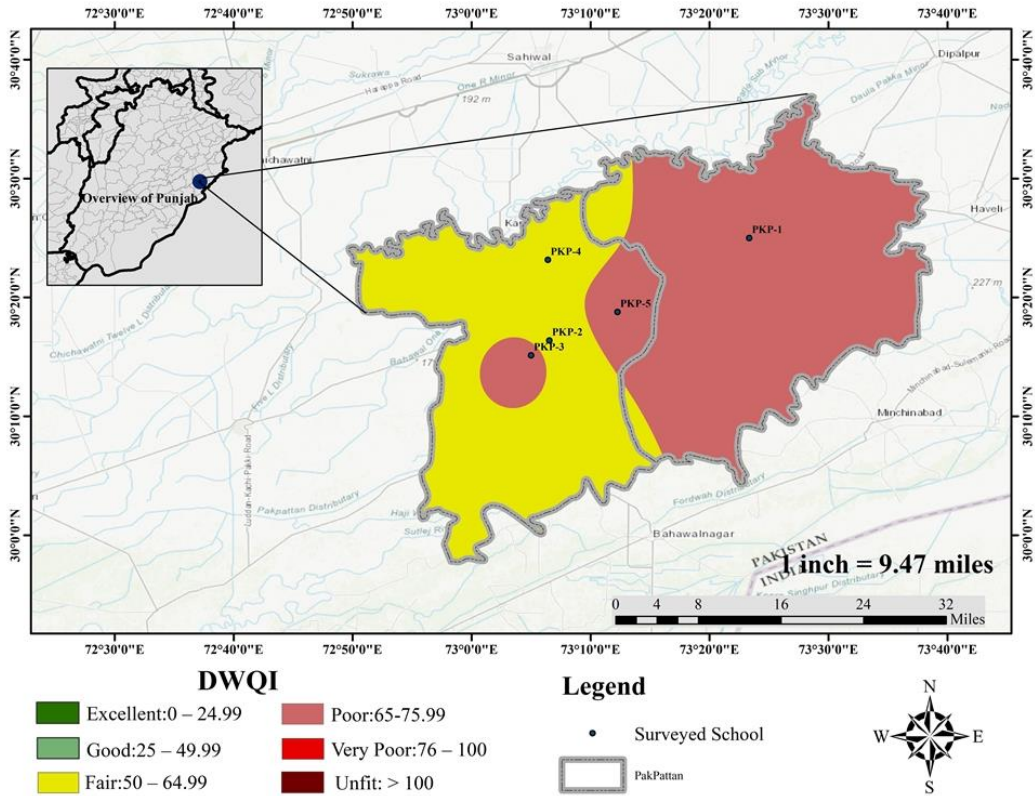
**4.10 DWQI of Sahiwal**



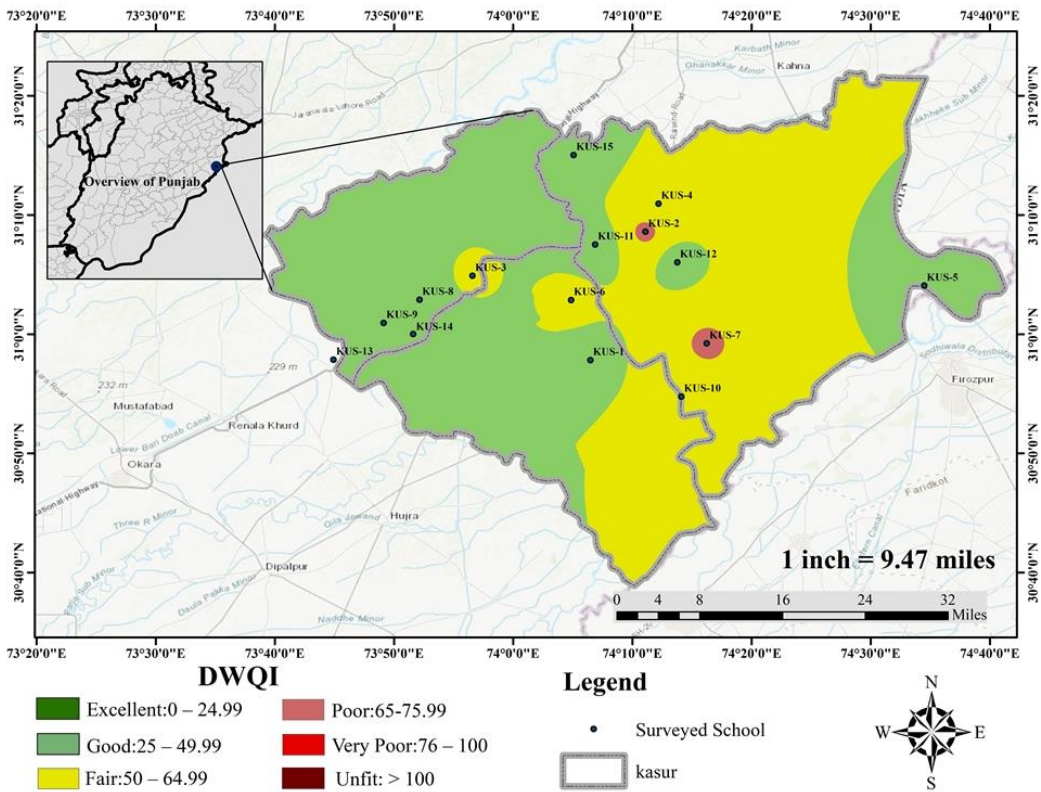
#### 4.11 DWQI of Okara



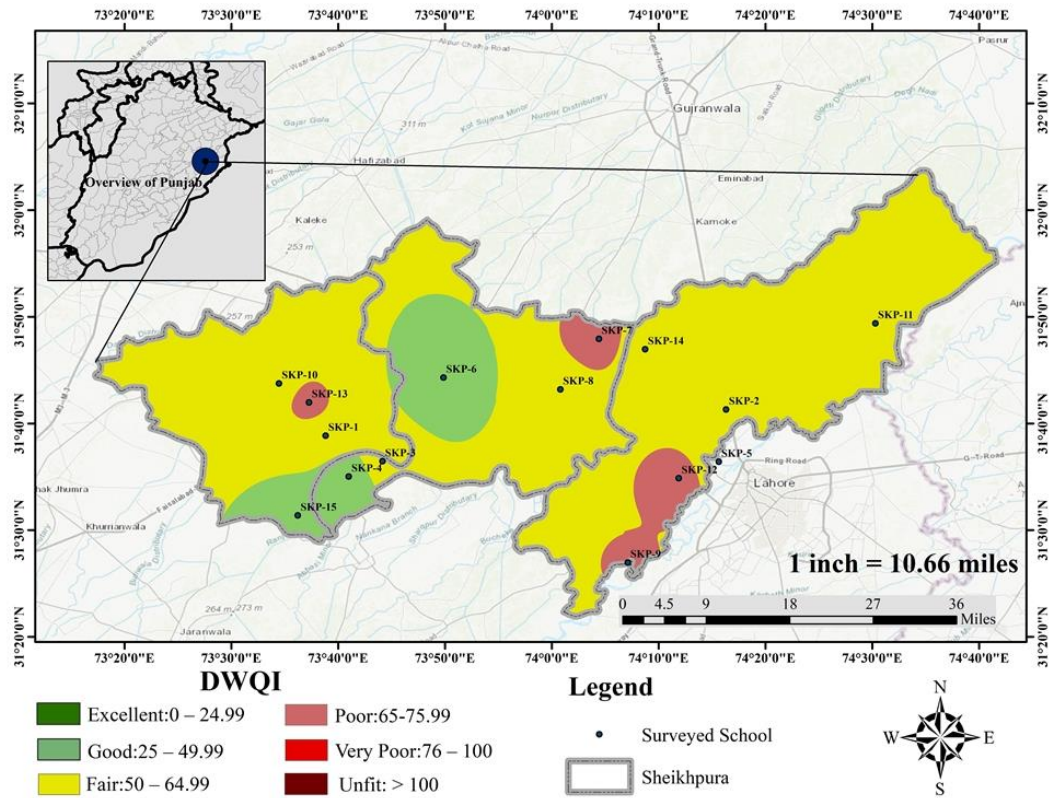
#### 4.12 DWQI of Jhang



### 4.13 DWQI of Pakpattan



### 4.14 DWQI of Kasur



4.15 DWQI of Sheikhpura

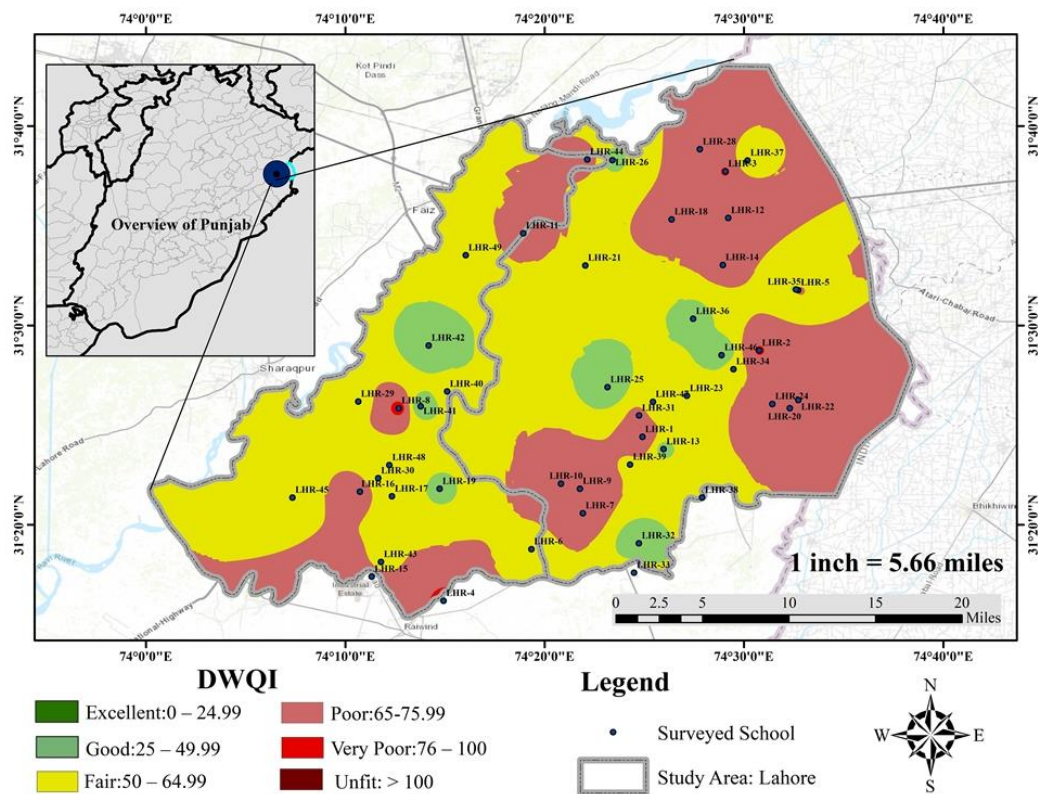
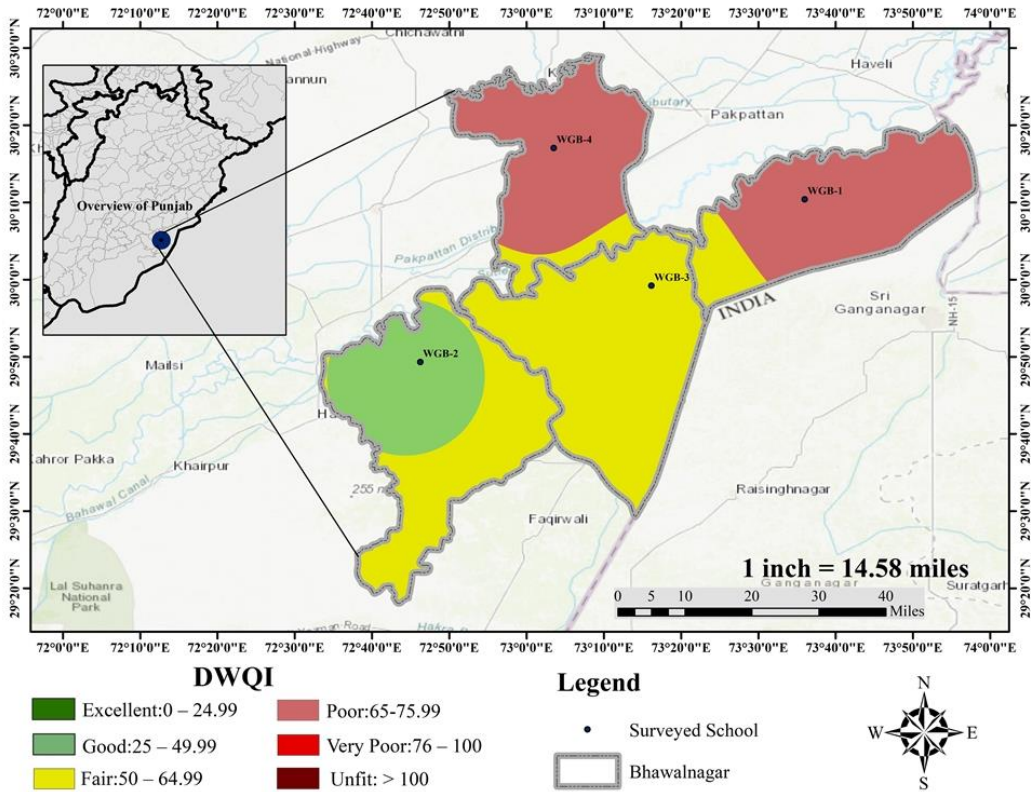
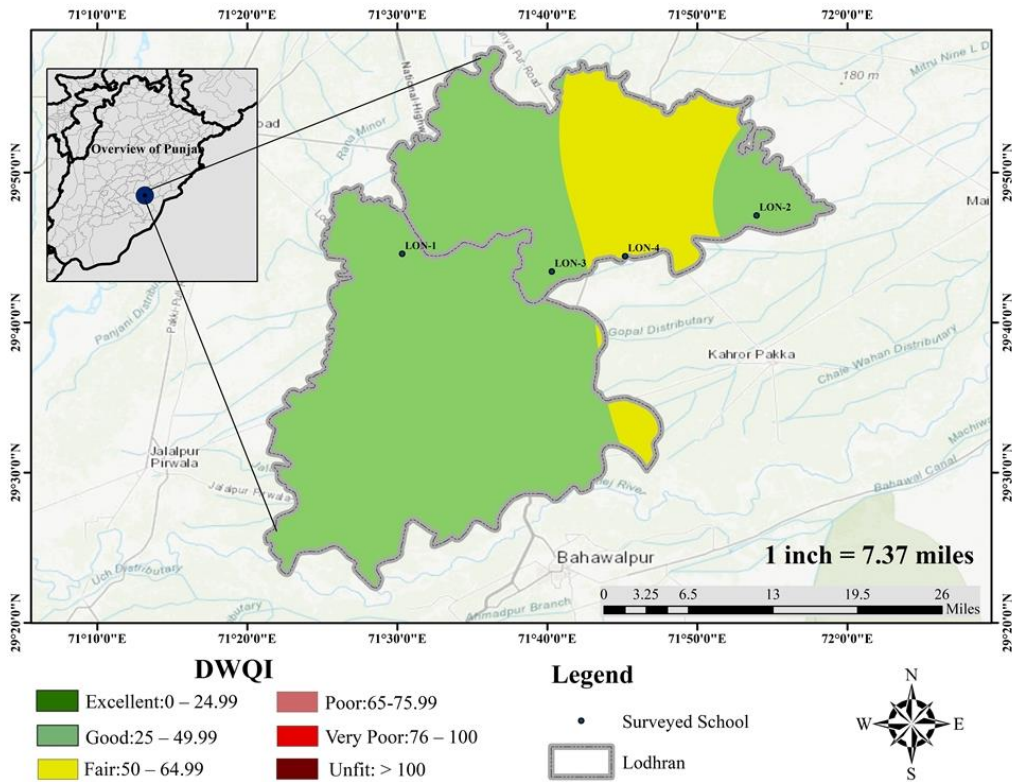


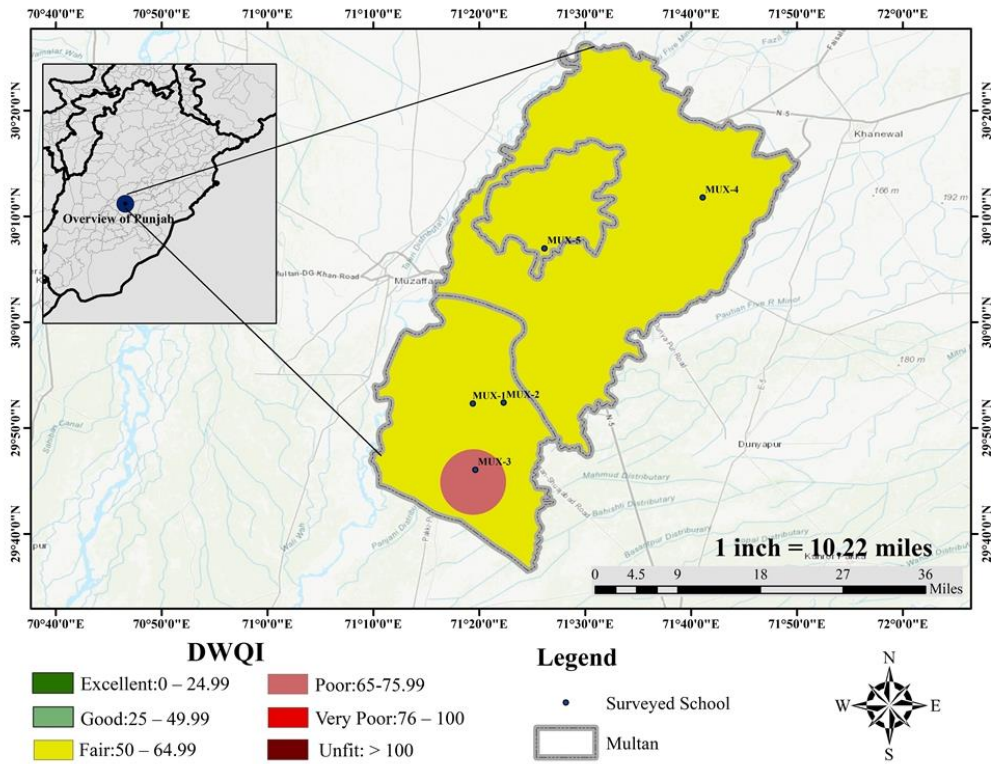
Fig 4.16 DWQI of Lahore



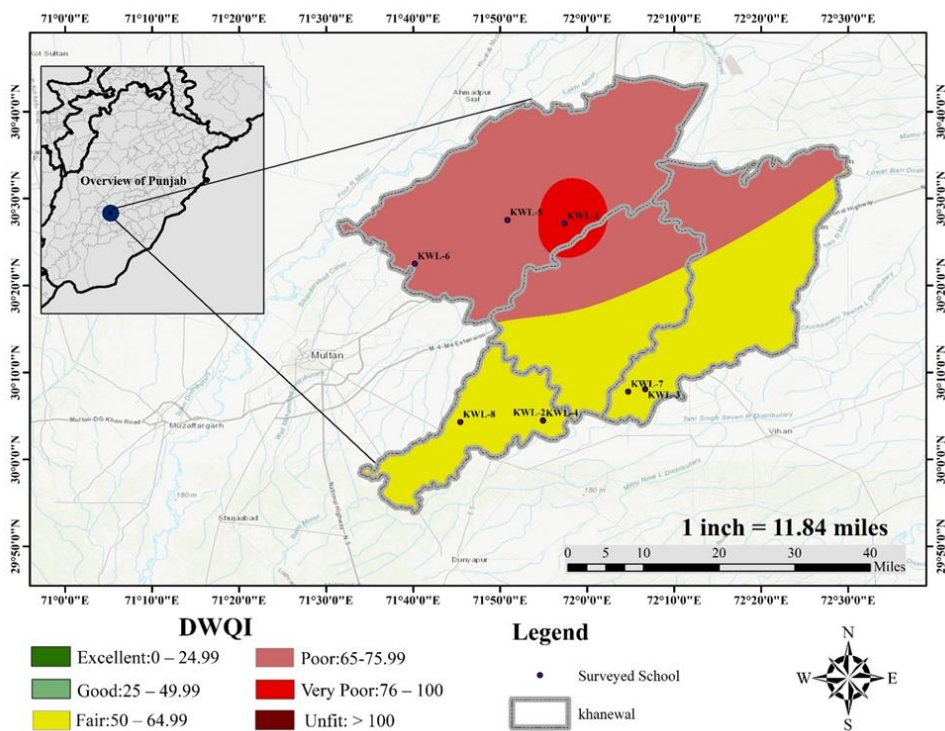
#### 4.17 DWQI of Bhawalnagar



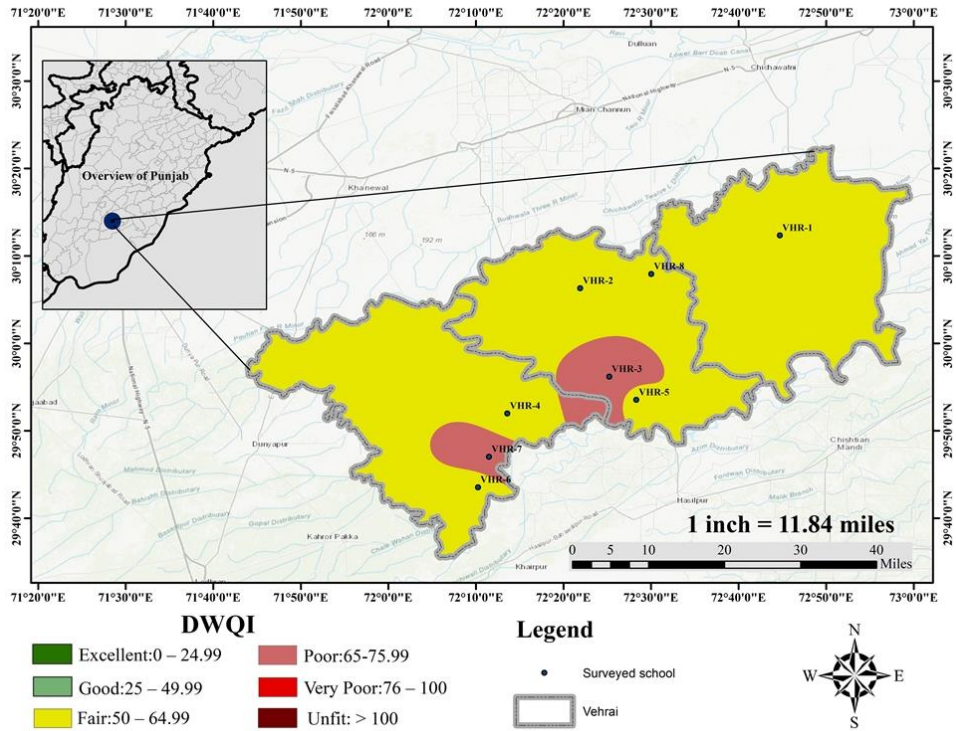
#### 4.18 DWQI of Lodhran



#### 4.19 DWQI of Multan



#### 4.20 DWQI of Khanewal



#### 4.21 DWQI of Vehari

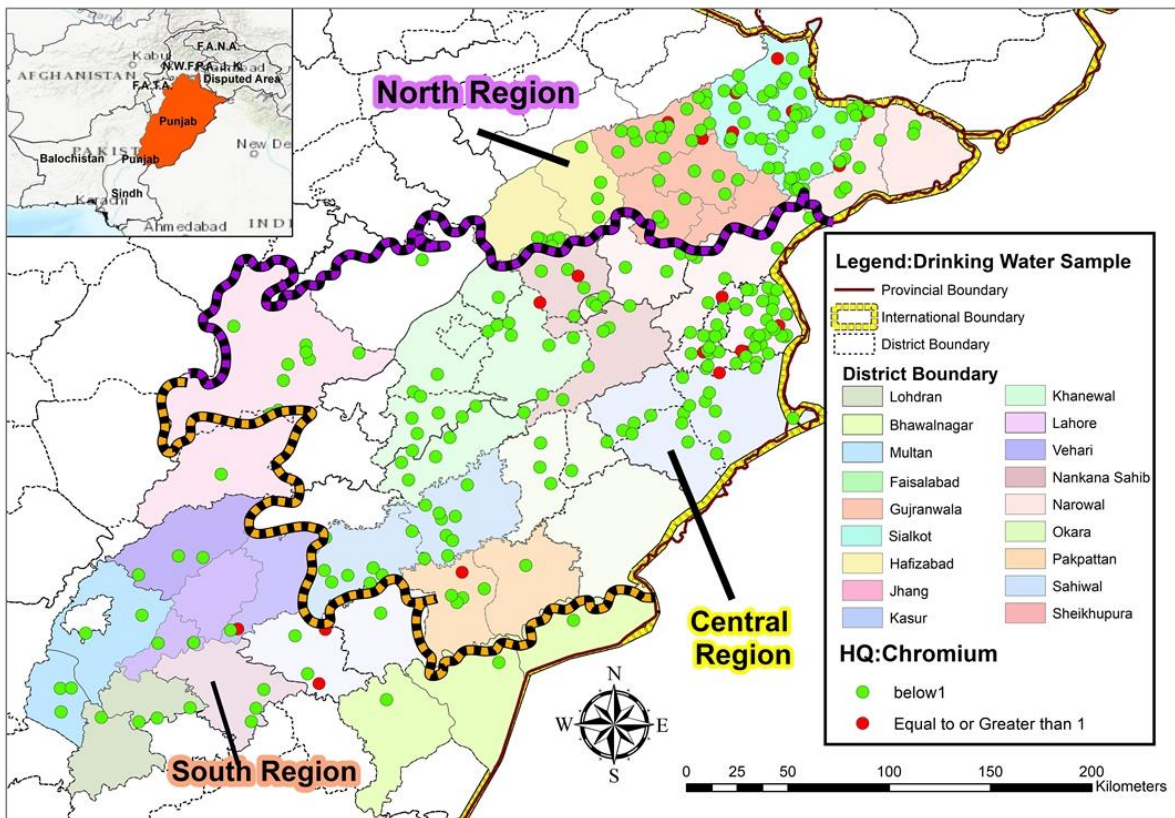


Fig 4.22 Hazard Quotient of Cr

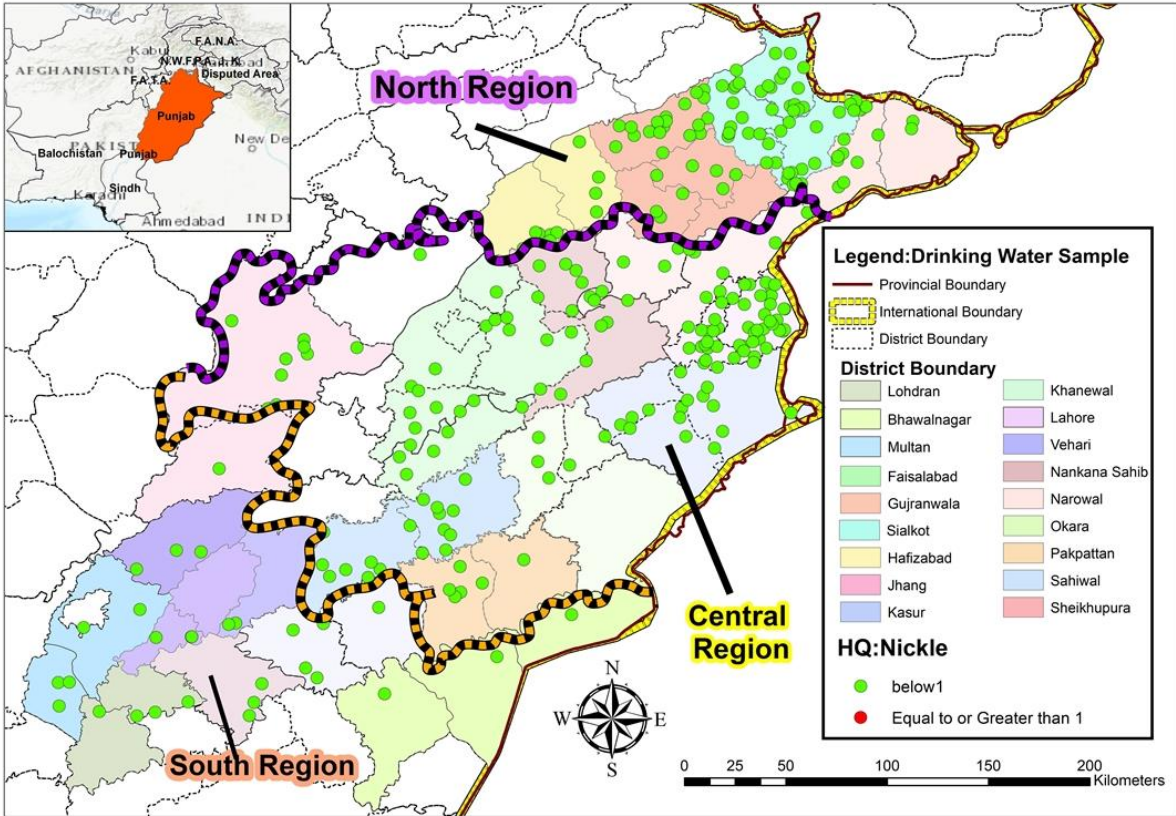


Fig 4.23 Hazard Quotient of Ni

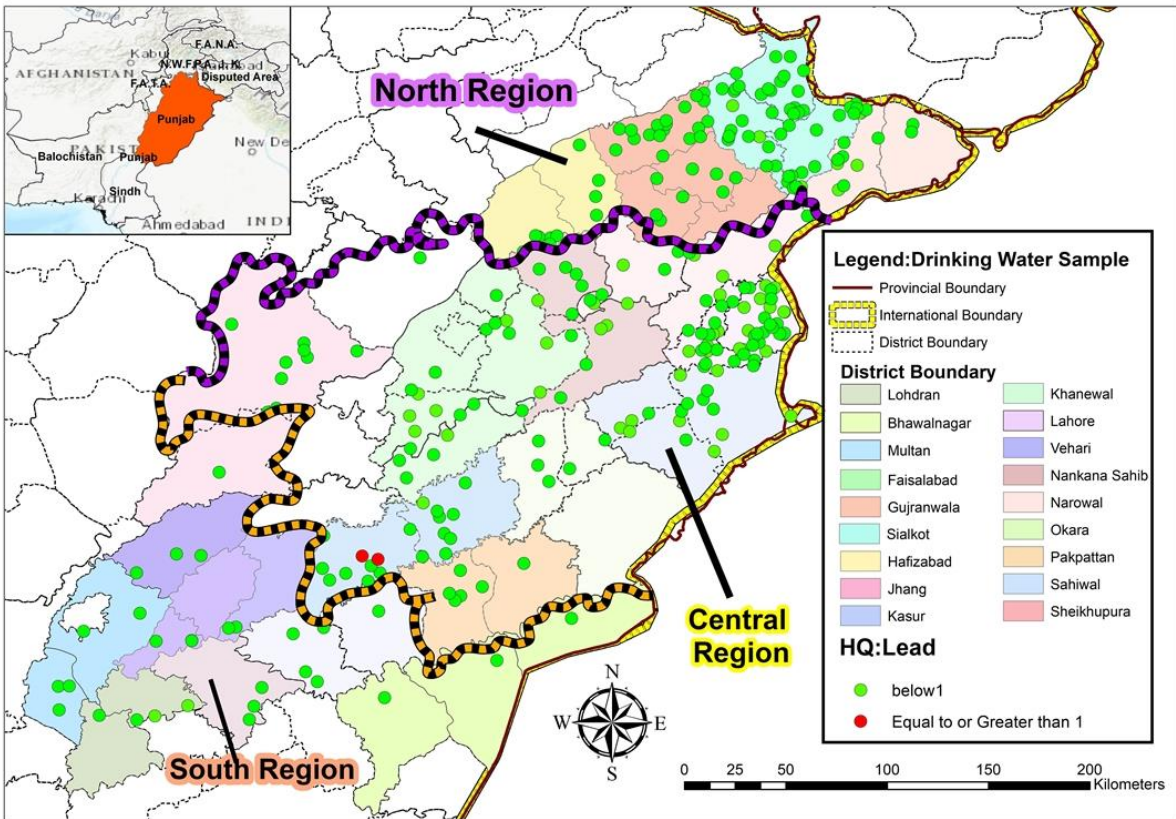


Fig 4.24 Hazard Quotient of Pb

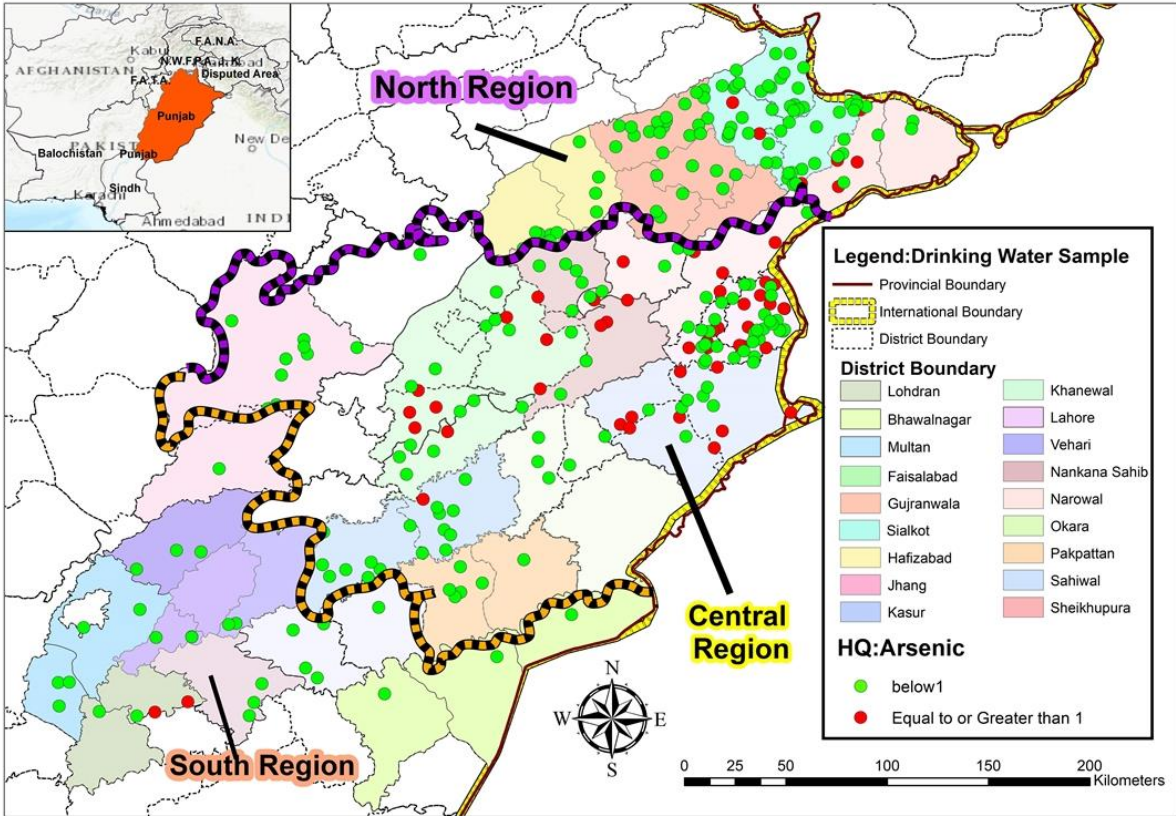


Fig 4.25 Hazard Quotient of As

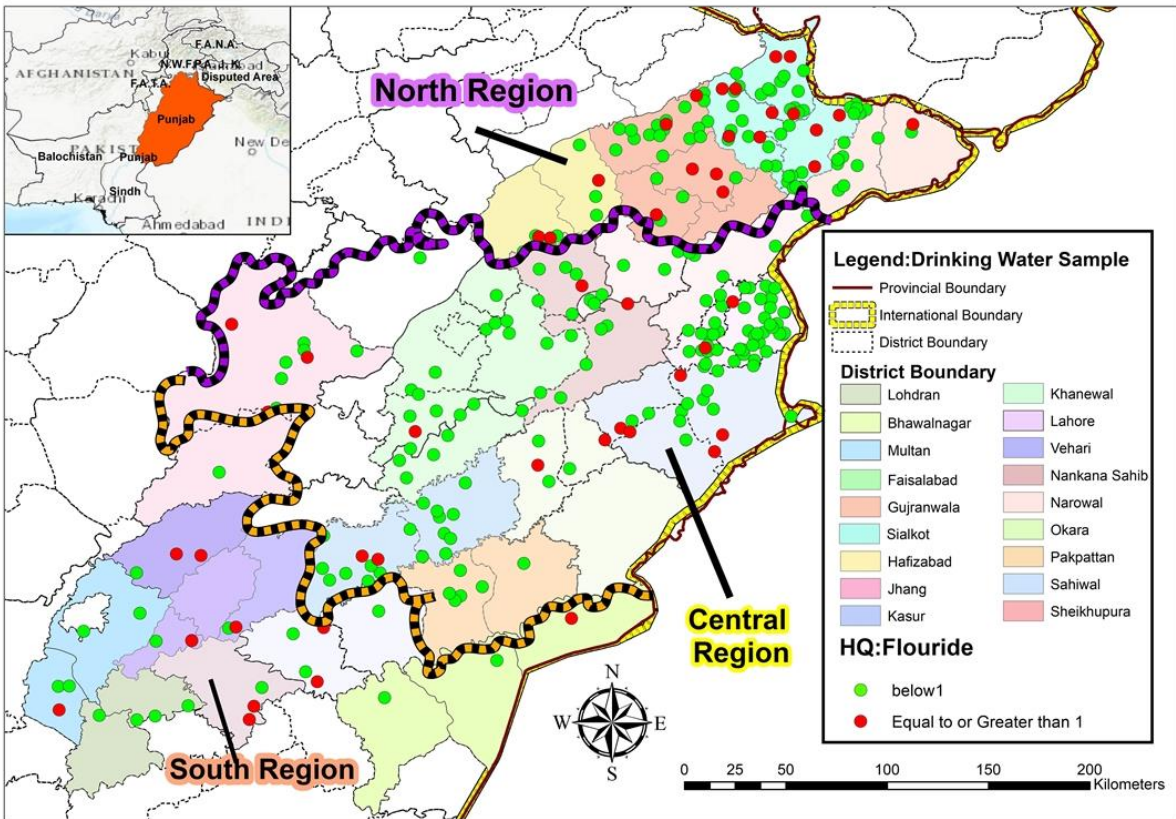


Fig 4.26 Hazard Quotient of Fluoride

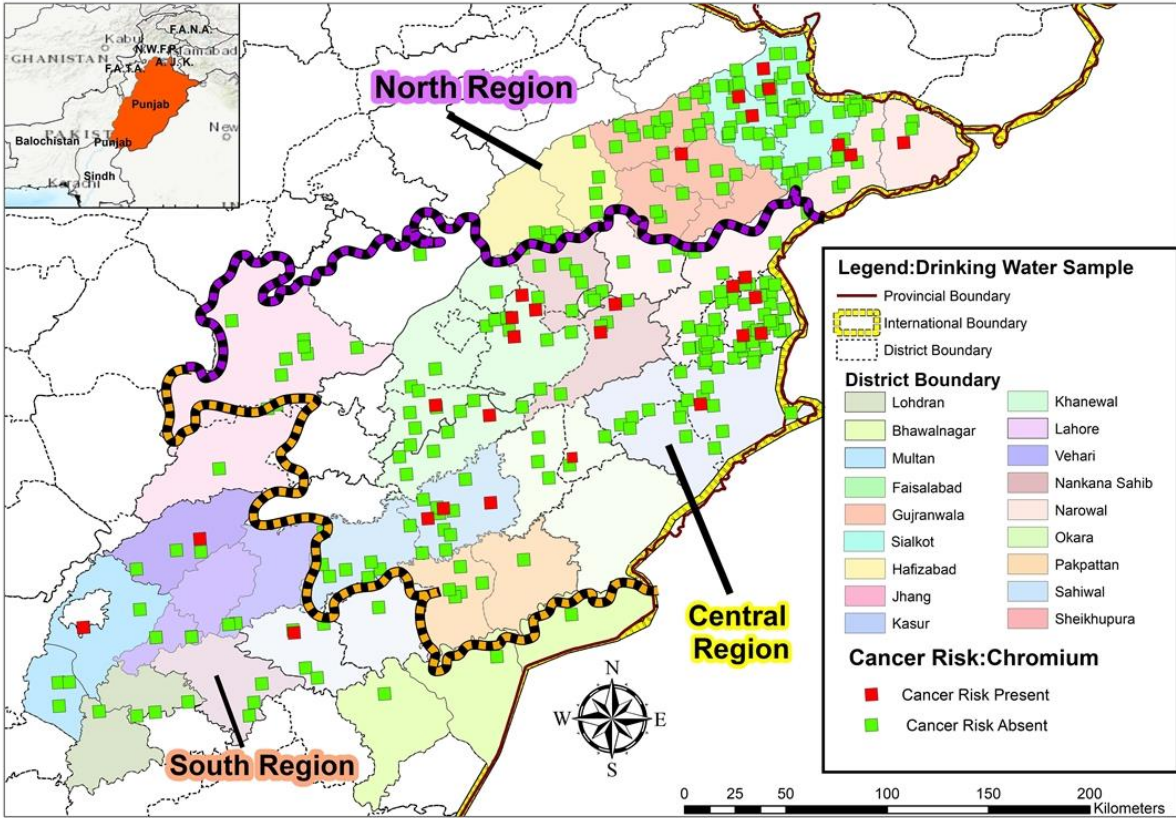


Fig 4.27 Cancer Risk of Cr

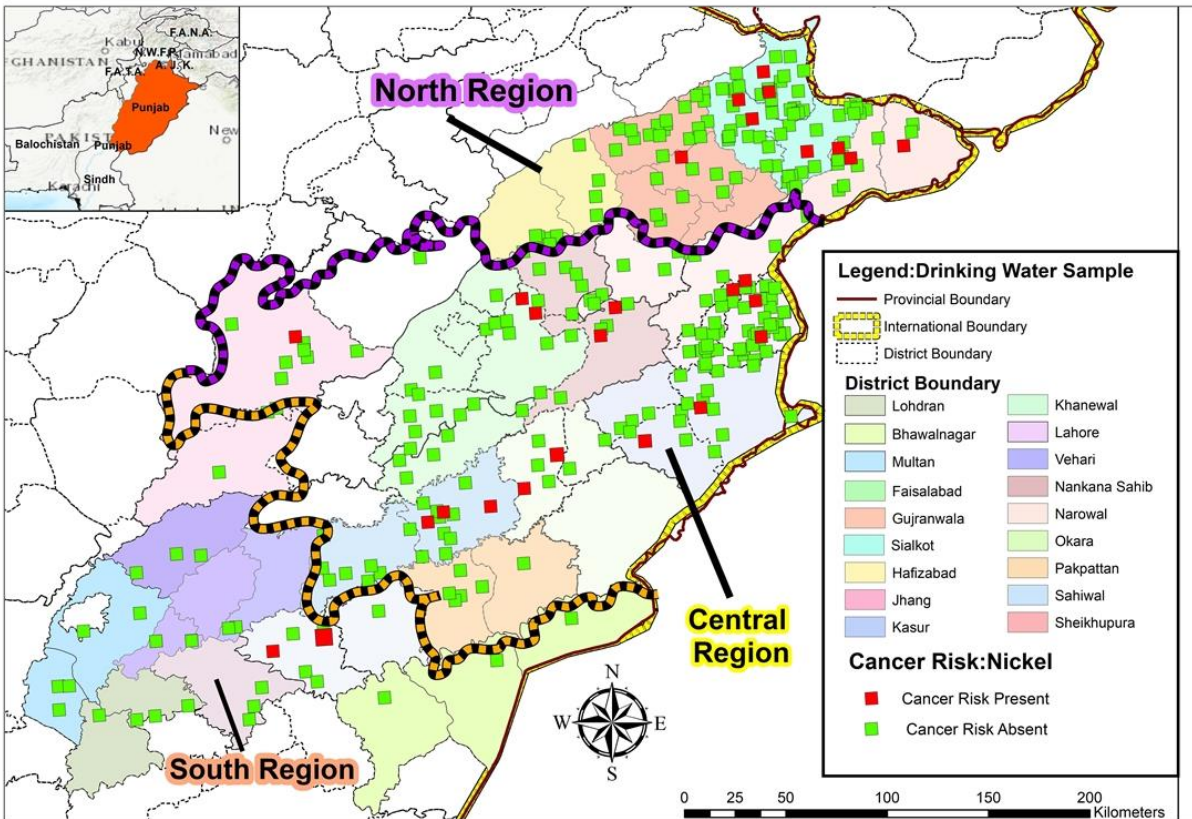


Fig 4.28 Cancer Risk of Ni

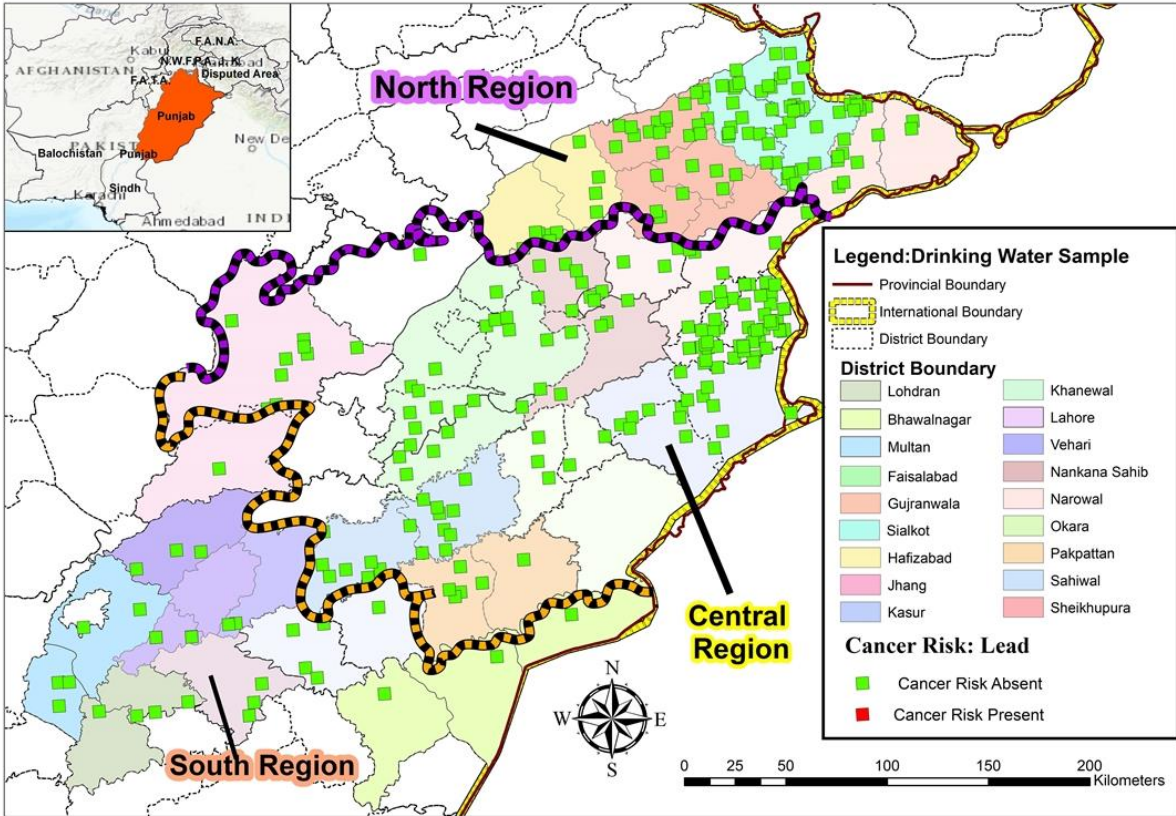


Fig 4.29 Cancer Risk of Pb

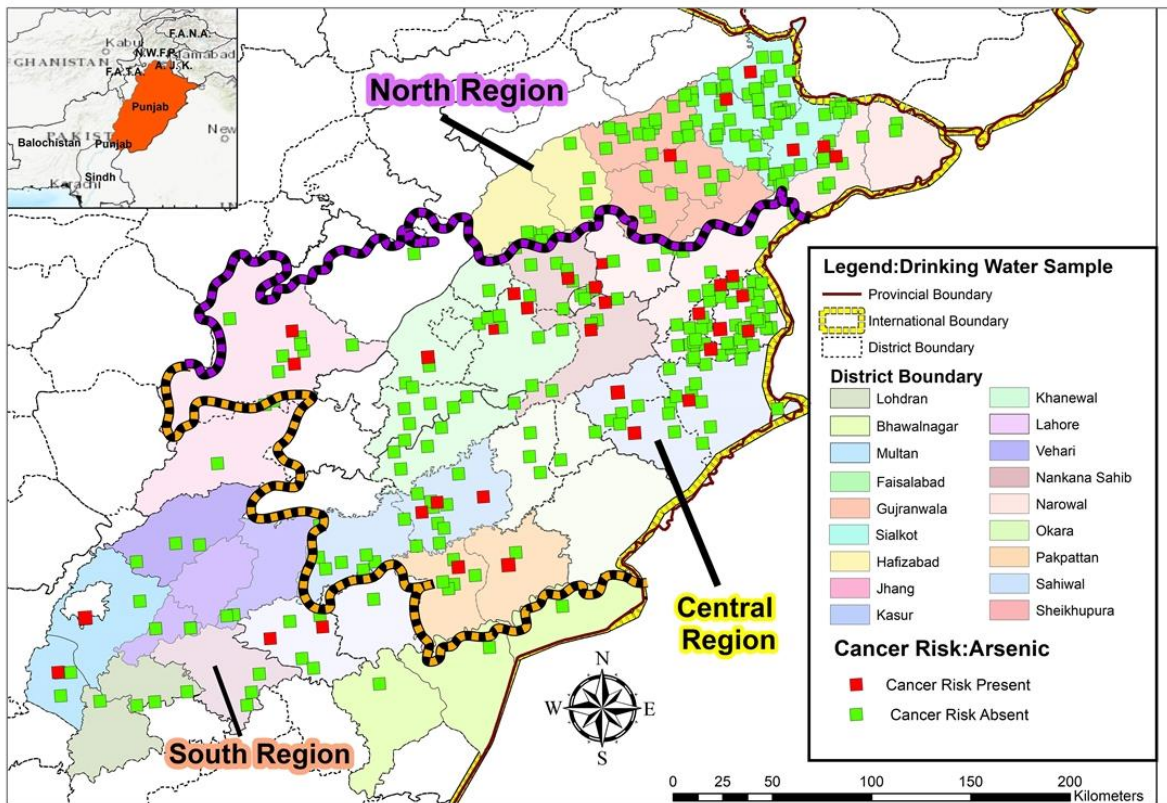


Fig 4.30 Cancer Risk of As

## 4.9 Questionnaire Survey

Children's health and wellbeing are significantly threatened by water-borne diseases on a global scale. Two types of questionnaire, Health Risk assessment (n=252) and Economic Valuation (WTP) (n=110), were administered to assess associated Health risks due to unsafe drinking water and the willingness of effecters to pay for the improvement of drinking water quality, respectively.

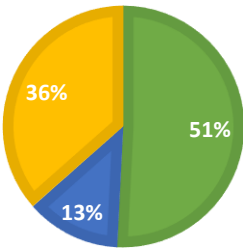
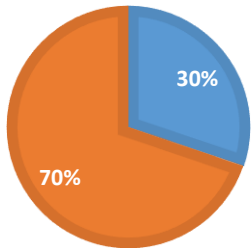
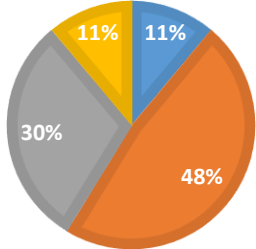
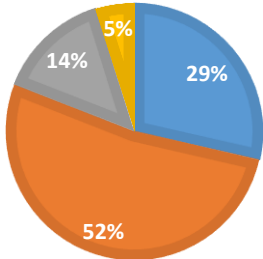
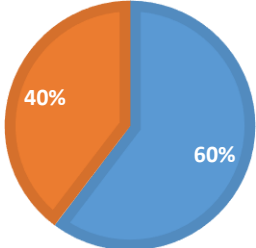
### 4.16 Health Risk Assessment of School Children

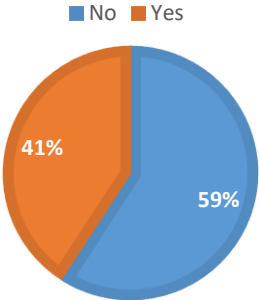
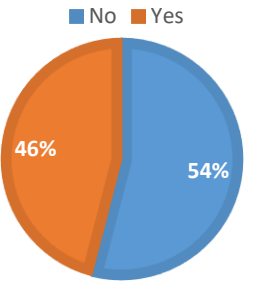
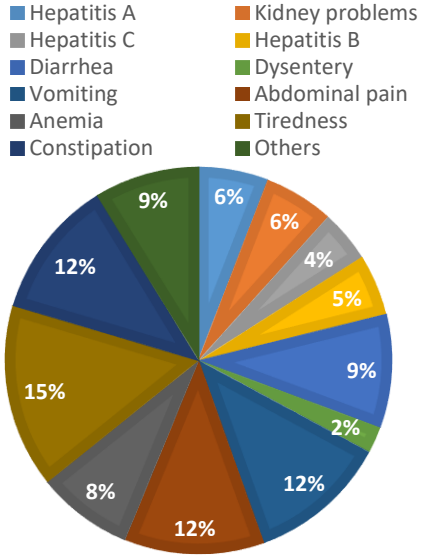
Section I: Demographic Information			
	Variable	Frequency	Percentage
<b>Gender</b>	Male	77	<p>■ Male ■ Female</p> <p>30.20 % 69.80 %</p>
	Female	175	
<b>Age (In years)</b>	4 to 7	48	<p>■ 4 to 7 ■ 8 to 10 ■ 11 to 16</p> <p>19% 47.60 % 33.30 %</p>
	8 to 10	120	
	11 to 16	84	
<b>Level of Education</b>	ECE	16	<p>■ ECE ■ Grade 1 ■ Grade 2 ■ Grade 3 ■ Grade 4 ■ Grade 5</p> <p>6% 16% 21% 24% 9% 24%</p>
	Grade 1	40	
	Grade 2	52	
	Grade 3	60	
	Grade 4	24	
	Grade 5	60	

<b>Weight (in kg)</b>	10-20	76	
	21-40	124	
	41-55	52	

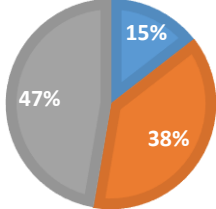
**Section II : Health Risk Assessment**

	<b>Variable</b>	<b>Frequency</b>	<b>Percentage</b>
<b>What is the primary source of drinking water in your kid's school?</b>	Govt water Hand Pump Other Water Pump	88 48 36 80	
<b>Do their school usually treat water before use?</b>	Yes No	112 140	
<b>Which method of treatment do their school usually use to make water safe to drink?</b>	Bleach/chlorine Boiling Others Solar-disinfection Water filter	12 28 52 12 148	
<b>Where do your kid store their drinking water?</b>	Metal bottle Others Plastic bottle Water bottle	64 12 88 88	

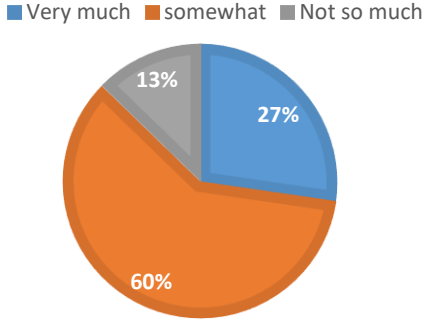
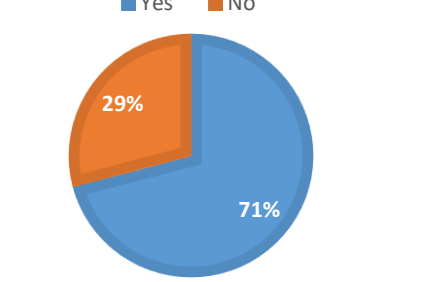
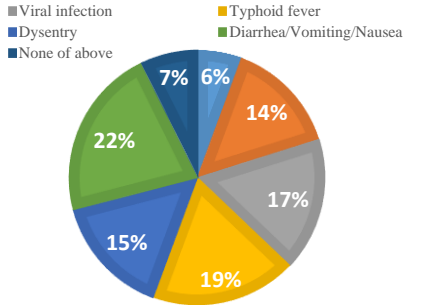
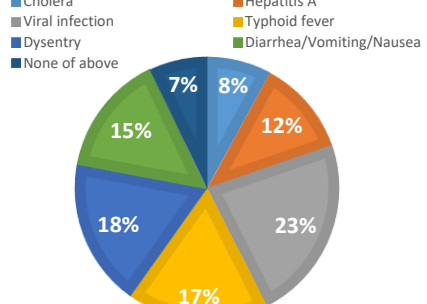
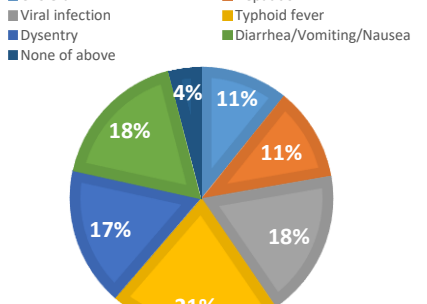
<p><b>How long does water stay in the storage container?</b></p>	<p>10 hrs 12 hrs 8 hrs</p>	<p>128 32 92</p>	 <p>Legend: 10 hrs (Green), 12 hrs (Blue), 8 hrs (Yellow)</p> <table border="1"> <thead> <tr> <th>Duration</th> <th>Percentage</th> </tr> </thead> <tbody> <tr> <td>10 hrs</td> <td>51%</td> </tr> <tr> <td>12 hrs</td> <td>13%</td> </tr> <tr> <td>8 hrs</td> <td>36%</td> </tr> </tbody> </table>	Duration	Percentage	10 hrs	51%	12 hrs	13%	8 hrs	36%		
Duration	Percentage												
10 hrs	51%												
12 hrs	13%												
8 hrs	36%												
<p><b>Are storage vessels covered?</b></p>	<p>No Yes</p>	<p>76 176</p>	 <p>Legend: No (Blue), Yes (Orange)</p> <table border="1"> <thead> <tr> <th>Coverage</th> <th>Percentage</th> </tr> </thead> <tbody> <tr> <td>No</td> <td>30%</td> </tr> <tr> <td>Yes</td> <td>70%</td> </tr> </tbody> </table>	Coverage	Percentage	No	30%	Yes	70%				
Coverage	Percentage												
No	30%												
Yes	70%												
<p><b>What do your kid uses to get the water from the storage container?</b></p>	<p>Pour directly Use cup with handle Use cup with no handle Others</p>	<p>120 76 28 28</p>	 <p>Legend: Others (Blue), Pour directly (Orange), Use cup with handle (Grey), Use cup with no handle (Yellow)</p> <table border="1"> <thead> <tr> <th>Method</th> <th>Percentage</th> </tr> </thead> <tbody> <tr> <td>Pour directly</td> <td>48%</td> </tr> <tr> <td>Use cup with handle</td> <td>30%</td> </tr> <tr> <td>Others</td> <td>11%</td> </tr> <tr> <td>Use cup with no handle</td> <td>11%</td> </tr> </tbody> </table>	Method	Percentage	Pour directly	48%	Use cup with handle	30%	Others	11%	Use cup with no handle	11%
Method	Percentage												
Pour directly	48%												
Use cup with handle	30%												
Others	11%												
Use cup with no handle	11%												
<p><b>What is your kid's Average daily intake of water?</b></p>	<p>1 litre 2 litre 3 litre More than 3</p>	<p>72 132 36 12</p>	 <p>Legend: 1 litre (Blue), 2 litre (Orange), 3 litre (Grey), More than 3 (Yellow)</p> <table border="1"> <thead> <tr> <th>Intake</th> <th>Percentage</th> </tr> </thead> <tbody> <tr> <td>2 litre</td> <td>52%</td> </tr> <tr> <td>1 litre</td> <td>29%</td> </tr> <tr> <td>3 litre</td> <td>14%</td> </tr> <tr> <td>More than 3</td> <td>5%</td> </tr> </tbody> </table>	Intake	Percentage	2 litre	52%	1 litre	29%	3 litre	14%	More than 3	5%
Intake	Percentage												
2 litre	52%												
1 litre	29%												
3 litre	14%												
More than 3	5%												
<p><b>Do you think that your kid can get sick from the school drinking water intake?</b></p>	<p>Yes No</p>	<p>152 100</p>	 <p>Legend: Yes (Blue), No (Orange)</p> <table border="1"> <thead> <tr> <th>Opinion</th> <th>Percentage</th> </tr> </thead> <tbody> <tr> <td>Yes</td> <td>60%</td> </tr> <tr> <td>No</td> <td>40%</td> </tr> </tbody> </table>	Opinion	Percentage	Yes	60%	No	40%				
Opinion	Percentage												
Yes	60%												
No	40%												

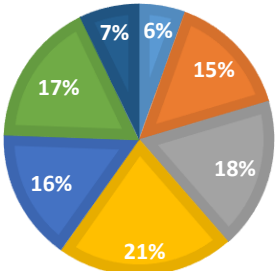
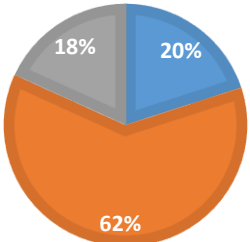
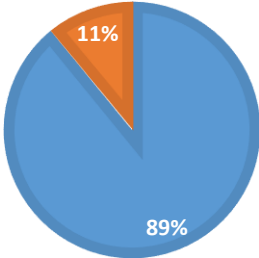
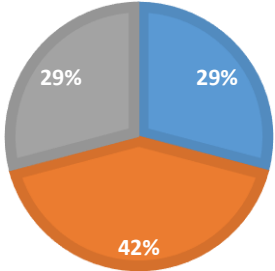
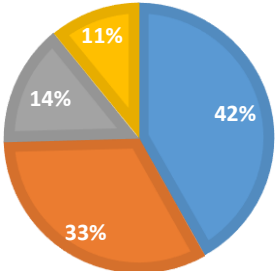
<b>Are you satisfied with the quality of water your kid uses?</b>	Yes	103	
	No	149	
<b>Do your kid knows what water-borne diseases are?</b>	Yes	116	
	No	136	
<b>Do your kid have any following illness? (you can choose more than one)</b>	Hepatitis A	32	
	Kidney problems	32	
	Hepatitis C	24	
	Hepatitis B	28	
	Diarrhea	52	
	Dysentery	12	
	Vomiting	64	
	Abdominal pain	64	
	Anemia	44	
	Tiredness	84	
	Constipation	64	
	Others	48	

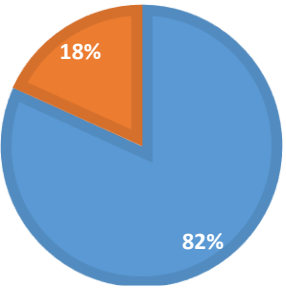
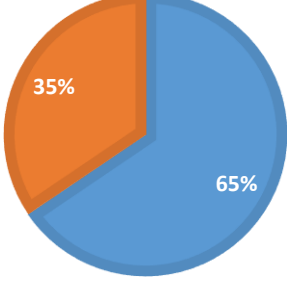
#### 4.17: Economic Valuation (Willingness of Schools to pay for improving drinking water quality)

Section I : Demographic Information			
	Variable	Frequency	Percentage
<b>Age</b>	20-30	16	
	31-40	42	
	41 and above	52	

<b>Gender</b>	Male Female	78 32	<p>■ Male ■ Female</p> <p>71% 29%</p>
<b>Education</b>	Intermediate Graduation Post graduation	12 50 48	<p>■ Intermediate ■ Graduation ■ Post graduation</p> <p>44% 45% 11%</p>
<b>Income (PKR)</b>	Less than 50,000 51,000 to 1 lac More than 1 lac	18 54 38	<p>■ Less than 50,000 ■ 51,000 to 1 lac ■ More than 1 lac</p> <p>16% 49% 35%</p>
<b>Occupation</b>	Principal Headmaster/ mistress others	63 40 7	<p>■ Principal ■ Headmaster/mistress ■ others</p> <p>57% 36% 7%</p>
<b>Section II : WTP for improving water quality</b>			
<b>Does water pollution physically bothers your students?</b>	Very much Sometimes Rarely Never	22 62 12 14	<p>■ Very much ■ Sometimes ■ Rarely ■ Never</p> <p>20% 56% 13% 11%</p>

<p><b>Do your students concerned with the effects of water pollution on health?</b></p>	<p>Very much somewhat Not so much</p>	<p>30 66 14</p>	 <p>■ Very much ■ somewhat ■ Not so much</p>
<p><b>Do your students know about waterborne diseases?</b></p>	<p>Yes No</p>	<p>78 32</p>	 <p>■ Yes ■ No</p>
<p><b>To become familiar with the health status of your School, could you tell us if you have ever had or have?</b></p>	<p>Cholera Hepatitis A Viral infection Typhoid fever Dysentery Diarrhea/Vomiting/Nausea None of above</p>	<p>14 36 42 46 38 54 18</p>	 <p>■ Cholera ■ Hepatitis A ■ Viral infection ■ Typhoid fever ■ Dysentery ■ Diarrhea/Vomiting/Nausea ■ None of above</p>
<p><b>To become familiar with the health status of your School, could you tell us if your faculty have ever had or have?</b></p>	<p>Cholera Hepatitis A Viral infection Typhoid fever Dysentery Diarrhea/Vomiting/Nausea None of above</p>	<p>20 30 58 44 46 38 18</p>	 <p>■ Cholera ■ Hepatitis A ■ Viral infection ■ Typhoid fever ■ Dysentery ■ Diarrhea/Vomiting/Nausea ■ None of above</p>
<p><b>To become familiar with the health status of your School, could you tell us if janitor staff have ever had or have?</b></p>	<p>Cholera Hepatitis A Viral infection Typhoid fever Dysentery Diarrhea/Vomiting/Nausea None of above</p>	<p>32 34 54 62 44 52 12</p>	 <p>■ Cholera ■ Hepatitis A ■ Viral infection ■ Typhoid fever ■ Dysentery ■ Diarrhea/Vomiting/Nausea ■ None of above</p>

<p><b>To become familiar with the health status of your School, could you tell us if your students have ever had or have?</b></p>	<p>Cholera Hepatitis A Viral infection Typhoid fever Dysentery Diarrhea/Vomiting/Nausea None of above</p>	<p>14 38 46 54 40 44 18</p>	 <p> <span style="color: blue;">■</span> Cholera  <span style="color: grey;">■</span> Viral infection  <span style="color: blue;">■</span> Dysentery  <span style="color: blue;">■</span> None of above  <span style="color: orange;">■</span> Hepatitis A  <span style="color: yellow;">■</span> Typhoid fever  <span style="color: green;">■</span> Diarrhea/Vomiting/Nausea </p>
<p><b>Do you think your students are in?</b></p>	<p>Good health Average Health Poor Health</p>	<p>22 68 20</p>	 <p> <span style="color: blue;">■</span> Good health  <span style="color: orange;">■</span> Average Health  <span style="color: grey;">■</span> Poor Health </p>
<p><b>Are you willing to pay for safe drinking water to improve the health of your students?</b></p>	<p>Yes No</p>	<p>98 12</p>	 <p> <span style="color: blue;">■</span> Yes  <span style="color: orange;">■</span> No </p>
<p><b>If yes, to whom your school prefer</b></p>	<p>Private organization Public organization Public private partnership</p>	<p>32 46 32</p>	 <p> <span style="color: blue;">■</span> Private organization  <span style="color: orange;">■</span> Public organization  <span style="color: grey;">■</span> Public private partnership </p>
<p><b>What is your schools combined willingness to pay (per month) in order to get clean drinking water?</b></p>	<p>PKR 100-1000 (\$ 1.75) PKR1100-2000 (\$ 4.5) PKR 2100-3000 (\$ 8) PKR 3100 and above (\$ 10)</p>	<p>46 36 16 12</p>	 <p> <span style="color: blue;">■</span> 100-1000 Rs.  <span style="color: orange;">■</span> 1100-2000 Rs.  <span style="color: grey;">■</span> 2100-3000 Rs.  <span style="color: yellow;">■</span> 3100 Rs. and above </p>

<p><b>Do you think by making the payment you can prove your schools drinking water quality?</b></p>	<p>Yes No</p>	<p>90 20</p>	 <p>■ Yes ■ No</p> <p>82% 18%</p>
<p><b>Do you think the amount you are willing to contribute is going to be a financial burden on your school?</b></p>	<p>Yes No</p>	<p>72 38</p>	 <p>■ Yes ■ No</p> <p>65% 35%</p>

**4.18: Linear Regression of WTP and other factors**

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	0.532	0.58		0.918	0.361
	Gender	0.465	0.199	0.212	2.336	0.021
	Education	0.272	0.159	0.193	1.753	0.041
	Income	0.62	0.157	0.428	3.956	0
	Occupation	-0.199	0.151	-0.122	-1.321	0.189

<sup>a</sup> Dependent Variable: School's combined willingness to pay per month

**4.19: Economic Valuation of schools for improved drinking water quality using  
Contingent Valuation Method (CVM)**

The linear regression model for WTP (Y) is represented as: $Y = \beta_0 + \beta_1 * \text{Gender} + \beta_2 * \text{Education} + \beta_3 * \text{Income} + \beta_4 * \text{Occupation}$	
$\beta_0$ (Constant) = 0.532 $\beta_1$ (Gender) = 0.465 $\beta_2$ (Education) = 0.270 $\beta_3$ (Income) = 0.62 $\beta_4$ (Occupation) = -0.199	X1 (Gender) =1.29 X2 (Education) =2.32 X3 (Income) =2.1 X4 (Occupation) =1.49
$Y = \beta_0 + \beta_1 \times X_1 + \beta_2 \times X_2 + \beta_3 \times X_3 + \beta_4 \times X_4$	
$Y = 0.532 + 0.465 \times 1.29 + 0.270 \times 2.32 + 0.62 \times 2.18 - 0.199 \times 1.49$	
$Y = 0.532 + 0.60 + 0.62 + 1.35 - (-0.29651)$	
$Y = \$ 3.406 = \text{PKR } 971.69$ (per month)	

**4.20: Pearson's Chi Square and Cramer's V test**

Pearson's Chi Square				
Study Area	Pearson's Chi Square	Value	df	Asymp. Sig. (2-sided)
Rural Punjab		20.491a	6	0.002
Cramer's V test				
Study Area	Cramer's V test	Value	Asymp. Sig. (2-sided)	
Rural Punjab		0.305	0.002	

**4.21: Analysis of Variance (ANOVA)**

ANOVA						
		Sum of Squares	df	Mean Square	F	Sig.
Gender	Between Groups	1.455	1	1.455	1.452	0.231
	Within Groups	108.218	108	1.002		
	Total	109.673	109			
Education	Between Groups	5.836	2	3.418	3.42	0.021
	Within Groups	106.837	107	0.998		
	Total	109.673	109			

<b>Income</b>	Between Groups	16.261	2	8.131	9.313	0.000
	Within Groups	93.411	107	0.873		
	Total	109.673	109			
<b>Occupation</b>	Between Groups	6.731	2	3.366	3.498	0.034
	Within Groups	102.941	107	0.962		
	Total	109.673	109			
<sup>A</sup> Schools combines willingness to pay per month						

#### 4.22: Correlations between WTP and other factors

		<b>Gender</b>	<b>Education</b>	<b>Income</b>	<b>Occupation</b>	<b>Schools combined WTP</b>
<b>Gender</b>	Pearson Correlation	1				
<b>Education</b>	Pearson Correlation	-.256**	1			
<b>Income</b>	Pearson Correlation	-.227*	.546**	1		
<b>Occupation</b>	Pearson Correlation	0.14	-.216*	-.339**	1	
<b>Schools combined WTP</b>	Pearson Correlation	0.115	0.137	.384**	-.223*	1
** Correlation is significant at the 0.01 level (2-tailed)						
* Correlation is significant at the 0.05 level (2-tailed)						

## CHAPTER V

### DISCUSSION

Water quality is directly linked to public health. Colour and odour in drinking water samples are important indicators of water quality, and can be used to visually assess the presence of impurities, contaminants, or other issues that can affect the safety and palatability of the water [86]. The WHO provides guidelines and recommendations for acceptable levels of colour and odour in drinking water. According to these guidelines water should be "colourless" with "unpleasant odour" [87]. Results revealed that the majority of water samples from northern, central and southern rural Punjab primary schools were "acceptable" in both colour and odour terms. Overall 4.3% and 11.6% samples had objectionable colour and odour. This is generally a positive sign as it suggests that a significant portion of the water supply in these areas meets the basic criteria. "Objectionable" colour and odour were observed in Gujranwala and Sialkot from Northern, Faisalabad and Lahore from central and Lodhran and Vehari from Southern region of rural Punjab. Similar results were reported in a study conducted in Chattogram city of Bangladesh, which showed 56% of the respondents reported unpleasant smell and odour due to the presence of impurities in drinking water [88]. Another study reported 12% modification in colour and odour of ground water in Vehari, Pakistan due to the contact of organic matter with drinking water [89]. This is a concerning finding as it indicates the presence of impurities or contaminants in the water. The presence of objectionable colour and odour can be due to various factors such as the presence of organic matter, minerals, or chemical pollutants.

The pH of drinking water is an important parameter as it can affect the taste, safety, and overall quality of the water. WHO recommends a pH range of 6.5 to 8.5 for drinking water to ensure it is safe and potable. The pH levels in these rural primary schools drinking water samples was generally within the WHO-recommended range, but there were some exceptions. The overall mean pH value of rural Punjab was close to neutral (pH 7), which is considered ideal for drinking water as it neither tastes too acidic nor too alkaline. Similar results were reported in a study conducted in Punjab, which showed a mean pH of 7.59 [90]. Sialkot (8.23) and Faisalabad (7.82) reported maximum pH values. This could be a concern as excessively high pH levels can lead to a bitter taste and may indicate the presence of alkaline substances in the water. Both of these cities are famous for their industrial activities and considered as the

industrial hub of Punjab. On the other hand, there are instances of low pH values  $<6.5$ , notably in Sahiwal, Lahore, Gujranwala, Sialkot, Kasur, Jhang and Faisalabad, with mean average pH of  $6.71 \pm 0.30$ ,  $7.02 \pm 0.32$ ,  $6.92 \pm 0.31$ ,  $6.97 \pm 0.40$ ,  $6.97 \pm 0.36$ ,  $6.98 \pm 0.30$  and  $7.01 \pm 0.34$ . Low pH can make the water acidic, which might be unpleasant to taste. It can accelerate the solubility and leaching of heavy metals. When acidic groundwater is used for irrigation, it can contribute to soil acidification over time, affecting crop health and productivity [91]. The northern Punjab region exhibited pH values within the WHO recommended range. However, the maximum industrial activities of Sialkot was an outlier with a minimum pH of 5.55 and a maximum pH of 8.23, followed by Gujranwala with minimum pH of 6.92, and Vehari with maximum pH of 7.52, indicates significant pH variability within this region. The Central region showed a relatively consistent mean pH, close to 7. However, there is significant variability within this region, as few samples of Sahiwal, Faisalabad, Jhang, Kasur, Sheikhpura and Lahore were lower acidic than the recommended range of WHO guidelines i.e  $<6.5$ . Agriculture is prevalent in this region, which can contribute to variations in pH due to pesticide and fertilizer usage [92]. The southern region maintained pH values within the WHO-recommended range (6.5-8.5). However, Multan, had the highest mean pH of  $7.26 \pm 0.12$  followed by Khanewal ( $7.14 \pm 0.24$ ), Vehari ( $7.11 \pm 0.35$ ) and Lodhran ( $6.98 \pm 0.17$ ). Similar study in southern Punjab reported that pH of ground water was slightly acidic to alkaline with 97% samples were within the WHO's recommended guidelines [93].

Electrical conductivity (EC) measures the water's ability to conduct an electrical current, primarily due to the presence of dissolved ions and minerals. WHO guidelines recommends conductivity of  $<1500$  uS/cm for drinking water [94]. Water with high electrical conductivity may taste salty or unpleasant. Results showed that, overall 15% of samples had conductivity above than 1500 uS/cm, while 85% of samples had EC less than 1500 uS/cm. As groundwater is the source of drinking water in Punjab, Pakistan, it often has higher conductivity due to natural mineral content and industrial or agricultural factors. Another study reported 26% of samples with EC greater than WHO recommended range in groundwater of Aurangabad, India due to application of fertilizer for agricultural activities [95]. The mean EC of northern region values ranged from  $863.6 \pm 279.84$  (Hafiz-Abad) to  $1017 \pm 355.34$  (Narowal). Gujranwala ( $908.04 \pm 392.6$ ) and Sialkot ( $946.10 \pm 470.4$ ) had the maximum EC of 1662 uS/cm and 2000 uS/cm. Gujranwala and Sialkot are primarily industrial cities, they are also located in agricultural regions. The use of fertilizers and pesticides in agriculture can result in runoff containing ions and minerals, contributing to higher conductivity in water sources [96]. The

central region exhibited a broad range of EC values. The high mean value in Okara  $1813.50 \pm 415.67$  was followed by Pakpattan ( $1530.60 \pm 454.72$ ) and Kasur ( $1553 \pm 540.19$ ) which suggests that industrial activities or other factors may be influencing water quality. While other cities, like Nankanasahib, Faisalabad and Sahiwal and Jhang, Sheikhpura and Lahore, had mean EC values within the recommended range of WHO. All the cities of Southern region had the mean EC values of Bhawal-nagar ( $717 \pm 368.57$ ), Lodhran ( $875.25 \pm 234.68$ ), Multan ( $705 \pm 203.76$ ), Vehari ( $1018 \pm 517$ ) and Khanewal ( $1145 \pm 498.26$ ), were within the recommended range. The highest value in this region is 2000 uS/cm in Multan. Another similar study in multan reported hazardous electrical conductivity of 4700 uS/cm in groundwater samples due to the contaminated municipal, commercial and industrial discharges to the groundwater [97].

High TSS levels (silt, clay and organic matter) can make water appear cloudy or turbid, which can affect its aesthetic quality while elevated TDS (metals, ions) levels can affect the taste, odour, and suitability of water. For drinking water, WHO recommended that TDS levels should be less than 1000 mg/L. WHO does not specify a specific limit for TSS in drinking water. Results found that 11% of samples had TDS above the recommended range of WHO [98]. The central region had overall higher TSS and TDS levels than northern and southern regions. At northern, central and southern region TSS was ranged between 0.25-155 mg/L, 0.3-126.5 mg/L and 0.15-108 mg/L, respectively, while TDS was ranged between 119-1267 mg/L, 55-1988 mg/L and 235-1232 mg/L, respectively. Northern region had the TDS level within the permissible levels with the maximum level of 767 mg/L while mean TSS level was  $46.54 \text{ mg/L} \pm 55.11$  for Narowal. the topography and geology of these areas may result in less sedimentation in water sources. At central region, Nankanasahib had relatively high TSS levels with a mean of  $82.71 \text{ mg/L} \pm 37.39$  followed by Faisalabad, Pakpattan, Okara, Sahiwal, Kasur, Lahore and Sheikhpura. Similar results have been reported in a study conducted by Farah D et al. which showed that mean TSS level in drinking water of Sheikhpura were closed 0 mg/L[99]. Mean TDS levels of Okara, Kasur and Sheikhpura were greater than the WHO recommended level (1035 to 1254 mg/L) . At Southern region, Vehari had the maximum TDS of 1232 mg/L while rest all the samples had TDS <1000mg/L. Similarly, another study in Vehari had maximum TDS level of 1151.82 mg/L due to the presence of aggregate quantity of salt anions and metal cations in water [100]. TSS were relatively lower in southern regions with mean of  $15.31 \text{ mg/L} \pm 18.27$ ,  $13.5 \text{ mg/L} \pm 11.77$ ,  $20.47 \text{ mg/L} \pm 21.84$ ,  $1.78 \text{ mg/L} \pm 2.25$ ,  $12.76 \text{ mg/L} \pm 11.47$  for Bhawalnagar, Lodhran, Multan, Vehari and Khanewal, respectively.

Turbidity and Dissolved Oxygen (DO) are significant parameter in assessing the suitability of drinking water. WHO recommends a minimum DO concentration of 5 mg/L [101]. Results showed that DO levels were within or close to the WHO-recommended range, indicating acceptable water quality in terms of oxygen content. Sothern Punjab had relatively low DO levels as compared to northern and central Punjab. The minimum concentration of DO for Khanewal, Multan and Vehari was between 3.06 to 4.28 mg/L. Rest all the cities maintained DO levels well within the recommended range (>5 mg/L). Mean average DO ranged between 5.18 mg/L  $\pm$  0.71 to 6.59 mg/L  $\pm$  0.87 for Multan and Sahiwal. WHO recommends turbidity levels of less than 5 NTU (Nephelometric Turbidity Units) for safe drinking water. Results showed that overall turbidity was ranged between 0.2-8.66 NTU. A similar study reported turbidity level of 0.5-9 NTU in drinking water of educational institutes of Bangladesh. High turbidity can affect the appearance and taste of water and may indicate the presence of contaminants [102]. Cities like Gujranwala and Jhang, exhibited maximum turbidity levels of 6.64 and 8.66 NTU, respectively, exceeding the WHO guidelines for drinking water. The overall mean turbidity was ranged 0.39  $\pm$  0.23 to 1.67  $\pm$  1.89. The variations in DO and turbidity levels in drinking water of rural Punjab can be attributed to a combination of factors, including pollution, sedimentation and treatment processes [103]

Calcium and Magnesium are essential minerals for human health, contributing to bone strength, blood clotting, and muscle function. High levels of calcium and magnesium in water are a major component of water hardness [104]. The WHO has not established specific numerical limits for calcium and magnesium for drinking water [85]. Results showed central region had the highest concentration of calcium and magnesium followed by northern region and southern region. The values of calcium and magnesium ranged between 16.03 to 216.43 and 5.82 to 78.63 mg/L for Northern Punjab. Central Punjab samples ranged between 16.03 to 444.89 and 7.28 to 161.62 mg/L for calcium and magnesium. While lower concentration of calcium and magnesium, ranged from 28.06 to 160.32 and 10.19 to 58.24 mg/L, was observed at southern Punjab. Similarly, Another study in southern region reported calcium and magnesium concentration from 7.1 to 115 mg/L and 4.55 to 40.7 mg/L, respectively [105]. Carbonates and Bicarbonates influence the pH of water, contribute to water hardness and can affect water quality. Mean concentration of carbonates ranged between 1.8 to 28.04, 1.56 to 3.60 and 2 to 86.25 meq/L for northern, central, southern Punjab regions. While bicarbonates ions ranged between 1 to 138, 0 to 64 and 0 to 319 meq/L. The concentration of carbonates and bicarbonates ions was higher in southern regions as compared to northern and central region of study area.

The presence of limestone and dolomite geological formations in the areas leads to the leaching of these ions into the groundwater. Regions geological characteristics also play an important role [106].

Sodium and potassium play essential roles in maintaining electrolyte balance in the body, influencing nerve function, muscle contractions, and overall health [107]. The WHO do not have any specific guidelines for acceptable level of sodium and potassium for drinking water [85]. Overall concentration of sodium ranged between 0 to 2820 mg/L in the study area, Okara had the highest sodium concentration. The data revealed a significant degree of variability in sodium levels among different cities or regions. At Northern region, mean sodium concentration was ranged between 66.03 mg/L in Sialkot to 87.22 mg/L in Hafizabad. At central region, Okara had the highest mean sodium concentration (674.74 mg/l), while Sahiwal had the lowest (48.62 mg/l). At southern region, the mean concentrations ranged from approximately 52 mg/L in Lodhran to 110 mg/L in Khanewal. Overall central region had the highest sodium concentration followed by southern and northern regions of Punjab. High concentrations of sodium in drinking water can contribute to hypertension (high blood pressure) and increase the risk of cardiovascular diseases. High potassium levels, if extremely elevated, can lead to hyperkalemia, potentially causing muscle weakness and heart rhythm disturbances [108].

Kasur (central region) had the highest mean potassium concentration (51.70 mg/L) followed by Sialkot (15.63 mg/L) (northern region) and Lodhran (9.62 mg/L) (southern region). Central Punjab is known for its extensive agricultural activities. Water used for irrigation, interacts with the soil, and the process of irrigation can lead to the leaching of sodium and potassium from the soil into the groundwater. Additionally, the use of sodium-containing fertilizers can contribute to higher sodium and potassium levels in the soil and, subsequently, in the groundwater. Similarly, the central region of Punjab, Pakistan, often experiences arid or semi-arid conditions with limited rainfall. In such climates, there may be reduced flushing of minerals from the soil and rock layers, allowing sodium and potassium ions to accumulate in groundwater over time [109].

Monitoring chloride levels in water is essential, as high concentrations can impact both environmental ecosystems and the suitability of water for drinking and agricultural purposes [110]. Highest mean chloride concentration (mg/L) ranged between  $322.69 \pm 180.39$  to  $510.61 \pm 362.99$ . Results revealed that overall 29.50 % of the samples had chloride concentration above the permissible limit of WHO for drinking water ( $<250$  mg/L). Another

study in Punjab revealed 28% samples had Chloride concentration above than the WHO proposed standard limit [111]. The northern region had the highest number of samples that exceeded the standard limits (250 mg/L). Hafizabad had the highest maximum level of 957.42 mg/L. The central region presents a wide spectrum of chloride levels, with an average ranging from  $219.80 \pm 91.63$  in Lahore to  $510.61 \pm 362.99$  in Pakpattan. These variations can be attributed to a combination of factors, groundwater contamination and local industrial and agricultural activities. The maximum chloride levels in this region range from 319.14 to 496.44, indicating potential localized sources of contamination or variations in water sources. On the other hand, the minimum chloride levels vary from 35.46 to 177.3, reflecting a range of local geological conditions and land use practices. The mean chloride levels in this region ranged from  $177.3 \pm 194.22$  to  $230.49 \pm 129.9$  for Lodhran and Khanewal, suggesting an overall moderate chloride content in the drinking water. Chloride ions can originate from various sources, including natural geological processes, industrial discharges, and agricultural runoff [112].

Total hardness as  $\text{CaCO}_3$  is a measure of the concentration of calcium and magnesium ions in drinking water. WHO guidelines recommend hardness limit of 500 mg/L for drinking water [113]. Total hardness of the samples was within the ranges of 100 mg/L (Lahore) to 3580 mg/L (Jhang) as  $\text{CaCO}_3$ . The average concentration of hardness in all three regions (north, central and south) were remained within the standard limit, except for Jhang ( $818.00 \pm 1066.45$ ). Areas with intensive agriculture and industrial activities might see higher levels of water hardness due to the leaching and discharge of minerals into the water [114]. Overall 16% of the samples had hardness above the permissible limit. Results revealed that 32.65% of the samples from northern region, 4.76% from central region and 17.24% from southern region had the hardness beyond the WHO recommended limit. Similar study in India reported 16% of the filtered water samples with calcium hardness more than the desirable limits due to geological formations and the presence of calcium and magnesium-rich minerals in the groundwater [114]. Consuming hard water is generally safe and not associated with direct health risks. In fact, it contains essential minerals like calcium and magnesium, which can be beneficial for human dietary intake. However, hard water can lead to inconveniences such as reduced soap effectiveness, potential skin and hair dryness and scale buildup in appliances and plumbing, which can increase maintenance costs and reduce their efficiency over time [114].

Flouride ( $\text{F}^-$ ) content of the water samples ranged from 0.04 to 3.37mg/L, and 12.04% of drinking water samples contained high-level fluoride concentration ( $\text{F}^- > 1.5$  mg/L), which

exceeds the WHO Guidelines for drinking water quality. Overall southern region (24.14%) had the highest number of samples exceeding WHO guidelines followed by central (13.61%) and northern region (6.12%). The presence of excessive fluoride in drinking water can have adverse health effects, including dental and skeletal fluorosis. The geological composition of the Earth's crust in Punjab, contains minerals that naturally release fluoride ions into the groundwater. Fluoride can be naturally present in rocks and minerals. When groundwater comes into contact with these minerals, it can dissolve fluoride ions, leading to elevated fluoride concentrations [115].

The concentrations of  $\text{NO}_3^-$  in drinking water varied from 10.74 to 97.46 mg/L. Overall 16.42% of samples had nitrate concentration exceeding the WHO guidelines for drinking-water quality (50 mg/L). The high percentage of nitrates (>50 mg/L) found in the southern region (27.59%), followed by northern (19.39%) and central region (12.24) can be due to various human-caused factors, including leaks from septic systems, the use of nitrogen-rich fertilizers, and waste from households, farming operations, and livestock in groundwater. A study in India found high concentration of nitrate in drinking water of rural areas as compared to urban [116] Another study in Iran found that 14.5% of the samples exceeded the standard limit in rural areas. Fertilizer use is common in the area, resulting in high  $\text{NO}_3^-$  levels in the groundwater, Nitrogen-rich sediments, organic nitrogen inputs into soil, groundwater contamination with nitrogen-rich wastes, biological denitrogenating fixation by microorganisms, animal and human waste, water in unutilized dug wells, nitrogenous inorganic fertilizers, and stagnant water are the common sources of  $\text{NO}_3^-$  in groundwater [117]. Agriculture is also one of the primary activities in the research area, and has been established that many applied agrochemicals permeate the soil and reach groundwater. As a result, the amount of  $\text{NO}_3^-$  in groundwater is likely to rise. The high  $\text{NO}_3^-$  level in the groundwater is caused by agricultural activities in the study area's southern, northern, and central regions [116,117].

Rural Punjab is predominantly an agricultural region. The use of fertilizers, pesticides, and herbicides in agriculture can lead to the contamination of groundwater. Some of these chemicals contain Cr and Ni, and their runoff or percolation into the groundwater can increase the metal concentrations [118]. In all the cities, the mean concentration (mg/l) Chromium in drinking water are well below the WHO limit of 0.05 mg/l. Overall 7% of samples had Cr concentration above than the safe limits of WHO. At northern region, maximum Cr concentration ranged from 0.048 in Hafizabad to 2.00 mg/L in Gujranwala. Most of the central cities had relatively low to moderate concentration of Cr contamination in their drinking water,

with mean concentrations generally in the range of  $0.006 \pm 0.0029$  to  $0.021 \pm 0.0289$  mg/l (within the safe limits). However, Lahore, Sahiwal and Sheikhpura exhibited the maximum Cr concentration of 0.098, 0.076 and 0.063 mg/l, At Southern region, Vehari had the maximum concentration 0.067 mg/l. Mean concentration was ranged  $0.0064 \pm 0.0044$  in Lodhran to  $0.035 \pm 0.034$  in Khanewal. Average concentration of Ni in drinking water was well below the WHO limit of 0.02 mg/L ( $0.004 \pm 0.0167$  to  $0.014 \pm 0.01$  mg/L). Results of this study align to the Afzal M et al., in which contaminated level of chromium was present in groundwater of Kasur ( $>0.02$  mg/L) due to industrial effluents [119]. Overall 92% of samples had Ni concentration within the permissible limit of WHO  $<0.02$  mg/L, while 8% of samples were contaminated with higher Ni concentration. Lahore and Sahiwal had the highest Ni concentration of 0.065 and 0.062 mg/l. While lowest concentration was found between 0.0076 mg/l in Lodhran to 0.012 mg/l Pakpattan. Another study extended the findings with high concentration of Cr and Ni, 2593 and 1306 ng/g, respectively, in various cities of Punjab, Pakistan, which were higher than the permissible limits suggested by the WHO [120].

In many rural areas, the water distribution systems and pipes are old and may contain lead components or lead solder. When water comes into contact with these materials, lead can leach into the drinking water [121]. Results showed that lead in all samples had concentration within the permissible level of 0.01 mg/L except for two specific samples from Sahiwal (0.12 mg/L) and Vehari (0.022 mg/L) due to old age-pipes that can leach lead into the water supply. Lead in drinking water can have significant harmful impacts on human health, including neurological effects, behavioral and cognitive issues, kidney damage, cardiovascular problems and reproductive complications, gastrointestinal distress, anemia, developmental delays in children, and behavioral changes in adults. These health risks are more pronounced in children and pregnant women, making it crucial to monitor and address lead contamination in drinking water to ensure safety [122].

Arsenic is a naturally occurring element found in rocks, soil, and groundwater. When the groundwater interacts with arsenic-rich geological formations, it can lead to elevated arsenic levels in drinking water sources. Prolonged exposure to arsenic-contaminated drinking water can lead to serious health problems, including skin lesions, cancers of the skin, bladder, and lungs, as well as cardiovascular and neurological issues. Vulnerable populations, such as children and the elderly, are at greater risk [123]. The permissible range of As intake in drinking water recommended by WHO is 0.01 mg/L (10  $\mu$ g/L) and by Pak-EPA is 0.05 mg/L (50  $\mu$ g/L). Results revealed that 11% of samples had As content  $>0.01$  mg/L, while 100% of the samples

had arsenic  $<0.05$  mg/L. The arsenic hotspots were mainly located in the central districts. Maximum concentration of Arsenic (mg/L) ranged 0.0019 to 0.038 mg/L. Central region had the maximum number of samples with As above the WHO limit, followed by southern and northern region. All the cities had the mean As concentration range  $0.00\pm 0.00$  in Pakpattan to  $0.0129\pm 0.0164$  in Lodhran. Results of this study are in contradiction with Shakoor et al., reported high concentration of arsenic from groundwater in rural areas of Punjab, Pakistan i.e 53% samples had arsenic above than the safe limit of WHO. Arsenic can find its way into groundwater through natural processes involving the minerals and compounds in the ground. One way this happens is through the oxidation of minerals like arsenopyrite (which contains both arsenic and iron). When these minerals are exposed to air and water, they break down, releasing arsenic into the groundwater, where it can become a health concern. Additionally, iron compounds in the ground can play a role in releasing arsenic. When these compounds reduce or break down, they can release various forms of arsenic into the water [124].

Total coliforms are a group of harmful bacteria that are commonly used as indicators of water quality. This group of bacteria includes various species, such as *Escherichia coli* (*E. coli*), *Klebsiella*, and *Enterobacter*, among others. While not all total coliforms are necessarily of fecal origin, their presence can indicate the potential for pathogenic (disease-causing) microorganisms, such as certain strains of *E. coli* or other pathogens, to be present in the water [125]. Overall 36% of samples (98/274) were found to be contaminated with total coliforms. All the cities had the mean average concentration of total coliforms were above the WHO permissible level (0 MPN/100 ml), which is an alarming sign. The presence of total coliforms is an indicator of potential fecal contamination, which may include harmful bacteria, viruses, or parasites that can cause waterborne diseases [126]. Consuming water contaminated with total coliforms can lead to waterborne illnesses, including gastrointestinal issues such as diarrhea, cramps, nausea, and vomiting. In severe cases, it can result in more serious diseases. Vulnerable populations, such as children, the elderly, and individuals with weak immune systems, are particularly at risk. Hence, maintaining safe drinking water quality, including controlling total coliform levels, is essential for safeguarding public health [127]. At northern region, Sialkot had the highest mean total coliform level at  $7.7318.90 \pm 33.20$  MPN/100 ml, while Narowal had the lowest mean level at  $4.50 \pm 10.15$  MPN/100 ml. 44% samples of Sialkot were contaminated with total coliforms. From central region, Pakpattan had the highest mean total coliforms of  $23.14\pm 51.74$  MPN/100 ml while Okara had the lowest concentration of mean total coliforms  $4.90\pm 8.27$  MPN/100 ml. Highest percentage of samples (53%) from Sheikhpura

were contaminated with Coliform bacteria. Southern region showed minimum coliforms of  $2.20 \pm 4.91$  MPN/100 ml in Multan and maximum of  $7.2 \pm 11.06$  MPN/100 ml in Vehari. 37% of total coliforms were present schools samples of Khanewal. Rural areas often have a significant agricultural presence. The use of fertilizers, pesticides, and manure in farming can introduce coliforms into water sources through runoff and leaching. Rural communities may rely on local wells, hand pumps, or surface water sources that may not have adequate protection against contamination. These water sources are more susceptible to coliform contamination [128].

Horton's (1965) Water Quality Index (WQI) is a valuable tool for assessing the overall water quality of different cities or regions based on multiple water quality parameters. Horton's (1965) rating scale typically categorizes water quality based on the calculated WQI into several classes, ranging from excellent to poor. The scale helps in providing a qualitative assessment of water quality. If the average DWQI for a city falls within the range associated with the "Excellent" category (0 to 24.99), it suggests that the water quality in that city is of very high quality, with minimal pollution or contamination. A "Good" rating (25-49.99) indicates that the water quality is generally good, with minor variations in quality parameters. The "Fair" category (50-64.99) suggests that the water quality is moderate, with some deviations from ideal conditions but still within acceptable limits. A "Poor" rating (65-75.99) signifies that the water quality is not ideal, and there may be significant pollution or contamination issues that need attention. If the WQI falls within the range for "Very Poor," (76-100) it indicates severe degradation of water quality, posing potential risks to human health and the environment. The lowest rating ( $>100$ ) on the scale, "Unsuitable for use," implies that the water quality is in a critical condition, making it unsuitable for most purposes [129].

Results showed that no school falls into the "Excellent" category which implies that none of the schools have water quality that can be considered as of very high quality with minimal pollution or contamination. Approximately overall 38%, fall into the "Good" water quality category. This indicates that a considerable number of schools have water quality that is generally good, with only minor variations in quality parameters. The largest percentage of schools, approximately overall 41%, are classified as having "Fair" water quality. This suggests that the majority of rural schools are dealing with water quality that is moderate, with some deviations from ideal conditions but still within acceptable limits. Around overall 16% of schools are categorized as having "Poor" water quality. This is a concerning finding as it indicates that a significant number of schools are experiencing water quality issues that may

affect the health and well-being of students. The "Very Poor" water quality category applies to approximately overall 4% of the rural schools. This rating suggests severe degradation of water quality in these schools, posing potential risks to the health of students. Finally, the "Unfit" category, representing overall 1% of the schools, implies that water quality in these schools is in a critical condition, rendering it unsuitable for most purposes, including drinking. Similar Study in Kabul Afghanistan found, The Kabul does not contain any groundwater with excellent quality. Moreover, only 40% of the tested water samples exhibited good water quality. In fact, over half of the sampled data indicates poor to very poor groundwater quality. Shockingly, more than 6% of the groundwater in Kabul is deemed completely unsuitable for human consumption [130]. Another study in Bangladesh found 4%, 54%, 26%, 6%, and 0% of the water samples were categorized as excellent water, good water, poor water, very poor water, and unsuitable for drinking, respectively[131].

Health risk assessment was calculated using Average daily dose (ADD), Hazard quotient (HQ) and Cancerous Risk (CR) to the children due to Cr, Ni, Pb, As and F. Human health risks were estimated through the HQ and CR assessment method provided by the US EPA. The non-carcinogenic health risks of school-going children due to exposure to Cr, Ni, Pb, As and F were estimated in terms of ADD and HQ for school-going children. The highest ADD was observed for F (North:  $0.034 \pm 0.107$ ; South:  $0.051 \pm 0.144$ ; Central:  $0.482 \pm 0.04126 \text{ mg kg}^{-1} \text{ d}^{-1}$ ), while the lowest was observed for Pb (North:  $0.0001 \pm 0.00028$ ; South:  $00.00 \pm 0.00$ ; Central:  $0.0001 \pm 0.00053 \text{ mg kg}^{-1} \text{ d}^{-1}$ ). The mean average ADD for Cr, Ni and As was (North:  $0.0015 \pm 0.010$ ; South:  $0.0006 \pm 0.0013$ ; Central:  $0.0006 \pm 0.00167 \text{ mg kg}^{-1} \text{ d}^{-1}$ ), (North:  $0.0003 \pm 0.001$ ; South:  $0.0003 \pm 0.00055$ ; Central:  $0.0003 \pm 0.00072 \text{ mg kg}^{-1} \text{ d}^{-1}$ ) and (North:  $0.0001 \pm 0.011$ ; South:  $0.0004 \pm 0.00019$ ; Central:  $0.0003 \pm 0.00028 \text{ mg kg}^{-1} \text{ d}^{-1}$ ). High ADD of fluoride for children was also reported in previous study of Punjab, Pakistan ( $0.02\text{--}4.84 \text{ mg kg}^{-1} \text{ d}^{-1}$ ) [132].

The hazard quotient index of selected heavy metals in drinking water of primary schools was calculated for each school.  $HQ > 1$  may pose health risk to children. The HQ indices for Pb and Ni in all the cities was less than one, which suggests no potential adverse health effect to the study population. While some samples showed  $HQ > 1$  for Cr, As and F. The increasing pattern of mean concentration of metal(loid)s was as follows: For northern region ,F ( $0.57 \pm 0.389 \text{ mg/L}$ )>Cr ( $0.50 \pm 3.38 \text{ mg/L}$ )>As ( $0.48 \pm 3.40 \text{ mg/L}$ )>Pb ( $0.019 \pm 0.86 \text{ mg/L}$ )>Ni ( $0.014 \pm 0.059 \text{ mg/L}$ ), For central region, As ( $0.977 \pm 0.08347 \text{ mg/L}$ )>F ( $0.765 \pm 1.63659 \text{ mg/L}$ )>Cr ( $0.186 \pm 0.48 \text{ mg/L}$ )>Pb ( $0.0173 \pm 1.656 \text{ mg/L}$ )>Ni ( $0.0152 \pm 0.0347 \text{ mg/L}$ ) and for southern region, As ( $1.30 \pm 0.03217 \text{ mg/L}$ )>F ( $0.8513 \pm 2.206 \text{ mg/L}$ )>Cr ( $0.197 \pm 0.452 \text{ mg/L}$ )>Ni ( $0.021$

$\pm 0.02718$  mg/L) $>$ Pb ( $0.0079 \pm 0.034$  mg/L). Overall pattern of heavy metals was As $>$ Cr $>$ Ni $>$ Pb. Results of health risk of heavy metals of this study are similar to those of other studies conducted earlier by Sajjad H et al. and Lu Y et al. [120, 133].

Cancer risk for the study population was analyzed for Cr, Ni, Pb and As. Permissible limits of CR is E-04. A CR of E-04 is the chance that a single person may develop cancer out of 10,000 persons subjected to a carcinogen. In some samples Cr, Ni and As were above the predefined tolerable limit of E-04. All the samples of Pb within the permissible limit. The increasing pattern of concentration at northern region was Cr ( $7.61E-04 \pm 5.08E-03$ ) $>$ Ni ( $2.64E-04 \pm 5.40E-02$ ) $>$ As ( $2.09E-04 \pm 2.90E-02$ ) $>$ Pb ( $5.80E-07 \pm 3.88E-04$ ), at central region As ( $4.40E-04 \pm 7.09E-04$ ) $>$ Cr ( $2.80E-04 \pm 1.35E-03$ ) $>$ Ni ( $2.77E-04 \pm 3.16E-02$ )  $>$ Pb ( $5.13E-07 \pm 7.45E-04$ ) and at southern region it was As ( $5.89E-04 \pm 2.73E-04$ ) $>$  Ni ( $2.81E-04 \pm 2.48E-02$ ) $>$ Cr ( $2.95E-04 \pm 6.79E-04$ ) $>$ Pb ( $2.34E-07 \pm 8.26E-04$ ) Similar other studies reported cancer risk posed by As, Cr and Ni consumption through drinking water for both children and adults in Pakistan [134, 135, 136].

Correlation is a statistical measure that describes the extent to which two variables change together. In other words, it quantifies the relationship between two sets of data. Correlation does not imply causation; it simply tells us whether there is a statistical relationship between the variables [137]. At northern Punjab, TDS and EC exhibit a strong positive correlation ( $r = 0.950$ ), indicating that as TDS increase in water, the EC also rises significantly. Hardness shows strong positive correlation with  $Ca^{+2}$  ( $r = 0.27$ ),  $Mg^{+2}$  ( $r = 0.27$ ),  $CO_3^{-2}$ ,  $HCO_3^-$  and ( $r = 0.142$ ), implying that the presence of chloride ions is closely associated with water hardness. Carbonates are strongly correlated ( $r = 0.861$ ) to bicarbonates. Total Coliforms strongly negatively correlated with turbidity ( $r = -0.108$ ) and nitrate ( $-0.211$ ). At central region, F shows a strong positive correlation with Cl ( $r = 0.396$ ). Nitrate exhibits significant positive correlations with multiple ions, including Cl ( $r = 0.209$ ) and F ( $r = 0.30$ ). The  $HCO_3^-$  demonstrates a significant positive correlation with water hardness ( $r = 0.168$ ). Ni demonstrate a significant positive correlation with Pb ( $r = 0.215$ ) and Cr ( $r = 0.292$ ). At southern region, Water hardness demonstrates strong positive correlations with both  $HCO_3^-$  ( $r = 0.184$ ) and  $CO_3^{-2}$  ( $r = 0.176$ ) ions. Chloride shows strong positive correlations with Na ( $r = 0.282$ ) and K ( $0.101$ ). A noteworthy positive correlation exists between F and nitrate levels ( $r = 0.29$ ). Cr, Ni, and P exhibit positive correlations with TDS. Similar correlations were observed earlier in previous studies [138,139].

GIS mapping using kriging and co-kriging is a geostatistical approach for spatial interpolation and prediction of data points across a geographic area. Kriging is a more advanced interpolation technique that takes into account the spatial correlation between data points. It provides not only an estimated value but also an estimation of the uncertainty associated with that value. [140]. Colour scale of DWQI is excellent “Dark green”, good ‘light green”, fair “Yellow”, poor “Pink”, very poor “ Red”, unfit for use “Maroon” Interpolation results of DWQI values, reveal significant disparities between areas with the highest and lowest DWQI values. Overall all the selected cities has good and fair quality of water. In Gujranwala, GRW-22 and GRW-23 had 141.33 and 131.83 (the highest DWQI) signalling substantial concerns about water quality and safety in certain parts of the city, followed by Faisalabad 108.78 (LYP-20), Sialkot 86.03 (SKT-25) and Lahore 84.56 (LHR-8). Similarly, in Hafizabad, the DWQI values vary from 31.64 (HFD-2) to 68.37 (HFD-10), indicating moderate variations in water quality. Jhang displays DWQI values between 52.95 (JNG-3) and 79.35 (JNG-10), suggesting moderate differences in water quality but relatively consistent overall. In contrast, Multan, Vehari, and Khanewal have more uniform water quality with moderate variations, ranging from 52.05 (KWL-2) to 80.91 in Khanewal (KWL-1). Bahawalnagar demonstrated moderate variability, with DWQI values spanning from 46.89 (WBG-2) to 73.86 (WBG-4).

Interpolation results of hazard quotient revealed following trends for Cr north>south>central, for Ni south>central>north, for Pb north>central>south, for As South>central>north and for F south>central>north. Interpolation results for cancer risk of Cr and Ni showed a significant range where central region had highest number of samples exhibiting cancer risk followed by northern and southern region while for As central region exhibited highest number of samples having potential to cause cancer followed by southern region while northern region had lowest potential to cause cancer risk. The analysis of lead exposure across various cities does not reveal any potential to cause cancer risk.

The interpolation of total coliforms (microbiological results) vary across different cities in the region. In Lahore, most sampling locations show relatively low levels of total coliforms, with many recording zero counts. However, a few areas in Lahore exhibited elevated levels, such as LHR-15 with 115.7, LHR-8 with 30.15, and LHR-9 with 94.92. Sheikhpura had lower levels of total coliforms, with SKP-9 having a count of 94.92 and SKP-10 with 115.7. In Kasur, there was a mix of low counts and higher counts, with KUS-7 having 76.1 and KUS-8 with 14.82. Okara reports a relatively low count of 9.55 in OKR-5. Sahiwal had varying counts, with SWN-3 having 9.69 and SWN-12 with 76.1. Lodhran's LON-1 showed a count of 20.74, while

Faisalabad's LYP-5 reported 30.15. Nankana Sahib's NNS-7 had 30.15, while Narowal's NRW-5 had 30.15. Sialkot exhibited diverse counts, including higher counts like SKT-9 (25.89) and SKT-14S165 (115.7). Gujranwala and Jhang had a few locations with slightly elevated counts, (JNG-6 with 27.4). Multan, Vehari, Khanewal, and Bhawalnagar had low to zero counts of total coliforms.

A health risk assessment based survey was conducted (n=252) to assess various aspects related to water quality, water storage, and health knowledge about the primary school children from their parents (Respondents) The survey respondents were primarily female (70%) compared to males (30%), indicating that females were more likely to participate in the survey. The age distribution shows that the 47% of respondents fell within the age range of 8 to 10 years, followed by 11 to 16 years (33%), and 4 to 7 years (19%). The level of education varied among respondents children, with Grade 5 and 3 having the highest representation of 58%, followed by Grade 2 (21%), Grade 1 (16%), Grade 4 (9%), and ECE (6%). The weight distribution indicates that the 49% of respondents children had a weight between 21-40 kg while 30% had and 21% had 41-55 kg weight. The majority of respondents reported that the primary source of drinking water in their child's school is from government water (35%), while a 32% reported the use of water pumps. Fewer respondents mentioned hand pumps (19%) and other sources (4%). A significant portion of respondents, 55% reported that their child's school does not treat water before use, while 45% respondents stated that their child's school treats water. Among those schools that do treat water, the survey reveals that various methods are employed. Most commonly, water is treated using water filters (59%), followed by boiling (11%), 10% using bleach/chlorine and solar-disinfection (12). Other methods were mentioned by 11% respondents. Contrary to the findings of this study's respondents in Faisalabad mostly boil their drinking water, as it is the cheapest method to use [141]. The survey found that a 70% of children store their drinking water in plastic bottles or water bottles while 25% use metal bottles and 5% have other storage methods.

51% (majority of respondents) indicated that water in storage containers stays for 10 hours, followed by 8 hours (36%) and 12 hours (13%). 70% reported that storage vessels are covered, indicating a good practice for maintaining water quality, while 30% respondents mentioned that the vessels are not covered. Similar finding in Swat found almost all the respondents (96.5%) claim that their water storage vessels are covered [142]. Pouring water directly (48%) was the most common method reported by respondents for getting water from storage containers. The survey found that a majority (52%) of children had an average daily intake of

2 litre of water, 29% had average intake of 1 litre and 19% had average intake of 3 litre or more than 3 litre. A 60% of respondents expressed concerns about their child getting sick from the school drinking water intake, while 40% respondents were not concerned. 59% of respondents were not satisfied with the quality of water their child uses, compared to 41% who were satisfied. Similar study in Vehari found that majority (62.5%) of the respondents were not satisfied with their water quality [143]. The survey revealed that a majority (54%) of children do know what water-borne diseases are, while 46% respondents indicated that their children do not have knowledge of such diseases. Respondents were asked about the presence of certain illnesses in their children. Among the illnesses mentioned, diarrhoea, vomiting, abdominal pain, and tiredness were reported by a significant number of respondents. Other illnesses mentioned included hepatitis A, kidney problems, hepatitis C, hepatitis B, dysentery, anaemia, constipation, and others. Similar study in Gujrat found that majority of the respondents had knowledge about water borne diseases and they were suffering from Dysentery (6.4%), Typhoid (10.9%), Cholera (4.2%), Diarrhea (6.8%) Gastro (21.5%) and Hepatitis A (53%) etc [144].

Another questionnaire survey was conducted to find their willingness to pay (WTP) among educators and school staff (n=110) to improve the drinking water quality of their schools. Most of the respondents (47%) were 41 years or older. These individuals likely have more experience in education and management roles. while 38% were 31-40 and 15% were 20-30 years of age. A larger percentage of respondents (71%) were male, while 29% were female. Half of the respondents (50%) had graduation degrees, while 48% had post-graduate degrees. Only 12% had intermediate-level education. Among the respondents, 35% earn more than 1 lac rupees , 49% earn between 51,000 and 1 lac, and 16% earn less than 50,000. The majority (57%) of respondents were school principals, 36% were headmasters/mistresses, and a few (7%) had other roles in education. About 56% of respondents mentioned that water pollution sometimes bothers their students, while 20% said it bothers them very much and 24% reported that it bothers them rarely or never.

Students might be affected by pollution due to its visible effects. A significant portion (60%) of respondents mentioned that their students are somewhat concerned about the health effects of water pollution, while 27% very concerned and 13% not so much concerned about the health effects of water pollution. This indicates that students understand the link between water quality and health. An impressive 71% of students were aware of waterborne diseases while 29% lacked awareness. Survey revealed that the rural primary school experience cases of

diseases among teachers, janitor staff and students, including cholera, hepatitis A, viral infections, typhoid fever, dysentery, and diarrhoea/vomiting/nausea. This suggests that water quality issues have had real health consequences in the schools. Most respondents (62%) believe that their students are in average health, with 20% in good health and 18% in poor health. Water quality can play a role in overall student health. A significant majority (89%) of respondents were willing to pay for clean drinking water to improve their students' health while 11% were not willing. This willingness to invest in clean water shows their dedication to their students' well-being. A study in Lahore found majority of respondents were willing to pay for clean drinking water services [145]. 42% of respondents preferred public organizations as the entities to provide clean water, while 59% preferred private organizations or public-private partnerships. Most respondents (42%) were willing to contribute PKR 100-1000 (\$ 1.75), 33% PKR 1100-2000 (\$ 4.5), 14% PKR 2100-3000 (\$ 8) and 11% PKR more than 3100 (\$ 10), per month for clean drinking water. This is a feasible amount that can make a difference in water quality. Similar study in Lahore found majority of respondents were willing to pay 500 to 800 PKR for improving water quality [146]. 82% of the respondents believed that making the payment can improve their schools drinking water quality while majority 65% of respondents do not consider their willingness to pay as a financial burden on the school. This means they believe they can afford the cost without straining the school's finances. A study in Bangladesh found majority of respondents considering that their income not constraining them financially to pay for this scheme, though they would be interested in contributing if they could afford to do so [147].

To evaluate the WTP of Schools, using the Contingent Valuation Method (CVM) for assessing the WTP for improved drinking water facilities in schools, linear regression model was employed. It is a statistical method used to analyze the relationship between a dependent variable and one or more independent variables by fitting a linear equation to the observed data. In the present study, independent variables were gender, education, income, and occupation and the dependent variable, was the school's combined willingness to pay per month. The model's formula,  $Y = \beta_0 + \beta_1 * \text{Gender} + \beta_2 * \text{Education} + \beta_3 * \text{Income} + \beta_4 * \text{Occupation}$ , where  $\beta_0$  was the constant, and  $\beta_1$  to  $\beta_4$  were coefficients assigned to gender, education, income, and occupation respectively [77]. It were utilized to predict the WTP (Y) based on the  $X_n$  values of these explanatory variables ( $X_1=1.29$ ,  $X_2=2.32$ ,  $X_3=2.1$ ,  $X_4=1.49$ ). Upon calculation the predicted monthly WTP for improved drinking water in schools were estimated at USD 3.406 or approximately PKR 971.69 (Per school). It signifies the perceived

importance of improved water supply in schools. Access to clean and safe drinking water is crucial for students' health, well-being, and educational outcomes. This economic valuation highlights the societal significance attached to ensuring such facilities in educational institutions (Table 4.18)

Tables 4.17 suggests that income (sig. 0.000), gender (sig. 0.021) and education (sig. 0.041) were significant predictors of the school's combined willingness to pay per month. Specifically, higher income and male gender were associated with greater willingness to pay. Another study reported that the ability to pay for these services was substantially connected to income and the need for water supply ( $r = 0.319, 0.307; p < 0.05$ ) [67]. Occupation (sig 0.189), on the other hand, does not appear to have a significant impact on willingness to pay in this analysis. It's essential to consider the practical and social implications of these results when planning interventions or policies related to willingness to pay for schooling or related services in this specific context.

The Pearson chi square is mainly used for the testing of relationships between categorical variables. In the present study chi square test shows significant relationship between income and willingness to pay for improved drinking water facility as  $p > 0.01$  ( $\chi^2 = 20.491, df = 6$ ). The small p-value of 0.002 suggests that there is a significant association between these two variables. Therefore, income appears to play a role in influencing people's willingness to pay for improving drinking water facility. Similarly, Cramer's V is a measure of association for categorical variables. In this case, it quantifies the strength of association between income and willingness to pay. The result provides a Cramer's V value of 0.305 and a p-value (Asymp. Sig.) of 0.002. Cramer's V value ranges from 0 to 1, with higher values indicating a stronger association. In this scenario, the Cramer's V value (shown in Table 4.35) is 0.305, relatively high, further confirming that there is a substantial relationship between income and willingness to pay improved drinking water quality. Similar study in Lahore suggested that various factors such as educational level, health status, and income are the determining factor of WTP for better quality of drinking water facilities [65]. Pearson correlation coefficient (denoted by  $r$ ) is the measure of strength of direct relationship between the two variables. Pearson correlation test (Table 4.37) showed the strong correlation ( $r = 0.384$ ) between the income levels and willingness to pay for improved drinking water facility while gender ( $r = 0.115$ ) and education ( $r = 0.137$ ) shows moderate correlation. Which means higher the income level, higher the amount will be paid for the improvement of drinking water facility in the area.

Analysis of Variance (ANOVA) to investigate the impact of various factors - Gender, Education, Income, and Occupation - on people's willingness to pay for an improved drinking water facility. Table 4.36 shows the significant relationship of between WTP and income and occupation and education level. The typical significance level should be  $<0.05$ . The ANOVA results for Gender indicate that there is no significant difference in people's willingness to pay based on gender. The F-statistic (F) is 1.452 with a corresponding p-value (Sig.) of 0.231. Since the p-value is greater than the typical significance level of 0.05, it suggests that gender does not play a significant role in determining individuals' willingness to pay for improved drinking water. The ANOVA results for Education reveal that there is statistically significant relationship with willingness to pay. The F-statistic (F) is 3.42, and the associated p-value (Sig.) is 0.0246, again less than the typical significance level. The results for income and occupation show a significant difference in willingness to pay based on income and occupation levels. The p-value (Sig.) is very close to zero for income and 0.34 for occupation. With a p-value  $<0.05$ , concludes that income and occupation significantly affects people's willingness to pay for improved drinking water. Similar studies reported significant relationship between occupation, education, income level and willingness to pay [148,149,150]

## CONCLUSION

On the basis of physiochemical and microbiological results of the drinking water quality using Water Quality Index and Health Risk Index, agricultural activities, domestic sewage and industrial discharge contributes to drinking water contamination in the study area. Some parameters that exceeded WHO standards include total dissolved solids (central>south>north), total hardness (north>south>central), chloride (central>south>north), fluoride (south>central>north), nitrate (south>north>central), heavy metals i.e Cr, Ni, Pb and As (south>central>north) and total coliforms (north>central>south). According to DWQI, majority of the schools are using good to fair quality of drinking water, following the trend fair>good>poor>very poor>unfit for use. Potential Health risk from the exposure of Cr, Ni, Pb, As and indicated that most of the schools were not at risk, but some schools from north, central and southern rural Punjab had  $HQ > 1$ . The rank order of HQ were  $As > Cr > Ni > Pb$ . Ni and Pb. The HQ indices for Pb and Ni in all the cities was less than one, which suggests no potential adverse health effect to the study population. While some samples had shown  $HQ > 1$  for Cr, As and F. All the samples of Pb were  $< E-04$ , in some samples Cr, Ni and As cancer risk was  $> E-04$ . Survey on health risk and WTP revealed that the rural primary school has experienced cases of diseases among teachers, janitor staff and students, including cholera, hepatitis A, viral infections, typhoid fever, dysentery, and diarrhoea/vomiting/nausea. A majority (89%) of respondents are willing to pay for clean drinking water to improve their students' health while 59% preferred private organizations or public-private partnerships as the entities to provide clean water while 42% of respondents preferred public organizations. WTP found most of principals/headmasters (42%) were willing to contribute PKR 100-1000 (\$ 1.75), 33% PKR 1100-2000 (\$ 4.5), 14% PKR 2100-3000 (\$ 8) and 11% PKR more than 3100 (\$ 10), per month for clean drinking water. ANOVA, Chi square, Cramm's V and linear regression test revealed, with a p-value  $< 0.05$ , conclude that income and education level significantly affects effectees willingness to pay for improved drinking water. The current data will provide significant information in designing future water and nutrition interventions in schools, particularly focused on children of ages 5–16 years.

## **RECOMMENDATIONS**

Assessing the drinking water quality in public primary schools in rural Punjab is essential for ensuring the health and well-being of students and staff. Below are some recommendations for addressing issues:

- Regularly monitoring of drinking water quality in public primary schools is important to ensure a safe and healthy learning environment for the students and staff.
- Immediate measures should be taken to apply suitable treatment techniques in the study area to bring the water quality up to acceptable standards.
- Educate school staff, students, and their families about the importance of clean and safe drinking water. Create awareness campaigns to encourage responsible water usage and hygiene practices
- It is essential to focus on localized solutions to address emerging water quality issues. This might involve promoting best practices for agricultural and industrial activities that could impact groundwater quality.

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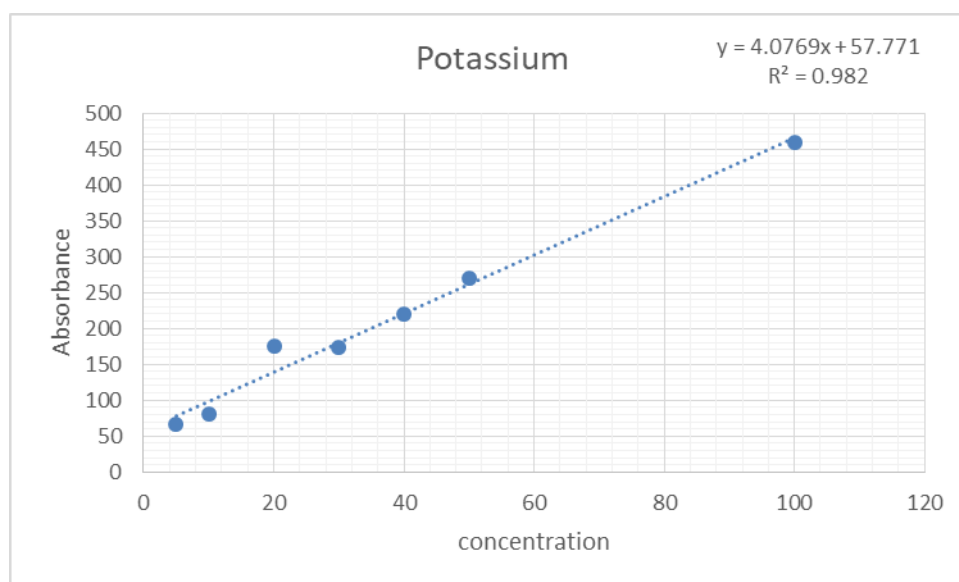
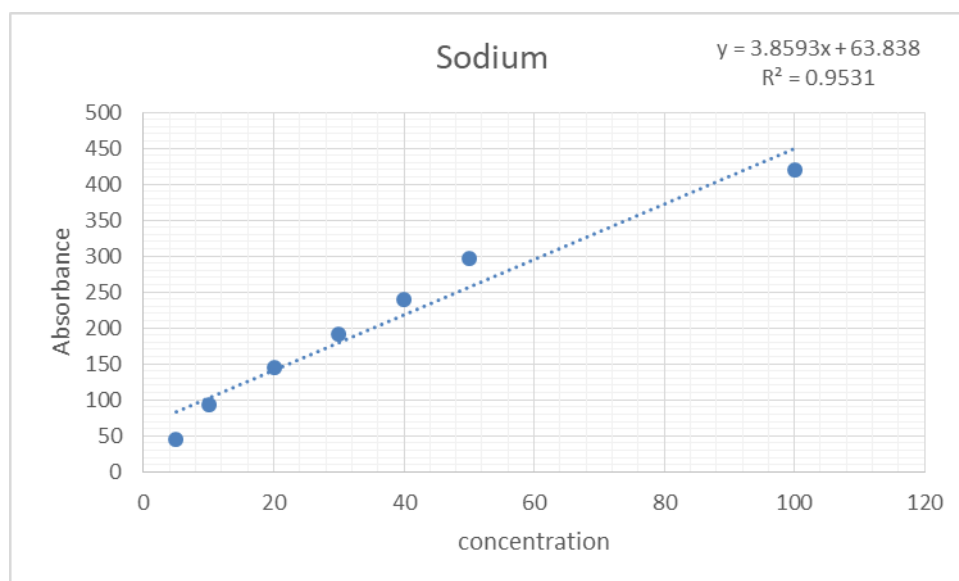
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## ANNEXURE



## Health Risk Survey

### Section I: Demographic Information of your kid

#### Gender

1. Male
2. Female

#### Age (In years)

1. 4-7
2. 8-10
3. 11-16

#### Level of Education

1. ECE
2. Grade 1
3. Grade 2
4. Grade 3
5. Grade 4
6. Grade 5

#### Weight (in kg)

1. 10-20
2. 21-40
3. 41 and above

### Section II

#### What is the primary source of drinking water in your kid's school?

1. Water Pump
2. Govt water
3. Hand Pump
4. Other

#### Do their school usually treat water before use?

1. Yes
2. No

#### Which method of treatment do their school usually use to make water safe to drink?

1. Boiling
2. Water filter
3. Bleach/chlorine
4. Solar disinfection
5. Others

#### Where do your kid store their drinking water?

1. Water bottle
2. Metal bottle
3. Plastic bottle
4. Others

**How long does water stay in the storage container?**

1. 8 hrs
2. 10 hrs
3. 12 hrs

**Are storage vessels covered?**

1. Yes
2. No

**What do your kid uses to get the water from the storage container?**

1. Pour directly
2. Use cup with handle
3. Use cup with no handle
4. Others

**What is your kid's Average daily intake of water?**

1. 1 litre
2. 2 litre
3. 3 litre
4. More than 3

**Do you think that your kid can get sick from the school drinking water intake?**

1. Yes
2. No

**Are you satisfied with the quality of water your kid uses?**

1. Yes
2. No

**Do your kid knows what wate- borne diseases are?**

1. Yes
2. No

**Do your kid have any following illness? (you can choose more than one)**

1. Hepatitis A
2. Kidney problems
3. Hepatitis C
4. Hepatitis B
5. Diarrhea
6. Dysentery
7. Vomiting
8. Abdominal pain
9. Anemia
10. Tiredness
11. Constipation
12. Others

## **Willingness to pay for improving drinking water quality**

### **Section I: Demographic Information**

#### **Age**

1. 20-30
2. 31-40
3. 41 and above

#### **Gender**

1. Male
2. Female

#### **Education**

1. Intermediate
2. Graduation
3. Post-graduation

#### **Income**

1. Less than Rs. 50,000
2. 51,000 to 1 lac
3. 1 lac or above

#### **Occupation**

1. Principal
2. Headmaster/mistress
3. Others

### **Section II: The effects of water pollution on health**

#### **Does water pollution physically bothers your students?**

1. Very much
2. Sometimes
3. Rarely
4. Never

#### **Do your students concerned with the effects of water pollution on health?**

1. Very much
2. Somewhat
3. Not so much

#### **Do your students know about waterborne diseases?**

1. Yes
2. No

**To become familiar with the health status of your School, could you tell us if the following individuals have ever had or have?**

	You	Your faculty	Janitor staff	Students
Cholera				
Hepatitis A				
Viral infection				
Typhoid fever				
Dysentery				
Diarrhea/vomiting/nausea				
None of above				

**Do you think your students are in?**

1. Good health
2. Average health
3. Poor health

**Are you willing to pay for safe drinking water to improve the health of your students?**

1. Yes
2. No

**If yes, to whom your school prefer**

1. Private organization
2. Public organization
3. Public Private partnership

**What is your schools combined willingness to pay (per month) in order to get clean drinking water?**

1. 100-1000 Rs.
2. 1100-2000 Rs.
3. 2100- 3000 Rs.
4. 3100 Rs. and above

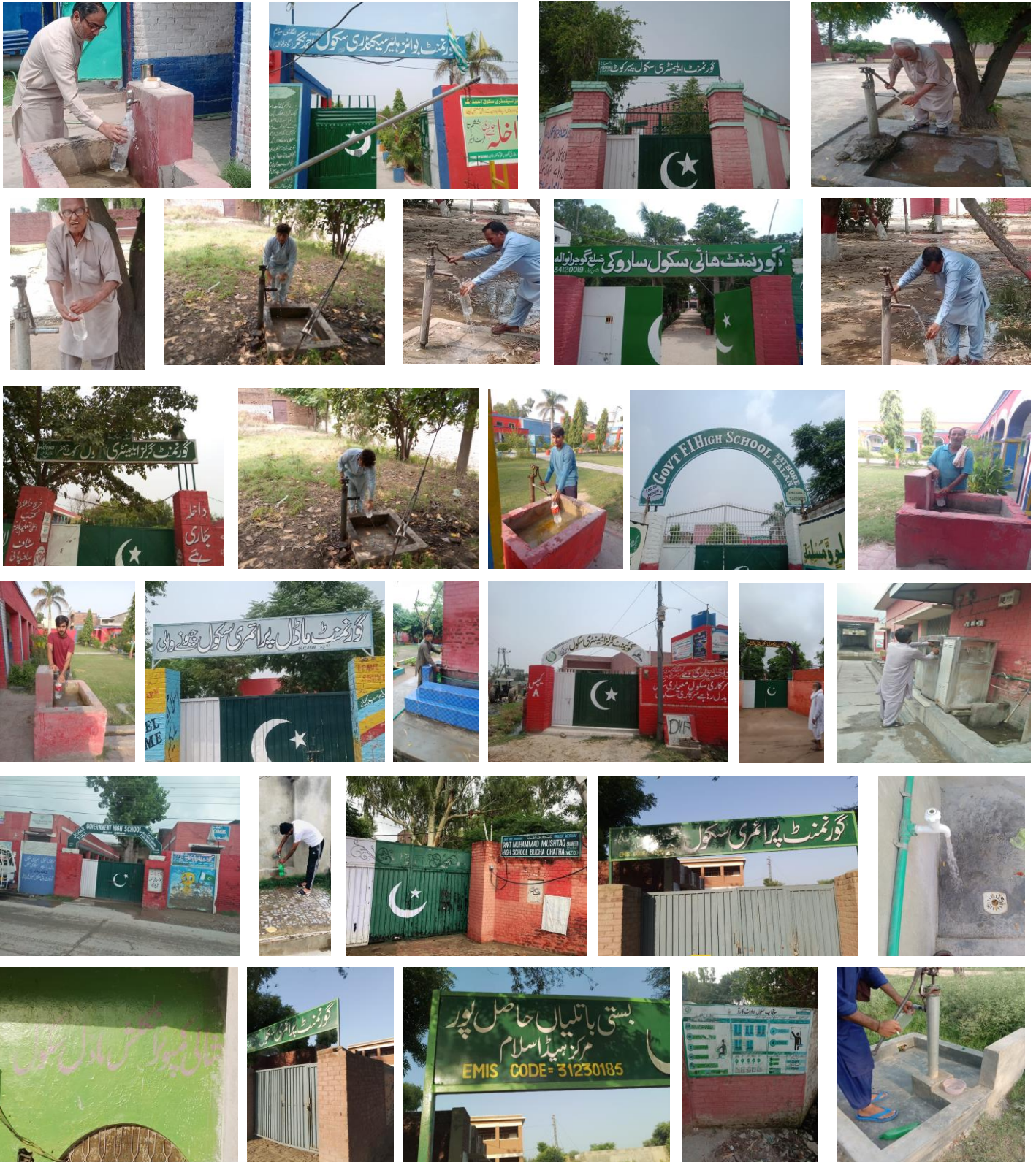
**Do you think by making the payment you can prove your schools drinking water quality?**

1. Yes
2. No

**Do you think the amount you are willing to contribute is going to be a financial burden on your school?**

1. Yes
2. No

# PICTORIAL PROOFS







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