ASSESSMENT OF DRINKING WATER QUALITY IN UNIVERSITY TOWN PESHAWAR, PAKISTAN

By

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CERTIFICATE OF ORIGINALITY

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Name of the Research Candidate: Maaha Malik

DEDICATION

I feel it an honour to dedicate this minute effort to my late grandparents Ammi and Abbu for their moral, mental support, and training in my early childhood which enabled me to achieve the higher ideals of my life.

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In the name of Allah SWT, the Compassionate and the Merciful, without who's grace and blessings it would not have been accomplished. I wish to express my appreciation and sincere thanks to my worth supervisor, Dr. Said Akbar Khan, for highly capable guidance, constructive suggestions, positive criticism and continuous criticism throughout this research. To all the valuable faculty members at Department of Earth and Environmental Sciences, Bahria University, Islamabad, who provided knowledge and support to accomplish my research. To Dr. Ghazala Ali Khan, Additional Director, (STI), Peshawar who always welcomed with a smiling face and never fail to offer me support especially in review of literature. My sincere gratitude is due to her. To Dr. Bushra Khan, Professor Department of Environmental Sciences, University of Peshawar, mentor in BS Environmental Sciences for her technical guidance, constructive criticism, valuable help during the tedious phase of synopsis writing. Sincere thanks are due to Mr. Ziad Raza, GIS specialist, Pakistan Forest Institute, Peshawar for helping in learning use of GPS for taking sample points and drawing study area map and M.Sc. Forestry Scholars Mr. Safwan Daud and Mr. Nazir Ullah for helping in tedious job of water sample collection.

Not to forget my papa, younger sister and fiancé, who were serene and considerate while I was busy. Finally, with my mother' prayers and strong determination, I have reached to my aspirations which seemed higher than sky!!

Maaha Malik

ABSTRACT

The study was conducted to find physiochemical and biological contamination of drinking water in University Town Peshawar (UC-36). A total of Fifty (50) water samples were collected from various sources and analyzed in PCSIR lab. The physical parameters like pH (7.13-7.81), electrical conductivity (613-791 µS/cm), total dissolved solids (417-597 mg/L) and turbidity (1-2 NTU) were within the permissible limits set by PCSIR, WHO and EPA. The chemical parameters analyzed included hardness (342-426 mg/L), chlorides (52-100 mg/L), sulphates (70-77 mg/L), sodium (30-36.8 mg/L), nitrites (0 mg/L) and alkalinity (135-246 mg/L). Most parameters were within the permissible limits except magnesium in some samples. Heavy metal concentrations of Nickel and Cadmium were found to be dangerously high at 0.175 mg/L and 0.6mg/L respectively. Microbiological analysis was carried out by testing for total plate count, total coliforms and fecal coliforms and 27 out of 30 samples crossed microbial contamination limits suggesting contamination of groundwater sources. A questionnaire survey containing different questions about water quality and waterborne diseases from 30 respondents showed that there is not a significant difference in the taste of water. It also indicated that the major source of contamination as groundwater, lack of proper cleaning of storage tank, rarely using measures to improve drinking water quality at household level. Lack of proper cleaning of water tanks, limited filtering/boiling of drinking water and lack of awareness on waterborne diseases was observed. The study concludes that the drinking water is contaminated in University Town which calls for monitoring of groundwater quality and proper supply system maintenance. It highlights the need for creating awareness on water borne diseases and building capacities for water quality testing.

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LIST OF ABBREVATIONS

Abbreviations	**Names**
$AgNO_3$	Silver Nitrate
$CaCO_3$	Calcium Carbonate
CaF	Calcium Fluoride
Cl^-	Chloride
EC	Electrical Conductivity
EDTA	Ethylene Diamine Tetra acetic acid
EIA	Environmental Impact Assessment
EPA	Environmental Protection Agency
G	Gram
H_2SO_4	Sulphuric Acid
HCl	Hydrochloric Acid
HCO_3	Bicarbonate
HDL	Highest Desirable Limit
K_2CrO_4	Potassium Chromate
KPK	Khyber Pakhtunkhwa
M	Molar
Mg	Milligram
ML	Milliliter
NaOH	Sodium Hydroxide
NC	Neighborhood Council
NEQS	National Environmental Quality Standards
NH_4OH	Ammonium Hydroxide
NTU	Nephelometric Turbidity Unit
NWQMP	National Water Quality Monitoring Program
PCSIR	Pakistan Council of Scientific and Industrial Research
PSQCA	Pakistan Standards & Quality Control Authority
pH	Power Of Hydrogen
Ppm	Parts Per Million
PSP	Postal Station Pump
TCU	True Color Unit
TDS	Total Dissolved Solids
TON	Threshold Odor Number
TMA	Tehsil Municipal Administration
UC	Union Councils
WHO	World Health Organization
WSSP	Water Sanitation Services` Peshawar
CaF	Calcium Fluoride

CHAPTER 1

INTRODUCTION

1.1 Back Ground

A basic human right is the availability of clean, safe drinking water, although many people worldwide do not have this access. Drinking water contamination by physical, chemical, and biological pollution is a serious problem that affects the environment and human health worldwide (Kumar et al., 2023). In Pakistan, drinking water contamination is a major issue, particularly in urban areas where the sanitation systems are inadequate. The city of Peshawar, with a population of about 2.28 million, is no exception. The assessment of drinking water quality in Peshawar is therefore imperative to analyze the extent of the problem and to identify potential solutions (Daud et al, 2017). Similarly, provision of safe drinking water in both urban and rural areas remains a key challenge. A recent nationwide water quality survey found that over two-thirds of water sources tested failed to meet the Pakistani drinking water standards (PCRWR, 2022). The situation is particularly concerning in the Khyber Pakhtunkhwa (KP) province in northern Pakistan, where groundwater pollution from both anthropogenic and natural sources is widespread (Khan et al., 2013).

University Town is a key suburb of Peshawar city, the capital of KP province. Its population relies predominantly on groundwater obtained from hand pumps and tubewells installed across the town to meet domestic and drinking water needs. However, no studies have systematically evaluated the key water quality parameters in University Town to determine its potability for drinking purposes (Inam Ullah et al, 2014).

Several studies have highlighted the significance of monitoring and assessing drinking water quality, emphasizing the need to establish water quality standards and implement effective management strategies. In Peshawar, previous research has revealed the presence of coliform bacteria and high levels of total dissolved solids, hardness, and alkalinity in the drinking water, indicating poor water quality. For instance, a study conducted by Inam Ullah and Alam in 2014 evaluated the drinking water quality of 32 locations inside Peshawar, revealing that a significant percentage of the samples were contaminated with coliform bacteria, rendering them unsuitable for human consumption (Inam Ullah et al, 2014).

In the context of University Town Peshawar, there is limited information on the drinking water quality. However, a study conducted on the groundwater quality of selected areas in Punjab and Sindh Provinces, Pakistan, found that chemical and microbiological aspects of groundwater quality were within permissible limits. This suggests that the groundwater in University Town Peshawar may have better quality, but it is essential to monitor and assess the water quality regularly to ensure its safety and suitability for drinking purposes (Khan et al, 2017).

Given the prevalence of drinking water contamination in many underdeveloped nations, including Pakistan, the evaluation of Peshawar's drinking water quality is essential. The World Health Organisation estimates that 4.2 billion people lack access to properly run sanitation facilities and 2.2 billion people lack access to safe drinking water globally. The situation is especially bad in Pakistan, where an estimated 21 million people do not have access to clean drinking water (WHO, 2021).

Significant health consequences result from not having access to clean drinking water, especially for vulnerable groups including children, pregnant women, and the elderly. Many waterborne illnesses, such as cholera, typhoid, and dysentery, can be brought on by contaminated drinking water. Severe dehydration, starvation, and even death are possible outcomes of these illnesses. Furthermore, long-term health consequences like cancer, developmental delays, and neurological impairment can result from exposure to high concentrations of specific pollutants like lead and arsenic (Lin, 2022).

The situation in Peshawar is further complicated by the rapid urbanization and population growth in the city. The increasing demand for water has put pressure on the existing water supply systems, leading to over-extraction of groundwater and contamination of surface water sources. In addition, the inadequate sanitation systems in the city have contributed to the contamination of water sources, exacerbating the problem of drinking water quality (Awan et al, 2022).

Moreover, the effects of climate change further exacerbate these challenges, altering precipitation patterns and affecting the distribution of water resources (IPCC, 2021). Inadequate infrastructure and sanitation systems in certain areas contribute to the persistence of waterborne diseases (Bartram et al., 2019). To address these issues, it is imperative to not only ensure the availability of drinking water but also to maintain its quality throughout the distribution network (WHO, 2018). Regular monitoring, treatment, and quality assessment are essential steps in safeguarding the integrity of drinking water (Khan et al., 2020).

The assessment of drinking water quality in University Town Peshawar is, therefore, a critical endeavor to ensure the well-being of the local community. By evaluating the water quality parameters and identifying potential sources of contamination, this study aims to contribute to the development of effective strategies for improving drinking water quality in the area. The study will collect water samples from various sources, including tube wells, household ends, and the University campus, and conduct chemical and bacteriological analysis to check their suitability for drinking purposes.

1.2 Water Sources of Pakistan

Pakistan, a country located in South Asia, relies heavily on a complex network of water sources to meet its diverse water needs. The Indus River, with its tributaries, serves as the backbone of Pakistan's water supply, supporting agriculture, industry, and domestic use (WAPDA, 2020). The Indus Basin Irrigation System, one of the largest in the world, has historically been the lifeline for Pakistan's agrarian economy (Qureshi & Shah, 2003). Additionally, groundwater plays a crucial role, especially in areas where surface water availability is limited (Shahid & Haroon, 2017). However, the sustainability of these water sources is threatened by factors such as population growth, urbanization, inefficient water management practices, and the impacts of climate change (Awan et al., 2021; Immerzeel et al., 2020). Ensuring the equitable distribution, efficient utilization, and effective management of these water sources is pivotal for Pakistan's socio-economic development and environmental sustainability (Jalil et al., 2019).

1.3 Literature Review

A study by Khan et al. (2010) analyzed various physicochemical parameters, including physical properties, anions, cations, and arsenic species in drinking water samples from rivers, streams, and the Indus River in the Kohistan region of northern Pakistan. They compared the water quality parameters to limits set by the Pakistan Environmental Protection Agency and the World Health Organization. The study found that some samples showed elevated levels of iron and arsenic exceeding permissible limits, indicating potential sources of contamination. The authors suggested geological composition and human activities in the area might contribute to pollution loads

Farid et al. (2012) performed a study assessing groundwater in two Pakistani cities. Water samples were taken from pumps located within 10 meters of the water pipeline. The samples were tested for pH, total dissolved solids (TDS), hardness, alkalinity, sulfate (SO_4), chloride (Cl), sodium (Na), and potassium (K) following standards and methods from the American Public Health Association. In this study, heavy metals including cadmium, chromium, copper, iron, lead, manganese, nickel and zinc were analyzed in the water samples using a Varian AA-1445 Series Atomic Absorption Spectrophotometer, according to ASTM (1993) methods. The findings showed that for the most part, the water samples did not meet drinking water quality standards.

Patil et al. (2013) examined the health impacts and assessment of trace metals in water. The analysis indicates that while water is essential for all life, it can become polluted with heavy metals and toxins like antimony, lead, arsenic, barium, fluoride, cadmium, chromium, copper, cyanide, cobalt and iron for various reasons. This review provides details on trace metals present in contaminated water and their health consequences, as well as investigative techniques. It comprehensively illustrates the causes of these trace metals forming in body water and their effects on living organisms. The key goal for people is to analyze the levels of trace metals present in water prior to using it for any purpose, and compare those to standard limits set by international bodies like WHO, US EPA, and Indian standards. This review also covers some techniques for detecting trace metal content.

Khan et al. (2017) conducted research on the contamination produced by marble industry wastewater in Khairabad, located in Pakistan's Nowshera District, Khyber

Pakhtunkhwa Province. The marble businesses situated along the Kabul River in this area release their waste directly into the waterway, which passes through the towns of Jehangira and Khairabad in Nowshwera district. Water samples were gathered by the researchers from chosen marble industry sites situated along the Kabul River. While pH, temperature, and conductivity assessments were carried out on site, evaluations of total suspended solids and total dissolved solids were performed utilizing lab analysis methods. Atomic absorption spectrophotometry was employed to analyze the presence of heavy metals in the water samples. The researchers compared their findings to the standards established by the Pakistan Environmental Protection Agency (Pak-EPA). While some levels fell within safe limits, concentrations of heavy metals were discovered to be extremely high in certain cases. This could pose a risk of contaminating water resources if not properly managed. Relevant organizations need to regularly inspect the marble factories to help address this issue.

A study by Ishtiaq et al. (2018) looked at levels of potentially harmful elements (PHEs) in coal dust near mining areas in Pakistan, and assessed the related health risks for humans. The researchers took dust samples from coal mines in Cherat, Pakistan and tested them to quantify concentrations of PHEs present. These PHE levels were then used to evaluate health risks from exposure. The findings showed that ingestion of contaminants was the main exposure route for PHEs from the coal dust, compared to other exposure pathways. Overall, the aim was to determine PHE amounts in the dusts and evaluate associated risks to nearby populations. The research by Ishtiaq et al. (2018) found that the calculated daily intake (CDI) of PHEs through ingestion exceeded the oral limit set by the Agency for Toxic Substances and Disease Registry (ATSDR). All the PHEs had chronic risk or hazard index (HI) values below 1, in the following order from highest to lowest: Pb>Cr>Cd>Ni>Cu>Co>Zn. As evidenced by the physical examinations in the study, the elevated levels of lead, chromium and cadmium can result in various health issues. The calculated cancer risk (CR) values were within the thresholds established by the US Environmental Protection Agency (EPA). However, if current practices continue, PHE levels will likely surpass these limits in the future. Therefore, the study recommends implementing safety measures, regulations, and policies to avoid potential health hazards going forward.

Jothivenkatachalam et al. (2010) explored the critical importance of water as a fundamental element for human survival. The study underscores the necessity of water filtration and water conservation. The logical structure and connections between the passages are maintained, and the text is free from incorrect grammar, spelling mistakes, and punctuation errors. Overall, the research emphasizes the vital need for water purification and water preservation. This research brings attention to the need for water filtration and conservation of water resources. The language utilized is clear, objective, and impartial, while also using understandable terminology. The text maintains a consistent structure and format with uniform introductions and citations. The content remains unchanged. The goal of this study is to enhance comprehension of groundwater quality through analysis of particular water samples. It examines various physical, chemical, and biological parameters including pH, conductivity, TDS, TH, Ca2, Mg_2, Cl, SO_4, total acidity, total alkalinity, and DO. The findings were compared against WHO and USPH standards (Jothivenkatachalam et al., 2010).

Trivedi et al. (2010) examined various physical parameters of water samples from Kanpur city across different seasons from April 2008 to March 2009. The parameters analyzed included turbidity, temperature, pH, total hardness, iron, chloride, dissolved solids, calcium, sulfate, nitrate, fluoride, chromium, and total alkalinity. The water samples came from surface water, Ganga water (GW), and water treatment plants during the summer, monsoon, and autumn seasons. Trivedi et al. (2010) scrutinized an array of physical parameters in water specimens collected from Kanpur urban area throughout distinct seasons spanning April 2008 to March 2009. The assessed factors encompassed turbidity, temperature, pH, overall hardness, iron, chloride, dissolved solids, calcium, sulfate, nitrate, fluoride, chromium, and complete alkalinity. The water samples were derived from surface water, groundwater, and water treatment facilities during the summer, monsoon, and autumn periods. Trivedi et al. (2010) delved into assorted physical attributes of water samples procured from Kanpur city across diverse seasons from April 2008 to March 2009. The parameters analyzed included turbidity, temperature, pH, total hardness, iron, chloride, dissolved solids, calcium, sulfate, nitrate, fluoride, chromium, and total alkalinity. The water samples came from surface water, groundwater, and water treatment plants during the summer, monsoon, and autumn seasons. This study found that the pH, turbidity, TH, and Cl values of TW samples were equal to or lower than the values of PSP groundwater samples in all five seasons. Between seasons, surface water samples from CGW and groundwater samples from Postal Station Pump (PSP) experienced no problems; This shows that PSP has better water quality in winter than in summer. In all seasons, eight key indicators of GW standards comply with drinking water limits set by WHO: TH, Mg, Cl, NO_3, SO4, F, Ca and SO_4. The water is good after purified by filter equipment. The pH of GW water samples increased in summer, spring, and autumn. During winter months, TDS levels are reduced to the limits set by the World Health Organization. Research indicates an enhancement in the groundwater quality during the monsoon compared to winter. The investigation revealed contamination of PSP groundwater by Cl in the summer, TA in both summer and summer (repeated), and TDS in autumn, spring, and summer. These levels exceeded the guidelines set by the World Health Organization for drinking highest desirable limit (HDL). Nevertheless, following treatment at the facility, surface water quality improved and remained uncontaminated across all seasons. In fact, the water quality in PSP is better than the groundwater quality in monsoon, autumn, spring and summer. It is worth noting that this report aims to provide objective and factual information without judging the content or negative language. Further research is needed by GW, CGW and PSP at different locations to compare the drinking water quality in Kanpur, India. The material found in 200MLD and the quality of groundwater should be compared at different times and places.

According to Patil et al. (2012), the planet is facing a significant risk due to unfavorable alterations in the physical, chemical, and biological characteristics of air, water, and soil. The escalation in population, industrialization, fertilizer usage, and human actions contribute to substantial pollution of water with detrimental pollutants. Natural water sources experience contamination through rock weathering, soil erosion, and mineral processes. It is imperative to conduct regular assessments of drinking water quality to avert waterborne diseases stemming from contaminated water. Ensuring access to high-quality water is crucial for enhancing the overall quality of life. The assessment of water quality encompasses parameters such as color, temperature, acidity, hardness, pH, sulfate, chloride, dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), and alkalinity. Special attention is given to heavy metals like lead (Pb), chromium (Cr), iron (Fe), and mercury (Hg), known for their potential to cause acute or chronic poisoning in aquatic organisms. The text illustrates a water analysis report as an exemplar, detailing physicochemical parameters for in-depth examination. Patil et al. (2012) furnish guidelines for the comparison of real water sample values, encompassing various physicochemical parameters.

The findings of Naeem et al. (2012) indicate that ensuring access to safe drinking water is of utmost importance for safeguarding global human health and well-being. The oversight of drinking water quality in both urban and rural areas of Pakistan is deficient, as multiple studies reveal the prevalence of physical and chemical contamination in the majority of drinking water sources. This research delved into the drinking water sources within the urban and rural regions of Kohat district, assessing their appropriateness for drinking purposes. A comprehensive set of 54 water samples was gathered from diverse sources, including hand pumps, streams, reservoirs, tube wells, and wells, covering 15 strategically chosen sampling locations within the primary population areas. Furthermore, six samples of bottled water were procured from the market. An analysis of physicochemical parameters, encompassing pH, conductivity, total dissolved solids (TDS), and total suspended solids (TSS), was conducted for all collected samples.

Shanmugasundaram et al. (2012) undertook an examination of the physicochemical attributes of drinking water derived from various outlets in Coimbatore. Retaining the original content, samples were sourced from fundamental outlets extensively used for drinking and domestic applications. Standard methodologies were employed to ascertain the physicochemical parameters of the water specimens, encompassing pH, electrical conductivity, total dissolved solids (TDS), alkalinity, entire alkalinity, complete hardness, magnesium (Mg), magnesium hardness, calcium, methyl alkalinity, phosphate (PO_4), and sulfate (SO_4). The analysis revealed that the quality of drinking water in the researched area is satisfactory, with no discernible levels of concerning pollutants. Nevertheless, pre-consumption, the water necessitates treatment, as the concentrations of certain parameters like alkalinity, TDS, overall hardness, and turbidity surpass the acceptable thresholds for potable water (Shanmugasundaram et al., 2012).

Pindi et al. (2013) initiated an examination to assess the bacteriological and physiochemical aspects of the drinking water supply in the Mahabubnagar district of India. A total of four samples were procured from Ramanpadu and Koilsagar water sources, encompassing both natural reservoirs and filtered outlets. Each sample underwent evaluation for both bacteriological and chemical parameters. In the bacteriological findings, the bacterial count reached its peak in Ramanpadu water (RP-736 CFU/ml) and reached its lowest in Koilsagar water (KS-06 CFU/ml). The total plate count exhibited the highest tally in Koilsagar filter (KSF) water and the lowest in Koilsagar (KS) water. The most probable number method was employed for identifying and quantifying total coliform and E. coli. The outcomes indicated the presence of only one indicator bacteria in two samples (RP and RPF). The examination involved monitoring various physicochemical attributes of the samples. This encompassed EC, turbidity, phenolphthalein alkalinity, residual chlorine, color, polynuclear aromatic hydrocarbons (PAH), total alkalinity, mineral oil, anionic detergents, phenolic compounds, cyanide, SO_4, NO_3, F, Cl, HCO_3, Ca_2, Mg2+, Na, K, Fe, Cu, Mn, Zn, Cd, Pb, Hg, Se, Ag, and Cr. The pH levels in the water samples displayed a range from 7.21 to 7.96, with an average value of 7.52, indicating alkalinity. Notably, all examined physicochemical parameters fell within acceptable limits, with none of the four samples surpassing the prescribed values for chemical parameters (Pindi et al., 2013).

Kerketta et al. (2013) initiated an investigation to assess the physicochemical attributes and levels of heavy metals in drinking water samples obtained from diverse sources in and around Ranchi, Jharkhand, India. A comprehensive set of 100 water samples was procured from hand pumps (44), wells (27), taps (20), rivers (3), and ponds (6). The examination encompassed the analysis of various parameters in the water samples, including gross appearance, taste, odor, temperature, pH, dissolved oxygen, biochemical oxygen demand, alkalinity, conductivity, total dissolved solids, as well as the concentrations of lead and cadmium. The transparency and absence of odor, coupled with a pleasant taste, characterized most water samples, excluding those sourced from rivers and ponds. The investigation revealed significant contamination in samples collected from ponds and rivers. Six water samples surpassed the recommended pH level, while dissolved oxygen fell below 5 ppm in 11 samples. Nineteen water samples exhibited a biochemical oxygen demand exceeding 6 ppm, and alkalinity surpassed 120 ppm in 14 samples. Additionally, conductivity exceeded 1400 µS/cm in two water samples. The concentrations of lead and cadmium surpassed permissible limits in the examined samples (Kerketta et al., 2013).

Werkneh and colleagues (2015) embarked on an exhaustive investigation into global natural potable water sources. The critical need to ensure the integrity of drinking water for the preservation of optimal health is apparent, given its susceptibility to a multitude of contaminants, encompassing chemical and microbiological agents that have the potential to pose significant health hazards. The research specifically honed in on the meticulous examination of physicochemical aspects dictating the quality of potable water in Jigjiga city, situated in the Somali Region of Ethiopia. Parameters such as temperature, pH, electrical conductivity, total dissolved solids, and total hardness underwent thorough scrutiny across diverse profiles of water quality. The experimental methodologies adhered to the drinking water standards established by WHO (1999) on an international scale. The mean values for temperature, pH, electrical conductivity, total dissolved solids, and total hardness were recorded. The findings suggest that, with the exception of total hardness and electrical conductivity, all parameters fall within the prescribed range of minimum and maximum permissible limits according to drinking water guidelines (Werkneh et al., 2015).

Yasin et al. (2015) undertook an inquiry in Serbo town and handpicked kebeles within the Kersa district of the Jimma zone in southwestern Ethiopia. Sociodemographic attributes of the study populace were systematically acquired using a structured and pre-tested questionnaire. The ascertainment of bacterial load and identification of coliforms were conducted in accordance with standard microbiological protocols. The physicochemical analysis adhered to the guidelines provided by the World Health Organisation and the American Public Health Association. This examination included measurements of a variety of parameters, such as biological oxygen demand (BOD), total suspended solids (TSS), total dissolved solids (TDS), phosphate and nitrate amounts, viscosity, and conductivity of electric current. Using SPSS software (version 20), correlations between measured properties of water samples obtained from various sources were computed. In the research area, tap water was only available to 18.1% (43/237) of the study population. Over half of the population relies on outside trash disposal. The Enterobacteriaceae, Bacillus, and Pseudomonas families contained the majority of the bacterial isolates found in the water samples. Total and faecal coliform (FC) tests on every water sample taken from sources of concern were positive.

Azizullah et al. (2011) state that water contamination in Pakistan is a serious hazard to public health. Due to poor management and oversight of drinking water quality, Pakistan's drinking water quality ranking is 80th out of 122 countries. All across the nation, surface and groundwater sources are contaminated by pesticides, heavy metals, and coliforms. The WHO drinking water quality guidelines are regularly broken. Human activities such as the careless discharge of industrial and municipal wastewater and the indiscriminate use of agrochemicals in agriculture are the primary causes of the degradation of water quality. Microbial and chemical pollutants can be the only cause of public health issues, or they can occur together. Using a focus on main pollutants, their sources, and related health concerns, this study provides a thorough examination of Pakistan's drinking water quality. This evaluation draws its material from a variety of sources, such as government and non-governmental organisation reports, national and international journals, and other publications.

In the drinking water of the chosen Lower Dir, Pakistan, location, Ilyas et al. (2017) noted the physicochemical properties and concentrations of light and heavy elements. The inhabitants of Lower Dir do not know the condition of their water or the harmful effects of tainted water. An awareness campaign about the value of clean and safe drinking water is based on the findings of this research. 22 water samples were gathered in order to do this, and they were examined for a number of factors. Phosphorus, temperature, salinity, electrical conductivity, and dissolved oxygen (DO) were the physical characteristics analysed. Complete dissolved solids (TDS), sulphates, chlorides (Cl), hardness, and alkalinity were the chemical characteristics examined. with Pb (0.04 mg/L) falling within allowable bounds. The heavy metals were subjected to health risk evaluations using the Hazard Quotient (HQ) and Average Daily Dose (ADD). The concentrations of heavy metals in the drinking water samples (CDI and HQ<1) did not pose any health risks, according to the data.

Water is deemed to be a necessary element for life by Hussain et al. (2012). On the other hand, over a billion people globally lack access to clean water due to rising demand. Using a number of criteria, the researchers examined the effluent. A sample taken from the GT Road near the Bara River, Sardar Garhi, revealed a high conductivity of 3800 µs/cm. A sample taken on the first day from the Sardar Garhi GT Road, close to the Bara River, has a high BOD level of 100 mg/L. In the same region, TSS analysis reveals a low level of 7.00 mg/L. A sample taken on the fourth day at 4:30 pm from Hazar Khawani, next to the police post ring road, revealed a COD level of 228.00 mg/L.

A study in 2021 by Awan et al. analyzed water samples from different sources (borewell, bottled water and tap water) in four districts of Khyber Pakhtunkhwa province of Pakistan – Peshawar, Mardan, Swat and Kohat. Ten samples from each urban and rural water source were taken from each of the fifty water samples that were obtained from each district. The following pollutants were detected in the samples: sulphates, nitrates, nitrites, chlorides, total dissolved solids, and E. Coli bacteria. The E. Coli contamination levels in the majority of the water sources were found to be undesirable, above 34 CFU/100 mL, as indicated by the results. The district of Mardan had the highest level, followed by Kohat, Swat, and Peshawar. Some sources also contained elevated chemical contaminants from fertilizers (nitrates/nitrates) and industrial/agricultural wastes (chlorides, sulfates), although fertilizer levels were within safe limits. Overall, water quality was worse in Kohat and Mardan compared to Peshawar and Swat. The study concluded that many sources of drinking water in these districts are chemically and bacteriologically unfit for human consumption and may pose a health hazard.

In 2014, Inam Ullah and A. Alam conducted a study on drinking water quality in Peshawar, Pakistan. They collected groundwater samples from 32 locations, including tube wells and household taps. The samples were analyzed for physical, chemical and bacteriological parameters as well as for the presence of heavy metals. The results showed that 96.87% of the samples met the physical and chemical guidelines. However, 84.35%

of household tap samples were contaminated with coliform bacteria and were considered unsafe for human consumption. Additionally, 31.2% of tubewell samples had questionable bacteriological results. The researchers concluded that faulty distribution infrastructure and lack of maintenance are the main causes of drinking water contamination in Peshawar.

In a more recent study from 2021, Babar et al. investigated the microbiological quality of drinking water in rural Peshawar. They collected 600 water samples from hand pumps and taps in three towns. Analysis showed that Salmonella (15%), Shigella (32.8%), and E. 45.7% of samples were positive for dangerous microorganisms including E. coli (11.7%). Growth of these pathogens was significantly higher in hand pump samples compared to tap water. The presence of these potentially deadly organisms indicates poor drinking water quality in rural environments, which can lead to waterborne diseases. Public health measures are needed to reduce the incidence of waterborne diseases in these areas.

Khalil et al. (2017) collected 30 drinking water samples from government and private schools in Peshawar, Pakistan. They tested the samples for E. coli contamination. The results show that E. 19 (63.3%) samples were positive for coli, including 11 (73.3%) from government schools and 8 (53.3%) from private schools. Total coliform bacteria were detected in 29 out of 30 samples.

Farhat et al. (2013) analyzed the bacteriological quality of drinking water from tube wells, hand pumps and open wells in rural Peshawar. They found high levels of total bacteria, total and faecal coliforms, and E. coli O157:H7 contamination, with 80% of open well samples not suitable for drinking according to WHO guidelines.

Joseph et al. (2013) studied chemical water quality in Nowshera after 2010 Pakistan flood. Sulphate, nitrite, sodium and total solids were found to be more than 60% of the WHO drinking water limit, indicating severe pollution from flooding.

Sardar Khan and others. (2020) assessed the quality of drinking water in the city of Peshawar. Although the physicochemical parameters are within the guidelines, they found bacterial contamination from faecal coliform, E. coli, Salmonella, Shigella, Vibrio, Staphylococcus aureus and Pseudomonas aeruginosa. They recommend chlorination or boiling before drinking.

1.4 Problem Statement

The provision of safe and clean drinking water is a fundamental right and a critical determinant of public health. However, in many urban areas, including University Town Peshawar in Pakistan, challenges persist in ensuring the quality of drinking water. Rapid urbanization, inadequate infrastructure, and environmental factors pose potential threats to the safety of water supplies, raising concerns about the health and well-being of the local population. Therefore, there is a pressing need for a comprehensive assessment of the drinking water quality in University Town Peshawar, considering factors such as potential contaminants, regulatory compliance, and the effectiveness of water treatment processes. By identifying the specific issues that affect drinking water quality in this urban context, effective strategies can be formulated to safeguard public health and promote sustainable water management practices.

Given its unique blend of urban development and climatic characteristics, the University of Peshawar campus represents a dynamic setting that explores the complexities of drinking water quality assessment. All the different zones, with climatic conditions and relative humidity, require a comprehensive study of water quality variables, regulatory requirements, and treatment effectiveness to ensure the provision of safe and clean drinking water for the local population. Peshawar University's water supply system is obtained from local sources such as groundwater and surface water and is managed by the respective municipalities. Given the increasing demand for water resources due to population growth and urban development, the research area offers an interesting context for investigating drinking water quality. Human activities, land use changes, and water resource interactions can affect the presence of pollutants and contaminants in water supplies, affecting the health and well-being of citizens and the academic community.

Safe drinking water availability is crucial for the health and welfare of locals and students in the study region. In order to be sure that the water in University Town is safe to drink, it is crucial to evaluate its quality. Comprehensive research is desperately needed to supply precise and trustworthy facts for prompt response. Research on drinking water evaluation is necessary to enhance field testing and source monitoring, develop and use innovative treatment solutions for low-quality water, and create new sources of safe drinking water.

Furthermore, the complex interplay of factors such as industrial activities, waste disposal practices, agricultural runoff, and aging infrastructure can contribute to the quality of drinking water in the region. Understanding these dynamics is crucial for implementing effective water quality management strategies that ensure the safety and sustainability of the water supply for both the present and the future.

1.5 Purpose of Study

This study's objective was to evaluate the drinking water quality in the study area, which is University Town in Peshawar, Pakistan's Khyber Pukhtunkhwa Province.

1.6 Objectives

Specific objectives of the study were;

1. To evaluate the physicochemical and microbiological parameters of water in University Town Peshawar.
2. To identify any potential sources of contamination in the water supply of University Town Peshawar.

CHAPTER 2
METHODOLOGY

2.1 Study Area

The study was conducted in the University Town of the city of Peshawar, Khyber Pakhtunkhwa, Pakistan. The town's catchment zones comprised a mix of urban and peri-urban landscapes, encompassing residential, educational, and commercial sectors. Climatic conditions in University Town Peshawar exhibit a semi-arid climate, typical of the larger region. With hot summers and relatively mild winters, the study area experiences significant temperature fluctuations throughout the year. Summer temperatures often soar above 40°C (104°F), fostering conditions of elevated evaporation rates and potential water scarcity concerns. Summers are marked by relatively low humidity levels, frequently below 30%, which can intensify the demand for water resources due to increased evaporation. During the winter months, temperatures can drop to around 5°C (41°F), contributing to varying water usage patterns. The winter months experience slightly higher humidity levels, with readings around 50%, influencing the perception of temperature and potentially affecting waterborne contamination dynamics.

The study area is in the Peshawar District which is the capital of Pakistan's Khyber Pakhtunkhwa province. Peshawar, is situated near the Afghan border in a broad valley near the eastern end of the famous Khyber Pass. The region is located between longitudes 71-220 and 71-420 east and latitudes 44-150 and 34-150 north. There are two million people living in the city, which has a total size of 1257 km² (Ali, J. 2010). Groundwater is the primary supply of drinking water for the city. It has a semi-arid climate. Mostly in July and August, during the monsoon season, rain pours.

The research domain University town is home to numerous universities and a sizable student body. The four tehsils that make up the Peshawar district are Peshawar-1, Peshawar-2, Peshawar-3, and Peshawar-4. A 'nazim' is elected to serve in each of the 93 union committees (UCs) that comprise these tehsils. Water, sanitation, and waste management services are provided by the Peshawar Development Authority (PDA) in all of the UCs, Hayatabad I and Hayatabad II, and University Town (inside the University Town UC). In June 2017, the WSSP relinquished control of these territories to the PDA.

The University town is recognized as Union Council 36 and comes under Zone D (Five zones, namely, i.e. A, B, C, D, and Hayatabad, have been formed by Municipal Water Supply system created on the basis of infrastructure mapping / WASSA). The University town has a population of 18786 (as per the 1998 Census of, Khyber Pakhtunkhwa. The University town of Peshawar was selected on the basis of its high population. The University town Peshawar (UC 36) has 26 Tube wells with an estimated water production of 32,400 m^3/day. One (01) filter unit and 995,000 (gallons) of useful storage capacity are available (Source: Infrastructure Mapping & WSSP). Note: An average pumping rate of 60.0 m3/h was used to compute the total pumping capacity. Pumping took nine hours a day on average. There is no independent confirmation of the real production in the lack of flow metre readings. There were just 4 that worked. Every unit has a capacity of 2 m3/h. The method is based on sand filtration that is enhanced with cartridges and UV light-disinfected. According to the GOP (2016), there are four primary sources of water in a household: a hand pump, a motor pump, a dug well, and the tap.

The study area is in Town III of Peshawar Urban, namely University Town UC-36. Tube wells and public bores are the current sources of drinking water. At present, the WSSP is in charge of 16 tube wells. The UC-36 study area comprises two neighbourhood councils (101 & 102) with a combined population of 56,994. The region spans 2.23 km² and features open spaces, green spaces, and thoughtfully designed infrastructure.

Table 2.1 Detail of the Study Area and Population

S.No	NC No	UC Name	Area (Km2)	Population	Estimated # of HH (6.7 person / HH)	# of Tube wells
1	101&102	University Town	2.23	56,994	8506	16

Source: AiD-NDC-JC 2019 reviewed and updated Peshawar's current urban water and sanitation master plan.

The map of the study area has been developed with the help of GIS lab of Pakistan Forest Institute, Peshawar. (Figure 2.1)

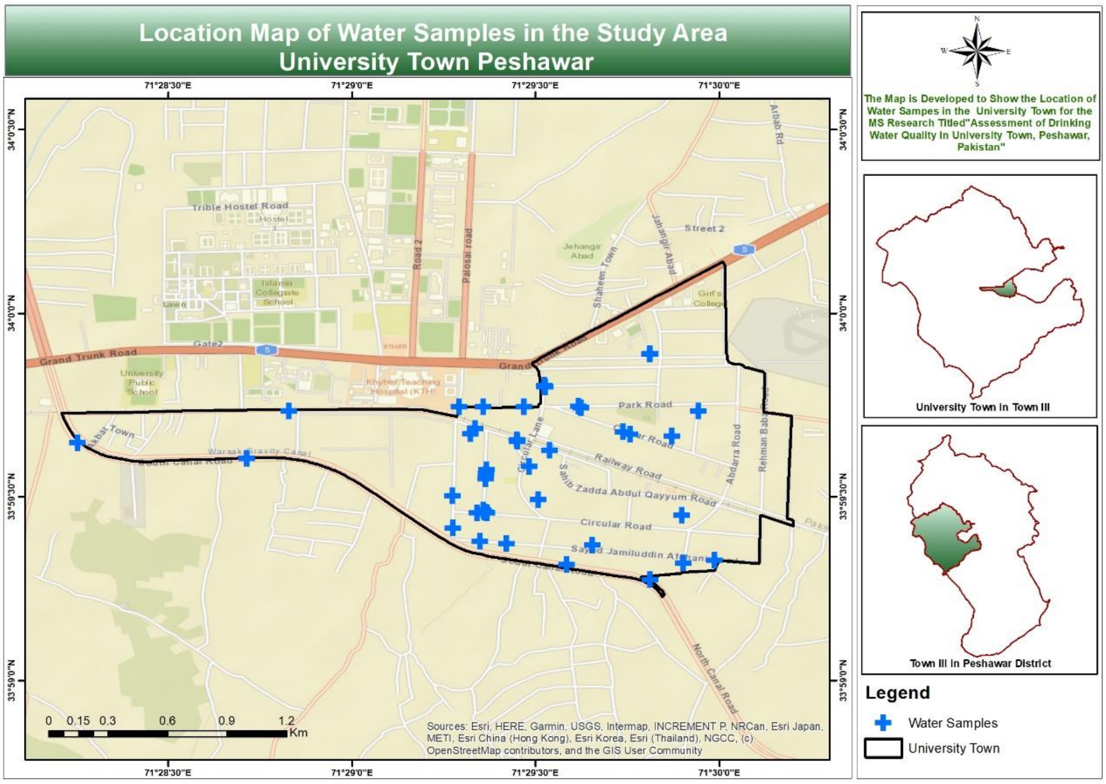


Figure 2.1 Map of the Study area

2.2 Research Methodology

The research methods used in carrying out the research are described in the sections 2.3, 2.4. They are presented in three sub sections namely: Sampling, Data Collection and Data Analysis.

2.3 Questionnaire Survey

A questionnaire survey containing different questions about water quality and waterborne diseases to get insight into water contamination issues was conducted. The respondents from 30 households were interviewed in face-to-face interviews. The survey aims to enhance understanding of the local water supply's quality. Questionnaire is given in Annexure-II.

2.4 Water Sample Collection

Samples of water were collected from 50 points in UC-36 from user points at different locations in sterilized bottles. A water sample of 1000ml was taken for chemical and physical analysis while about 250ml sample for microbial analysis was taken. A photo gallery is given in Annexure-I.

Samples were collected with the help of GPS points. The location of sample points has been shown in the map in Figure 2.1 and in Annexure-III. The present research was conducted to analyze physiochemical and microbiological analysis of the drinking water quality of University Town UC-36 Peshawar and find if there are any potential sources of contamination. Simple random sampling was used to collect water from various water sources including Tap water source tube well, and Tap water source bore of University Town Peshawar. Water Samples were collected as per the sampling protocols of Pak EPA. The 'Sterilized plastic bottles were used to collect water samples that was sealed, labeled, and transported to the testing lab for Physical, Chemical, and biological parameters.

Upon collection, preserving the integrity of water samples becomes paramount to ensure accurate and representative results during the subsequent analysis of drinking water quality. Proper water sample preservation protocols are essential to prevent the degradation of contaminants, chemical reactions, or microbial growth that could potentially alter the composition of the collected samples. In the case of the present study conducted in University Town Peshawar, Pakistan, water samples were meticulously preserved following established guidelines. Samples were collected using sterile containers and immediately refrigerated at temperatures below 4°C (39.2°F) to impede microbial activity and chemical reactions. Furthermore, the addition of preservation agents was carried out to maintain the original state of the samples. Adequate labeling, documentation of sampling conditions, and adherence to a stringent chain of custody were diligently maintained to ensure the reliability of the collected data. By implementing robust water sample preservation procedures, the study aimed to generate accurate insights into the quality of drinking water within University Town Peshawar, facilitating informed decision-making and sustainable water management practices.

2.5 Experimental Work

In laboratory of PCSIR samples were analysis for physiochemical parameters, bacterial and heavy metal contamination.

2.6 Physical Parameters

The list of physical parameter consists on examined pH, Total Dissolved Solid, electrical conductivity and turbidity; all the samples were analyzed in the lab of PCSIR, Peshawar.

2.6.1 pH

Procedure

We assessed the pH of the water samples in the lab using a model PHH222 pH metre. After thoroughly cleaning the electrode with distilled water, the test samples' pH levels were determined. Prior to taking the final reading and noting the stabilised reading, the electrode was dipped into the sample and allowed to settle in the system.

2.6.2 Electronic Conductivity

Procedure

The conductivity of the water samples was measured in the lab using an AZ8301 conductivity meter. To take accurate readings, the meter electrodes were first rinsed with distilled water. Each water sample was poured into a 100ml beaker, with enough volume to submerge the electrode bulb. The meter was switched to conductivity mode and the reading recorded. After each measurement, the electrode was washed with distilled water again before immersing it in the next sample. This rinse-measure-rinse process was repeated for all collected water samples.

Calibration

For calibration of conductivity meter 0.01 M solution of KCl will give 1412µmo/cm or µS/cm.

2.6.3 Total Dissolved Solid (TDS)

Procedure

Impurities were kept in the oven for some time to measure their initial dry weights. The total dissolved solids were measured using the China dish method. First of all, China dishes were taken according to sample number, they were washed with HCL and distilled water to remove initial weight, and filtration of the samples was done using P40 filter paper in a conical flask using a funnel. 100 ml of each sample was passed through filter paper. The filtered water was then kept in China dishes and was oven-dried for 24 hours at 120°C.

Equation

Weight of China dish = W1

Weight of China dish after passing the solution, oven dried and TDS = W2

$$\frac{W2 - w1 \times 1000 \times 1000}{\text{Sample size used}}$$

2.6.4 Turbidity

A turbidity test was done through a turbidity meter (Model AL250T-IR). First standards were set for turbidity test by applying standard tests, which were 1, 10, 100, and 1000 respectively. There were some small-scale errors in standards, which were adjusted accordingly in the results.

Procedure

To measure turbidity, water samples were collected in 10ml bottles with a white fill line. The bottles were filled to the line with the sample water. Each bottle was placed in the turbidity meter, aligning the white line on the bottle with the white line on the meter. The lid was closed over the bottle and the turbidity reading taken. To determine the average turbidity, the test was performed three times on each sample bottle. The three readings were averaged to calculate the final turbidity result for that water sample. This process was repeated with new sample bottles for each water source tested.

$$\text{Calculation Average turbidity} = \frac{\text{1st test + 2nd test +3rd test}}{\text{No of test}}$$

2.7 Chemical Parameters

2.7.1 Total Hardness

When we talk about total hardness, we're talking about the milligrams of calcium and magnesium ions mixed in one litre of calcium carbonate. Water hardness and its capacity to precipitate soap are connected. Using the complexometric titration standard method (1992), the researcher examined the hardness of the water. Using a complexometric titration procedure, the total calcium and magnesium ions in the water samples were measured. The overall hardness value for every water sample was determined by adding the quantities of calcium and magnesium ions. Harder water that rapidly precipitates soap is indicated by higher quantities.

Procedure (Total Hardness)

First, a solution of 500 ml EDTA (0.01 M) was prepared and was placed in a burette. Then we took 30 ml each sample and added the following:

1 ml of buffer solution pH 10

1 to 2 drops of Eriochrome Black T indicator

1 to 2 drops of KCN (Potassium Cyanide)

EDTA (0.01 M)

Furthermore the sample was titrated with EDTA solution until the red tinge color disappeared and the final color appeared blue.

Calculation

$$\frac{(\boldsymbol{A}-\boldsymbol{B}) \times \mathbf{0.01}\boldsymbol{M} \times \mathbf{1000} \times \mathbf{100}\ \boldsymbol{as\ Caco}\mathbf{3}}{\boldsymbol{volume\ of\ sample\ used}}$$

2.7.2 Chloride Ion (CI)

Chloride is a common inorganic ion found in water and wastewater. Chloride levels tend to be higher in wastewater compared to raw water. High chloride content can corrode metal pipes and structures, and damage plants. The researchers analyzed chloride concentrations using the silver nitrate titration standard method. This involved titrating the water samples with silver nitrate, which reacts with the chloride ions. The amount of silver nitrate required to completely react with the chlorides indicates the chloride ion concentration in the water sample. This titration analysis provided quantitative chloride levels for the collected water samples.

Procedure

Reagents

1) Silver nitrate ($AgNO_3$)

2) Potassium dichromate (K_2Cr2O_7)

$AgNO_3$

$$\mathbf{107} + \mathbf{14} + \mathbf{16} \times \mathbf{3} = \mathbf{169}\text{gm}$$

$$\frac{\mathbf{169} \times \mathbf{0.0141} \times \mathbf{500} = \mathbf{1.1}\text{gm}}{\mathbf{1000}}$$

1.19 gm dissolved in 500 ml of distill water, 1ml = 0.5 mg

2.38 gm dissolved in 1000 ml of distill water, 1ml = 1 gm

Procedure

- 1000 ml $AgNO_3$ solution was prepared and was placed in burette. 30 ml of sample was taken each and following were added

1 to 2 drops of $K_2Cr_2O_7$ indicator (Potassium dichromate)

Normality of $AgNO_3$ was taken of double strength, $\mathbf{0.0141} + \mathbf{0.0141} = \mathbf{0.0282}$

Calculation

$$\frac{\boldsymbol{A} - \boldsymbol{B} \times \mathbf{0.0282} \times \mathbf{35.5} \times \mathbf{1000}}{\text{Volume of sample used}}$$

2.7.3 Total Alkalinity

Reagents

1) Standard sulfuric acid solution

Take 27 ml of concentrated sulphuric acid and dilute it up to 1 liter of distilled water in a volumetric flask this is the stock solution. Now take 20 ml from this 1N solution and dilute this 1 liter in a volumetric flask to 0.02 N

Calculation

1 mole of H_2SO4 = 98 g

Equivalent wt. (H_2SO4) = 49 g

Density of H2SO4 = 1.84 g/m

V= mass (g)/density = 49g/1.84g/ml

V=26.63 ml Average purity of H2SO4 = 96.5 %

100×26.63/96.5 = 27.25 ml

2) Phenolphthalein indicator 2-3 drops in each sample

3) Methyl orange indicator

One (1) drop in each solution

Procedure (Acid-base titration method)

Procedure

To measure alkalinity, a 100ml burette was filled with 0.02N sulfuric acid solution. 30ml of each water sample was poured into a beaker. 3 drops of phenolphthalein indicator were added, but no color change occurred, indicating absence of p-alkalinity. Next, 3-4 drops of methyl orange indicator were added, producing a yellow color signifying the presence of M-alkalinity. The sulfuric acid solution was titrated into the sample, recording initial and final burette readings, until the yellow turned orange showing the endpoint for total alkalinity. The volume of sulfuric acid required to reach the color change was used to calculate the total alkalinity. This process was repeated for all 50 water samples to determine their alkalinity values.

Calculation

$$\text{Alkalinity as CaCO3} = \frac{\text{ml of sulphuric acid used} \times \text{N of acid} \times \text{equivalent w.t of CaCO3} \times 1000}{\text{ml of sample used}}$$

2.7.4 Calcium Hardness

Procedure (Calcium Hardness)

500 ml EDTA (0.01 M) was prepared and was placed in burette. Then we took 30 ml each sample and added the following:

1 ml of buffer solution pH 12.5

1 ml of sodium hydroxide (NAOH) added

1 to 2 drops of murexide indicator

EDTA (0.01 M)

Calculation

$$\frac{(A-B)\times 0.01M \times 1000 \times 40 \text{ as } Ca}{\text{volume of sample used}}$$

2.7.5 Magnesium and Potassium

Magnesium is naturally present in water in the form of dissolved salts. The concentration of magnesium salts in water samples can be determined by calculating the difference between total hardness and calcium hardness. Total hardness measures the combined concentration of both calcium and magnesium salts. Calcium hardness specifically measures just the calcium salt content. By subtracting the calcium hardness from the total hardness, the remaining hardness is attributable to magnesium salts. This provides a way to quantify the magnesium salt concentration in the water samples. The presence of magnesium salts contributes to the overall total hardness of natural waters.

Calculation

mg/L (as $CaCO_3$) = Total hardness – Calcium hardness=Magnesium

2.8 Bacteriological Contamination

DelAqua Portable Water Testing Kit is used for determination of bacteriological contamination in water.

2.8.1 Sterilization of Medium and Glassware

Glassware such as beakers, flasks, test tubes, Petri plates used in the laboratory during analysis was properly washed using any detergent available in the laboratory. After scrubbing with a brush, the glassware was rinsed with water. It was then rinsed with distilled water until all dirt and dust was removed. To sterilize the medium, the glassware was autoclaved at 121°C for 15 minutes using a pressure of 15 pounds per square inch (psi). After autoclaving, the glassware was dried in an oven at a temperature of 60°C (140°F) prior to use.

2.8.2 Sterilization of The Filtration Apparatus

1. Take the plastic collar and secure the filter funnel in a loose but not free position. This will allow the formaldehyde gas to penetrate all areas of the filter head.
2. Pour about 10 to 15 drops of methanol into the vacuum suction cup.
3. Use a cigarette lighter to ignite the methanol in the suction cup. The cup should be on a flat surface which is not subject to heat damage.
4. Allow the methanol to burn for a few seconds and when it is almost completely extinguished (i.e. when the flames die away), place the filter head over the suction cup and press firmly to form a good seal.
5. Leave the filter to stand for at least 15 minutes before use.

2.8.3. Total Plates Count

Total Plate Count (TPC), also known as Standard Plate Count (SPC), refers to a laboratory technique used to estimate the total number of viable microorganisms, such as bacteria and fungi, present in a sample of drinking water. The procedure involves the following steps:

1. Sample Collection: A representative sample of the drinking water is collected in a sterile container to avoid contamination.

2. Inoculation: Known volumes of the sample are spread or poured onto agar plates. The agar provides a suitable environment for the growth of microorganisms.

3. Incubation: After that, the agar plates are kept in an incubator for a predetermined amount of time at the proper temperature. This promotes the bacteria in the sample to proliferate.

4. Colony Counting: After incubation, visible colonies of microorganisms appear on the agar plates. These colonies are counted manually or using automated colony counters.

It's important to note that the TPC provides an estimation of the overall microbial load in the water sample. Different microorganisms have varying growth requirements, and not all may grow under the conditions used for TPC. Therefore, TPC is a general indicator rather than a definitive count of specific microbial species.

The procedure should be conducted by trained personnel in a controlled laboratory setting to ensure accuracy and minimize contamination risks. Additionally, local regulations and standards may dictate specific procedures and acceptable microbial levels for drinking water.

2.8.4. Total Coliform Bacteria

One type of bacterium that is frequently used to indicate both the possibility for fecal contamination in drinking water and the quality of the water is total coliform. They consist of many kinds of bacteria that are present in the intestines of humans and other animals with warm bodies. The observation of total coliform bacteria in drinking water raises the possibility of faecal matter or other contaminants contaminating the water.

The procedure to test for total coliform bacteria in drinking water typically involves the following steps:

1. Sample Collection: A sample of the drinking water is collected using a sterile container to prevent contamination.
2. Incubation: The collected water sample is added to a specific growth medium designed to promote the growth of coliform bacteria. The medium may contain nutrients and indicators that help in detecting the presence of these bacteria.
3. Incubation Period: The inoculated growth medium is then incubated at a specific temperature for a specific period, usually 24 hours. During this time, if coliform bacteria is present in the water sample, it will multiply and produce visible colonies.
4. Colony Examination: After incubation, the medium is examined for the presence of colonies that resemble coliform bacteria. These colonies may appear as distinct, often reddish-colored growths.
5. Confirmation Tests: While total coliform bacteria are a general indicator, further tests may be conducted to confirm the presence of fecal coliforms or E. coli, which are more specific indicators of fecal contamination and potential health risks.
6. Interpretation: The results are interpreted based on the presence or absence of coliform colonies and any confirmed presence of fecal coliforms or E. coli.

High levels of coliforms or the presence of confirmed fecal indicators may indicate a potential health risk and the need for corrective actions.

It's important to follow standardized procedures and guidelines established by regulatory authorities or organizations when testing for total coliform bacteria in drinking water. These tests help ensure the safety of drinking water and the protection of public health.

2.8.5. Heavy Metal Concentration

Heavy Metal concentration in samples will be analyzed through atomic absorption spectroscopy. Samples collected will be digested and sealed prior to their transportation to LAB.

The samples will be preserved according to the US EPA analytical techniques references. The sample will be preserved with HCl and bottles sealed and transported to lab in board boxes.

CHAPTER-3

RESULT AND DISCUSSION

To ascertain the various physiochemical properties of the drinking water at University Town (UC-36), Peshawar, a total of fifty samples were taken from consumer sites. After collection, the samples were immediately transported to PCSIR Lab Peshawar to avoid maximum contamination and analysis. The results are given in the form of tables and discussed in comparison with the standard permissible limits.

3.1 **Result of Physical Parameters**

The results of physical parameters of drinking water are given in Annexure-IV. The physical parameters are discussed in the following figures.

3.1.1 pH

pH was measured by pH meter (4500-H*B) with expanded uncertainty of 0.18. Results obtained from the samples were plotted in figure No. 3.1.1 pH values of all the samples were in permissible limit 6.5 -8.5 as per **PSQCA/ NEQS/ WHO** standard limits for drinking water 2010). The maximum value of pH was 7.81 and minimum pH among all the samples was 7.31.

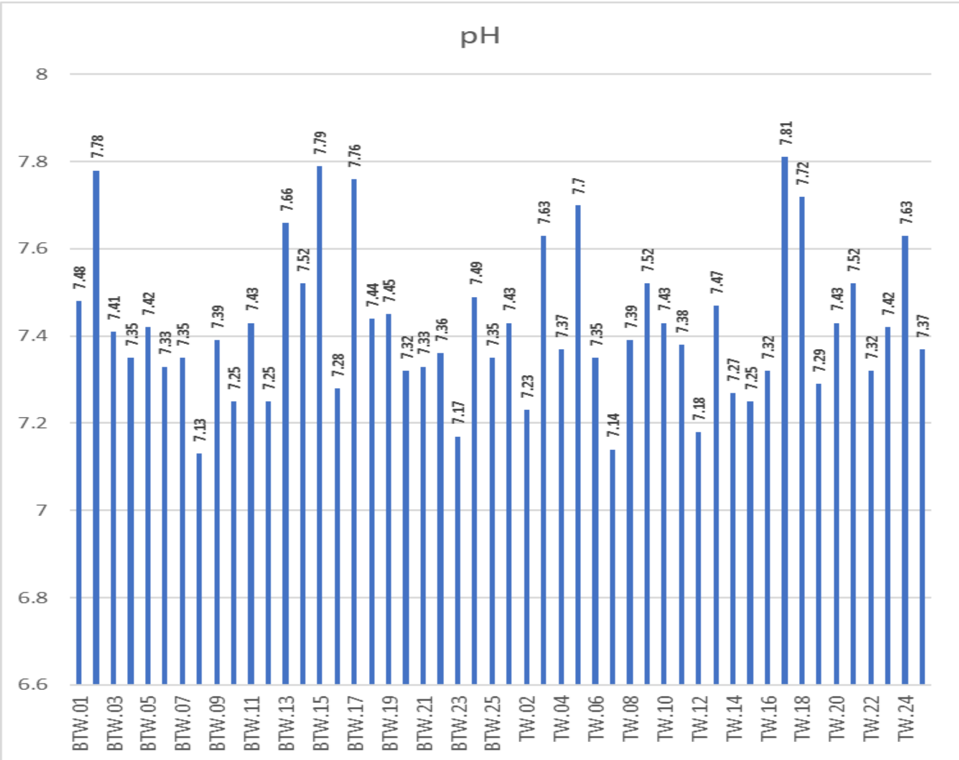


Figure 3.1.1 pH values of analyzed water samples

3.1.2 Electric Conductivity

Electric conductivity (EC) was measured by conductivity meter. The maximum Electric conductivity found was 791.2 while the minimum Electric conductivity 613 was among all the samples. Results obtained from the samples are given in Figure No 3.1.2 .

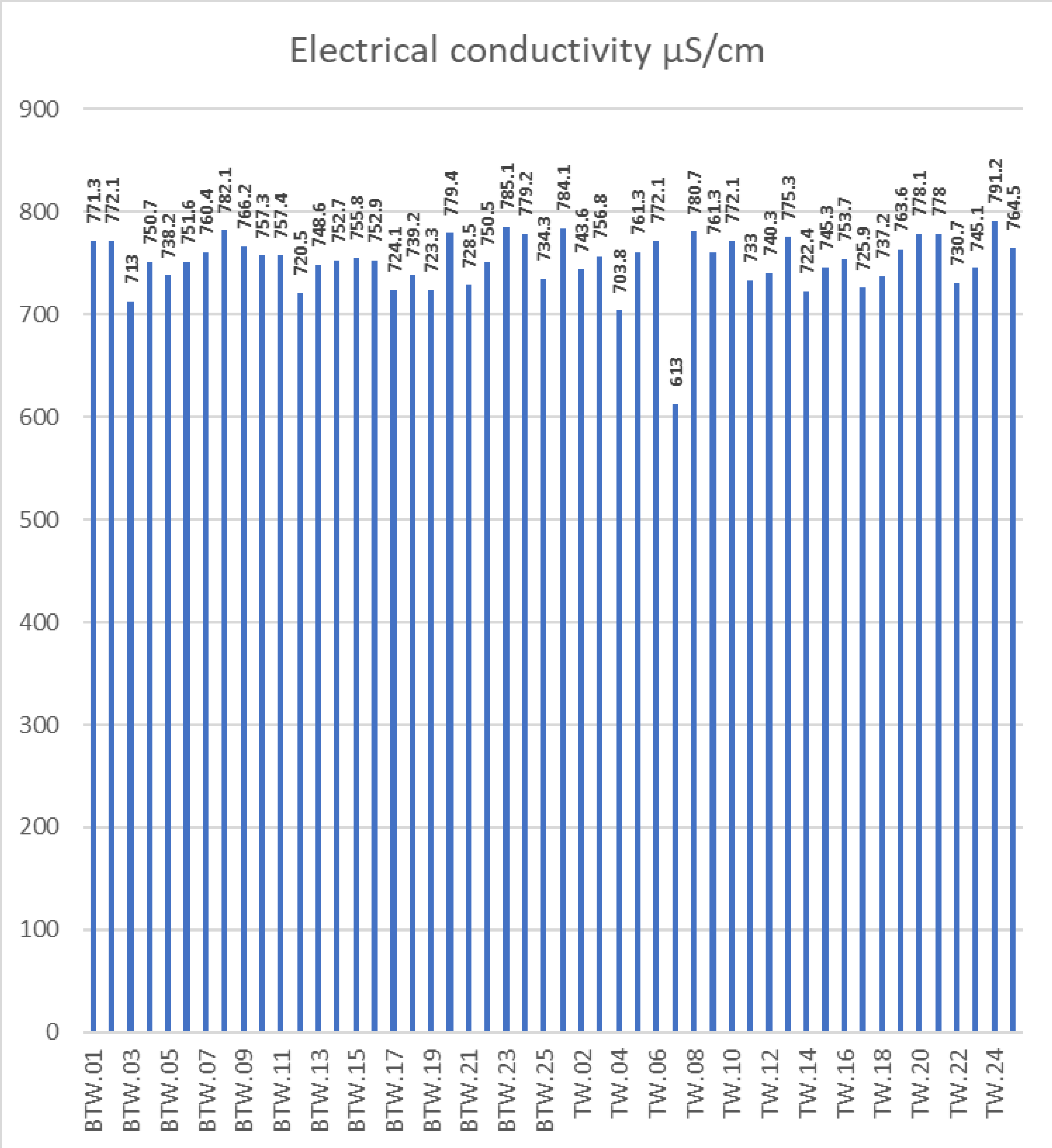


Figure 3.1.2 Electric conductivity of analyzed water samples

3.1.3 Total Dissolved Solid

TDS was measured by TDS meter. Results obtained from the samples are given in figure No. 3.1.3. The maximum and minimum values of TDS among all samples were 597.5 & 417.8 respectively.

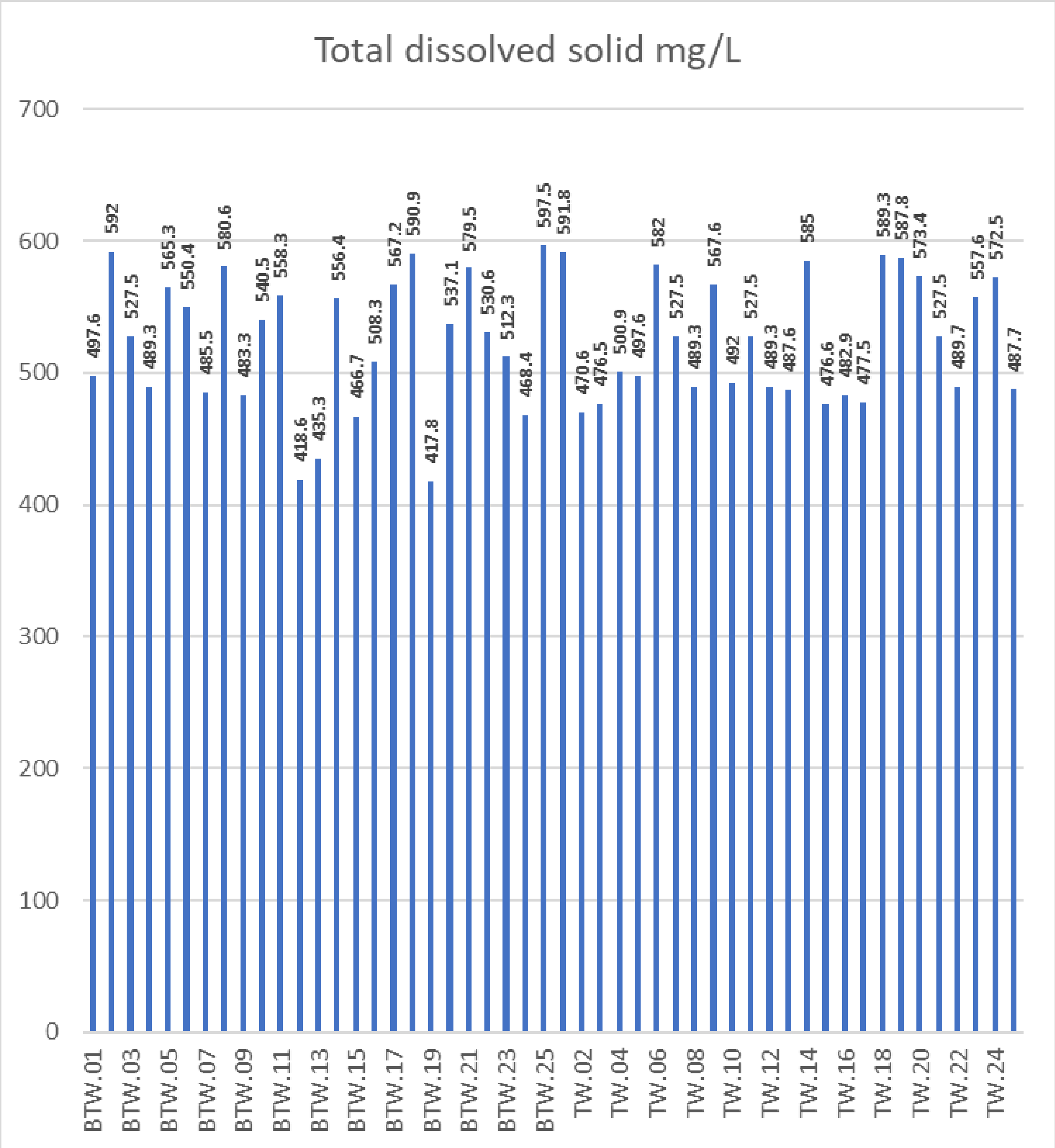


Figure 3.1.3 TDS values of analyzed water samples

3.1.4 Turbidity

Turbidity was measured in PCSIR lab carefully. Results obtained from the samples are given in diagram No. 3.1.4. The maximum and minimum values of Turbidity among all samples were 2.1 & 1.0 respectively.

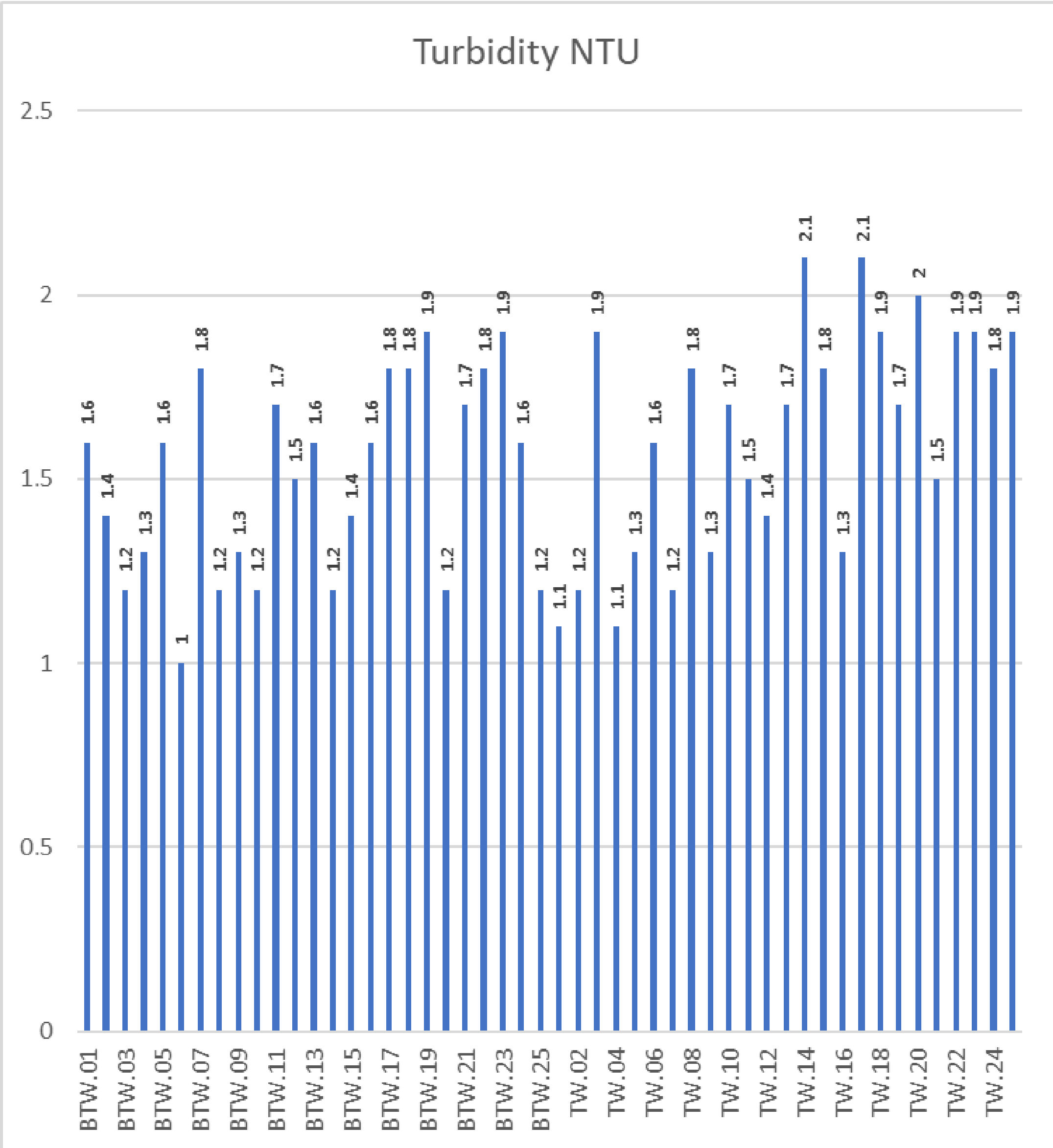


Figure 3.1.4 Turbidity values of analyzed water samples

3.2 Result of Chemical Parameters

The result of chemical analysis of drinking water samples are given in Annexure-V. The chemical parameters are discussed one by one in the following figures.

3.2.1 Total Hardness

Total hardness was measured in PCSIR lab carefully. Results obtained from the samples are given in Figure No. 3.2.1. The maximum and minimum values of Total hardness among all samples were 426.9 & 342.1 respectively.

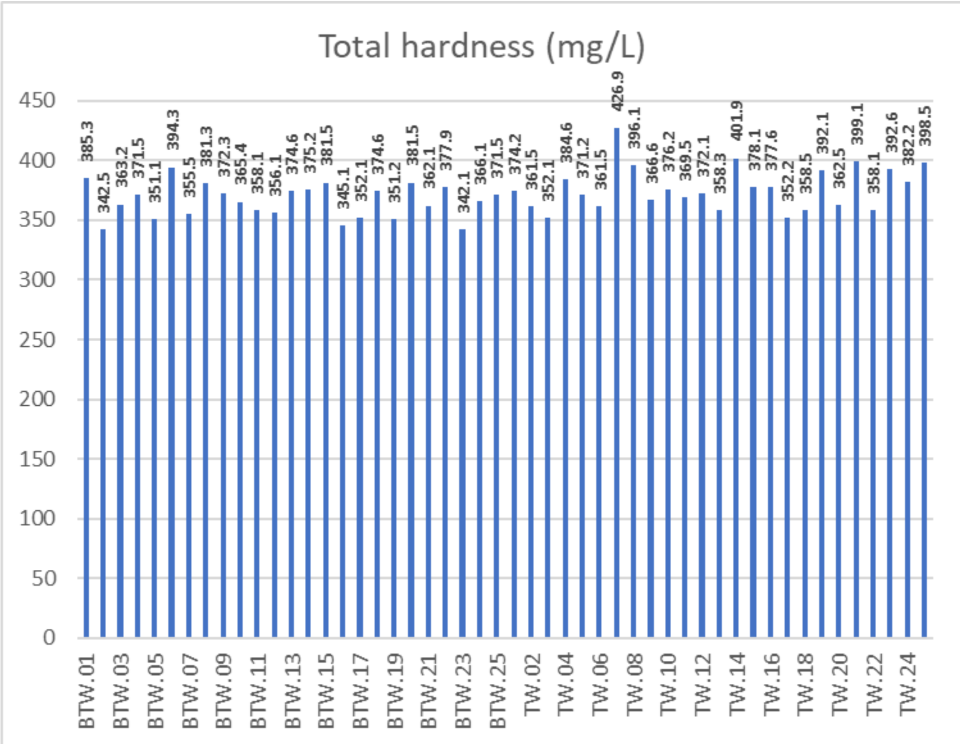


Figure 3.2.1 Total hardness of analyzed water samples

3.2.2 Chlorides

Chlorides were measured in lab carefully. Results obtained from the samples are given in Figure No. 3.2.2. chlorides value of all the samples were in permissible limit 500mg/L as per PSQCA standard limits for drinking water 2010.The maximum and minimum values of Chloride among all samples were 426.9 & 342.1 respectively.

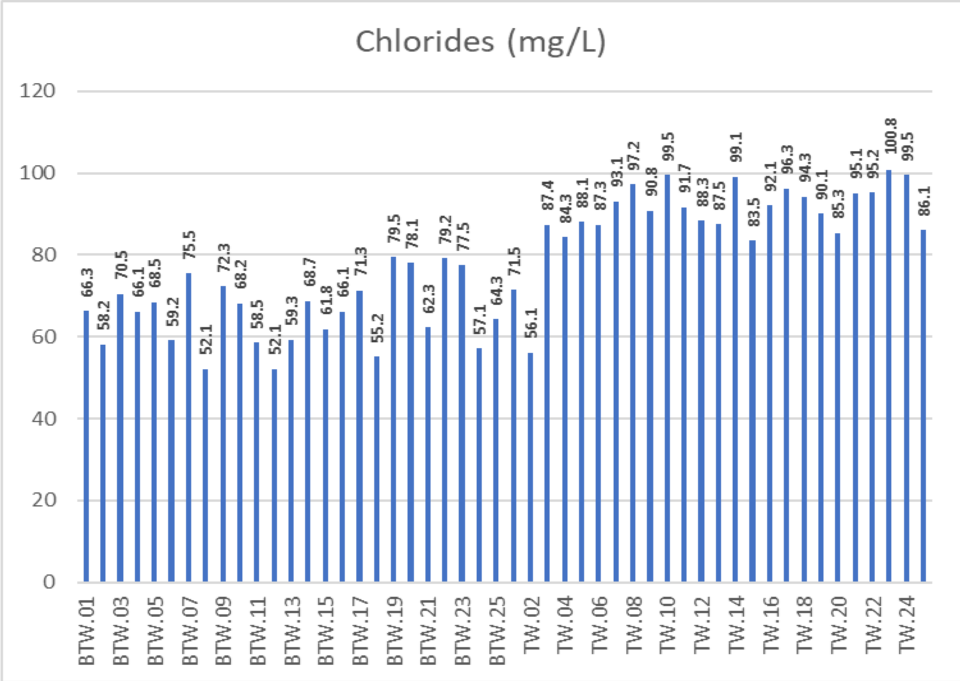


Figure 3.2.2 chlorides values of analyzed water samples

3.2.3 Sulphate as SO4 mg/L

Sulphates were measured in PCSIR lab carefully. Results obtained from the samples are given in Figure No. 3.2.3. Sulphates value of all the samples were in permissible limit 400mg/L as per PSQCA standard limits for drinking water 2010.The maximum and minimum values of Sulphate among all samples were 426.9 & 342.1 respectively.

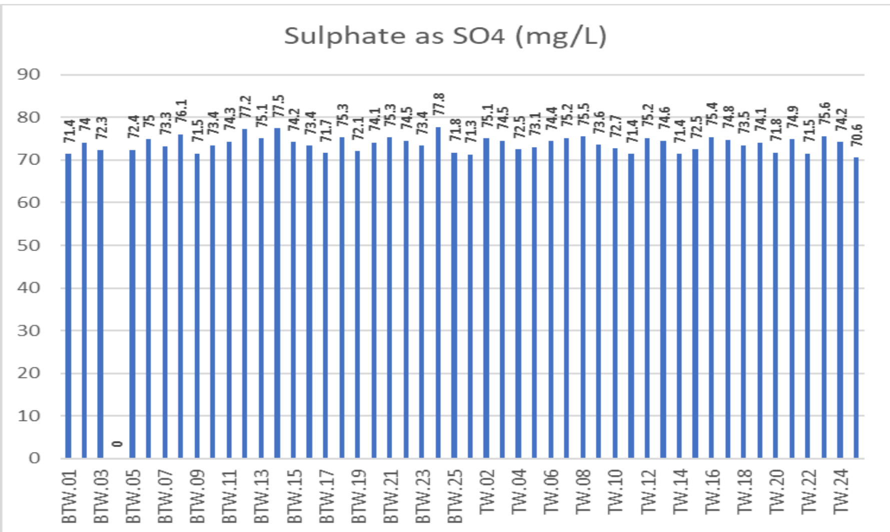


Figure 3.2.3Sulphat values of analyzed water samples

3.2.4 Sodium as Na mg/L

Sodium was measured in PCSIR lab carefully. Results obtained from the samples are given in Figure No. 3.2.4. Sodium value of all the samples were in permissible limit 200mg/L as per PSQCA standard limits for drinking water 2010. The maximum and minimum values of Sodium among all samples were 36.8 & 30.0 respectively. Nitrite was also measured in PCSIR lab carefully, however the Nitrite value of all the samples were found Nil.

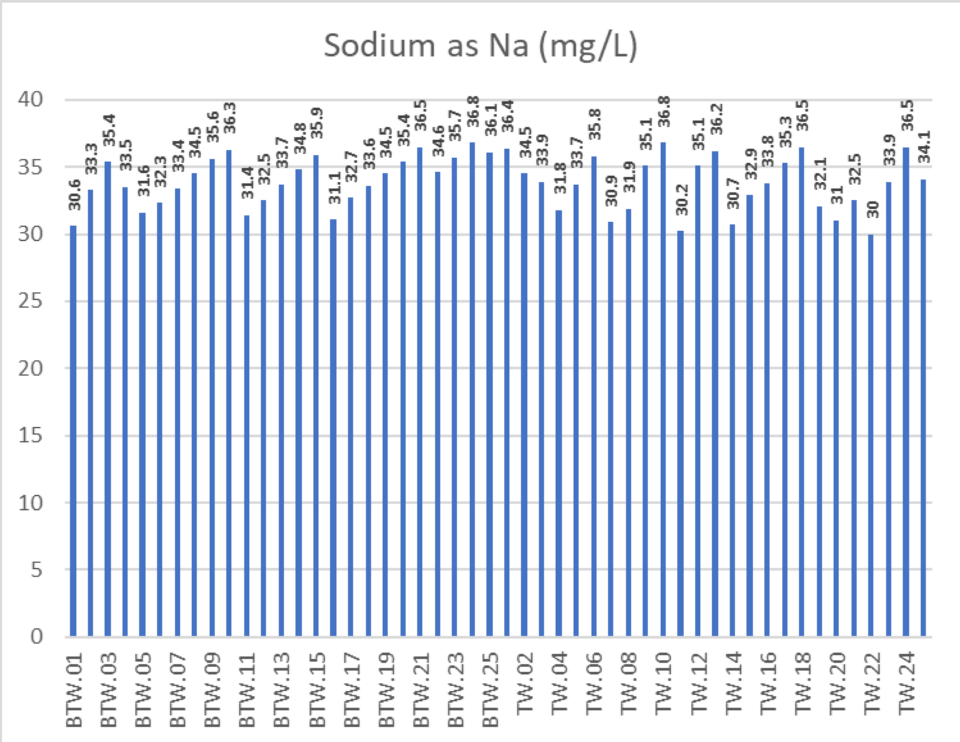


Figure 3.2.4 Sodium values of analyzed water samples

3.2.5 Total alkalinity

Total alkalinity was measured in PCSIR lab carefully. Results obtained from the samples are given in Figure No. 3.2.5. Total alkalinity values of all the samples were in permissible limit 600mg/L as per PSQCA standard limits for drinking water 2010.The maximum and minimum values of Sodium among all samples were 36.8 & 30.0 respectively.

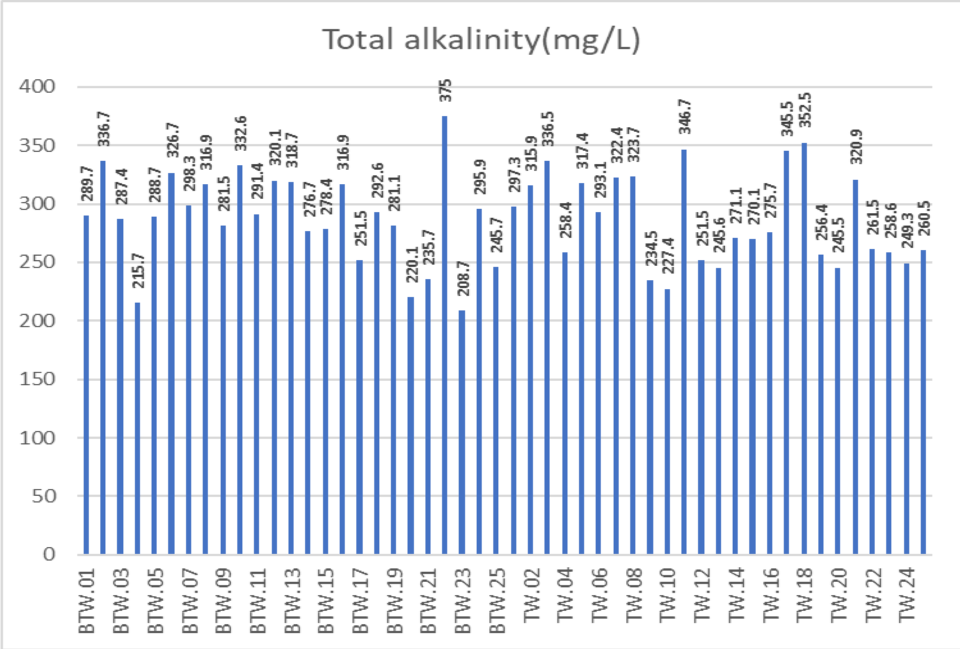


Figure 3.2.5 Total Alkalinity values of analyzed water samples

3.2.6 Calcium

Calcium values of water was measured in lab carefully. Results obtained from the samples are given in Figure No. 3.2.6. Sample BTW06 having maximum value 246 while sample TW16 with minimum values 135mg/L among all the samples.

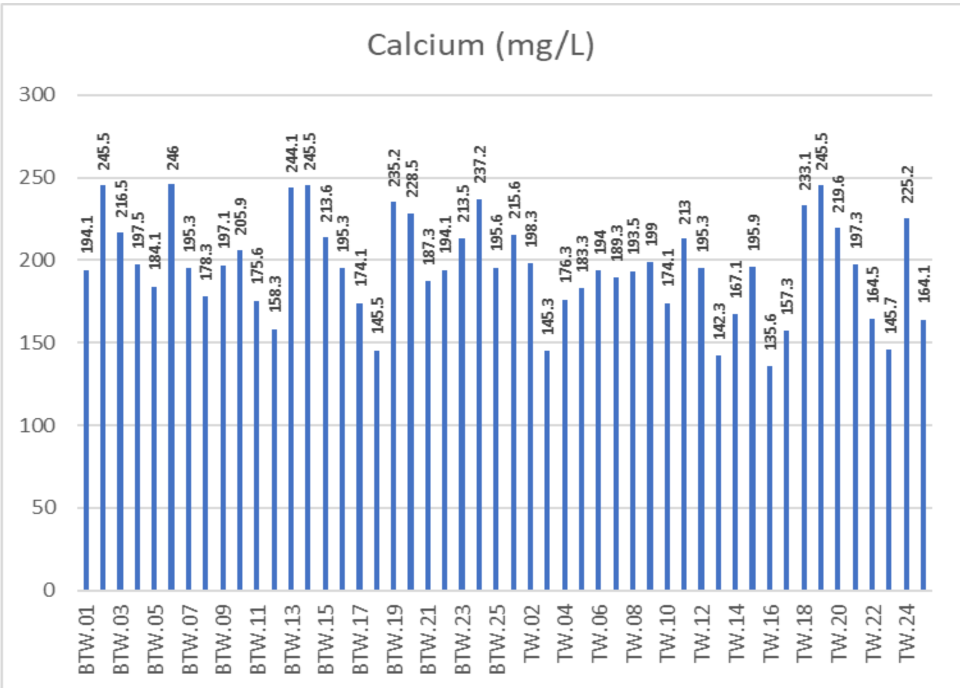


Figure 3.2.6 Calcium of analyzed water samples

3.2.7 Potassium as K mg/L

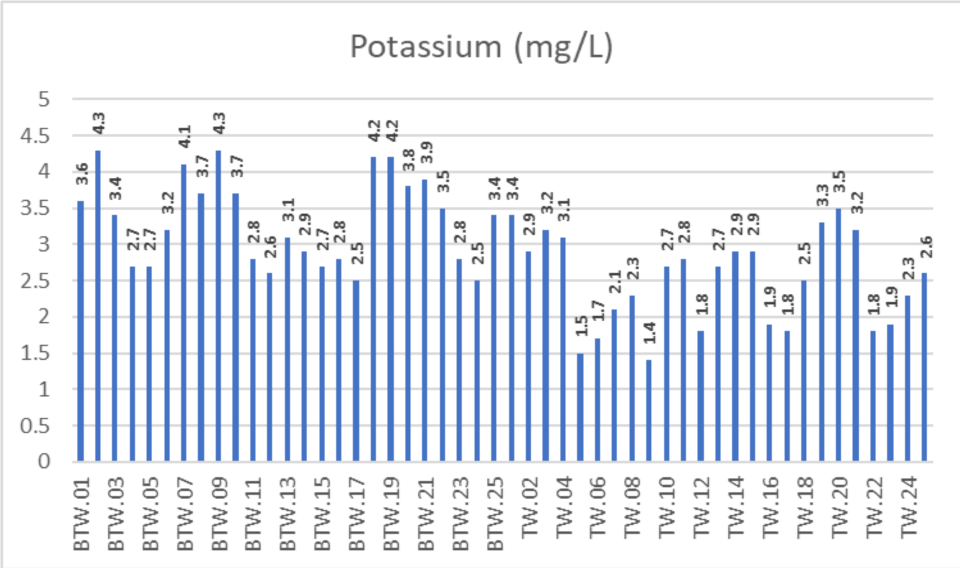


Figure 3.2.7 Potassium of analyzed water samples

Potassium values were carefully measured in the laboratory. The results obtained from the samples are shown in Figure No. 3.2.7. Sample BTW.09 has the maximum value of 4.3 while sample TW09 has the minimum value of 1.4 among all the samples. The values of some of the samples were within the permissible limit.

3.3 Bacteriological Analysis

Microbial values were measured in lab. Results obtained from the samples are given in Annexure-VI.

3.3.1 Total Plate Count

Total plate count analysis can indicate general drinking water quality and the potential presence of pathogens even when coliforms are not detected. It measures the total bacterial population in a water sample. In this study, 30 water samples were analyzed for total plate counts. 3 samples (S1, S3, S24) had total plate counts within WHO permissible limits of <1.1 CFU/ml and no coliform contamination. However, 27 samples exceeded the limit, indicating bacterial contamination. Even if the bacteria species present are not confirmed pathogens, their presence signifies contamination and poses a health risk. The high total plate counts suggest issues with water disinfection at the source, or infiltration of contaminated water through leaks and cross-connections. Regardless of the specific bacteria types, the total counts exceeding guidelines are a concern for human health. This method revealed bacterial loading in the water samples that routine coliform testing did not detect.

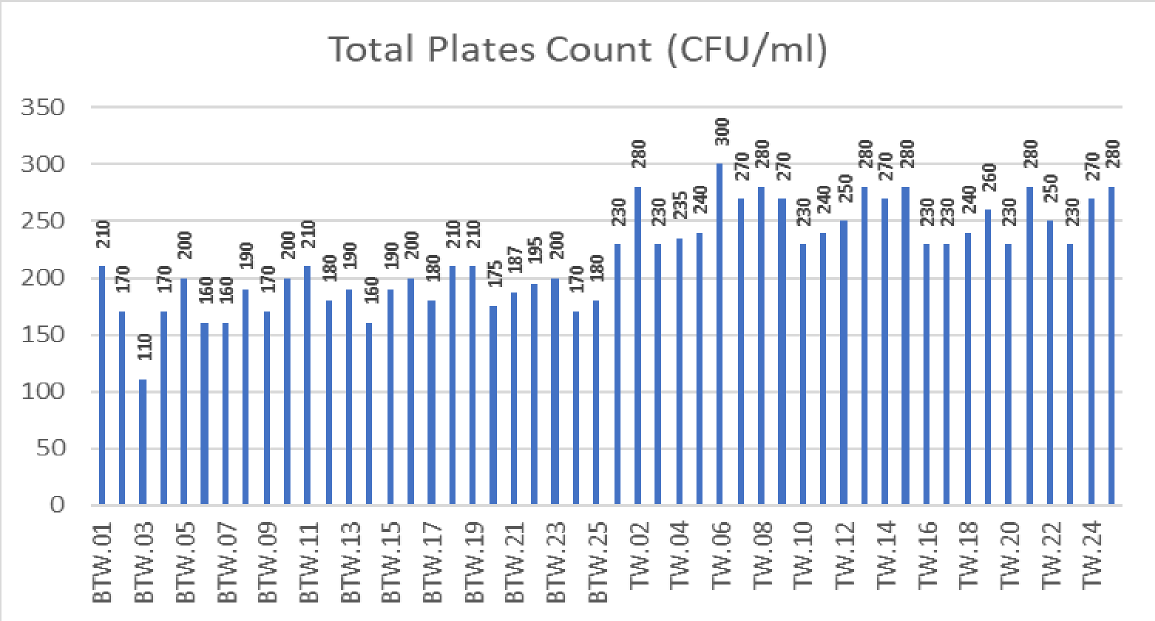


Figure 3.3.1 Total Plate Count of analyzed water samples

3.3.2 Total Coliform Bacteria

Fecal coliform analysis was performed on 30 water samples. 27 samples tested negative for total coliform bacteria. However, 3 samples (11, 20, and 29) tested positive with total coliform counts of 2.2, 3, and 2.5 respectively. Coliform bacteria are an important indicator of drinking water quality and possible sewage contamination. Their presence signifies contamination from surface sources, treatment failures, or leaks from septic systems or drains. While most samples were negative, the detection of coliforms in 3 samples reveals shallow subsurface or surface contamination entering the water supply. Even at low levels, coliform bacteria indicate issues with the water source or delivery infrastructure that require further investigation and remediation. Their presence is a warning sign for potential threats to drinking water safety and public health (Anderson et al., 2002).

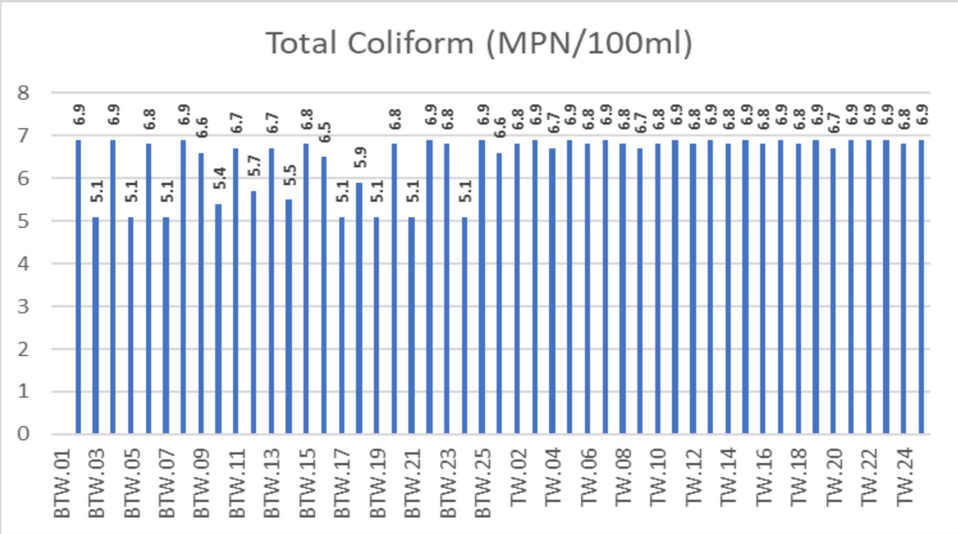


Figure 3.3.2 Total Coliform Bacteria of analyzed water samples

3.3.3 Fecal Coliform

A total of 50 samples were analyzed for fecal coliform bacteria. The results shows that 23 samples contain fecal coliform bacteria. While in 27 sample of water the range of fecal coliform bacteria is in permissible limit (no coliform bacteria found).

The presence of fecal coliform in the water refers to the existence of fecal contaminants and thus the presence of pathogens. Tests for the coliform group of bacteria may point out intestinal bacteria and does not reveal the possible contaminants that are responsible for ears, eyes, nose, and throat infection. Because coliform bacteria can be destroyed rapidly by chlorine, and thus not a good indicator for chlorine resistant microorganisms, coliform group of bacteria may point out contamination from barnyards, feedlots, pastures, broken septic systems, rangelands, damaged wastewater treatment plants, manure storage facilities etc.

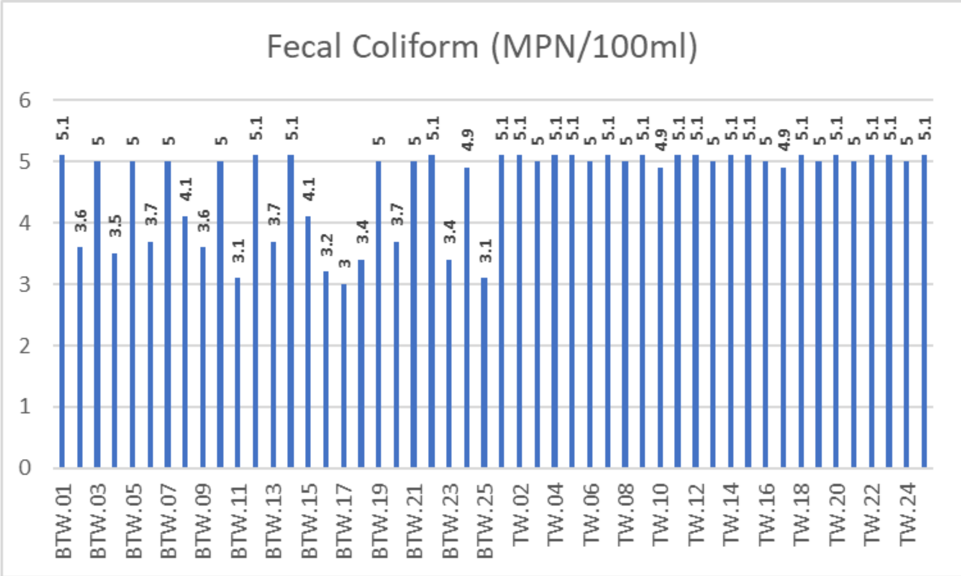


Figure 3.3.3 Fecal Coliform of analyzed water samples

3.4 Heavy Metals

Water pollution by heavy metals is a serious global environmental issue. Heavy metals are categorized into two groups - those like copper, iron, manganese, and zinc that are essential for life in small amounts but become toxic when levels get too high, and those like lead, mercury, cadmium, and nickel that are non-essential and toxic even at low concentrations. Both types, but especially the second group, raise major health concerns when present in drinking water. For this research, the investigators utilized atomic absorption spectroscopy to analyze and measure levels of heavy metal contamination in the water samples collected. This sensitive laboratory technique can detect tiny quantities of dissolved metals in water. The results provided important data on the presence and concentrations of potentially hazardous heavy metals in the different water sources under examination. Careful monitoring of heavy metal pollutants is vital for safeguarding drinking water quality and protecting public health. Contamination of surface and groundwater drinking water is a general welfare problem that has been increasing since the 1990s with population growth, urbanization and industrialization (Rahman et al., 2013). The result of heavy metal concentration levels of drinking water samples is given in Annexure-VII.

3.4.1 Iron

The concentration of iron in the collected water samples was analyzed and compared with the PAK-EPA limit value, which is 0.3 mg/L and WHO limits of <0.1mg/L. The concentration of Fe in the collected samples showed a range of 0.001 - 0.052 mg/L with the mean value of 0.02498 mg/L. It clearly shows that the concentration of iron in some of the samples was above the permissible limit of PAK-EPA while some of the samples showed the concentration in the range of 0.001 - 0.052 mg/L with the mean value of 0.02498 mg/L. On the other hand, some of the samples showed the concentration of iron below the detection limit. Anthropogenic activities in urban areas may be the reason for the considerable high concentration of iron especially in streams. Galvanized water pipes used in households to transport water may be another reason. Corrosion causes iron to dissolve in the water. This increases the concentration (Sun, 2017).

3.4.2 Zinc

Zinc from collected samples was analyzed and compared with PAK-APA standard limit which is 3.0 mg/L. Zinc concentration ranged in 0.004 - 0.773 mg/L with the mean value of 0.1212 mg/L. The results of zinc analyzed form samples collected from different samples. The zinc concentration was found to be within the permissible limit from the analysis of the collected zinc samples. The dilution factor (Liu et al., 2013) could be the reason for the low level of zinc. Zn is known to be associated with most metabolic pathways in humans. Its deficiency can increase hunger loss, developmental disorders, skin changes and immunological irregularities (Kambe, 2015).

3.4.3 Nickel

Nickel from the collected samples was analyzed and compared with the Pak-EPA limits which is 0.02 mg/L and WHO standard which is 0.07mg/L. From all the samples the nickel concentration ranged in 0.075 - 0.250 mg/L with the mean value of 0.17518 mg/L.

Ni concentrations were discovered to be lower in the current study than they were in the earlier investigation on drinking water sources in Pakistan's Peshawar metropolis (Khan et al. 2011). Low ultramafic rock dissolution in the region may be related to the low Ni concentration in all drinking water sources (Duda-Chodak & Blaszczyk 2008). The worrying thing about heavy metals is that there has been an increase in the concentration of these metals over time. This is the result of the need for strict implementation of ecological laws. As time goes by, the development of private companies, poultry farms and leisure activities is increasing. There has been an increase in the number of inhabitants in the towns in the catchment area. Waste water is discharged untreated into the tributaries from various activities such as agriculture, households, car workshops and industry. It is believed that malnutrition and infections, e.g. gastric distress, anorexia, cardiovascular diseases, hypertension, liver and kidney diseases and various types of malignant tumours could be caused due to deficiencies and unnecessary intake of heavy metals in polluted food and drinking water (Yuan, 2016).

Table 3.1 Comparison of Mean Concentration of Heavy Metals with WHO & PAK-EPA Limit

Metals	Mean	WHO Standards	EPA limit
Cd(mg/L)	0.06	0.003	0.01
Fe(mg/L)	0.02498	<0.1	0.3
Zn(mg/L)	0.1212	00	3.0
Ni(mg/L)	0.175	0.07	0.02

3.4.4 Cadmium

The cadmium in the collected samples was further analyzed. It was compared with the standard limit of PAK-EPA which is 0.01 mg/L and WHO limits of 0.003 mg/L. The concentration of cadmium ranged from 0.047 - 0.087 mg/L. The mean value was 0.06178 mg/L from the collected samples. The results of the must of the sample were within the permissible limit of the PAK-EPA. The presence of cadmium in water is shown in the figure above. Cadmium is a toxic metal that occurs naturally in the environment and the results of cadmium analysis from the collected samples showed a range of concentrations from 0.047 to 0.087 mg/L. Higher concentrations of cadmium in water can cause kidney problems. Cadmium in water is caused by activities such as the burning of fossil fuels, the use of fertilizers, the disposal and burning of waste and the activities of car workshops in the catchment area. Cadmium is also produced by anthropogenic activities. These include agriculture and industry. Cadmium is recognized as a neurotoxin. It is responsible for kidney failure and osteoporosis (Souid et al. 2019). It is a necessary component of a number of chemicals and is of vital importance for hemoglobin (Myint, 2018).

3.5 Survey Results

Thirty (30) respondents were interviewed and questionnaires were filled. The results of the survey are given in figures.

3.5.1 Sources of drinking water

Figure 3.5.1 shows the results of the type of drinking water used in the house. Out of the 30 respondents, bore water is used in 12 houses, tube well water is used in 10 houses and both types of water sources are used in 08 houses.

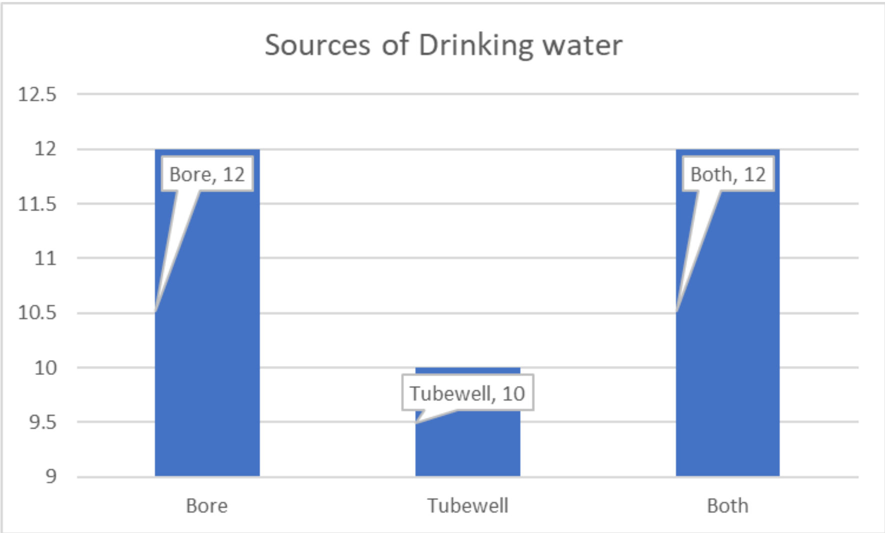


Figure 3.5.1: Sources of drinking water

3.5.2 Taste and Smell of water

The results of the survey showed the perception of water taste among samples of 30 respondents. All 30 respondents stated that the water had no discernible taste and therefore the water was not objectionable. The water has no unpleasant odor, according to all respondents. Therefore, the water is not objectionable.

3.5.3. Method of Storage of Drinking Water

The results shown in Figure 3.5.2 indicates how 30 households store water for drinking purpose. It was found that plastic tanks were used by 10 households while cement tank used by 12 and plastic & cement both used by 08 households.

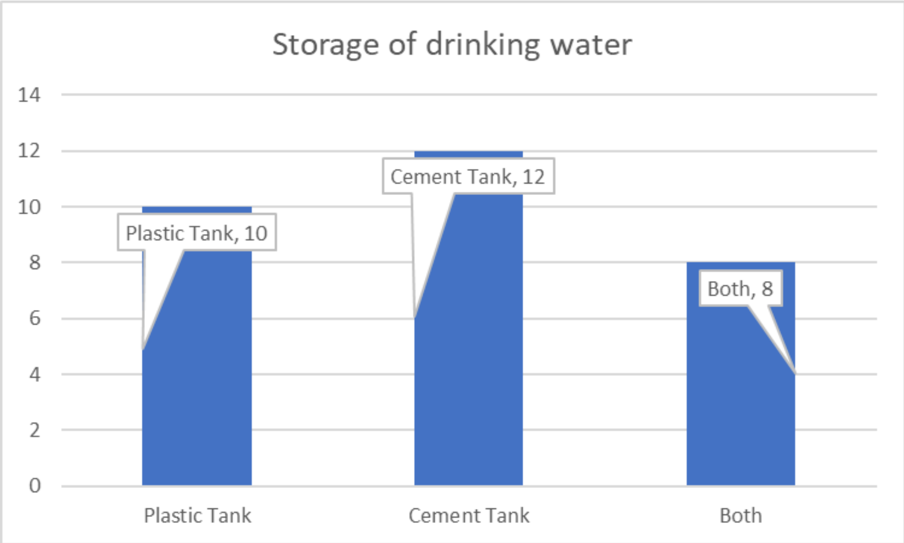


Figure 3.5.2: Storage of drinking water

3.5.4. Cleaning of Tank

Figure 3.5.3 shows the results of the date of the last cleaning of the water storage tank in these 30 houses. Between 1 and 6 months only 3 houses clean their water storage tank, between 6 and 12 months 7 houses, between 1 and 2 years 15 houses, while between 2 and 3 years 5 houses clean their water storage tank.

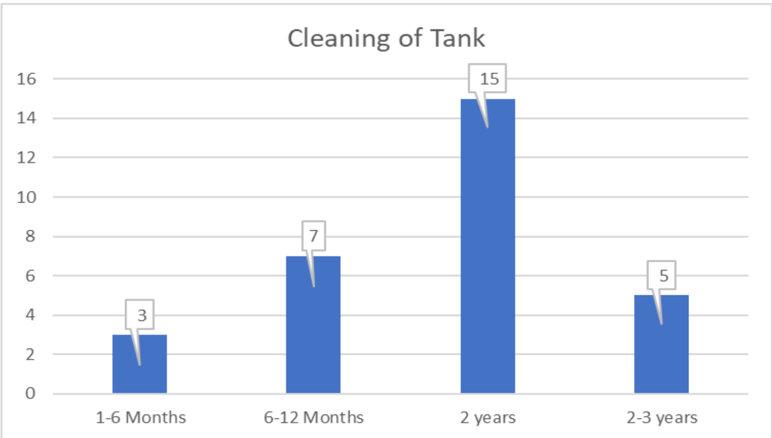


Figure 3.5.3: Cleaning of Tank

3.5.5 Effort to Make Water Safer to Drink

In Figure 3.5.4 it is clearly showed that about 8 houses boil water, 12 use filters to make it safer to drink, while 10 houses don’t treat water.

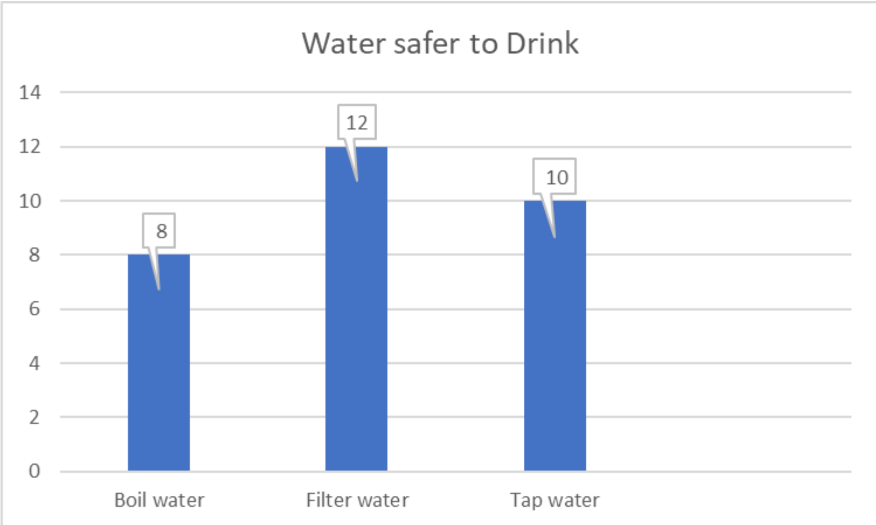


Figure3.5.4: Effort to make water safer to drink

3.5.6 Distance between Source of Water and Sewerage Line

The distance between the water source and the sewerage is shown in Figure 3.5.5. The survey results showed that in the distance between 5-10 feet we have 16 houses, while in the distance 10-15 feet, 15-20 feet and 20-25 feet we have 7, 3 and 4 houses respectively.

However, many respondents express their worry about complaints of issues of leakage of sewerage lines nearby.

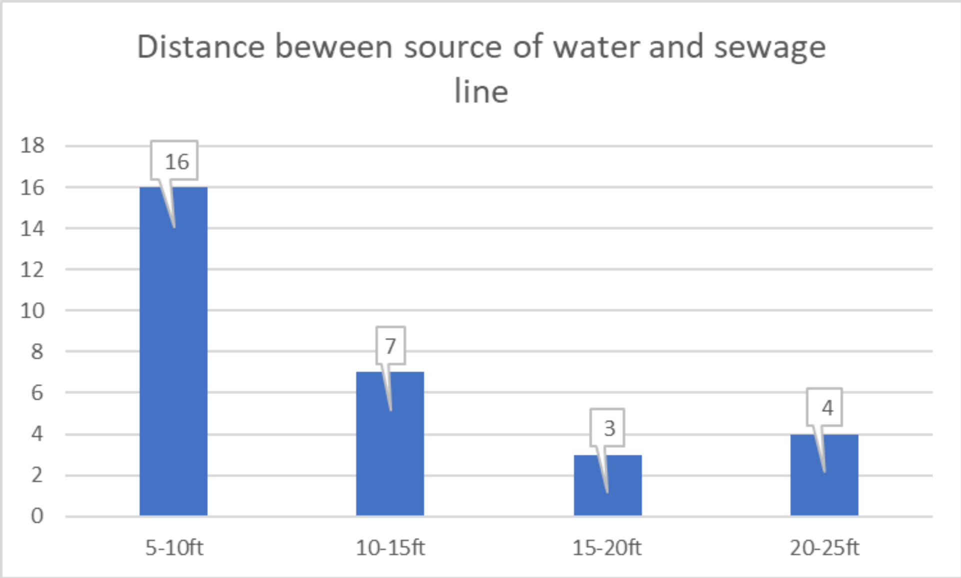


Figure3.5.5: Distance between source of water and sewerage line

3.5.7 Water storage for daily needs

The survey results regarding water storage showed that majority of respondents i.e. 21 (70%) rely on a rooftop tank, 06 (20%) have a ground tank for water storage whereas only 03 (10%) use simple containers to store water.

3.5.8 Awareness of Water Borne Diseases

People of the area aware of water borne diseases in Figure 3.5.6 shows result, in which 12 houses are aware having some knowledge about water borne disease while 18 houses are unaware. The contamination issues due to mixing of contaminated water underground due to seepage was mater of concerned of majority of repondents.

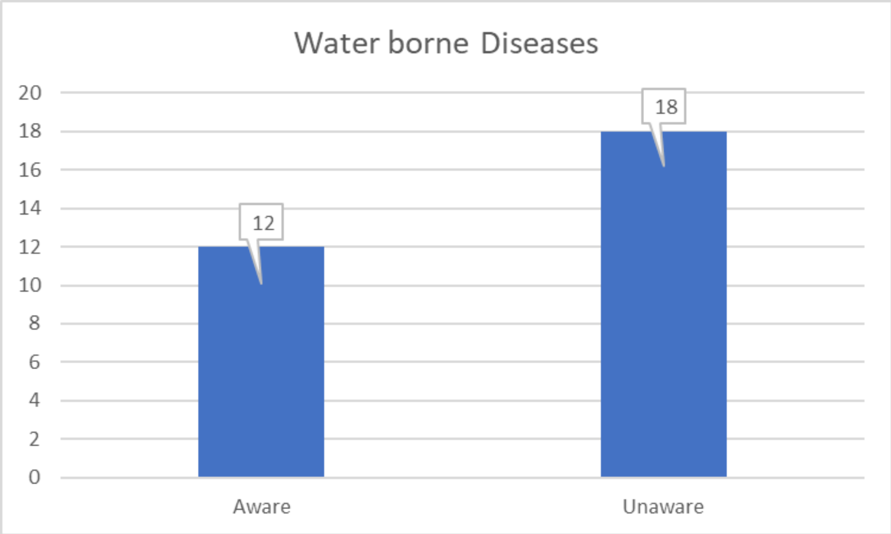


Figure 3.5.6: Awareness of water borne disease

3.5.9 Measures to improve drinking water quality

The survey results showed that only 50% respondents treat water to make it safer to drink. The results revealed that about 04 households boils water, 10 households use filters and only 01 household has replaced old pipelines with plastic ones to make water safer to drink, while 15 households have not adopted any treatment methods.

3.5.10 Occurrence of diseases with age

The occurrence of diseases with age in 30 houses is shown in Figure 3.5.7. The results of diarrhoea, cholera, typhoid, hepatitis and vomiting show that in the age of 5-10 years it is present in 45, 2, 3, 2 and 15. Diarrhoea, cholera, typhoid, hepatitis and vomiting were present in 15, 0, 0, 5 and 8 children between the ages of 10 and 20. Diarrhoea, cholera, typhoid, hepatitis and vomiting are present in 8, 0, 0, 3 and 5 in the age of 20 to 30 years. Diarrhoea, cholera, typhoid, hepatitis and vomiting occur in 5, 3, 0, 0 and 6 cases in the age of 30 to 40 years. Diarrhoea, cholera, typhoid, hepatitis and vomiting occur in 3, 0, 3, 1 and 3 at the age of 40 to 50 years. While in the age of over 50 years diarrhoea, cholera, typhoid, hepatitis and vomiting is present in 10, 1, 2, 2 and 7.

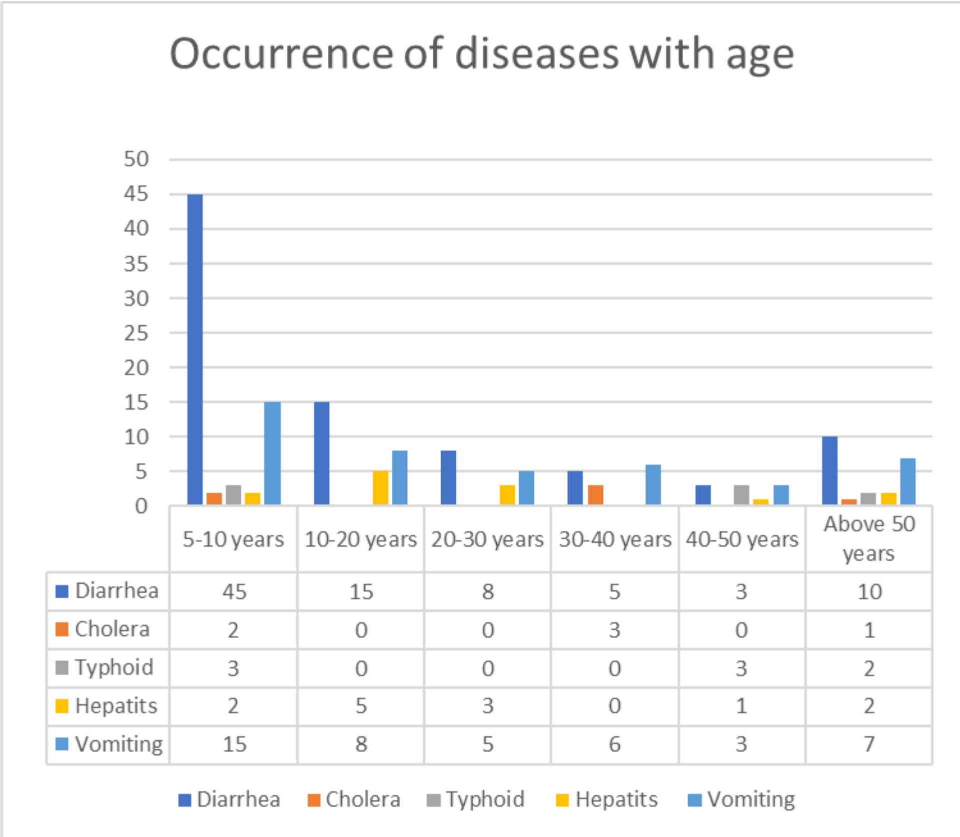


Figure3.5.7: Occurrence of diseases with age

CONCLUSIONS

The evaluation of University Town UC-36's drinking water contamination, both physiochemically and biologically was conducted. Samples were gathered from fifty distinct water points. The outcomes were compared with PCSIR, PSQCA standard values and WHO data.

Regarding the chemical characteristics, all values were within acceptable bounds with the exception of magnesium hardness, for which certain samples exceed acceptable bounds.

The physical parameters, on the other hand, were all within acceptable bounds.

The drinking water's bacteriological quality reveals that pollution has gotten significantly worse, endangering both human health and the ecosystem. These findings unequivocally demonstrate that the prevention of infectious illnesses and other health issues in University Town Peshawar depends heavily on the quality of the drinking water.

RECOMMENDATIONS

1. To control the germs found in these sources of drinking water, the Union Council Organization, Municipalities, and the Government should act immediately.
2. To meet the demand for drinking water in the area, new tube wells with advanced treatment technology should be installed.
3. Sewage treatment plants should be in place for the health of the local people. The proper sewerage system should be installed to control waste water pollution.
4. There should be replacement of old sewerage pipes with new ones as well as the walls and base of the sewerage system should be cemented.
5. The appropriate distance between sewerage and water pipes should be kept to avoid any chance of contamination due to leak.
6. It is also important to educate the local population on the value of clean drinking water. Water should be boiled or chlorinated before drinking.
7. To avoid bacterial diseases, it should be recommended that organic waste should not be disposed in drains.

REFERENCES

Abeer, N., Khan, S. A., Muhammad, S., Rasool, A., & Ahmad, I. (2020). Health risk assessment and provenance of arsenic and heavy metal in drinking water in Islamabad, Pakistan. Environmental Technology & Innovation, 20, 101171.

Agensi A, Tibyangye J, Tamale A, Agwu E, & C. Amongi., (2019). Contamination Potentials of Household Water Handling and Storage Practices in Kirundo Subcounty, Kisoro District, Uganda. Journal of Environmental and Public Health, pp. 1–8.

Ahmad, I., Hassan, S., & Ahmad, I. (2013). Bacteriological Quality Analysis of Drinking Water of Rural Areas of Peshawar, Pakistan. *hospitals*, *8*, 9.

Ahmad, S., Shan, F., Ali, S. B., Ali, N., Khan, M. K., & Ahmad, W. (2021). 40. Health risk attributed to poor microbial quality of drinking water from rural area of Peshawar, Pakistan. *Pure and Applied Biology (PAB)*, *10*(4), 1364-1368.

Ahmad, S.R., Khan, M.S., Khan, A.Q., Ghazi, S. and Ali S., (2012). Sewage water intrusion in the groundwater of Lahore, its causes and protections. Pakistan Journal of Nutrition, Vol. 11, No. 5, pp.484-488.

Akbar, S., Ali, Z., Hussain, S., Mohammad, A., Riaz, Y., Shakeel, A., Ahmad, I., Mussarat, M., Malik, R.N., Khan, K.Y. and Sohail, M., (2021). Metal accumulation potential, human health risks, and yield attributes of hundred bread wheat genotypes on irrigation with municipal and remediated wastewater. Environmental Science and Pollution Research, 28, pp.35023-35037.

Akuffo, I., Cobbina, S. J., Alhassan, E. H., & Nkoom, M. (2013). Assessment of the quality of water before and after storage in the Nyankpala community of the Tolon-Kumbungu District, Ghana.

Al-Bahry, S. N., Elshafie, A. E., Victor, R., Mahmoud, I. Y., & Al-Hinai, J. A. (2011). Opportunistic pathogens relative to physicochemical factors in water storage tanks. Journal of water and health, 9(2), 382-393.

Al-Bahry, S. N., Mahmoud, I. Y., Al-Khaifi, A., Elshafie, A. E., & Al-Harthy, A. (2009). Viability of multiple antibiotic resistant bacteria in distribution lines of treated sewage effluent used for irrigation. Water Science and Technology, 60(11), 2939-2948.

Aldrees, A., Khan, M.A., Tariq, M.A.U.R., Mustafa Mohamed, A., Ng, A.W.M. and Bakheit Taha, A.T., (2022). Multi-Expression Programming (MEP): Water Quality Assessment Using Water Quality Indices. Water, 14(6), p.947.

Alemayehu, E., Melak, F., Sharma, S. K., Van der Bruggen, B., & Lennartz, B. (2017). Use of porous volcanic rocks for the adsorptive removal of copper. Water and Environment Journal, 31(2), 194-201.

Al-Ghanim, K. A., Abd El-Salam, M. M., & Mahboob, S. (2014). Assessment of water quality for some roof tanks in Alkharj Governorate, KSA. Pakistan J. Zool, 46(4), 1003-1012.

Alhamlan, F. S., Al-Qahtani, A. A., & Al-Ahdal, M. N. A. (2015). Recommended advanced techniques for waterborne pathogen detection in developing countries. The Journal of Infection in Developing Countries, 9(02), 128-135.

Ali, U., Batool, A., Ghufran, M. A., Asad-Ghufran, M., Sabahat-Kazmi, S., & Hina-Fatimah, S. (2019). Assessment of heavy metal contamination in the drinking water of muzaffarabad, Azad Jammu and Kashmir, Pakistan. Int J Hydro, 3(5), 331-337.

Aliabadi, N., Pham, H., Curns, A. T., Rha, B., Tate, J. E., & Parashar, U. D. (2019). Diarrhea- Associated Mortality in Children Less Than 5 Years of Age in the United States, 2005–2016. The Pediatric Infectious Disease Journal, 38(7), e153-e154.

Alizai, M. N., Abid, H., Ibrahim, M., & Khan, J. (2008). Preliminary evaluation of pathogens existence in school drinking water Peshawar (Pakistan). Pakistan Journal of Biochemistry and Molecular Biology, 41.

Anwar, M.S., Lateef, S. and Siddiq. I, G.M., (2010). Bacteriological quality of drinking water in Lahore. Biomedica, vol. 26, pp. 66-69.

Arshad, A., Intikhab, A. Q., & Durray, S. (2011). Low-cost filter for flood affected areas of Pakistan. Electronic Journal of Environmental, Agricultural and Food Chemistry, 10(10), 2945- 2950.

Ather, D., Muhammad, S. & Ali, W. (2022). Fluoride And Nitrate Contaminations Of Groundwater And Potential Health Risks Assessment In The Khyber District, North-Western Pakistan. International Journal Of Environmental Analytical Chemistry, 1-16.

Awan F, Ali MM, Afridi IQ, Kalsoom S, Firyal S, Nawaz S, Akhtar R, Iqbal A, Saeed S, Naseer R, Mehmood T, Luqman N, Ahmad HM, Sadia H, Taseer MSA, Khan AR, Rafique N. (2022). Drinking water quality of various sources in Peshawar, Mardan, Kohat and Swat districts of Khyber Pakhtunkhwa province, Pakistan. Braz J Biol. 2022 Jan 7;84:e255755.

Awan, M. A., Siddiqui, M. T., Khan, R. A., & Shah, A. H. (2002). Combined effect of salinity and industrial effluents on the growth of Eucalyptus camaldulensis dehnh. *Pakistan Journal of Agricultural Sciences (Pakistan)*.

Awan, U. K., Waqas, A., & Ahmad, S. (2021). An evaluation of climate change impact on water resources in Pakistan: A review. Climate, 9(1), 6.

Azizullah, A., Khattak, M. N. K., Richter, P., & Häder, D. P. (2011). Water pollution in Pakistan and its impact on public health—a review. *Environment international*, *37*(2), 479-497.

Alarcón-Herrera, M. T., Bundschuh, J., Nath, B., Nicolli, H. B., Gutierrez, M., Reyes-Gomez, V. M., & Sracek, O. (2013). Co-Occurrence Of Arsenic And Fluoride In Groundwater Of Semi-Arid Regions In Latin America: Genesis, Mobility And Remediation. *Journal of Hazardous Materials*, *262*, 960-969.

Abugri, D. A., & Pelig-Ba, K. B. (2011). Assessment Of Fluoride Content In Tropical Surface Soils Used For Crop Cultivation. *African Journal Of Environmental Science And Technology*, *5*(9), 653-660.

Bagchi, I. (2019). The Indus Waters Treaty at 60: Water scarcity lessons for Indus Basin States. Water Policy, 21(6), 1159-1176.

Bartram, J., Brocklehurst, C., Fisher, M. B., Luyendijk, R., & Hossain, R. (2019). Global monitoring of water supply and sanitation: History, methods and future challenges. International Journal of Environmental Research and Public Health, 16(21), 4299.

Bartram, J., Brocklehurst, C., Fisher, M. B., Luyendijk, R., & Hossain, R. (2019). Global monitoring of water supply and sanitation: History, methods and future challenges. International Journal of Environmental Research and Public Health, 16(21), 4299.

Ball, P. (2008). Water—An Enduring Mystery. Nature, 452**,** 291-292.

Blagojević, S. D., Jakovljević, M. D., & Radulović, M. (2002). Content Of Fluorine In Soils In The Vicinity Of Aluminium Plant In Podgorica. *Journal Of Agricultural Sciences (Belgrade)*, *47*(1), 1-8.

Brown, M. E., Treviño, L. K., & Harrison, D. A. (2005). Ethical Leadership: A Social Learning Perspective For Construct Development And Testing. *Organizational Behavior And Human Decision Processes*, *97*(2), 117-134.

Brahman, K. D., Kazi, T. G., Afridi, H. I., Naseem, S., Arain, S. S., & Ullah, N. (2013). Evaluation of High Levels Of Fluoride, Arsenic Species And Other Physicochemical Parameters In Underground Water Of Two Sub Districts Of Tharparkar, Pakistan: A Multivariate Study. *Water Research*, *47*(3), 1005-1020.

Bern, C., Martines, J., De Zoysa, I., & Glass, R. I. (1992). The magnitude of the global problem of diarrheal disease: a ten-year update. Bulletin of the world health organization, 70(6), 705.

Bjorklund, G., Chartrand, M., & Aaseth, J. (2017). Manganese exposure and neurotoxic effects in children. *Environmental Research*, 155, 380–384. https://doi.org/10.1016/j.envres.2017.03.003.

Bustami, R., Bessaih, N., Bong, C. & Suhaili, S. (2007). Artificial Neural Network For Precipitation And Water Level Predictions Of Bedup River. Iaeng International Journal of Computer Science, 34.

Bruaset, S., Sægrov, S., & Ugarelli, R. (2018). Performance-based modelling of long-term deterioration to support rehabilitation and investment decisions in drinking water distribution systems. Urban Water Journal, 15(1), 46-52.

Carotenuto, R., Capriello, T., Cofone, R., Galdiero, G., Fogliano, C., & Ferrandino, I. (2019). Impact of copper in Xenopus laevis liver: Histological damages and atp7b downregulation.. *Ecotoxicology and environmental safety*, 109940 . https://doi.org/10.1016/j.ecoenv.2019.109940.

Carrasco, G., Chen, M., Boyle, E., Tanzil, J., Zhou, K., & Goodkin, N. (2018). An update of the Pb isotope inventory in post leaded-petrol Singapore environments.. *Environmental pollution*, 233, 925-932 . https://doi.org/10.1016/j.envpol.2017.09.025.

Chalchisa D, Megersa M, Beyene A. (2017) Assessment of the quality of drinking water in storage tanks and its implication on the safety of urban water supply in developing countries. Environ Syst. Res. 6:1

Chien, C., Ho, T., Sanborn, M., Yin, Q., & Paytan, A. (2017). Lead concentrations and isotopic compositions in the Western Philippine Sea. *Marine Chemistry*, 189, 10-16. https://doi.org/10.1016/J.MARCHEM.2016.12.007.

Chia M, Oniye S, Swanta A. (2013) Domestic water quality assessment: microalgal and cyanobacterial contamination of stored water in plastic tanks in Zaria, Nigeria. Eur J. Sci. Res. 110(4):501–510.

Coleman, B. L., Louie, M., Salvadori, M. I., McEwen, S. A., Neumann, N., Sibley, K., & McGeer, A. J. (2013). Contamination of Canadian private drinking water sources with antimicrobial resistant Escherichia coli. Water research, 47(9), 3026-3036.

Clarkson, J. J., & Mcloughlin, J. (2000). Role Of Fluoride In Oral Health Promotion. *International Dental Journal*, *50*(3), 119-128.

D'alessandro, W. (2006). Human Fluorosis Related To Volcanic Activity: A Review. *Environmental Toxicology.*, *1*, 21-30.

Daud MK, Nafees M, Ali S, Rizwan M, Bajwa RA, Shakoor MB, Arshad MU, Chatha SAS, Deeba F, Murad W, Malook I, Zhu SJ. (2017). Drinking Water Quality Status and Contamination in Pakistan. Biomed Res Int. 2017;2017:7908183. doi: 10.1155/2017/7908183. Epub 2017 Aug 14. PMID: 28884130; PMCID: PMC5573092.

Daud, M. K., Nafees, M., Ali, S., Rizwan, M., Bajwa, R. A., Shakoor, M. B., & Zhu, S. J. (2017). Drinking water quality status and contamination in Pakistan. BioMed research international.

Deeba, F., Abbas, N., Butt, M., & Irfan, M. (2019). Ground water quality of selected areas of Punjab and Sind Provinces, Pakistan: Chemical and microbiological aspects. *F. Deeba, N. Abbas, MT Butt and M. Irfan. Ground water quality of selected areas of Punjab and Sind Provinces, Pakistan: Chemical and microbiological aspects. Chemistry International*, *5*(4), 241-246.

Edmunds, W. M., & Smedley, P. L. (1996). Groundwater Geochemistry And Health: An Overview. *Geological Society, London, Special Publications*, *113*(1), 91-105.

Douhri H, Raissouni I., Tazi S, Badia D (2015) Effect of house storage on water's quality in rural areas of Tangier-Tetuan Region (Morocco). Larhyss J 24:301–314

Drinking water quality status and contamination in Pakistan. *BioMed research international*, *2017*.

Daud, M., Nafees, M., Ali, S., Rizwan, M., Bajwa, R. A., Shakoor, M. B., Arshad, M. U., Chatha, S. A. S., Deeba, F. & Murad, W. (2017). Drinking Water Quality Status And Contamination In Pakistan. Biomed Research International, 2017.

Eisenberg, D. & Kauzmann, W. (2005). The Structure And Properties Of Water, Oup Oxford.

Farah N., Anjum Z., Khalil U.R. and Munir A.S. (2012). "Quality characteristics and treatment of drinking water of Faisalabad" International Journal of Agriculture and Biology, 347–349.

Farooq, S., Hashmi, I., Qazi, I. A., Qaiser, S., & Rasheed, S. (2008). Monitoring of coliforms and chlorine residual in water distribution network of Rawalpindi, Pakistan. Environmental monitoring and assessment, 140(1), 339-347.

Flörke, M., Kynast, E., Bärlund, I., Eisner, S., Wimmer, F. & Alcamo, J. (2013). Domestic And Industrial Water Uses Of The Past 60 Years As A Mirror Of Socio-Economic Development: A Global Simulation Study. Global Environmental Change, 23**,** 144-156.

Galal-Gorchev, H., Ozolins, G., & Bonnefoy, X. (1993). Revision Of The Who Guidelines For Drinking Water Quality. *Annali Dell'istituto Superiore Di Sanitã*, *29*(2), 335-345.

Giovambattista, N., Debenedetti, P. G. & Rossky, P. J. (2007). Effect Of Surface Polarity On Water Contact Angle And Interfacial Hydration Structure. The Journal Of Physical Chemistry B, 111**,** 9581-9587.

Gleick, P. H. (1993). Water In Crisis, New York: Oxford University Press.

Gleick, P. H. (2003). Water Use. Annual Review Of Environment And Resources, 28**,** 275-314.

Giammanco, S., Ottaviani, M., Valenza, M., Veschetti, E., Principio, E., Giammanco, G., & Pignato, S. (1998). Major And Trace Elements Geochemistry In The Ground Waters Of A Volcanic Area: Mount Etna (Sicily, Italy). *Water Research*, *32*(1), 19-30.

Gleick, P. H. (2002). Dirty water: Estimated deaths from water-related diseases 2000–2020. Pacific Institute for Studies in Development, Environment, and Security.

GOP. (2016). Pakistan Social and Living Standards Measurement Survey (2014-15). Islamabad: Pakistan Bureau of Statistics, Statistics Division Government of Pakistan.

GOP. "Economic Survey of Pakistan (2019–20)." Ministry of Finance, Government of Pakistan, Islamabad, 2020.

Greenberg, A. F., Clescerl, L. S. & Eaton, A. D. Gwimbi, P., (2011). Standard Methods for the Examination of Water and Wastewater. American Public Health Association, Washington, DC. The microbial quality of drinking water in Manonyane community: maseru District (Lesotho). African Health Sciences, vol. 11, no. 3, pp. 474-480.

Guo, Q., Wang, Y., Ma, T., & Ma, R. (2007). Geochemical Processes Controlling The Elevated Fluoride Concentrations In Groundwaters Of The Taiyuan Basin, Northern China. *Journal Of Geochemical Exploration*, *93*(1), 1-12.

Henderson-Sellers, B. (1984). A New Formula For Latent Heat Of Vaporization Of Water As A Function Of Temperature. Quarterly Journal Of The Royal Meteorological Society, 110**,** 1186-1190.

Howard, G., Bartram, J., Water, S. & Organization, W. H. (2003). Domestic Water Quantity, Service Level And Health.

Hanan, A. (2010). Sidra., S & M. Usman. A. Bacteriological Analysis Of Drinking Water From 100 Families Of Lahore By Membrane. Filtration Technique And Chromagar. *Biomedica*, *26*(13), 152-156.

Henriques J.J and Louis G.E. (2011) "A decision model for selecting sustainable drinking water supply and grey water reuse systems for developing communities with a case study in Cimahi, Indonesia." Environmental Management, 2011, 92: 214–222.

Holt S (2005) A survey of water storage practices and beliefs in households in Bonao, Dominican Republic in 2005. Springer, Berlin.

Ho, K. C., Chow, Y. L., & Yau, J. T. S. (2003). Chemical And Microbiological Qualities Of The East River (Dongjiang) Water, With Particular Reference To Drinking Water Supply In Hong Kong. *Chemosphere*, *52*(9), 1441-1450.

Huang, G. H., & Xia, J. (2001). Barriers to sustainable water-quality management. Journal of environmental management, 61(1), 1-23.

Hughes, J. M., & Koplan, J. P. (2005). Saving lives through global safe water. *Emerging Infectious Diseases*, *11*(10), 1636.

Hussain, J., Shah, J., Khan, F. A., Hussain, W., Rehman, I. U., Khan, I., & Nascimento, I. A. (2012). Physicochemical evaluation of sewage waste of Peshawar City, KPK, Pakistan. *Middle-East J. Sci. Res*, *11*(6), 796-799.

Hussain, M., Rasool, S. A., Khan, M. T., & Wajid, A. (2007). Enterococci vs coliforms as a possible fecal contamination indicator: baseline data for Karachi. *Pak J Pharm Sci*, *20*(2), 107-11.

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

Immerzeel, W. W., Wanders, N., Lutz, A. F., Shea, J. M., & Bierkens, M. F. (2020). Reconciling high-altitude precipitation in the upper Indus basin with glacier mass balances and runoff. Hydrology and Earth System Sciences, 24(4), 1851-1866.

Inam Ullah, Alam. (2014). Evaluation of Drinking Water Quality of Peshawar, Pakistan. Journal of Environmental and Analytical Toxicology, 4(4), 1-5.

Inam Ullah, E., & Alam, A. (2014). Assessment of drinking water quality in Peshawar, Pakistan. *Bulgarian Journal of Agricultural Science*, *20*(3), 595-600.

IPCC (2021). Climate Change 2021: Impacts, Adaptation, and Vulnerability. Intergovernmental Panel on Climate Change. Cambridge University Press.

IPCC, (2021). Climate Change 2021: Impacts, Adaptation, and Vulnerability. Intergovernmental Panel on Climate Change. Cambridge University Press.

Jadoon, S., Hilal, Z., Ali, M., & Muhammad, S. (2019). Potentially toxic elements in drinking water and associated health risk assessment in Abbottabad city, northern Pakistan. Desalin Water Treat, 151, 392-402.

Jagals P., Jagals C., Bokako T. (2003) The effect of container-biofilm on the microbiological quality of water used from plastic household containers. J. Water Health 1(3):101–108

Jalil, R. A., Ashraf, M., & Ahmad, S. (2019). Assessment of water governance indicators in Pakistan. Water Policy, 21(6), 1083-1097.

Jain, C. K., Kumar, C. P., & Sharma, M. K. (2003). Ground Water Qualities Of Ghataprabha Command Area, Karnataka. *Indian Journal Environ And Ecoplan*, *7*(2), 251-262.

Jabal, M. S. A., Abustan, I., Rozaimy, M. R., & Al-Najar, H. (2014). Fluoride Enrichment In Groundwater Of Semi-Arid Urban Area: Khan Younis City, Southern Gaza Strip (Palestine). *Journal Of African Earth Sciences*, *100*, 259-266.

Jiang, S. C., Ryu, H., Lee, S., & Choi, S. (2018). Water quality and health: Review of turbidity and coliforms as microbial indicators of water pollution. Journal of Microbiology, 56(1), 1-9.

Jones, F. E. (2018). Evaporation Of Water: With Emphasis On Applications And Measurements, Crc Press. Ministry of Planning, Development and Reform Pakistan Millennium Development Goals Report; Planning Commission: Islamabad, Pakistan, 2013; pp. 1–195.

Jothivenkatachalam, K., Nithya, A. & Mohan, S. C. (2010). Correlation Analysis Of Drinking Water Quality In And Around Perur Block Of Coimbatore District, Tamil Nadu, India. Rasayan Journal Of Chemistry, 3**,** 649-654.

Kambe, T., Fukue, K., Ishida, R., & Miyazaki, S. (2015). Overview of Inherited Zinc Deficiency in Infants and Children.. *Journal of nutritional science and vitaminology*, 61 Suppl, S44-6 . https://doi.org/10.3177/jnsv.61.S44.

Kerketta, P., Baxla, S. L., Gora, R. H. & Kumari, S. (2013). Analysis Of Physico-Chemical Properties And Heavy Metals In Drinking Water From Different Sources In And Around Ranchi, Jharkhand, India. Veterinary World, 6.

Khalil, K. U. R., Sarwar, A., Hamayun, M., Naeem, W., & Ahmad, M. (2017). Bacteriological quality of drinking water in schools of Peshawar, Khyber Pakhtunkhwa. *Journal of Medical Sciences*, *25*(4), 433-436.

Khan M., AlMadani A (2016) Assessment of microbial quality in household water tanks in Dubai. United Arab Emirates Environ Eng Res 22(1):55–60

Khan M., T. Ihsanullah, F. Mehmood and A. Satar. (2000). Occurrence of pathogenic microorganism in food and water supplies in different areas of Peshawar, Nowshera and Charsada. Pak. J. Food Sci. 10(3-4):3740

Khan, F. J., & Javed, Y. (2007). Delivering access to safe drinking water and adequate sanitation in Pakistan (No. 30). Pakistan Institute of Development Economics.

Khan, M. S., & Khan, M. A. (2017). Groundwater quality assessment of selected areas in Punjab and Sindh Provinces, Pakistan. Environmental Earth Sciences, 76(3), 1-12. doi: 10.1007/s12665-017-6407-5

Khan, S. A., Muhammad, S., Nazir, S., & Shah, F. A. (2020). Heavy metals bounded to particulate matter in the residential and industrial sites of Islamabad, Pakistan:

Implications for non-cancer and cancer risks. Environmental Technology & Innovation, 19, 100822.

Khan, S. U., Ahmad, I., & Shahbaz, M. (2020). Water quality assessment and hydrochemical characteristics of urban groundwater supplies in Peshawar Valley, Pakistan. Applied Water Science, 10(3), 59.

Khan, S., Ali, S., Muhammad, S., Khan, B., Ali, A., Hesham, E. L., & Begum, S. (2020). Bacterial contamination in drinking water of urban Peshawar: a comparative study at the sources and user points of tube wells. *Desalination and Water Treatment*, *181*, 221-227.

Khan, S., Ali, S., Muhammad, S., Khan, B., Ali, A., Hesham, E. L., & Begum, S. (2020). Bacterial contamination in drinking water of urban Peshawar: a comparative study at the sources and user points of tube wells. *Desalination and Water Treatment*, *181*, 221-227.

Khan, S., Rauf, R., Muhammad, S., Qasim, M., & Din, I. (2016). Arsenic and heavy metals health risk assessment through drinking water consumption in the Peshawar District, Pakistan. *Human and ecological risk assessment: an international journal*, *22*(3), 581-596.

Khan, S., Shinwari, M.I., Haq, A., Ali, K.W., Rana, T., Badshah, M. and Khan, S.A., (2018). Fourier-transform infrared spectroscopy analysis and antifungal activity of methanolic extracts of Medicago parviflora, Solanum nigrum, Melilotus alba and Melilotus indicus on soil-borne phytopathogenic fungi. Pakistan Journal of Botany, 50(4), pp.1591-1598.

Khan, S.A., Ishtiaq, M., Shah, I., Zaheer, A., Naseer, M., Hassan, S.Z.U. and Abdullah, H., (2020). Physio-Chemical Parameters of Waste water and Ground water in District Faisalabad-Pakistan. THE STETHO, 1(3), pp.1-8.

Khan, S.A., Rehman, S., Khan, M.A., Khan, M.A., and Shah, M.T. (2016). Water Quality Assessment of Groundwater Resources in Pakistan: A Review. Environmental Science and Pollution Research, 23(5), 4147-4168.

Koppenburg, P., Abe, K., Abe, T., Adachi, I., Aihara, H., Akatsu, M., & Wang, C. C. (2004). Inclusive Measurement Of The Photon Energy Spectrum In B→ S Γ Decays. *Physical Review Letters*, *93*(6), 061803.

Kosek, M., Bern, C., & Guerrant, R. L. (2003). The global burden of diarrhoeal disease, as estimated from studies published between 1992 and 2000. Bulletin of the world health organization, 81, 197-204.

Kumar L, Kumari R, Kumar A, Tunio IA, Sassanelli C (2023). Water Quality Assessment and Monitoring in Pakistan: A Comprehensive Review. *Sustainability*. 2023; 15(7):6246.

L. H. (2004). Effect of water and sanitation on childhood health in a poor Peruvian peri-urban community. The Lancet, 363(9403), 112-118.

Lévesque B., Pereg D, Watkinson E, Maguire J, Bissonnette L, Gingras S, Rouja P, Bergeron M, Dewailly É (2008) Assessment of microbiological quality of drinking water from household tanks in Bermuda. Can J Microbiol 54(6):495–500.

Lin, L., Yang, H., & Xu, X. (2022). Effects of Water Pollution on Human Health and Disease Heterogeneity: A Review. *Frontiers in Environmental Science*, *10*, 880246. https://doi.org/10.3389/fenvs.2022.880246

Liu, H., Deng, S., Li, Z., Yu, G., & Huang, J. (2010). Preparation Of Al–Ce Hybrid Adsorbent And Its Application For Defluoridation Of Drinking Water. *Journal Of Hazardous Materials*, *179*(1-3), 424-430.

Lubineau, A. & Augé, J. (1999). Water As Solvent In Organic Synthesis. Modern Solvents In Organic Synthesis, 1-39.

M.C.P. (2018). Muncipal Corporation Peshawar report Vol. Government of Khyber.

Manga, M., Bartram, J., & Evans, B. E. (2020). Economic cost analysis of low-cost sanitation technology options in informal settlement areas (case study: Soweto, Johannesburg). International Journal of Hygiene and Environmental Health, 223(1), 289-298.

Manga, Musa, et al. (2021). "The effect of household storage tanks/vessels and user practices on the quality of water: a systematic review of literature." Environmental Systems Research 10.1 (2021): 1-26.

MCP, (1997). Municipal corporation of Peshawar report Vol. 1 government of N.W.F.P 1997.

Mirza, M. Q., & Ahmad, I. (2015). Challenges of water resources management in Pakistan: A review. Environmental Science and Pollution Research, 22(12), 8802-8813.

Misra , S. G,. Dinesh D., (1991), soil pollution ashing pulishing house, New Delhi India.

Muhammad, N., Nafees, M., Ge, L., Khan, M. H., Bilal, M., Chan, W. P. & Lisak, G. (2021). Assessment Of Industrial Wastewater For Potentially Toxic Elements, Human Health (Dermal) Risks, And Pollution Sources: A Case Study Of Gadoon Amazai Industrial Estate, Swabi, Pakistan. Journal Of Hazardous Materials, 419, 126450.

Mohsin, M., Safdar, S., Asghar, F., & Jamal, F. (2013). Assessment of drinking water quality and its impact on residents health in Bahawalpur city. *International Journal of Humanities and Social Science*, *3*(15), 114-128.

Molla N.A. Ali G., Mollah K.A., Wongwit W., Shipin O., Ramasoota P., et al. (2017). “Migration, Health and Socioenvironmental safety among children of Dhaka, Bangladesh.” Archives of Environmental and Occupational Health, 2017, 72 (6): 336–342.

Mora, A., Mac-Quhae, C., Calzadilla, M., & Sánchez, L. (2009). Survey Of Trace Metals In Drinking Water Supplied To Rural Populations In The Eastern Llanos Of Venezuela. *Journal Of Environmental Management*, *90*(2), 752-759.

Muhammad, S., Shah, M. T., & Khan, S. (2010). Arsenic health risk assessment in drinking water and source apportionment using multivariate statistical techniques in Kohistan region, northern Pakistan. Food and Chemical Toxicology, 48(10), 2855-2864.

Myint, Z., Oo, T., Thein, K., Tun, A., & Saeed, H. (2018). Copper deficiency anemia: review article. *Annals of Hematology*, 97, 1527-1534. https://doi.org/10.1007/s00277-018-3407-5.

Luo, X., Huo, X., Zhang, Y., Cheng, Z., Chen, S., & Xu, X. (2021). Increased intestinal permeability with elevated peripheral blood endotoxin and inflammatory indices for e-waste lead exposure in children.. *Chemosphere*, 279, 130862 . https://doi.org/10.1016/j.chemosphere.2021.130862.

Liu, M., Bao, S., Bolin, E., Burris, D., Xu, X., Sun, Q., Killilea, D., Shen, Q., Ziouzenkova, O., Belury, M., Failla, M., & Knoell, D. (2013). Zinc deficiency augments leptin production and exacerbates macrophage infiltration into adipose tissue in mice fed a high-fat diet.. *The Journal of nutrition*, 143 7, 1036-45 . https://doi.org/10.3945/jn.113.175158.

Leyssens, L., Vinck, B., Straeten, C., Wuyts, F., & Maes, L. (2017). Cobalt toxicity in humans-A review of the potential sources and systemic health effects.. *Toxicology*, 387, 43-56 . https://doi.org/10.1016/j.tox.2017.05.015.

Nabeela, F., Azizullah, A., Bibi, R., Uzma, S., Murad, W., Shakir, S. K. & Häder, D. P. (2014). Microbial contamination of drinking water in Pakistan—a review. Environmental Science and Pollution Research, 21(24), 13929-13942.

Naeem, K., Syed, T. H., Javid, H., Nargis, J., Shabir, A., Riaz, U., Zain, U. & Abdus, S. (2012). Physiochemical Evaluation Of The Drinking Water Sources From District Kohat, Khyber Pakhtunkhwa, Pakistan. International Journal Of Water Resources And Environmental Engineering, 4**,** 302-313.

NDC-JC. (2019). Review and Updation of existing Urban Water and Sanitation Master Plan for Peshawar by AiD- NDC-JC 2019.

Niru B., Jitendra U., Nandani G., Tirtha R. B., Anup B. C., Deepa S. R., Niranjan K. and Bhoj R. P. (2020). Physical, chemical and microbiological characterization of processed drinking water in central Nepal: current state study. Journal of Water, Sanitation and Hygiene for Development., Vol. 10, No.1.

Nkere, C. K., Ibe, N. I., & Iroegbu, C. U. (2011). Bacteriological quality of foods and water sold by vendors and in restaurants in Nsukka, Enugu State, Nigeria: a comparative study of three microbiological methods. Journal of health, population, and nutrition, 29(6), 560.

Nnaji, C. C., Nnaji, I. V., & Ekwule, R. O. (2019). Storage-induced deterioration of domestic water quality. Journal of Water, Sanitation and Hygiene for Development, 9(2), 329-337.

Neal, C., House, W. A., Jarvie, H. P., Neal, M., Hill, L., & Wickham, H. (2005). Phosphorus Concentrations In The River Dun, The Kennet And Avon Canal And The River Kennet, Southern England. *Science Of The Total Environment*, *344*(1-3), 107-128.

Norman, G., Pedley, S., & Takkouche, B. (2010). Effects of sewerage on diarrhea and enteric infections: a systematic review and meta-analysis. The Lancet infectious diseases, 10(8), 536- 544.

Ochoa, T. J., Salazar-Lindo, E., & Cleary, T. G. (2004, October). Management of children with infection-associated persistent diarrhea. In Seminars in pediatric infectious diseases (Vol. 15, No. 4, pp. 229-236). WB Saunders.

Odamaki, T., Bottacini, F., Mitsuyama, E., Yoshida, K., Kato, K., Xiao, J. Z., & van Sinderen, D. (2019). Impact of a bathing tradition on shared gut microbes among Japanese families. Scientific reports, 9(1), 1-8.

Odrigo S, Sinclair M, Leder K (2010) A survey of the characteristics and maintenance of rainwater tanks in urban areas of South Australia. Water Sci Technol 61(6):1569–1577

Omezuruike, O. I., Damilola, A. O., Adeola, O. T., Fajobi, E. A., & Shittu, O. B. (2008). Microbiological and physicochemical analysis of different water samples used for domestic purposes in Abeokuta and Ojota, Lagos State, Nigeria. *African Journal of Biotechnology*, *7*(5), 617-621.

PCRWR (2022). Water Quality Status in Pakistan (2022). Islamabad: Pakistan Council of Research in Water Resources.

PCRWR (2013–14)Annual Report,. Pakistan Council of Research in Water Resources, Islamabad, Pakistan, 2014.

Padday, J. & Uffindell, N. (1968). The Calculation Of Cohesive And Adhesive Energies From Intermolecular Forces At A Surface. The Journal Of Physical Chemistry, 72**,** 1407-1414.

Patil, P., Sawant, D. & Deshmukh, R. (2012). Physico-Chemical Parameters For Testing Of Water-A Review. International Journal Of Environmental Sciences, 3**,** 1194.

Pimentel, D., Houser, J., Preiss, E., White, O., Fang, H., Mesnick, L., Barsky, T., Tariche, S., Schreck, J. & Alpert, S. (1997). Water Resources: Agriculture, The Environment, And Society. Bioscience, 47**,** 97-106.

Pradeep, J. K. (1998). Hydrogeology And Quality Of Ground Water Around Hirapur, District Sagar (Mp). *Pollution Research*, *17*(1), 91-94.

Pindi, P. K., Yadav, P. R. & Kodaparthi, A. (2013). Bacteriological And Physico-Chemical Quality Of Main Drinking Water Sources. Polish Journal Of Environmental Studies, 22.

Qureshi, A. S., & Shah, A. (2003). Impact of institutional change on the performance of public irrigation systems: A case study of the Indus Basin Irrigation System, Pakistan. The World Bank.

Qureshi, A. S., Hussain, I., Ahmad, N., & Sabir, M. (2017). Estimating sedimentation volume in Tarbela reservoir using remotely sensed data. Pakistan Journal of Agricultural Sciences, 54(2), 313-318.

Rahman Abu Hamed, A., & Sannen, A. M. H. (2013). The development of rural water supply in the province of Fayoum, Egypt. Water Science and Technology, 27(9), 37-46.

Ramírez-Castillo, F. Y., Loera-Muro, A., Jacques, M., Garneau, P., Avelar-González, F. J., Harel, J., & Guerrero-Barrera, A. L. (2015). Waterborne pathogens: detection methods and challenges. Pathogens, 4(2), 307-334.

Rao, K. D. (2005). Multi-criteria spatial decision analysis for forecasting urban water requirements: a case study of Dehradun city, India. *Landscape and Urban Planning*, *71*(2-4), 163-174.

Rashid, A., Khan, S., Ayub, M., Sardar, T., Jehan, S., Zahir, S., ... & Ullah, H. (2019). Mapping human health risk from exposure to potential toxic metal contamination in groundwater of Lower Dir, Pakistan: Application of multivariate and geographical information system. *Chemosphere*, *225*, 785-795.

Rahmanian, N., Ali, S. H. B., Homayoonfard, M., Ali, N., Rehan, M., Sadef, Y. & Nizami, A. (2015). Analysis Of Physiochemical Parameters To Evaluate The Drinking Water Quality In The State Of Perak, Malaysia. Journal Of Chemistry, 2015.

Rahman, M., Asaduzzaman, M., & Naidu, R. (2013). Consumption of arsenic and other elements from vegetables and drinking water from an arsenic-contaminated area of Bangladesh.. Journal of hazardous materials, 262, 1056-63 . https://doi.org/10.1016/j.jhazmat.2012.06.045.

Rehman, Z.U., Sardar, K.H.A.N., Shah, M.T., Brusseau, M.L., Khan, S.A. and Mainhagu, J., (2018). Transfer of heavy metals from soils to vegetables and associated human health risks at selected sites in Pakistan. Pedosphere, 28(4), pp.666-679.

Rafique, T., Naseem, S., Usmani, T. H., Bashir, E., Khan, F. A., & Bhanger, M. I. (2009). Geochemical Factors Controlling The Occurrence Of High Fluoride Groundwater In The Nagar Parkar Area, Sindh, Pakistan. *Journal Of Hazardous Materials*, *171*(1-3), 424-430.

Reardon, E. J., & Wang, Y. (2000). A Limestone Reactor For Fluoride Removal From Wastewaters. *Environmental Science & Technology*, *34*(15), 3247-3253.

Rosemann, N. (2005). Drinking water crisis in Pakistan and the issue of bottled water: the case of Nestlé's 'Pure Life.'. Actionaid Pakistan, 4, 37.

Sardar Khan, Maria Shahnaz, Noor Jehan, Shafiqur Rehman, M. Tahir Shah, Islamud Din, (2012). Drinking water quality and human health risk in Charsadda district, Pakistan, Journal of Cleaner Production, https://doi.org/10.1016/ j.jclepro. 2012.02.016

Shanmugasundaram, K., Nikhila, R. & Janarthanan, B. (2012). Physico-Chemical Analysis Of Drinking Water From Different Sources In Coimbatore District, Tamilnadu And India. Inter. J. Res. Sci. & Adv. Tech, 3**,** 005-012.

Schafer C. (2010) Impact of tank material on water quality in household water storage systems in Cochabamba, Bolivia. Springer, Berlin.

Sciortino Jr, C. V. (1993). An immunofluorescent stain for Helicobacter pylori. *Hybridoma*, *12*(3), 333-342.

Shah, M. T., Ara, J., Muhammad, S., Khan, S., & Tariq, S. (2012). Health risk assessment via surface water and sub-surface water consumption in the mafic and ultramafic terrain, Mohmand agency, northern Pakistan. Journal of Geochemical Exploration, 118, 60-67.

Shahid, S. U., Iqbal, J., & Khan, S. J. (2017). A comprehensive assessment of spatial interpolation methods for the groundwater quality evaluation of Lahore, Punjab, Pakistan. *NUST Journal of Engineering Sciences*, *10*(1), 1-13.

Shahid, S. U., Iqbal, J., & Khan, S. J. (2017). A comprehensive assessment of spatial interpolation methods for the groundwater quality evaluation of Lahore, Punjab, Pakistan. NUST Journal of Engineering Sciences, 10(1), 1-13.

Shahid, S., & Haroon, N. (2017). Groundwater resources assessment in Pakistan: Challenges and opportunities. Hydrogeology Journal, 25(7), 1979-1992.

Sofola, T. O., & Lawal, M. (1983). Bacteriological analysis of water samples from main taps and domestic water storage tanks in metropolitan Lagos Niger. *Med. Pract*, *6*(3), 95-98.

Souid, G., Souayed, N., Yaktiti, F., & Maaroufi, K. (2013). Effect of acute cadmium exposure on metal accumulation and oxidative stress biomarkers of Sparus aurata.. *Ecotoxicology and environmental safety*, 89, 1-7 . https://doi.org/10.1016/j.ecoenv.2012.12.015.

Shams, M., Nodehi, R. N., Alimohammadi, M., & Mahvi, A. H. (2009). A Survey Of Nitrate And Fluoride In Water Distribution Networks Of Tabas, Iran. *World Applied Sciences Journal*, *7*(12), 1516-1520.

Stokdyk, J. P., Spencer, S. K., Walsh, J. F., de Lambert, J. R., Firnstahl, A. D., Anderson, A. C., & Borchardt, M. A. (2019). Cryptosporidium incidence and surface water influence of groundwater supplying public water systems in Minnesota, USA. *Environmental science & technology*, *53*(7), 3391-3398.

Sun, H., Shi, B., Yang, F., & Wang, D. (2017). Effects of sulfate on heavy metal release from iron corrosion scales in drinking water distribution system.. *Water research*, 114, 69-77 . https://doi.org/10.1016/j.watres.2017.02.021.

Trivedi, P., Bajpai, A. & Thareja, S. (2010). Comparative Study Of Seasonal Variation In Physico-Chemical Characteristics In Drinking Water Quality Of Kanpur, India With Reference To 200 Mld Filtration Plant And Ground Water. Nature And Science, 8**,** 11-17.

Troell, M., Naylor, R. L., Metian, M., Beveridge, M., Tyedmers, P. H., Folke, C., Arrow, K. J., Barrett, S., Crépin, A.-S. & Ehrlich, P. R. (2014). Does Aquaculture Add Resilience To The Global Food System? Proceedings Of The National Academy Of Sciences, 111**,** 13257-13263.

Thakur, J. K., Neupane, M., & Mohanan, A. A. (2017). Water poverty in upper Bagmati River basin in Nepal. Water Science, 31(1), 93-108.

Tahir Shah, M., & Danishwar, S. (2003). Potential Fluoride Contamination In The Drinking Water Of Naranji Area, Northwest Frontier Province, Pakistan. *Environmental Geochemistry And Health*, *25*(4), 475-481.

Tsega, N., Sahile, S., Kibret, M., & Abera, B. (2013). Bacteriological and physico-chemical quality of drinking water sources in a rural community of Ethiopia. African health sciences, 13(4), 1156-1161.

Ullah, R., Malik, R. N., & Qadir, A. (2009). Assessment of groundwater contamination in an industrial city, Sialkot, Pakistan. African Journal of Environmental Science and Technology, 3(12).

Ullah, R., Muhammad, S., & Jadoon, I. A. (2019). Potentially harmful elements contamination in water and sediment: Evaluation for risk assessment and provenance in the northern Sulaiman fold belt, Baluchistan, Pakistan. *Microchemical journal*, *147*, 1155-1162.

Udhayakumar, R., Manivannan, P., Raghu, K. & Vaideki, S. (2016). Assessment Of Physico-Chemical Characteristics Of Water In Tamilnadu. Ecotoxicology And Environmental Safety, 134, 474-477.

WAPDA (2020). Water resources of Pakistan, Water and Power Development Authority.

Waghmare, S. S., & Arfin, T. (2015). Fluoride Removal From Water By Various Techniques. *Int. J. Innov. Sci. Eng. Technol*, *2*(3), 560-571.

Werkneh, A. A., Medhanit, B. Z., Abay, A. K. & Damte, J. Y. (2015). Physico-Chemical Analysis Of Drinking Water Quality At Jigjiga City, Ethiopia. American Journal Of Environmental Protection, 4, 29-32.

WHO (2018). *Antimicrobial resistance and primary health care* (No. WHO/HIS/SDS/2018.56). World Health Organization.

WHO (2018). *Antimicrobial resistance and primary health care* (No. WHO/HIS/SDS/2018.56). World Health Organization.

WHO (2021). Drinking-water. Retrieved from https://www.who. intnews-room.fact-sheets/drinking-water

W.H.O (2017). WHO Guidelines for Drinking-Water Quality: First Addendum to the Fourth Edition; World Health Organization: Geneva, Switzerland.

Wright, C. M., Parkinson, K. N., & Drewett, R. F. (2004). Why are babies weaned early? Data from a prospective population based cohort study. Archives of disease in childhood, 89(9), 813- 816.

Yang, D., Yang, Y. & Xia, J. (2021). Hydrological Cycle And Water Resources In A Changing World: A Review. Geography And Sustainability, 2, 115-122.

Yasin, M., Ketema, T. & Bacha, K. (2015). Physico-Chemical And Bacteriological Quality Of Drinking Water Of Different Sources, Jimma Zone, Southwest Ethiopia. Bmc Research Notes, 8, 1-13.

Yu, J., Fedorova, N. D., Montalbano, B. G., Bhatnagar, D., Cleveland, T. E., Bennett, J. W., & Nierman, W. C. (2011). Tight Control Of Mycotoxin Biosynthesis Gene

Expression In Aspergillus Flavus By Temperature As Revealed By Rna-Seq. *Fems Microbiology Letters*, *322*(2), 145-149.

Yuan, W., Yang, N., & Li, X. (2016). Advances in Understanding How Heavy Metal Pollution Triggers Gastric Cancer. *BioMed Research International*, 2016. https://doi.org/10.1155/2016/7825432.

Yousaf, S., Zada, A., & Owais, M. (2013). Physico-chemical characteristics of potable water of different sources in District Nowshera: A case study after flood–2010. *Journal of Himalayan earth sciences*, *46*(1), 83-87.

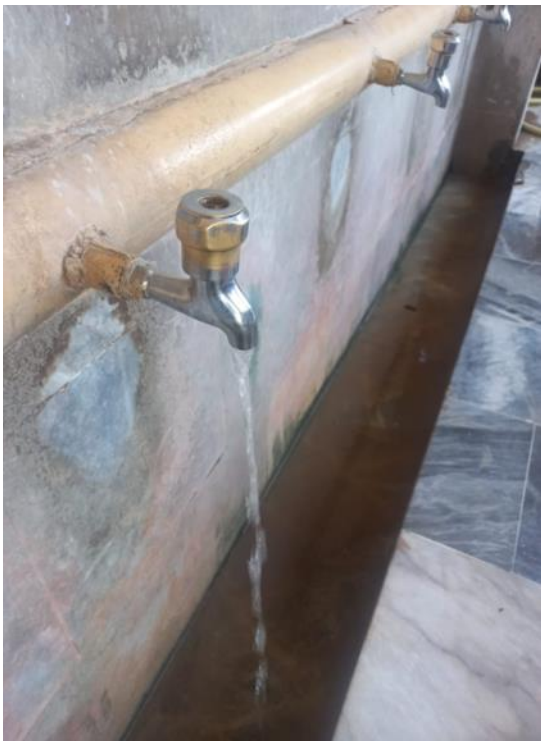
Yousuf, F. A., Siddiqui, R., & Khan, N. A. (2014). Survey of gram negative and gram positive bacteria in drinking water supplies in Karachi, Pakistan. British Microbiology Research Journal, 4(6), 592.

Zaman, S. (2008) National Standards For Drinking Water Quality, Pp. 3-29. Available At:Http://Www. Environment. Gov. Pk/Act-Rules/Dwqstd-May2007.Pdf.

Ziadat, A., (2005). Impact of storage tanks on drinking water quality in Al-Karak Province-Jordan. J. Appl. Sci. 5(4):634–638.

ANNEXURE-I

PHOTO GALLERY

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ANNEXURE-II

QUESTIONNAIRE

Form No.

Date: ___________________

Name of Respondent: _______________ Age _________

1. Where do you get your current drinking water from? Is that drinking water source available in for your household?
   (a) Tube well / Tap (b) House bore/Tap (c) Both

2. How far is your home's water source (e.g. well, municipal water pipe) from your sewer/septic line?
   i. 05-10 feet
   ii. 10-15 feet
   iii. 15-20 feet
   iv. 20-25 feet

3. What is the mode of water storage
   - Roof top tank
   - Under ground tank
   - Simple containers

4. What is the frequency of cleaning the well?
   - Once in a quarter
   - Once in six months
   - Once a year
   - Not cleaned in the last year

5. Generally, how does the water smell?
   - No smell
   - Feel smell

6. Generally, does the water have a taste?
   - Yes
   - No (tasteless)

7. What are you doing to improve drinking water quality at household level?
    - Water Neutralization/ Boiling
    - Using Filters
    - Replaced old pipelines with plastic ones and installed filters
8. Have you observed any complaints due to contamination issues in water?
9. The occurrence of water borne diseases in the family, If YES, Which of these disease found in your family?
    - Cholera
    - Typhoid
    - Hepatitis A and E
    - Diarrhea
    - Dermatitis
    - Worm infestation

ANNEXURE-III

SAMPLE LOCATIONS OF THE STUDY AREA UNIVERSITY TOWN, PESHAWAR

Sample IDs	Longitude	Latitude	Type
BTW.01	71.492077	33.996682	Bore/ Tap
BTW.02	71.493624	33.995776	Bore/ Tap
BTW.03	71.493738	33.995716	Bore/ Tap
BTW.04	71.495651	33.994615	Bore/ Tap
BTW.05	71.48968	33.980192	Bore/ Tap
BTW.06	71.493752	33.981551	Bore/ Tap
BTW.07	71.495968	33.994513	Bore/ Tap
BTW.08	71.478569	33.993408	Bore/ Tap
BTW.09	71.470894	33.99413	Bore/ Tap
BTW.10	71.48049	33.995571	Bore/ Tap
BTW.11	71.488651	33.996714	Bore/ Tap
BTW.12	71.487989	33.995633	Bore/ Tap
BTW.13	71.491154	33.995758	Bore/ Tap
BTW.14	71.48915	33.989643	Bore/ Tap
BTW.15	71.490354	33.989544	Bore/ Tap
BTW.16	71.50172	33.98873	Bore/ Tap
BTW.17	71.50177	33.99009	Bore/ Tap
BTW.18	71.47824	33.99599	Bore/ Tap
BTW.19	71.49978	33.9914	Bore/ Tap
BTW.20	71.49469	3.99165	Bore/ Tap
BTW.21	71.49474	33.99192	Bore/ Tap
BTW.22	71.493	33.99268	Bore/ Tap
BTW.23	71.50573	33.99007	Bore/ Tap
BTW.24	71.50217	33.99204	Bore/ Tap
BTW.25	71.4991	33.99147	Bore/ Tap
TW.01	71.49208	33.98224	Bore/ Tap
TW.02	71.499068	33.995558	Tubewell
TW.03	71.495968	33.994513	Tubewell
TW.04	71.493291	33.985144	Tubewell
TW.05	71.4893	33.99575	Tubewell
TW.06	71.487905	33.99172	Tubewell
TW.07	71.489412	33.99248	Tubewell
TW.08	71.48945	33.992891	Tubewell
TW.09	71.489435	33.99096	Tubewell
TW.10	71.489414	33.99096	Tubewell
TW.11	71.489387	33.990959	Tubewell
TW.12	71.489033	33.99094	Tubewell
TW.13	71.493099	33.988591	Tubewell
TW.14	71.487915	33.990261	Tubewell
TW.15	71.496868	33.987917	Tubewell
TW.16	71.498377	33.988661	Tubewell
TW.17	71.49981	33.988799	Tubewell
TW.18	71.49614	33.99204	Tubewell
TW.19	71.49463	33.98826	Tubewell
TW.20	71.49341	33.98885	Tubewell
TW.21	71.49687	33.98982	Tubewell
TW.22	71.49709	33.99141	Tubewell
TW.23	71.48155	33.99328	Tubewell
TW.24	71.47823	33.99767	Tubewell
TW.25	71.47131	33.99791	Tubewell

Note: BTW= Bore / Tap Water; TW= Tubewell water

ANNEXURE-IV

RESULT OF PHYSICAL PARAMETERS OF DRINKING WATER SAMPLES

Sample IDs	Parameters			
	pH	Electrical conductivity µS/cm	Total dissolved solid mg/L	Turbidity NTU
BTW.01	7.48	771.3	497.6	1.6
BTW.02	7.78	772.1	592.0	1.4
BTW.03	7.41	713.0	527.5	1.2
BTW.04	7.35	750.7	489.3	1.3
BTW.05	7.42	738.2	565.3	1.6
BTW.06	7.33	751.6	550.4	1.0
BTW.07	7.35	760.4	485.5	1.8
BTW.08	7.13	782.1	580.6	1.2
BTW.09	7.39	766.2	483.3	1.3
BTW.10	7.25	757.3	540.5	1.2
BTW.11	7.43	757.4	558.3	1.7
BTW.12	7.25	720.5	418.6	1.5
BTW.13	7.66	748.6	435.3	1.6
BTW.14	7.52	752.7	556.4	1.2
BTW.15	7.79	755.8	466.7	1.4
BTW.16	7.28	752.9	508.3	1.6
BTW.17	7.76	724.1	567.2	1.8
BTW.18	7.44	739.2	590.9	1.8
BTW.19	7.45	723.3	417.8	1.9
BTW.20	7.32	779.4	537.1	1.2
BTW.21	7.33	728.5	579.5	1.7
BTW.22	7.36	750.5	530.6	1.8
BTW.23	7.17	785.1	512.3	1.9
BTW.24	7.49	779.2	468.4	1.6
BTW.25	7.35	734.3	597.5	1.2
TW.01	7.43	784.1	591.8	1.1
TW.02	7.23	743.6	470.6	1.2
TW.03	7.63	756.8	476.5	1.9
TW.04	7.37	703.8	500.9	1.1
TW.05	7.70	761.3	497.6	1.3
TW.06	7.35	772.1	582.0	1.6
TW.07	7.14	613.0	527.5	1.2
TW.08	7.39	780.7	489.3	1.8
TW.09	7.52	761.3	567.6	1.3
TW.10	7.43	772.1	492.0	1.7
TW.11	7.38	733.0	527.5	1.5
TW.12	7.18	740.3	489.3	1.4
TW.13	7.47	775.3	487.6	1.7
TW.14	7.27	722.4	585.0	2.1
TW.15	7.25	745.3	476.6	1.8
TW.16	7.32	753.7	482.9	1.3
TW.17	7.81	725.9	477.5	2.1
TW.18	7.72	737.2	589.3	1.9
TW.19	7.29	763.6	587.8	1.7
TW.20	7.43	778.1	573.4	2.0
TW.21	7.52	778.0	527.5	1.5
TW.22	7.32	730.7	489.7	1.9
TW.23	7.42	745.1	557.6	1.9
TW.24	7.63	791.2	572.5	1.8
TW.25	7.37	764.5	487.7	1.9
WHO/MEQS/PSQCA	**6.8-8.5**	**1000**	**<1000**	**<5NTU**

ANNEXURE-V

RESULT OF CHEMICAL ANALYSIS OF DRINKING WATER SAMPLES

Sample IDs	Parameters								
	TH mg/L	Chlorides mg/L	SO4 mg/L	Na mg/L	NO_2 mg/L	T alk mg/L	Calcium mg/L	$CaCO_3$ mg/L	K mg/L
BTW.01	385.3	66.3	71.4	30.6	Nil	289.7	194.1	161.9	3.6
BTW.02	342.5	58.2	74.0	33.3	Nil	336.7	245.5	181.4	4.3
BTW.03	363.2	70.5	72.3	35.4	Nil	287.4	216.5	171.6	3.4
BTW.04	371.5	66.1	74.1	33.5	Nil	215.7	197.5	152.4	2.7
BTW.05	351.1	68.5	72.4	31.6	Nil	288.7	184.1	183.2	2.7
BTW.06	394.3	59.2	75.0	32.3	Nil	326.7	246.0	178.3	3.2
BTW.07	355.5	75.5	73.3	33.4	Nil	298.3	195.3	168.3	4.1
BTW.08	381.3	52.1	76.1	34.5	Nil	316.9	178.3	179.4	3.7
BTW.09	372.3	72.3	71.5	35.6	Nil	281.5	197.1	186.3	4.3
BTW.10	365.4	68.2	73.4	36.3	Nil	332.6	205.9	174.9	3.7
BTW.11	358.1	58.5	74.3	31.4	Nil	291.4	175.6	157.9	2.8
BTW.12	356.1	52.1	77.2	32.5	Nil	320.1	158.3	127.9	2.6
BTW.13	374.6	59.3	75.1	33.7	Nil	318.7	244.1	183.5	3.1
BTW.14	375.2	68.7	77.5	34.8	Nil	276.7	245.5	155.4	2.9
BTW.15	381.5	61.8	74.2	35.9	Nil	278.4	213.6	171.9	2.7
BTW.16	345.1	66.1	73.4	31.1	Nil	316.9	195.3	176.9	2.8
BTW.17	352.1	71.3	71.7	32.7	Nil	251.5	174.1	187.3	2.5
BTW.18	374.6	55.2	75.3	33.6	Nil	292.6	145.5	173.5	4.2
BTW.19	351.2	79.5	72.1	34.5	Nil	281.1	235.2	154.3	4.2
BTW.20	381.5	78.1	74.1	35.4	Nil	220.1	228.5	174.3	3.8
BTW.21	362.1	62.3	75.3	36.5	Nil	235.7	187.3	172.1	3.9
BTW.22	377.9	79.2	74.5	34.6	Nil	375.0	194.1	173.3	3.5
BTW.23	342.1	77.5	73.4	35.7	Nil	208.7	213.5	163.2	2.8
BTW.24	366.1	57.1	77.8	36.8	Nil	295.9	237.2	182.3	2.5
BTW.25	371.5	64.3	71.8	36.1	Nil	245.7	195.6	174.9	3.4
TW.01	374.2	71.5	71.3	36.4	Nil	297.3	215.6	181.5	3.4
TW.02	361.5	56.1	75.1	34.5	Nil	315.9	198.3	162.3	2.9
TW.03	352.1	87.4	74.5	33.9	Nil	336.5	145.3	185.3	3.2
TW.04	384.6	84.3	72.5	31.8	Nil	258.4	176.3	176.7	3.1
TW.05	371.2	88.1	73.1	33.7	Nil	317.4	183.3	176.7	1.5
TW.06	361.5	87.3	74.4	35.8	Nil	293.1	194.0	163.2	1.7
TW.07	426.9	93.1	75.2	30.9	Nil	322.4	189.3	163.9	2.1
TW.08	396.1	97.2	75.5	31.9	Nil	323.7	193.5	161.1	2.3
TW.09	366.6	90.8	73.6	35.1	Nil	234.5	199.0	175.4	1.4
TW.10	376.2	99.5	72.7	36.8	Nil	227.4	174.1	181.4	2.7
TW.11	369.5	91.7	71.4	30.2	Nil	346.7	213.0	180.5	2.8
TW.12	372.1	88.3	75.2	35.1	Nil	251.5	195.3	183.4	1.8
TW.13	358.3	87.5	74.6	36.2	Nil	245.6	142.3	167.9	2.7
TW.14	401.9	99.1	71.4	30.7	Nil	271.1	167.1	165.3	2.9
TW.15	378.1	83.5	72.5	32.9	Nil	270.1	195.9	175.3	2.9
TW.16	377.6	92.1	75.4	33.8	Nil	275.7	135.6	174.2	1.9
TW.17	352.2	96.3	74.8	35.3	Nil	345.5	157.3	183.3	1.8
TW.18	358.5	94.3	73.5	36.5	Nil	352.5	233.1	184.2	2.5
TW.19	392.1	90.1	74.1	32.1	Nil	256.4	245.5	183.2	3.3
TW.20	362.5	85.3	71.8	31.0	Nil	245.5	219.6	176.4	3.5
TW.21	399.1	95.1	74.9	32.5	Nil	320.9	197.3	171.4	3.2
TW.22	358.1	95.2	71.5	30.0	Nil	261.5	164.5	181.2	1.8
TW.23	392.6	100.8	75.6	33.9	Nil	258.6	145.7	168.3	1.9
TW.24	382.2	99.5	74.2	36.5	Nil	249.3	225.2	164.3	2.3
TW.25	398.5	86.1	70.6	34.1	Nil	260.5	164.1	165.9	2.6
WHO/NEQS	**<500 mg/L**	**<250 mg/L**	**<1000**	**<5NTU**	**-**	**<500 mg/L**	**200 mg/L**		
PSQCA	**<500 mg/L**	**<500 mg/L**	**<400 mg/L**	**<200 mg/L**	**-**	**<600 mg/L**			

ANNEXURE-VI

RESULT OF BACTERIOLOGICAL ANALYSIS OF DRINKING WATER

S.No	Sample ID	Total Plates Count (CFU/ml)	Total Coliform (MPN/100ml)	Fecal Coliform (MPN/100ml)
1	BTW.01	210	6.9	5.1
2	BTW.02	170	5.1	3.6
3	BTW.03	110	6.9	5.0
4	BTW.04	170	5.1	3.5
5	BTW.05	200	6.8	5.0
6	BTW.06	160	5.1	3.7
7	BTW.07	160	6.9	5.0
8	BTW.08	190	6.6	4.1
9	BTW.09	170	5.4	3.6
10	BTW.10	200	6.7	5.0
11	BTW.11	210	5.7	3.1
12	BTW.12	180	6.7	5.1
13	BTW.13	190	5.5	3.7
14	BTW.14	160	6.8	5.1
15	BTW.15	190	6.5	4.1
16	BTW.16	200	5.1	3.2
17	BTW.17	180	5.9	3.0
18	BTW.18	210	5.1	3.4
19	BTW.19	210	6.8	5.0
20	BTW.20	175	5.1	3.7
21	BTW.21	187	6.9	5.0
22	BTW.22	195	6.8	5.1
23	BTW.23	200	5.1	3.4
24	BTW.24	170	6.9	4.9
25	BTW.25	180	6.6	3.1
26	TW.01	230	6.8	5.1
27	TW.02	280	6.9	5.1
28	TW.03	230	6.7	5.0
29	TW.04	235	6.9	5.1
30	TW.05	240	6.8	5.1
31	TW.06	300	6.9	5.0
32	TW.07	270	6.8	5.1
33	TW.08	280	6.7	5.0
34	TW.09	270	6.8	5.1
35	TW.10	230	6.9	4.9
36	TW.11	240	6.8	5.1
37	TW.12	250	6.9	5.1
38	TW.13	280	6.8	5.0
39	TW.14	270	6.9	5.1
40	TW.15	280	6.8	5.1
41	TW.16	230	6.9	5.0
42	TW.17	230	6.8	4.9
43	TW.18	240	6.9	5.1
44	TW.19	260	6.7	5.0
45	TW.20	230	6.9	5.1
46	TW.21	280	6.9	5.0
47	TW.22	250	6.9	5.1
48	TW.23	230	6.8	5.1
49	TW.24	270	6.9	5.0
50	TW.25	280	6.8	5.1
	WHO	**<1CFU/100ml**	**<1.1**	**<1.1**

ANNEXURE-VII

HEAVY METAL CONCENTRATION LEVELS IN DRINKING WATER

Iron (Fe), Zinc (Zn), nickel (Ni), Cadmium (Cd)

Sample IDs	Fe mg/L	Zn mg/L	Ni mg/L	Cd mg/L
BTW.01	0.023	0.037	0.126	0.071
BTW.02	0.011	0.665	0.095	0.024
BTW.03	0.021	0.765	0.125	0.087
BTW.04	0.016	0.203	0.138	0.065
BTW.05	0.005	0.301	0.111	0.019
BTW.06	0.001	0.024	0.098	0.023
BTW.07	0.003	0.025	0.178	0.067
BTW.08	0.032	0.036	0.076	0.065
BTW.09	0.016	0.034	0.132	0.054
BTW.10	0.013	0.017	0.165	0.064
BTW.11	0.026	0.032	0.126	0.064
BTW.12	0.023	0.051	0.178	0.062
BTW.13	0.019	0.061	0.152	0.081
BTW.14	0.017	0.023	0.173	0.084
BTW.15	0.002	0.032	0.123	0.074
BTW.16	0.023	0.041	0.099	0.072
BTW.17	0.034	0.171	0.167	0.071
BTW.18	0.023	0.023	0.075	0.073
BTW.19	0.037	0.018	0.178	0.068
BTW.20	0.001	0.773	0.176	0.087
BTW.21	0.032	0.005	0.175	0.078
BTW.22	0.025	0.021	0.207	0.048
BTW.23	0.023	0.004	0.185	0.047
BTW.24	0.052	0.008	0.175	0.073
BTW.25	0.045	0.032	0.195	0.068
TW.01	0.039	0.045	0.223	0.058
TW.02	0.032	0.164	0.222	0.056
TW.03	0.025	0.144	0.226	0.045
TW.04	0.016	0.312	0.199	0.021
TW.05	0.043	0.024	0.222	0.027
TW.06	0.023	0.026	0.229	0.028
TW.07	0.023	0.638	0.223	0.067
TW.08	0.034	0.054	0.197	0.076
TW.09	0.028	0.523	0.250	0.081
TW.10	0.027	0.143	0.197	0.029
TW.11	0.025	0.028	0.099	0.036
TW.12	0.032	0.092	0.249	0.078
TW.13	0.007	0.082	0.096	0.075
TW.14	0.043	0.042	0.197	0.054
TW.15	0.025	0.013	0.217	0.073
TW.16	0.029	0.011	0.223	0.075
TW.17	0.032	0.016	0.243	0.049
TW.18	0.038	0.008	0.198	0.053
TW.19	0.024	0.004	0.099	0.078
TW.20	0.027	0.090	0.215	0.087
TW.21	0.032	0.024	0.218	0.076
TW.22	0.036	0.062	0.234	0.075
TW.23	0.034	0.032	0.226	0.074
TW.24	0.023	0.053	0.219	0.080
TW.25	0.029	0.028	0.210	0.049
WHO/NEQS	**<500 mg/L**	**<250 mg/L**	**<1000**	**<5NTU**
PSQCA	**<500 mg/L**	**<500 mg/L**	**<400 mg/L**	**<200 mg/L**
Mean	0.02498	0.1212	0.17518	0.06178
Max	0.052	0.773	0.25	0.087

ASSESSMENT OF DRINKING WATER QUALITY IN UNIVERSITY TOWN PESHAWAR, PAKISTAN

ORIGINALITY REPORT

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