ASSESMENT OF DRINKING WATER QUALITY OF DISTRICT MANSEHRA, KHYBER PAKHTUNKHAWA, PAKISTAN

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2021

ASSESMENT OF DRINKING WATER QUALITY OF DISTRICT MANSEHRA, KHYBER PAKHTUNKHAWA, PAKISTAN

A thesis submitted in fulfilment of the requirements for the award of the degree of MS Environmental Sciences

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2021

Bahria University

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Islamabad Campus, Islamabad

Date. 27/01/2021

Certificate

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ABSTRACT

Drinking water quality of the major water resources of district Mansehra of Khyber Pakhtunkhwa (KP) province was assessed for detection of concentration of various containments. Physico-chemical, microbiological contamination is the major component of assessment of drinking water quality. The objective of this study was to assess various drinking water resources to identify the containments and to detect their chemical and biological concentrations. More than 210 drinking water samples were collected from 56 different locations of the district. The samples were analysed for drinking water, aesthetic, physical parameters, chemical and biological parameters through APHA standard methods and field and laboratory-based instruments. The results from the analysis were further compared with Pakistan National Environmental Quality Standards (NEQS) and World Health Organization (WHO) water quality guidelines. The results have shown that the high level of microbiological contamination exists in all the water sources except tube well. Large number of populations is dependent on contaminated water sources such as springs, supply schemes, streams and dug wells. More than 89 % of the samples were recorded with high level of bacteriological presence. Similarly, high concentration of TDS, turbidity, Iron, Nitrate, and hardness were also found above desirable safe limits making water unfit for human use. However toxic heavy metals such as Arsenic, Copper, Chromium, Lead, Mercury and Zinc were detected in few water samples but are within permissible limits of WHO. The limited detection of heavy metal is district Mansehra is due to limited industrial activities. It was concluded through evidence that existing water resources due to high level of microbiological contamination are unfit for human consumption and authorities must provide low-cost water filtration technologies such as chlorination and increase public outreach to enhance awareness about various harmful effects of water contamination.

ACKNOWLEDGEMENTS

All praises for **Almighty ALLAH** who is the ultimate source of knowledge. We are most grateful to Him, the most beneficent and the benevolent whose protection is sorted by all and who bestowed us the mental abilities and wisdom from His unfathomed treasure to complete this research. Foremost, I would like to express my sincere gratitude to my advisor senior assistant professor **Dr. Said Akbar Khan** for the continuous support in my master research, patience, motivation, enthusiasm, and vast information. His guidance helped me in data collection for research and write up of this thesis. Especially, I would like to thank **Dr. Hifza Rasheed** (Director Water Quality Programme, PCRWR), **Dr. Zaigham Abbas** (Deputy Director, Pak EPA), **Mr. Imtiaz Hussain Memon (**Environmetal Inspector, Pak EPA), for helping me in my research work.

Last but not the least; I would like to thank my loving mother, my teachers, my all friends, my beloved sister **Gul-E-Rehana** and especially to my beloved brothers **Syed Mohsin Shah** and **Syed Naveed Shah** for supporting me.

ABBREVIATIONS

Alk	Alkalinity
APHA	American Public Health Association
As	Arsenic
BDL:	Below Detection Limit
Ca	Calcium
CFU	Colony Forming Unit
Cl	Chloride
CO3	Carbonate
Cr	Chromium
Cu	Copper
E.*Coli*	Escherichia Coli
EC	Electric Conductivity
F	fluoride
Fe	Iron
Hg	Mercury
K	Potassium
KP	Khyber Pakhtunkhwa
Mg	Magnesium
MPN	Most Probable Number
mg	Milligram
Na	Sodium
NEQS	National Environmental Quality Standards
NDWQS:	National Drinking Water Quality Standards
NGVs	No Guideline Value Set
NO3	Nitrate
NTU	Nephelometric Turbidity Unit

Pb	Lead
PCRWR	Pakistan Council for Research in Water Resources
PHED	Public Health and Engineering Department
ppb	Parts Per Billion
ppm	Parts Per Million
PSQCA:	Pakistan Standard Quality Control Authority
QA:	Quality Assurance
QC:	Quality Control
SDG	Sustainable Development Goals
SDPI	Sustainable Development Policy Institute
SO4	Sulphate
TDS	Total Dissolved Solids
WAPDA	Water and Power Development Authority
WB	World Bank
WHO:	World Health Organization
Zn	Zinc

CONTENTS

CHAPTER 1

INTRODUCTION

CHAPTER 2

MATERIALS AND METHODS

CHAPTER 3

RESULTS AND DISCUSION

TABLES

FIGURES

CHAPTER 1

INTRODUCTION

1.1. Environmental Challenges and related water quality issues

The world is under serious threat due to exponential population growth and frequent climate change events. Without water the existence of life is not possible on earth that's the reason of abundance of water-1.4 trillion cubic meters of water (Bilal and Rahman., 2013) exist on earth. Even though a large area of the earth constitutes of water, 97% of the water is available in the form of oceans and ice with only 3 % available as fresh water (Miller, 1997). The amount of clean drinking water available for human consumption is very small. Water is important element in human body and due to multiple reason, the water become polluted with hazardous metals, trace elements and microbiological contamination. (Patil et al., 2013) Due to ongoing anthropogenic activities huge threat to the earth is pollution, causing damage to all-natural resources thus effecting ecosystems. Uncontrolled population. Increased population caused chemical, physical and biological changes in the eco-system thus impacting air, soil and land resources. (Patil et al., 2013) The enhanced economic growth triggered the Huge rate of urbanization and industrialization across the globe and the consequences are tons of waste generated every day (Patiel et al., 2013). Similarly, un regulated population growth is one of the biggest contributing factors to deteriorating water quality in most of the regions of the planet earth. (Domenech and Suri, 2011).

Common pollutants on earth include both trace elements and microbes. Aquatic system exposed to various types of contamination which is mainly due to natural processes including rock weathering, aerosols from the atmosphere, infiltration in the soil, volcanic eruptions, Earth quakes etc. (Patil et al., 2013)

Water resources spread across various continents become polluted due to human activities and natural calamities impacting both quality and availability (Fernandez et al., 2013). The metals having densities greater than 5g/cm3 is called heavy metals (HM) or trace elements (Bilal and Rahman., 2013). High concentration of containments impacted countless number of individuals everyday who suffer from long term health implication caused by toxic heavy metals (HM). Trace elements are form of metals which has profound impact in minute quantity and our body need them in small concentration for its growth and proper functioning (Bilal and Rahman., 2013) The health implications of HM contamination require more rigorous research to share with the general public. The HM contamination in ground water is due to natural erosion of rocks and anthropogenic activities. That's why sometimes the HM pollution is eminent in areas of proximity of mining sites compared to other areas (Bilal and Rahman., 2013)

Fresh water resources of the world are under threat due to waste generated by the human. Most of the domestic and industrial waste which has high quantities of metals is disposed of in nearby canals, rivers and oceans. Heavy metals are the major contributor to the pollution, and they were released in the environment. HM are vigorously polluting ground water resources as these can be easily dissolved in water or transported as suspended sediments (Bilal and Rahman., 2013) They are toxic to crops due to their non-biodegradable nature and found in upper layer of soil and can be easily incorporated in the food chain through plants. HM were found in drinking water of all the continents.

It is also noticeable that the alarming population increase especially in Asia and Africa stressed the existing water levels available for drinking. However, the water issues in developed world has also increased due to industrialization in United Kingdom (UK), United States (U.S.) and European (EU) Countries. Despite having developed water management systems and water management and governing laws, water remains an issue of utmost importance. With development and increased water demand water has become national security issue in many countries of the world. Trans-boundary water issues witnessed increased in recent decades, especially in less developed nations.

Number of residents of under developed countries have limited access to clean drinking, the issue is multi facet and involve both scarcity and accessibility issues. The existing water filtration and water purification technologies are expensive to afford for poor nations of the world, even not exposed to basic purification techniques due to limited resources (Fernandez et al., 2013). The other important aspect of water management is water quality testing capabilities which are limited across the globe especially in less privileged countries. The need for more water expert and testing capabilities have increased over the years. Very few countries have proper capabilities and resources for water quality testing and analysis which include U.S. UK, and European countries.

Water quality issues further complicate the problems for poor nations due to its link with health risks (Kavacar et al., 2008). It is need of the time for every human settlement on the earth to build capacity to do drinking water quality analysis. This will help identify various types of containments and their concentration which can be compared with existing international standards of WHO. There is greater challenge of bacteriological contamination due to fecal pollution in drinking water causing deaths in millions due to water related illness. (Patil et al., 2013).

It is also evident from multiple research studies that children and other vulnerable population group are more prone to water related diseases and children die more from Cholera than another disease. (Fernandez et al., 2013) Water borne illness are mainly originates from chemical or microbiological activity. The consumption of polluted drinking water exposes the masses to a greater risk of water borne diseases. Poor hygiene conditions further aggravated the problem for young children are more expose to environment and ground. Their direct contact with polluted water and soil increase chances of contact with excreta & contaminates which are the sources of diseases. According to WHO study, 4 billion cases of diarrhoea like illnesses are reported every year, which is attributed to consumption of unsafe drinking water.

Although diarrhoea is a treatable disease but still due to lack of personal hygiene and mal sanitation practices, lack of clean drinking water and malnutrition more than 760,000 children die every year in third world countries (WHO 2013). Further UNICEF child mortality data shows about half of under-five deaths occur in India, Nigeria, Democratic Republic of the Congo (DRC), Pakistan, and China. It was estimated that 783 million people are living without improved drinking water worldwide, China topped the list with 119 million in China, 97 million in India; 66 million in Nigeria; 36 million in DRC; and 15 million in Pakistan (UNICEF, 2013). Like microbial contamination, health risks associated with chemical contamination are a huge concern for children health, as they are more vulnerable to various diseases (WHO, 2011)

HM contamination is affecting millions everyday throughout the world. The inhabitants are drinking water with high level of HM contamination on daily bases but due to lack of data on related illnesses limit the research to produce evidence to convenience policy makers (Fernandez et al. 2013). Some metals such as Iron, copper and manganese are important for human body functions, but their excessive quantities have long lasting health implications in human and animals. Several metals and trace elements present in drinking water are beneficial for health but if their concentration exceeds the permissible limits can cause adverse health implications (Tahir et al., 1996) The high quantity of metals in drinking water have adverse impact on human body and cause severe damage to body organs and can easily cause failure of kidney and lungs (Kavacar et al., 2008).

It was revealed by research that 5 million people die due to heavy metal contamination found in water, making water toxic for their bodies (Patil et al., 2013) anthropogenic activities and geographical transformations are the cause’s water contamination. Water bodies are contaminated with metals and trace elements due to weathering of rocks, volcanic eruptions, mining’s ultimately disturbing the ecosystem (Muhammad et al., 2011) Cardio-Vascular Disease, Gastro-intestinal disease-Respiratory infections, Cancer, allergies, liver and lungs failure, diabetes mellitus and Alzheimer and it was found that high quantities of arsenic can aue skin lesions at concentration of 50 ug/l (WHO, 2011).

Cadmium is found in aquatic animals above permissible limits and cadmium has carcinogenic effects having implication on endocrine functioning, similarly Lead has very hazardous effects on all types of life and majorly come from agricultural inputs and automobiles. (Patil et al., 2013) Fluorides are toxic to bones and tooth and if the fluoride exceeds the permissible limit and 2mg/l, it contributes to tooth decay and fluorosis. The high level of copper in drinking water effect efficiency of liver and kidney resulting failure of the organs. Most of the chemical in their high concertation causing harmful impact on human metabolism resulting many diseases.

Water pollution has become a big challenge for most of the developing countries due to enhanced human activities causing industrialization and urbanization and the waste generation and its disposal become a challenge. It was observed that large number of metals are present in sea water, but the concentration of these trace elements is very low (Patil et al., 2013). With improved education and awareness, people tend to understand the impacts of harmful HM contamination but due to economic and political sensitivities the issue is not on priority list. Due to non-availability of related data due to limited resources or political will further hinder the polices formulation which is critical in under developed countries (Fernandez et al., 2013).

The water related challenges increased in recent decades due to uncontrolled urbanization and industrialization, which is required to fulfil the needs of growing population. To fulfil the needs, more land and other natural resources are utilized thus over burdening the existing limited natural resources. With stressing the natural resources whole of the eco-system is disturbed and the balance of life has been affected due to pollution (Kavacar et al., 2008). It was estimated that approximately 2.3 billion people are suffering from water related diseases thus emphasizing water contaminations as an issue of global importance (UNESCO, 2003). In developing countries more than 2.2 million people die every year due to poor water and sanitation condition (WHO, 2000).

Potassium and sodium constitute vital indicator for water testing, despite the fact that they are not trace elements (Tahir et al., 1996) Water usually contain trace elements in certain limits which are not effecting human health, in fact some metals, sodium, calcium, Zinc, Iron and copper are useful for human body as they have role in body functioning (Patil et al., 2013). It is revealed by research study that plant have capacity to accumulate metals in the tissue, the concentration of these metals is above the limits and human and animal depends on food in these plants so these metals can easily get part of the food chain (Patil et al., 2013).

Metals such as Ca, Mg, Na and K are present in human body in low levels play a major role as catalysts to enzymes. High level of hazardous metals such as Arsenic, aluminium, chromium and Cadmium, lead, and mercury are very toxic for human body. More than 5 million deaths are attributed heavy metal contaminated water. Heavy metal has capacity for bioaccumulation and harming the ecosystem and its inhabitants.

1.2. Drinking water situation in Asia

The population of the word is not equitably divided in various continents such as Asia has the highest population compared to other continents. Due to high population density the need for drinking water has increased tremendously which has affected water quantities available for human use and deteriorated quality of water used for drinking purposes.

Asia Continent is home of the 60 % of the world population which is approximately 4.3 billion people. Three of countries with alarming population growth rate, China, India. Pakistan lies in this continent. The countries like China, India, Pakistan, Thailand, Bangladesh, Taiwan and Nepal, all the eight countries have health issues due to deteriorating water quality in the convenient. High level of Arsenic was found in most of the countries and often other HM were found violating World Health Organization permissible limits. (Fernandez et al., 2013). Common diseases caused by high level of HM include but not limited to Cardio-Vascular Disease, Gastro-intestinal disease- Respiratory infections, Cancer, allergies, liver and lung failure, diabetes mellitus and Alzheimer. It was found in most of the epidemiological research studies that HM has daring impact on human health and they are highly carcinogenic in nature. (Fernandez et al., 2013)

Public health concerns have tremendously increased in last few decades. It became a major issue for developing countries in Asia, where the population is suffering due to health complications related to poor water quality. In developing countries, the water governing regulations don't exist even if it exists the implementation remind the biggest challenge. Most of the countries do not have municipal water filtration Plants. The filtration plants are not even functioning or are just not sufficient for the country's need (Fernandez et al., 2013).

It was reported by World Health Organization (WHO) that water contamination account for more than 80 % of human health problems. It was also found in multiple research studies that in south Asia alone around 0.5 million infants die each year due to poor quality of water and sanitation (Abdul et al., 2012). It was confirmed through study that the city of Bholakpur Hyderabad in India that 16 people die and more than 500 admissions were recorded due to diarrhoea. It was also recorded that the drinking water samples were contaminated with metals and trace elements such as Fe, Pb, cu, Ni, Al and these are above permissible limits of WHO and toxic for human body (Abdul et al., 2012). It was further analysed and confirmed that drinking water contains high level of microorganisms which is unsafe for drinking.

The bacteriological contamination is due to mixing of drinking water and sewerage water, which usually happens where the water supply is through old rustic pipes thus infiltration of sewerage water pollutes drinking water. Unavailability of clean drinking water increased diseases and situation become alarmingly in developing nations (Abdul et al., 2012). Due to exponential population growth, the farmers aim to increase agricultural productivity through enhanced fertilizer input to the soil which resulted high nutrients and contaminated the soil, crop and water with metals and trace elements. (Patil et al., 2013)

Pathogenic organisms have great potential to deteriorate water quality and are major contributor of pollution causing disease. It was evident that approximately 25 million people die annually due to water borne diseases, including number of children. One of the major reasons for microbiological contamination is poor management and unconventional treatment of human waste. The issue of contamination is complex and can be easily linked to other health indicators, the country has the highest infant mortality rate of 12.6 percent. More than 25 % of the patient in the hospitals were found suffering from water related disease which are due to fecal contamination (Daud et al., 2017).

1.3. Drinking Water Issues in Pakistan

Pakistan is located in south East Asia and bordering with world most populous countries such as China and India. The country has mountain ranges of Himalaya, Karakorum and Hindukush. In the east border with India Himalaya and Karakorum ranges exist while in the north, Hindukush mountain ranges spread on large areas. These mountain ranges have significant importance for Pakistan, as these areas are water sheds of the country and most of the rivers also originates or enter in Pakistan through these areas. Some of the peaks for these mountain ranges are 4700 m. In the west of the Pakistan Baluchistan plateau exist.

Pakistan climatic conditions are diversified but it can fall in arid to semiarid with variations in rainfall across Pakistan. Indus river, also called life line of the Pakistan is the main river of the country originating from Karakorum ranges and ending in Arabian Sea after passing through various districts of the country. Pakistan is an agrarian economy and agriculture is the major contributor of GDP. More than 27% of the total land of the country is being used for farming to grow multiple staple crops, rice, wheat, maize, pulses, cotton, vegetables and sugarcane. Pakistan has witness increased growth in both population and urbanization. To fulfil the requirements of increasing population, agriculture is further intensified. To enhance agriculture productivity, chemical inputs, such as pesticides, and fertilizers are applied in most parts of the country. Industrializations has also increased in last few decades without proper planning and management (Daud et al., 2017).

Pakistan is among those countries where the availability of water is decreasing on alarming rate due to prevailing climatic condition. Weather patterns are constantly changing, especially monsoon seasons and maximum temperature recorded in summers and winters. Pakistan with its limited storage capacity received its fair share of water in short span of 3 month. According to Indus River System Authority (IRSA) 70 % of the country's water which usually enter in water system came from ice melt and monsoon is from July- September (WAPDA, 2005).

With limited storage infrastructure and weak water management the country is prone to the threat of water scarcity. According to International Panel on Climate Change (IPCC)Pakistan is ranked number 8th on climate change vulnerable countries list. Pakistan has faced huge losses due to phenomena of climate change, according to the Global Climate Risk Index annual report for 2020, the cumulative economic losses attributed to climate change is worth approximately USD 3792.52 million.

Water related extreme disasters topped the list of extreme climate change events responsible for huge loses. The country has witnessed 152 extreme weather conditions from 1999 to 2018 (Economic Survey of Pakistan 2019-2020). There are serious concerns related to diminishing water levels and deteriorating water quality and experts fears the country might become water scares in coming years.

According to Chairman, WAPDA, the per capita water availability in Pakistan has significantly reduced compared to the time of its independence, when it was 5,600 cubic meters. The water availability has been decreased considerably to 1,038 cubic meters in 2010. If this situation persists, the fear is by 2025 the water availability will further plummet to alarming level of 660 cubic feet and the country become water scarce (Daud et al., 2017). According to Pakistan Council for Research in Water Resources (PCRWR) Islamabad, 2015 report, the decrease in water availability in Pakistan is directly related with increased water consumption due to uncontrolled population growth.

Health issues have become a real threat for Pakistan due to its uncontrol population growth, rising urbanization and environmental pollution. Government was compelled to enhance health expenditure, the cumulative health expenditures by federal and provincial governments for health in FY2019 increased to Rs 421.8 billion from Rs 416.5 billion last year, (Pakistan Social and Living Standard Survey, 2019). In Pakistan, the water related diseases cause national income losses of Rs 25-28 billion annually, which is approximately 0.6-1.44 % of the country's GDP (Sustainable Development Policy brief, 2018).

Water scarcity is a booming challenge for Pakistan, the data by Indus River system Authority (IRSA) and Water and Power Development Authority (WAPDA) reported massive reductions in water quantities and deteriorating quality. Due to unregulated ground water extraction the fresh water resources are diminishing and exponential population growth over stressed ground water aquifer and exposed water to toxic heavy metals such as Arsenic and fluoride. In the World drinking water quality Index of 122 nation, Pakistan ranked on number 80 due to high level of containments in both surface and ground water, high level of coliform, toxic metal and pesticides were detected in multiple water resources. (PCRWR, 2005).

The water issues are multifaceted influenced by number of factors are affecting large number of population due to urbanization and climate change. The issue of water availability is complex having multi-dimensional challenges, due to climate changes, the level of water availabilities has been affected. Due to population and urbanization the water qualities have been compromised. Unregulated water uses and grey water discharge in fresh water resources become a huge challenge.

Over extraction of ground water further exposed toxic metals and increased disease burden of the country. In most of the urban settlements the sewerage collection system normally discharged in nearest water body. It was estimated that less than 50 % sewerage water collected in urban cities of Pakistan and only 10 % of that water is treated (World Wide Fund report, 2007). Large number of Pakistani citizens do nt have access to clean water and approximately 25% of the population have access to safe drinking water. Lack of water availability has direct connection with poor quality and supply of drinking water. Water usage and management issues increased and per capita water consumption in Pakistan is much higher compared to the region and world. The water efficiency in industrial and agricultural activities are lacking which further impact water quantity and cause water pollution (Daud et al., 2017).

Like many other mountainous countries, Pakistan is also dependent on surface water and ground water for drinking purposes. Sources of surface water include, springs, rivers, nallah, streams and ground water are extracted through bore holes, dug wells and tube wells. It was evident from the data that both surface water and ground water have pollution due to urbanization and industrialization and agriculture waste. With limited to no waste disposal system, and agricultural runoff is affecting fresh water resources in the ground. Mixing of sewerage water, salinity, agriculture run off including pesticides are common in various parts of the country. In major settlements, the population is dependent upon the ground water sources which are high level of pathogens such as bacteria, virus and other protozoans. Only 20% of the total population of Pakistan has access to safe drinking water and the remaining 80% of population is forced to use unsafe drinking water due its unavailability and compromised quality.

Pakistan common drinking water sources are categorised in tap water, motorized pump, hand pump, dug well, spring, bottle Water, filtration plant and tanker / truck / water bearer. Most of the urban and rural population is dependent on Tap water in Pakistan, it is water delivery system through pipeline network from its collection point. In current situation in urban areas of the country water comes into house though pipes are stored in tanks in roof tanks, the system is called tap water supply. Hand Pump is a pump operated manually to draw water from a bored hole. Dug Well is of two types, Open or Clos Well. In rural households the residents travel long distances in search of drinking water and often that water is unfit for human consumption. Overall Pakistan, 70 % of the households have drinking facility inside their homes and rest of the 30 percent travel to fetch water (Pakistan Social and Living Standard Survey, 2019). In various cities of Pakistan, the drinking water supply pipelines and sewerage lines run in parallel, and old rustic and broken water supply system is prone to leakages and intermixing with sanitation lines results in contamination of drinking water.

Clean and safe drinking water availability and accessibility has become a major public health concern for number of citizens of Pakistan. It was reported in various studies the water quality challenges have been increased over last few decades. In Pakistan 70 % of the drinking water is come from ground and country is facing water quality issues due to high level of contamination in drinking water. The research studies have proven that in Pakistan, the disease-causing microbial presence in the drinking water has become real threat and attributer for deaths among poor population, especially vulnerable group- children who are most vulnerable (Sustainable Development Policy Institute, Policy brief, 2018).

In the year 2006, Pakistan has reported around 4.5 million diarrhoea like illnesses, 14% of which were children under age of 5, additionally diarrhoea is the second major cause of death in the children. It was reported in Pakistan National Conservation Strategy, that the water-related diseases represent 40% of the total communicable diseases. The common water related illnesses are typhoid, giardiasis, intestinal worms, diarrhoea and gastroenteritis. According to International Union on Conservation of Nature (IUCN) report the Pakistan has the highest infant mortality rate caused by water-related diarrhoea in the Asia (Daud et al., 2017). The country has highest out of pocket expense on health compared to other developing nations.

Further studies conducted by WHO and UNICEF estimated that approximately 30 percent of the diseases and 40% of all deaths occurred due to microbial contamination in Pakistan. Moreover approximately 40% of the hospital admissions are due to drinking of polluted water causing diarrhoea, Typhoid and other lethal water related diseases (SDPI Policy brief, 2018). Healthcare units in Rawalpindi alone is reporting 80,000 cases related to water related sickness and the country has hospital admission of 20%–40% of the people that are suffering from these diseases according to United Nation International Children Emergency Fund (UNICEF). It was also revealed that the microbial contamination in the drinking water has reached to an alarming level in urban and rural water resources (PCRWR, 2005). It was estimated that around 0.2-0.25 million children die every year in Pakistan due to diarrhoea or other related illness (WWF, 2007).

The study conducted by PCRWR in 2012 recorded that the water supplied through water supply schemes in Pakistan has high level of containments and more than 88 % of the water is not safe for human consumption due to adverse effects. The water pollution is due to multiple factors, but a large contributor is industries and agriculture. In Pakistan, limited data is available on water quality due to lack of water quality assessment and monitoring programs.

The major issue remained non-availability of laboratories required for regular testing for chemicals especially toxic metals and chemicals found in pesticides. There are few national laboratories accredited for water testing having efficient quality assurance and quality control, yet the lack pesticide testing capabilities (Tariq et al., 2007). In developing countries like Pakistan, it is difficult to measure the impact of water borne disease, due to non-availability of data and records at hospitals. It was estimated by the World Bank study that 40 % of the patients in hospitals are suffering from water borne diseases which include, typhoid, Cholera, hepatitis, dysentery, cryptosporidiosis and these disease account one third of all the deaths in Pakistan (World Bank, 2006).

In Pakistan, availability and accessibility of clean drinking water is major problems in urban centres and rural settlements, it was found in monitoring study that only 15-18 % water supplied through various water schemes at national level is fit for drinking (PCRWR, 2018). The study also revealed that water is contaminated with metal and trace elements and high level of microbiological contamination.

The drinking water quality assessment of city of Quetta revelled that the water samples have bad taste, foul smell and contaminated with microbes. It was also noticed that the drinking water quality was badly effected due to pathogens in the districts of Ziarat, Loralai, Quetta, and Khuzdar of Baluchistan province, making water unsafe for human consumption and majority of samples were found contaminated with Nitrate. It was also confirmed that approximately 50% of the samples, collected from Ziarat have Nitrate concentration above permissible limits of WHO (Daud et al., 2017).

Many parts of Pakistan showed bacteriological contamination, the water quality monitoring study conducted in Islamabad revelled that alkalinity, hardness, and total dissolved solids in all the drinking water samples were below the permissible limits set by Environmental Protection Agency (EPA) Pakistan. However coliform and E. coli were found in all water samples, making water unfit for drinking purposes. It was also found that higher amount of calcium, lime stone, and magnesium carbonate is hardness causing agents in water (Daud et al., 2017).

PCRWR recent study to analyse water quality of capital of Pakistan, the analysis of 200 tube wells supplying water to Capital inhabitants shown promising results. It was found that 23 tube well out of 200 were supplying contaminated water to the people of Islamabad Capital Territory (ICT) which is unsafe for human consumption. It was also determined from an assessment of drinking water of Islamabad that 20 samples out of 30 samples collected from various colleges of Islamabad has Fecal microbes and making water unfit for drinking purposes. Another study conducted in of Rawalpindi and Islamabad indicated that 56 percent of water samples were found to have microbial contamination. Microbial contamination of fecal coliforms, E. coli, and total coliforms was 23.8%, 20%, and 12.3%, respectively (Daud et al., 2017).

According to PCRWR report of 2005, the contamination in drinking water is a growing cause of concern in the mega cities of Pakistan, high level of chemical and biological contaminations exists in drinking water of Peshawar, Karachi, Lahore, Rawalpindi, Faisalabad and Gujrat, whether its surface water or ground water. In Pakistan the urban population is dependent on ground water, tube wells and bore wells while in rural setting the water sources are multiple which include, springs, rivers, nallah and dug wells. The research studies confirmed the deteriorating water quality is due to multiple natural and human induced events. It was also found that in rural areas of

Punjab, the drinking water of ground water resources has high level of electric Conductivity, Iron, Fluoride, Magnesium and lead.

In Sindh province the status of drinking water quality is not different than other provinces, perhaps it is much worst in some parts of the province. The water samples collected from Karachi, Hyderabad and Sukkar showed have level of both chemical and biological contamination and 67%–93% were found contaminated. The drinking water quality of many district of Sindh were found contaminated with high level coliform and faecal coliform thus confirming that water is not suitable for drinking. The high concentration of coliform and fecal coliform in drinking water mostly in urban centres is due to water supply networks, which promotes mixing of sewerage with drinking water (Daud et al., 2017).

Ground water quality of many cities of Punjab is deteriorating due to industrial activities. Most of the cities are well known hubs for textile, dye, instrument manufacturing, paints and leather industries. Faisalabad is popular for its water and air pollution because industrial waste is discharged in water and air without having appropriate treatment facilities. It was studies that the ground water quality of some parts of Faisalabad is getting worst and as 90% of samples tested for Na, K, Cl, and SO were found above the WHO safe limits.

The water quality analysis of 12 districts of Punjab confirmed high level of biological and chemical contamination, found in all the 12 districts. 100 % of the water samples collected from Lahore and Kasur has As. In Multan total 94 of the sample were found contaminated with As compared to Bahawalpur where 88 % samples have contamination (Daud et al., 2017). In many parts of the largest agriculture province of the country, salinity become the huge problem, due to the porous nature of the soil the metal concentration increases compared to other adjoining non saline soils (Tahir et al., 1996).

The analysis of the underground water of the district Swabi of Khyber Pakhtunkhwa (KP) province indicated that the physical and chemical parameters which include pH, temperature, EC, TSS, and BOD were within safe limits of National Drinking Water Quality Standards (NDWQS). However, the water quality assessment of district Peshawar indicated contamination of Lead and Cadmium in both rural and urban areas. The study further indicated that high level of As, Cu, Co, Hg, Ni, and Zn were also found in drinking water which is above than the safe levels of WHO (Daud et al., 2017)

1.4. Disease Burden of Water borne Diseases:

Globally, the water related illnesses become a huge burden on under developed nations. Water quality is compromised due to multiple factors such as sanitation system, non-availability of treatment technologies. The indication of lethal microorganisms and toxic chemicals make water unfit for consumption and have significant health implication for human. The drinking water become contaminated due to Fecal presence thus causing multiple illnesses such as typhoid, diarrhoea, cholera, hepatitis common in various areas of Pakistan.

It is difficult to get data to estimate the danger of water related diseases due to lack of medical record and under reporting in basic health units and secondary and tertiary healthcare facilities. It is also evident from research that the drinking water available in health facilities are of the poor quality and plays a role in infection spreading. High concentration of metals and microorganisms are the contributor in various diseases and have direct link with health-related issues. The higher level of nitrate in drinking water cause blue baby syndrome. Similarly, higher concentration of Potassium is related to kidney diseases and improper digestion. However, reduce level of potassium is also dangerous for body functions and causing hypertension, heart disease and kidney diseases and sometimes asthma. Moreover, the excessive iron in drinking water has multiple health implication for human body and can contribute to deadly diseases such as high blood pressure, weakening of cardiovascular tissue, diarrhoea and vomiting, weakening of central nervous system and kidney, and liver failure. The decrease of iron in the human body also cause multiple health issues because iron is important constituents of several enzymes and myoglobin and haemoglobin

In Pakistan, the drinking water quality is compromised due to various level of contamination in urban and rural areas. In Peshawar, coliform bacteria were found in most of the drinking water samples. In Rawalpindi, it was found that contamination in drinking water is major cause of the gastroenteritis in 2000. In multiple districts of Sindh province, microbiological contamination is common, in Karachi, total and Fecal coliform were found in drinking water samples and potential source of water related diseases among children. In Islamabad and Rawalpindi hundreds of patients were registered for hepatitis due to deteriorated drinking water and lack of treatment facilities.

1.5. Water Quality Management in Pakistan

Water Management in Pakistan is very complex due to involvement of multiple stakeholders. Many Federal and provincial level water bodies are involved in water management. Some of the federal organization include, Ministry of Water resources, WAPDA, Federal Flood Commission (FFC) Indus water Commission of Pakistan (IWCP), IRSA and PCRWR. At provincial level Water was managed through provincial irrigation and agricultural department, public health and engineering departments. Water management in Pakistan is complex due to sensitives involved in water distribution among provinces, the governing body of water Accord- which is instrument for water distribution among provinces is IRSA. Water Storages and water flows are being handled by WAPDA. Currently country has 3 major reservoir Tarbela, Mangla Water (WAPDA, 2014), due to silting and sedimentation the storage capacity is decreasing.

Khyber Pakhtunkhwa (KP) previously known as Northern western frontier Province (N.W.F.P) is a strategically important for Pakistan. Due to its geographical location and boundaries with India, china and Afghanistan from where the river Indus and Kabul, Nellum Jhelum originates. Whole of the irrigation system of Pakistan depends on centuries old network of water canals. KP has a lot of importance for Pakistan due to its geographical location and landscape, it acts as water shed for the whole country. The province constitutes of 6 divisions stretching from North to west and 30 districts.

1.6. Drinking Water Quality Challenges of Khyber Pakhtunkhwa (KP)

In the KP province of Pakistan (excluding merged Areas & including merged areas), main source of drinking water is Motorized Pump which is 35 % in 2018-19. Overall in Pakistan, 30% of households are getting drinking water from supply schemes, as main source of drinking water followed by motor pumps 30%, while 27% have access through hand pumps. 56% population in urban areas using tap water, only 17% in rural areas. In KPK, 44% of the households are dependent on tap water which is highest amongst provinces (Ministry of Environment, 2009). Like other provinces of Pakistan, Local Government Rural Development Department (LGRDD) and Public health Engineering Department (PHED) is responsible for management of drinking water and sanitation facilities in KP districts. The departments get allocations of budget and provides drinking water and sanitation facilities through public water and sanitation schemes, each scheme serves targeted number of beneficiaries within the population in a geographical setting. (Centre for Public Policy Research, 2010).

In KP, the cities of Peshawar, Marden, Charsada and Nowshehra more than 50 % of the total population have no access to clean drinking water. They use the drinking water from wells and shallow wells which are not reliable water sources and contaminated due to biological pollutants from the surrounding sources such as toilets, underground damaged sewerage lines and seepage/percolation of contaminated surface water. Over six million residents of KP have no access to safe drinking water, majority of the population depends on contaminated water resources.

It was further revelled that more than 50% of the residents of the district Mardan, Peshawar, and Noshera and Charsaddaa dependent on water supply networks provided by public health departments. 50 % of the water samples collected from the public supply schemes were found contaminated. According to KP-Health Department report of 2015, 50 % government-run health facilities have access to drinking water and 25 % of those facilities are getting contaminated water from public resources.

Pakistan Council of Research in Water Resources (PCRWR) in 2016 monitored drinking water quality of 25 major cities of Pakistan. Only 31% were found safe whereas 69% samples were found unsafe for drinking purpose. Overall, 469 water samples were collected from Nowshera District, out of those 133 (27%) were found unsafe whereas 363 (73%) were found safe.

In the Haripur district of KP province, high level of lead was in drinking water especially in surface water due to Industrial estate established in Haripur called Hatter Industrial state. The industrial run off is the leading cause of lead contamination in Haripur (Jabeen et al., 2013). It was a noticeable, the deterioration in drinking water quality in district Haripur attributed to enhanced industrialization. Biological Oxygen demand (BOD) was also proven an issue by many research studies, also carbonates, chemical oxygen demand (COD), TDS, sulphates, bicarbonates and carbonates were also detected in high levels in various water samples (Bilal and Rahman., 2013).

The results of the water quality assessment study conducted in Peshawar revealed that 47% of the water samples collected from tube wells and storage tasks of public water supply schemes were found to be highly contaminated with E. coli. It was also found that the samples have high level of magnesium and also seven samples have higher pH values compared to WHO standards. The study of drinking water quality of Haripur and Bannu detected microbes and chemical contamination thus making water unfit for drinking purposes (Jabeen et al., 2013) The underground drinking water quality monitoring of district Swabi revealed that more than 90 % of the samples demonstrated microbial contamination. Further it was noticed that the physical parameters were within permissible limits, but samples have high concentration of chemicals such as Pb and nitrate concentrations, found above WHO limits

It chemical and microbial analysis of water samples from four district of KP, Abbottabad, Mardan, Peshawar, and Manghora, confirmed high level of microbiological contamination, in few urban areas more than 55% of the samples were contaminated. In Most part of KP iron contamination were found and especially in mardan 67 % of samples were found contaminated due to higher level of iron. Also, in KP the drinking water of district Charsadda (KP) also have quality issues and found high level of nitrate, sulphate and heavy metals. The water also contains coliform bacteria.

In KP approximately 93 percent of the population is dependent on shallow ground water resources extracted through either hand or motor pumped. Across the KP province sewerage system is not well developed and only 90 percent of the population is relaying on flushed pit latrines (Nawab et al., 2017). According to KP government health indicator survey, 89 % of the total population of the province have access to improved water resources, the percentage is higher in Urban areas compared to rural settings. Similarly, overall 22.2 percent of population relies on piped water.

Like many other districts of KP, drinking water of District Mansehra is also shallow ground water with vulnerabilities for contamination. It was evident that 100 percent of drinking water samples collected from various villages of tehsil Oghi were found contaminated with E. coli indicating poor sanitation practices in the area (Ahmed et al., 2017). There is lack of public awareness about safe disposal of sewerage and there are clear signs of mixing of water lines with household sewage system, the reason can be direct mixing of sewage in drinking water or open defecation practices, which are common in rural areas of Mansehra and adjoining districts. It was found in microbiological analysis of Oghi tehsil that 98 % of the drinking water samples tested were not suitable for drinking and are above the WHO guidelines, as absence of any microorganism in drinking water is clean and safe for human use. If the microbes' number is from 1-10, it is in equitable quality while 11-100 is considered as contaminated water and above 100 is hazardous and above 1000 very hazardous). It was found in 175 water samples collected from Oghi that all water samples have 100 % E. coli and coliform. The contamination in drinking water is causing multiple health diseases in the area such as typhoid, vomiting, Jaundice, hepatitis, diarrhoea, skin diseases, dysentery and cholera (Ahmed et al., 2017).

1.7. Objectives of the Study

The present research work will be focused on:

- Assessment of Drinking water quality of district Mansehra to highlight types of containments, Physio- chemical, biological and Heavy Metals contaminations.

CHAPTER 2

METHODOLOGY

2.1. Study Area

District Mansehra is the northern part of KP province and located at the east longitudes 72º - 49´ to 74º - 08´and 34º - 14´ to 35º - 11´ north latitudes. The total cover area of district Mansehra is 4,579 Square kilometers. The population of the District, according to the 2017 census, is 1,556,460, 51 % female population and 49 % male population with average annual growth rate of 2.4 percent. The life expectancy is 63 years, household size 6.7 persons. Total house hold in district Mansehra are 239,275 among them, 217,494 households are in rural areas.

District Mansehra is administratively divided into three Tehsils; Mansehra, Balakot and Oghi and Kala Dhaka, which is provincially administered tribal area. There are total 58 union council in the districts. Mansehra has its neighbouring districts in south, Abbottabad, on north Kohistan and Battagram districts, on the east to Muzaffarabad district of Azad Jammu & Kashmir, and on the west Shangla as shown in fig. 1.2. The district is gate way to major tourists' destination and route to many natural valleys and Karakorum highway is passing through the main city (NDMA, 2008).

Mansehra District is dominated by high mountains, varying in elevation from 200 meters in the south to over 4500 meters above sea level in the north. The famous Babusar pass is situated on the north-eastern boundary of the district. The Nanga Parbat Mountain is located about 40 kilometres from the north eastern boundary of the district as shown in fig 1. 1.

Most of the areas of District Mansehra are cold in winter and summer is usually not much warmer. There are two distinct seasons in Mansehra; Summer from April to September, while winter starts in October and ends in March. The mean maximum and minimum temperatures during the month of June are about 35° C and 21° C respectively. During the coldest month of January, the mean maximum and minimum temperatures are 14° C and 2° C (Bibi et al., 2011). However, some of the northern parts of the district faces extreme cold in winter and it receives heavy snow fall which sometimes starts in November (NDMA, 2008).

The district capital and district headquarter is Mansehra City. Approximately 32 percent of the population has the facility of drinking water available inside the homes the main source of income in the region is agriculture. According to IUCN assessment report around 55% of all houses in the district are using piped water and mostly this facility located outside the house. Despite limited degree of irrigational facilities, 36 percent of the total population is dependent om irrigation. The agricultural activity is dependent on rainfall, barani agriculture. The total cultivatable land is 80,747 hectares, and only 12,484 is irrigated to grow various crops (Pakistan Social Living Standard Measurement Survey, 2014).

There are two main water tributaries called, River Kunhar and River Siren. River Siren is being used for irrigation of Pakhal valley popular for vegetables farming. River Kunar originates from lake Saiful-Muluk and then passes through mountainous terrains and reaches to Balakot and Garhi Habibullah and then reaches to Muzaffarabad to meets River Neelum. Mansehra district has plenty of natural resources and mining has increased in various parts of the district for extraction Granite, marble, coal phosphate and feld spar. (NDMA, 2008)

The district was worst hit by 2005 which also brough changes, climate change is also affecting the districts with changes in weather patterns especially in monsoon trends and rainfall and snowfall quantities and timings. Winters gets longer and summers are more intense in the district. Also, the construction of mega projects and heavy machinery and introduction of building materials is changing the overall environment of the districts (IUCN, 2007)

Currently there is none to limited efforts for water quality testing and purification methods. The alarming rate of population growth and natural calamities further aggregate the water quality issues in the district. District Mansehra has an important location due to its connection with northern mountainous region and urban centres. The district is also neighbouring to District Kohistan where WAPDA is building the biggest water storge dam. Two run of river dams, Dasu I and Dasu II are also affecting the water flows of the district. In north the areas of Naran and Kaghan there is small hydro-power project of Shuki Kinari Dam and towards the bordering areas of Azad Jammu and Kashmir the Neelam Jhelum hydro-power was constructed. All the construction of hydro-power and diversions of rivers effecting their natural routes and natural environmental flows have direct link with water quality of the resources (WAPDA, 2019).

The District water infrastructure is old and in most of cases it is not functioning properly. The infrastructure was damaged during earth quake of 2005 still need to be repaired and replaced. It was estimated that around 35% of the water infrastructure of the district was damaged (NDMA, 2008). Most of District Mansehra inhabitants are residing in rural areas of district and 58 % population is getting water from water supply networks and in urban dwellings, approximately 71% population is dependent on tape water to fulfil their drinking water needs.

There is a fraction of population which depends on other water sources such as river, springs and dug wells. (Pakistan Social Living Standard Measurement Survey, 2014). The studies carried out in various Tehsil of district Mansehra proved that high level of bacterial contamination was found water resources. The available drinking water sources in urban areas of district have both E. coli and faecal coliform contamination and only 27% of samples were free from microbial contamination (Haq et al., 2018).

It was found in the study of the one of the important rivers of the Mansehra valley that due to waste water discharge and solid waste dumping in natural water stream, the pollution level is alarmingly high especially microbiological. Alarming contamination of microbes in water is confirmation of high level of wastes thrown in water. Other chemical parameters such as COD, EC, TDS, nitrogen was also found above the permissible limits. (Bibi et al., 2011)

2.2. Study Area Map

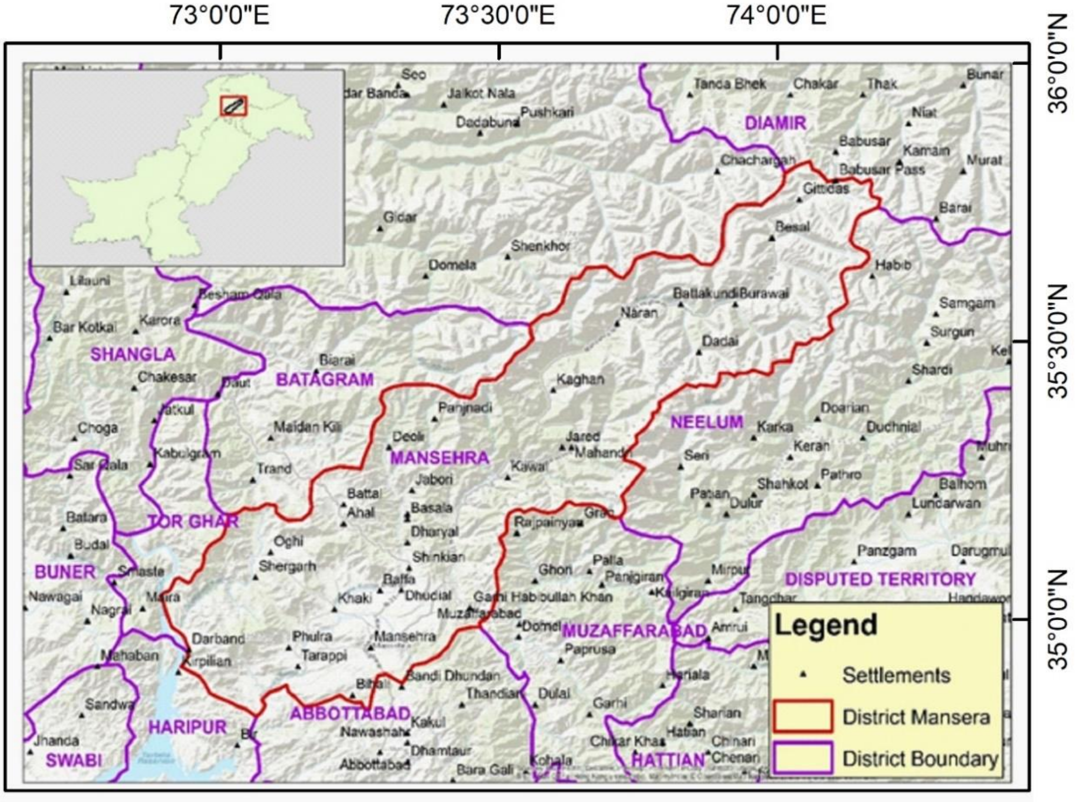

Fig. 2.1 Location Map of District Mansehra

2.3. Sampling Methodology

The water sampling sites were selected after conducting a pre-survey in the district. The drinking water samples were collected from field, preserved and prepared to transport for analysis in water testing laboratory. All the samples were transported to test in Islamabad at National Water Quality laboratory at PCRWR. The techniques and technologies employed for identification and measurement of concentration of various trace elements in drinking water were based on analytical chemistry. The water quality assessment constitutes of the procedure that involve various steps which include, identification of location, identification of pollutants, selection of quality parameters, site selection, sample collection and preparation, data analysis and final step was discussion on the results. (PCRWR standard protocol, 2018)

Drinking water quality samples were collected before monsoon in the month of June and July, total 56 samples were collected from different sources from three tehsils of district Mansehra. The samples were collected from urban tehsil headquarters including, Mansehra, Balakot and Oghi Tehsil. In the site selection it was ensured that samples were collected from all major urban towns and rural settlements (PCRWR, 2018). The locations of the sampling sources and sites are shown in figure.

2.3.1. Site Selection

In the site selection efforts were made to select sampling sites from both urban and rural centres. Most of the District's population reside in the rural setting which are often on high altitude and rough terrain. To enhance the coverage and collection of samples from various parts of the district the total area was divided into grid (PCRWR, 2010). The sampling sites were selected based on population use. For the assessment of drinking water quality of District Mansehra, various factors were considered before finalizing the appropriate sampling design. Keeping in few the factors of population density, access, extent and ruggedness of the area, grid size sampling design was adopted for the assessment (U.S. EPA, 2014)

2.3.2. Sample Design

For any scientific research the sampling design plays a critical role, as it is directly related with data, which provide realistic evidence. The evidence is a decision-making tool for the policy makers. The data collection tools are utmost important to provide real-time reliable information needed for evidence-based decisions. Similarly, well designed and reliable sampling design is the key to ensure well representative data is collected and conclusion is drawn.

For research studies, reliable data gathering tools are required to collect accurate information for science-based decision. There are multiple sampling techniques used to gather accurate information about environmental pollutants. For accuracy and management of bulk of samples, proper sampling design was selected and consider the important points such as; accuracy of sample collection method, its appropriateness and required handling procedures. (Bibi et al., 2011).

It was also considered that the degree of measurement errors, the quality of laboratory analysis are related factors. Representativeness of the study area to fully achieve the study objectives is key for successful and reliable research study. Representativeness is usually measurement of accuracy and ensuring that characteristics of population, variations in environment and parameters are properly considered (American Standard of Quality Control, 1994)

2.3.3. Grid Sampling Method

Development of appropriate sample design is the key in gathering accurate, reliable and trustworthy data which is true representation of problems investigated through the study. In grid sampling technique a random number generator is used to decide about initial sampling point, while the remaining points are usually depending on a specific pattern such as square, rectangular, square or triangular. In grid sampling design, samples are taken at regularly spaced intervals over space (U.S. EPA, 2012).

The sampling techniques helped to generate data about estimation, testing or proportion and highlighting hotspots or vulnerable points. The technique is effective in collection of data for scoping studies, initial assessments and pilot studies. The technique is useful especially when there is very limited prior information and spacing make easy for sampling collection. The initial location was chosen at random, and then the remaining sampling locations were defined so that all locations are at regular intervals over an area or grid (U.S. EPA, 2012)

For management of quality of environmental data, grid sampling design used for screening the situation, identify the areas of contamination and estimating and testing containments concentration. This sampling method is also used to search for hot spots to highlight vulnerabilities of locations and for other parameters (U.S. EPA Grid Sampling guidelines, 2018). The selected design was practical and easy method for designating sample collection process through ensuring uniform coverage of a site. The systematic grids include square, rectangular, triangular, or radial grids (Cressie, 1993). The sampling designed used for collection of drinking water samples for water assessment is square grid.

For assessment of water quality of district Mansehra the grid sampling design was adopted and whole district was divided into square shape grids of 20 km by 20 km. According to the total size of the districts, the area of 4,579 km2 was divided into 20*20 KM grids and total 27 grids were obtained as shown in Fig. 1.2. The grids which have more than 50 % of the district Mansehra area was selected for sample collection. 18 sampling grids qualify and selected for sample collection.

There are few grids having less than 25 % of the district area, which were not selected for sample collection (PCRWR, 2005). Also, those areas fall in high altitude mountainous regions with fairly limited number of inhabitants' usually seasonal migrants and nomads' population. Within each grid, the drinking water sources were identified and water samples from all drinking water sources were also collected including water supply schemes (both from source and at consumer end). Special consideration was done in selecting of sampling location and those locations of drinking water was chosen which is in extensive public use (PCRWR, 2010).

Each grid was assigned a code and then in each grid drinking water resources were assessed. Based on availability and accessibility of available drinking water resources, the sampling points were further assigned codes. Sampling locations within the grid was selected in a way that it considers both rural and urban population. The number of samples collected from each grid is different due to number of sources of water, in few grids the only source of drinking water is spring water/tape water. Similarly, tube wells are not common in Mansehra and they exist only in thickly populated and agricultural towns. There are some urban grids, from where 5 samples were collected from each grid because the location has multiple sources of drinking water (PCRWR, 2005). Towards the north of the district, which is mountainous area and inhabitants are mainly relying on spring water which is channelled to houses through pipes (IUCN, 2008).

Due to landscape of the district most of the population is sparsely distributed in rural settings and far long mountainous areas. Surface water is in abundance in Mansehra and most of the population is dependent on shallow water sources such as springs, dug wells and bore holes. The water supply schemes were also dependent majorly on shallow water sources, there are only few tubes well in the Tehsil Mansehra and Tehsil Oghi (IUCN, 2008). The tube well water is majorly for irrigation purposes. Like other Districts of KP, common drinking water sources are water Supply schemes, dug wells, springs, motorized water pumps (bore holes) and tube wells. Most of the district drinking water supply schemes are fed by natural Spring or canal water (NDMA, 2008).

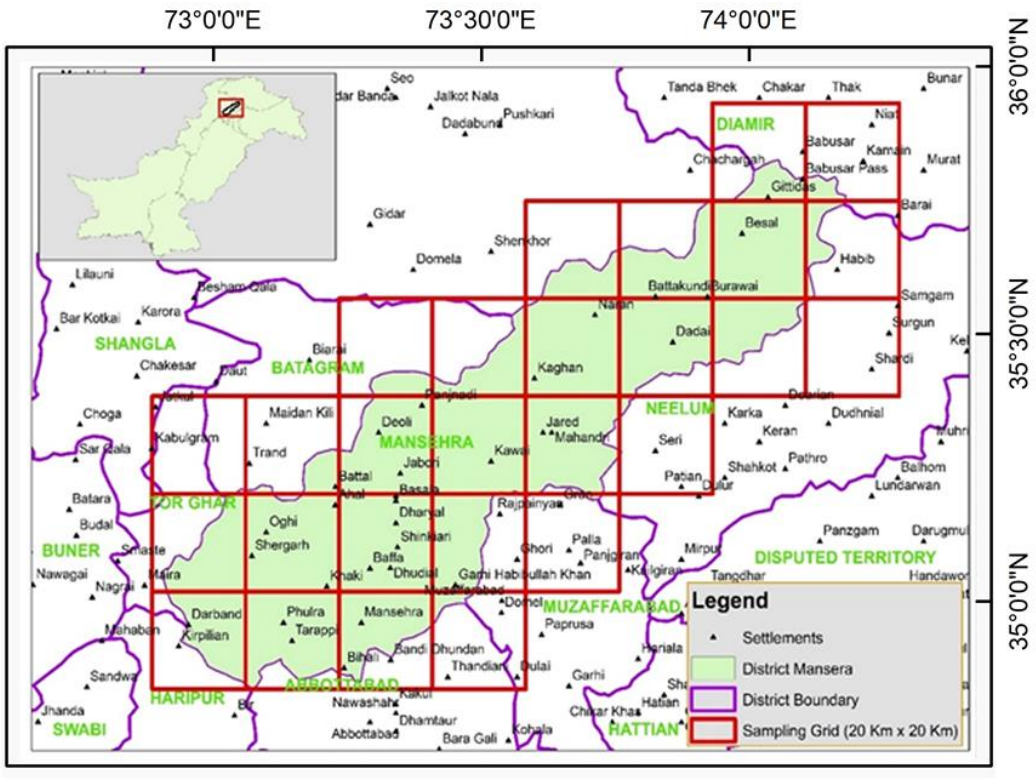

Fig. 2.2 Sampling Grids of Mansehra District

All the sampling grids were considered during collection of water samples to get maximum results. Even though some of the thinly populated grids are located in high altitude and nomadic population only went there in summers the areas were included in research. Samples were collected from all the major settlements and special consideration was given to urban centres having bulk of population. In some of the high-altitude grids in the north, the major portion of population is dependent on spring water, which is freely available. Locals have arranged spring water at their homes through small scale water supply schemes (PCRWR, 2010). In few locations, the only sources of drinking water are springs and tap water that’s why samples were collected from only those sources. In the mountainous region, dug well and bore well are not available because of surface water availability (Muhammad et al., 2010)

Table 2.1 Detail of Sampling Grids and Sampling Codes

S. No.	**Sampling Location**	**Sampling Code**	**Tube Well**	**Tape water**	**Dug Well**	**Bore Hole**	**Spring**	**Total Samples**
1	Mansehra	WS – 001	1	1	1	1	1	5
2	Shinkari	WS – 002	1	1	1	1	1	5
3	Jabori	WS – 003	0	1	1	0	1	3
4	Phulra	WS – 004	0	1	1	1	1	4
5	Oghi	WS – 005	1	1	1	1	1	5
6	Shergarh	WS – 006	0	1	1	1	1	4
7	Darband	WS – 007	0	1	1	1	1	4
8	Garhi Habib	WS – 009	0	1	1	1	1	4
9	Balakot	WS – 009	0	1	1	1	1	4
10	Kawai	WS – 010	0	1	0	0	1	2
11	Jared	WS – 011	0	1	0	0	1	2
12	Kaghan	WS – 012	0	1	0	0	1	2
13	Naran	WS – 013	0	1	0	0	1	2
14	Battakundi	WS – 014	0	1	0	0	1	2
15	Burawae	WS – 015	0	1	0	0	1	2
16	Dadai	WS – 016	0	1	0	0	1	2
17	Besal	WS – 017	0	1	0	0	1	2
18	Gittidas	WS – 018	0	1	0	0	1	2
	Total		03	18	09	08	18	56

From the 18 grids more than 56 samples were collected 29 samples from surface water, such as spring and stream water as shown in table 1.1. Moreover 27 samples were collected from ground water resources such as dug well, bore hole, tube wells. 18 samples were collected from various springs, 18 water samples were taken from tap water, 03 samples were from the tube well, 09 samples were taken from dug well and 08 from bore hole were taken for testing and analysis. (PCRWR, 2018).

2.4. Sampling Locations with Coordinates

Table 2.2 drinking water sampling points with I.D. codes and Coordinates

S. No	Sample Code	Location	Nature of Source	Longitude	Latitude
1	WS – 009 / Spring	Balakot	Spring	34° 33' 01.52"	73° 20' 40.23"
2	WS – 009 / Dug Well	Balakot	Dug Well	34° 33' 10.52"	73° 20' 40.32"
3	WS – 009 / Tap	Balakot	Tap	34° 32' 47.27"	73° 21' 15.17"
4	WS – 009 / Bore Hol	Balakot	Bore Hole	34° 32' 54.86"	73° 21' 25.31"
5	WS – 014 / Spring	Batta Kundi	Spring	34° 56' 14.39"	73° 46' 22.93"
6	WS – 014 / Tap	Batta Kundi	Tap	34° 55' 43.30"	73° 46' 44.08"
7	WS – 017 / Spring	Besal	Spring	35° 03' 06.87"	73° 56' 07.43"
8	WS – 017 / Tap	Besal	Tap	35° 03' 10.79"	73° 56' 12.10"
9	WS – 015 / Spring	Burwae	Spring	34° 56' 32.77"	73° 52' 24.56"
10	WS – 015 / Tap	Burwae	Tap	34° 56' 23.13"	73° 52' 04.83"
11	WS – 016 / Spring	Dadai	Spring	34° 51' 06.15"	73° 47' 38.36"
12	WS – 016 / Tap	Dadai	Tap	34° 51' 09.71"	73° 47' 25.35"
13	WS – 007 /Dug Well	Darband	Dug Well	34° 21' 44.35"	72° 51' 39.06"
14	WS – 007 / Bore Hol	Darband	Bore Hole	34° 21' 52.65"	72° 51' 37.50"
15	WS – 007 / Spring	Darband	Spring	34° 21' 46.74"	72° 51' 55.50"

16	WS – 007 / Tap	Darband	Tap	34° 21' 49.18"	72° 51' 40.27"
17	WS – 008 / Spring	Gari Habibullah	Spring	34° 24' 07.81"	73° 22' 29.96"
18	WS – 008 / Dug Well	Gari Habibullah	Dug Well	34° 23' 57.41"	73° 23' 06.18"
19	WS – 008 / Bore Hol	Gari Habibullah	Bore Hole	34° 24' 12.25"	73° 23' 02.29"
20	WS – 008 / Tap	Gari Habibullah	Tap	34° 24' 03.99"	73° 22' 56.60"
21	WS – 018 / Spring	Gittidas	Spring	35° 07' 16.17"	74° 00' 13.86"
22	WS – 018 / Tap	Gittidas	Tap	35° 07' 28.31"	74° 00' 25.21"
23	WS – 003 /Spring	Jabori	Spring	34° 36' 11.80"	73° 15' 18.02"
24	WS – 003 /Tap	Jabori	Tap	34° 36' 18.20"	73° 15' 37.06"
25	WS – 003 / Dug Well	Jabori	Dug Well	34° 36' 26.11"	73° 15' 32.80"
26	WS – 011 / Spring	Jared	Spring	34° 40' 37.58"	73° 33' 18.96"
27	WS – 011 / Tap	Jared	Tap	34° 40' 37.79"	73° 33' 31.48"
28	WS – 012 / Spring	Kaghan	Spring	34° 46' 47.29"	73° 31' 06.18"
29	WS – 012 / Tap	Kaghan	Tap	34° 46' 41.12"	73° 31' 47.47"
30	WS – 010 / Spring	Kawai	Spring	34° 37' 51.07"	73° 26' 37.40"
31	WS – 010 / Tap	Kawai	Tap	34° 37' 52.24"	73° 26' 37.77"
32	WS – 001 / Tap	Mansehra	Tap	34° 19' 43.84"	73° 11' 33.39"

33	WS – 001 / Bore	Mansehra	Bore Hole	34° 19' 26.24"	73° 11' 56.39"
34	WS – 001 / Dug Well	Mansehra	Dug Well	34° 19' 30.42"	73° 11' 27.39"
35	WS – 001 / Spring	Mansehra	Spring	34° 19' 15.82"	73° 12' 43.10"
36	WS – 001 / Tub Well	Mansehra	Tube Well	34° 19' 07.15"	73° 12' 28.64"
37	WS – 013 / Spring	Naran	Spring	34° 54' 32.98"	73° 39' 19.34"
38	WS – 013 / Tap	Naran	Tap	34° 54' 18.99"	73° 38' 55.24"
39	WS – 005 / Dug Well	Oghi	Dug Well	34° 30' 03.97"	73° 01' 06.32"
40	WS – 005 /Bore Hol	Oghi	Bore Hole	34° 30' 02.45"	73° 01' 39.84"
41	WS – 005 / Spring	Oghi	Spring	34° 30' 06.66"	73° 00' 14.17"
42	WS – 005 / Tub Well	Oghi	Tube Well	34° 30' 01.17"	73° 01' 49.28"
43	WS – 005 / Tap	Oghi	Tap	34° 29' 58.45"	73° 01' 21.20"
44	WS – 004 / Dug Well	Phulra	Dug Well	34° 20' 14.60"	73° 03' 20.45"
45	WS – 004 / Bore Hol	Phulra	Bore Hole	34° 20' 08.28"	73° 03' 21.51"
46	WS – 004 / Spring	Phulra	Spring	34° 20' 02.43"	73° 03' 17.05"
47	WS – 004 / Tap	Phulra	Tap	34° 20' 07.27"	73° 03' 20.34"

48	WS – 006 / Dug Well	Sher Garh	Dug Well	34° 27' 26.54"	72° 59' 31.65"
49	WS – 006 / Spring	Sher Garh	Spring	34° 27' 19.40"	72° 59' 07.78"
50	WS – 006 / Tap	Sher Garh	Tap	34° 27' 21.43"	72° 59' 24.53"
51	WS – 006 / Bore Hol	Sher Garh	Bore Hole	34° 27' 26.39"	72° 59' 19.95"
52	WS – 002 / Dug Well	Shinkiari	Dug Well	34° 28' 15.03"	73° 16' 34.83"
53	WS – 002 / Bore Hol	Shinkiari	Bore Hole	34° 28' 19.39"	73° 16' 17.14"
54	WS – 002 / Spring	Shinkiari	Spring	34° 28' 29.91"	73° 16' 07.45"
55	WS – 002 / Tap	Shinkiari	Tap	34° 28' 15.92"	73° 16' 14.98"
56	WS – 002 / Tub Well	Shinkiari	Tube Well	34° 28' 31.14"	73° 16' 46.88"

2.5. Sample Collection and Preservations

The drinking water samples was collected from each sampling point with special care and samples collected from each locations of District Mansehra for, Physio-chemical and bacteriological and heavy metal analysis, in duly sterilized bottles of I.5 litre following the American Public Health Association Standard (APHA, 2012) protocols and standards for drinking water quality. Field blank and replicate samples for quality control purpose were also collected beside other samples. One out of ten sites were selected for replicate and which were analysed to evaluate the reproducibility of analytical results. In the collection procedure of water samples, the APHA guidelines of 2005 for drinking water were thoroughly followed in the field. Multiple checklists were prepared to conduct sampling collection procedure in more organized way ensuring quality control;

2.5.1. Tasks Required for Sample Collection

List of the task were prepared to follow before, during and after sample collection process. The checklist followed before sample collection include, arrangement of sample collection bottles, gloves and mask, lighter for samples collected for microbiological analysis. Other important items include, cleaning agent to wash tap and other water points, preservatives, ice used to keep samples in cool place for microbiological and writing book, pen sampling forms, distilled water (PCRWR, 2005).

The check list of tasks followed during sample collection include; sample containers with proper I.D. codes written on them, handy district map and location maps, collection of four water samples and proper marking, collection field blanks and replicates required for quality assurance, careful collection and preservation, note of depth of water source and other minute details and calibration of field Equipment (PCRWR, 2005).

The action required after sample collection includes, its preservation and storage of sample in organized manner and keeping them on required temperature. Samples were then transported to testing laboratory within recommended timeframe to keep it in clean and safe place (PCRWR, 2005).

2.5.2. Guidelines for collection and handing

There are four types of samples collected for assessment of the drinking water, the first type was for bacteriological analysis which were in sterile bottle. The second category of samples were for trace elements and samples were preserved with HNO3. The third category was for analysis of Nitrate and samples were preserved with addition of boric acid. For physical analysis, the samples were collected without preservatives (PCRWR, 2018).

To ensure quality control and quality assurance, four samples were collected from each location for assessment purpose and three types of samples were taken for quality control. For cross analysis of samples, and reproducibility additional 10 percent samples were collected, and for the field blanks, additional 10 percent samples were collected separately (PCRWR, 2018).

Water sample was collected from supply schemes from both source of water and at consumer end. This procedure was adopted keeping in view the issue of pollution. The water distribution networks are prone to water pollution and collection of water from source and consumer end-tap capture the level of pollution and helped in evaluating water quality. The water samples were collected slowing to discourage turbulence and ensure less air bubbles. (PCRWR, 2005)

For collection of water from tapes it was ensured that the taps are un-rusted taps and properly cleaned. The tape was opened for few minutes to allow water flow then the bottle of sample was thoroughly washed with tape water before collection of desired samples (PCRWR, 2005).

For collection of samples for tube well, it was allowed to run for 10 minutes. The water flow for 10 minutes was allowed to ensure representative ground water sample was taken for analysis. The bottle of sample was washed with the well water before taking sample and the depth of tube well and location was noted (PCRWR, 2010).

The water samples from the spring was collected in sterile bottles with special care to ensure unwanted material and outside contaminates do not enter in bottle. The sterile bottles used for collection of samples for microbiology testing is without preservatives (PCRWR, 2010).

Collection of water from dug well was done after purging of well. To get a representative ground water samples, purging is important and it depends on the depth of the bug well. The more the depth, the greater the purging number (PCRWR, 2005).

To get representative ground water sample through bore hole purging was done in case of hand pump. In case of motorized bore hole, the water was allowed to run for 5 minutes before getting desired sample for testing (PCRWR, 2005).

For testing of water samples four samples collected from each sampling sites and sample ID for assessment purpose was marked according to prescribed sequence to avoid amalgamation of collected samples. Following identifications as per prevailing practice will be marked on samples collected for different analytical purposes from each of the selected sampling points: Standard sampling methods of American Public Health Association (APHA, 2012) were adopted for collection of samples.

2.5.3. Sampling Types and Preservatives

The four types of samples collected were categories in sample categories A, B, C and D. Category A is marked for Physical analysis, category marked B for metals or Nitrate analysis, category C was for Heavy Metal Trace elements and Category D for Bacteriological analysis (Abdul et al., 2012).

Table.2.3 Types of Samples and their preservatives

Sample Type	Preservative	Water Quality Parameters	Reference
Type A: Physical analysis	No preservative	Physical and aesthetic parameters (colour, taste and odor) Major Cations and anions (Temperature, pH, conductivity, hardness, Turbidity, Alkalinity TDS) Carbonates, bicarbonates, sodium, Iron, Calcium, Chlorides, Fluorides, Magnesium, Potassium, Phosphate, Sulphates,	PCRWR, 2018
Type B: Metals or Nitrate analysis	1ml/100ml boric acid as preservative	Nitrate	PCRWR, 2018
Type C: Heavy Metal / Trace elements	2ml/liter HNO3 as preservative for trace elements	Heavy Metal/ trace elements Arsenic, lead, Iron chromium, Copper, Zinc and Mercury	PCRWR, 2018
Bacteriological analysis	Sterilized sampling bottles for microbiological analysis	Total Coliforms, faucal Coliform & E-coli (indicator organisms)	PCRWR, 2018, Azizullah et al., 2013

All the water samples were collected from the field and transported to National water quality testing laboratory of PCRWR and stored 4 °C temperature (Abdul et al., 2012). The samples collected for replicates and field blanks were also tested in the same laboratory to evaluate the quality and reproducibility of the results. Cross samples were also sent to water quality testing laboratory of Environmental Protection Agency Islamabad to observe the accuracy of results through comparison with that laboratory.

1.5 litre clean plastic bottles with screw cap were utilized to take samples for physiochemical and trace element analysis while sterile bottles were used to collect microbiological samples (Abdul et al., 2012). The bottle is washed with phosphate free detergent, then with regular water and soaked in 10 % HCL (Bilal and Rahman., 2013). Then these bottles were washed with regular tap water and final wash with deionized water thrice. The bottles were then dried in oven at 60 °C and cooled at room temperature and labelled for sample collection. (Abdul et al., 2012).

The samples for bacteriological contamination were taken clean, sterile 200ml bottles (Bilal and Rahman., 2011). To avoid accidental contamination, precautionary measures were taken during sampling. The samples were taken from the taps which were not leaking to control outside contamination. The drinking water samples collected with special care were then transported from field to the national laboratory on the same day of collected. The samples were collected in the hottest month of June and July and special arrangements were made to keep them cool. All the samples were transported to laboratory in ice containers to ensure minimal impact of environmental factors on samples (PCRWR, 2010).

2.5.4. Location Map

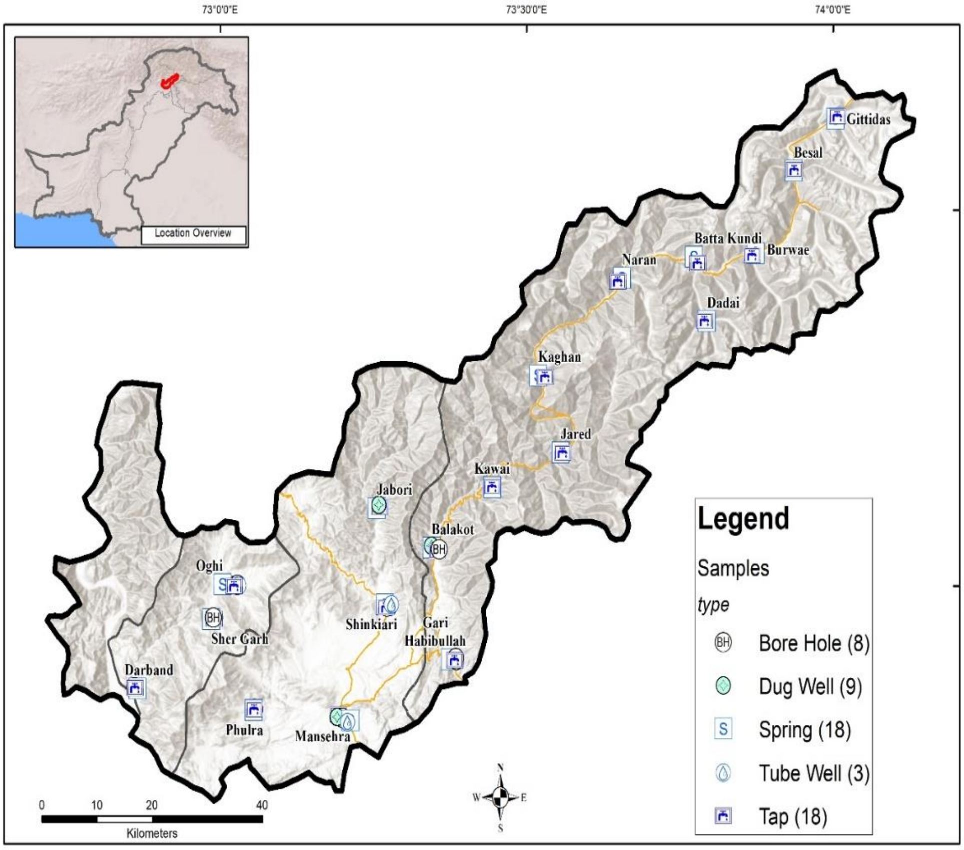

Fig. 2.3 Location Map of Sampling sites

2.6. Instrumentation and Methodology

The water samples collected from field were kept at National Water Quality Laboratory National Water Testing Laboratory of PCRWR and analysed by using various reliable instruments and approved standard methods. The samples analysed for aesthetic, physic-chemical and microbiological parameters by using American Public Health Association (APHA) Standard Methods (APHA, 2012).

NWQL at PCRWR is an ISO-17025 accredited laboratory having analytical capabilities to conduct test for more than 200 parameters. The NWQL is a premier laboratory of water quality in Pakistan. The laboratory has the capacity to analyse more than 114 water quality parameters (drinking, irrigation and wastewater) and is fully capable to support industry, research institutes and universities in this area. The NWQL has three main sections: Microbiological Analysis Section; Chemical Analysis Section; and Wastewater Analysis Section. Pakistan National Accreditation Council (PNAC) conducted full assessment audit for all the labs of PCRWR in July 2015.

Before the analysis, the glassware used in laboratory was washed following same procedure used for washing of sample bottles. The acidified water samples were analysed for Iron, Arsenic, Chromium, copper, lead, zinc and Mercury through Atomic Absorption Spectrophotometry (AAS) under standard operating procedure and method recommended by U.S. Environmental Protection Agency and APHA (Patil et al., 2013). For accuracy of results each sample was analysed in triplicate and reproducibility of 95 %. Field blank and replicate samples for quality control purpose were also analysed to evaluate the reproducibility of analytical results. The sample average value was used for interpretation purpose (Muhammad et al., 2010)

The standard stock solution of all six elements used were prepared. The standard stock solution was prepared through dilution of 1000 mg/L U.S. PerkinElmer's certified standard solutions and double distilled water. Analytical grade reagents were used in the analysis of all the samples and analysis were done (APHA, 2012). To ensure accuracy and precision of the results, the AAS instrument calibration was done through pure reagents.

Many samples were processed with specific regents to limit the matrix effects and samples were also diluted to adjust concentration and for creating a standard curve, while the reagent blanks were also used to zero the instrument. High quality reagents were used in laboratory to eliminate interferences.

2.7. Water Quality Parameters

Drinking water quality properties such as, physical, biological, and chemical are of utmost important because a minor variation in the properties can have direct implication for human use and consumption (Fernandez et al., 2-13) All the properties have great importance and a slight fluctuation may lead to consequences and can affect human health. pH is an important water quality parameter which has direct link with water pollution due to its role in microbiological growth in water bodies (Daud et al., 2017).

To assess the various water quality parameters multiple method for analysis, exist, having capability to determine the type of contamination and its concentration. Furthermore, it is not only detection of contaminant the concentration can also be found by using these standard methods. The analytical methods used for identification of various pollutants and to assess their concentration in drinking water below mentioned methods and techniques were employed (PCRWR, 2005)

Table 2.4 Water Quality Parameters and Analytical Methods Used for Analysis of various Parameters

S. No	**Parameter**	**Analytical Method**	**Instrument/Laboratory**
1	Color (TCU)	PCRWR, 2005	Sensory Test
2	Taste	PCRWR, 2005	Sensory Test
3	Odor	PCRWR, 2005	Sensory Test
4	Temperature	PCRWR, 2005	Potable thermometer
5	pH	Standard Method APHA, 2012	table top pH meter Model 8519, Italy
6	Hardness (mg/l)	2340-C, EDTA Titration, Standard Method, APHA, 2012	EDTA Titration
7	Turbidity (NTU)	2130-B, Nephelometric Method, Standard Method, 2012	Turbidity meter
8	Alkalinity (m.mol/l as CaCO3)	2320-B, Standard Method, APHA ,2012	Alkalinity meter
9	Conductivity (µS/cm)	2510-B, Standard Method, APHA, 2012	EC meter, HACH-44600, USA, Jenway, 4320.
10	Total Dissolved Solids (TDS) mg/l	2540C, Standard Method APHA, 2012	National Water Quality Laboratory PCRWR
11	Bicarbonate (mg/l)	2320-B, Standard Method, APHA, 2012	National Water Quality Laboratory PCRWR
12	Calcium (mg/l)	3500-B, Standard Method APHA, 2012	National Water Quality Laboratory PCRWR
13	Carbonate (mg/l)	2320-B, Standard Method APHA, 2012	National Water Quality Laboratory PCRWR
14	Chloride (mg/l)	4500-BTitration (Silver Nitrate), Standard Method (2012) APHA	National Water Quality Laboratory PCRWR
15	Magnesium (mg/l)	3500-B, Standard Method (2012) APHA	National Water Quality Laboratory PCRWR
16	Nitrate-Nitrogen (mg/l)	4500-B, Standard Method, APHA, 2012	National Water Quality Laboratory PCRWR
17	Potassium (mg/l)	3500-B, APHA Standard Method, APHA, 2012	Flame photometer PFP7, UK
18	Sodium (mg/l)	3500-B, Standard Method, APHA, 2012	Flame photometer PFP7, UK
19	Sulfate (mg/l)	4500-E, Standard Method, APHA, 2012	SulfaVer4 (Hach-8051) by Spectrophotometer
20	Fluoride (mg/l)	4500-C. Ion-Selective Electrode Standard Method APHA, 2012	National Water Quality Laboratory PCRWR

2.7.1. Physical Quality Analysis

Color, Taste and Odor

The colour of natural water is light blue but sometimes due to various reason the colour become greenish, brown yellow or orange. Colour is usually considered for qualitative context. Due to colour of metals and organic compounds the water become coloured. WHO recommended 15 TCU is the level for acceptance of water, above this the colour of water become objectionable.

For colour, taste and odour sensory test were conducted. Taste of sample refer to sensations called salty, sweet sour or bitter, salty, sour and sweet which is result of a chemical stimulation of the sensory nerve located in the tongue. Flavour are the complex sensation due to the chemical stimulation of sensory nerve located in the tongue, oral or nasal cavity. For sensory analysis the water samples were taken into the mouth to produce a flavour.

It was performed for the samples which were suitable for ingestion. During the method of analysis, the part of sample was taken in mouth to wash the tongue for few seconds. The results are qualitive analysis and there are only two categories, objectionable and unobjectionable taste. Special care was done and avoided eating, drinking before the test. The test sensation used include salty, sweet, bitter and sour sensations. The sample analysed were majorly tasteless.

Evaluation of odour was through sense of smell. To evaluate quality of raw and finish water odour of the water is an important consideration. The organic and inorganic substances usually contribute toward bad odour of water. The biological growth in water especially in summer when temperature become hot, also impart fishy and grassy smell to the water. The water without any specific odour is suitable for drinking. The sample analysed were all non-objectionable and odourless.

Determination of Temperature

The temperature of water samples ranged from 22-34°C. Some of the water was taken in morning and evening and few samples was also taken at maximum temperature of day. Highest temperature range was observed in tap which was 34°C and lowest was observed at spring which was 5.6°C. Environmental conditions are the reasons for the fluctuation in temperature. The temperature is usually not a big concern from human consumption point of view, and it does not have any implication on drinking water quality.

There are no guidelines available for drinking water temperature and it is dependent on individual preference and taste. However, temperature is important parameter of drinking water quality it has direct relation with chemical and biological activities.

Determination of Turbidity

Cloudiness of water is referred as turbidity and it does not have any direct implication on health. However, Turbidity provide suitable condition for microbial growth and can easily influence the process of disinfection thus turbidity may show presence of microbes like bacteria viruses which causes cause nausea, vomiting headache etc. When light is passed through the samples, rather than transmitting as straight line, it gets scattered and absorbed which was measured as turbidity.

The turbidity is optical property and it was measured to estimate the concentration of suspended substances in portable water. The method was used for characterization of quality of water and was based on comparison of the intensity of light scattered by the sample under defined conditions and with the intensity of light scattered by a standard reference suspension under the standard conditions. The higher the intensity of scattered light, the higher the turbidity. The turbidity causing agents are silt, clay, soluble compounds, organic and inorganic compounds, microscopic organisms.

It is difficult to find correlation of turbidity with weight of suspended matter due to their shape, size refractive index of suspended particles which impact the scattering properties of light. Such as activated carbon, optically black particles absorbed light and ultimately increased turbidity readings. Turbidity is very important parameter due to the reason that it is used for characterization of the water quality and to design the water treatment methodologies and gives accurate measurement and estimation of un-dissolved substances.

Turbidity was measured soon after sample was arrived, to avoid irreversible changes, which can happen due to long storage at laboratory. The instrument used for measurement of turbidity of water solution is Hanna turbidity meter Lamotte, Model 2008, USA.

The reagents used in analysis were the standards of 4000 FTU & 10FTU and Distilled Water. Turbidity is determined once the water samples are free from debris and other coarse sediments. The turbidity measurements can be easy effected by vibration which are usually caused by dirty glassware or presence of air bubbles. Thus, the visibility of the sample gives false results. Before testing samples, the cuvet was washed properly with deionized water and the instrument was calibrated with standard of known turbidity -10NTU

Determination of Electric Conductivity (EC)

The measurement of conductivity is the electric current carrying ability of water solution. Through the measurement of electric conductivity of the portable water, the number of ions present in water solution was calculated. Usually the electric current carrying ability of the solution depends upon multiple indicators, identification of ions, their concentration, valance and mobility with respect to temperature. Through this standard method, the concentration of electrolytes in the samples.

The instrument used for the analysis of solution for EC is conductivity meter HACH-44600, USA. The reagent used in the analysis is a hydrous Potassium Chloride and distilled water. Before the analysis and measurement, the samples were stirred thoroughly and then allowed for stabilization to promote removal of bubbles. To properly record the conductivity of samples electrodes and glassware were washed with deionized water.

The instrument was calibrated by using potassium chloride, 0.01 M standard solution at the temperature of 25 oC and electrodes were dipped in standard solution. The electrodes were dipped in 50ml of the sample in the beaker and when reading become stable the result was noted from the screen of EC meter.

Temperature affects conductivity that varies by about 2% per 1 ℃. The temperature of 25 oC is taken as standard Simultaneously temperature of sample was checked, and it was compared with instrument temperature and readings were recorded. Three replicates were analysed for each sample and EC was measured in µS/cm. After each sample the electrode was dipped in ionized water. The reading was recorded for each sample following the same procedure.

Determination of Total Dissolved Solids (TDS)

Dissolved solids are the solid particles which have ability to pass from standard filter. The major constituents of the TDS are cations of calcium, sodium, magnesium and anions of chlorides, sulphate, nitrate and bicarbonates. According to WHO guidelines the recommended TDS for drinking water below 1000mg/l which is safe for consuming water for drinking purposes.

The palatability of drinking water with respect to TDS concentration are rated in three categories; samples with TDS below 300 mg/1 will fall in Excellent, the sample from TDS range 300-600 mg/1 will be good and samples will be in Fair category if the

TDS levels will be in range of 600-900 mg/1. Similarly, the sample will have high TDS and lies between the limits of 900-1200 mg/1 will be poor and above 1200mg/l will be unacceptable.

The estimation of concentration of dissolved solid in drinking water is considered as important parameter due to many industrial processes. The TDS of the water samples were measured by using Gravimetric Method: A portion of water sample was, and 10 ml of the filtrate water was taken into a pre-weighed evaporating dish. Filtrate water samples were then dried through oven. The dish was then allowed to cool at room temperature; The TDS of the samples was calculated through following formula;

TDS = [(A−B) ×1000]/ml sample

TDS = [(A−B) ×1000]/ [(A - B) ∗1000]ml sample.

A is the combined weight of evaporating dish + filtrate

B is the weight of the evaporating dish only

2.7.2. Chemical Quality Analysis

Determination of pH

Portable pH meter was used for the analysis of pH of water samples. The bottle of samples was complete filled with tight stopper to avoid changes in composition of the water. The method adopted for analysis is a refence method- called electrometric method. pH of the sampling was determined through using the Hanna microprocessor and it was standardized by following the manufacturer's instruction. Through this method it was found if sample is acidic or basic nature.

For determination of hydrogen ion which is required for pH measurement, standard hydrogen electrode and reference electrode was used, usually glass electrodes were used for this process. The pH scale usually ranges from 0-14 and the exact neutrality was at middle value which is 7. The pH of any aqueous solution is usually ranging from 4.5 and 8.5.

The reagents used for analysis is buffer of pH 4,7,10 and 12 and distilled water. After warming pH meter for five minutes, the calibration of meter was checked by known buffer of pH (4.00, 7.00, 10.00 or 12.00). To dip the electrodes in sample 50 ml of sample was taken in beaker and values were recorded when they become stable. The reading was taken in unstirred solution to control loss of both Carbon-dioxide and volatile compounds. pH meter was removed from sample and placed in standard with Ph 7.0 and three replicates were analysed for each sample.

Determination of Alkalinity (Alk)

Alkalinity of the water sample is measured as acid-neutralizing capacity. Carbonate. Bicarbonate and co contents of hydroxide are the contributor of alkalinity. The measurement of alkalinity of water is an important aspect of water quality because treatment process and technologies require this data. The 2320 Standard Method (1992) was used for analysis of water samples for alkalinity.

The reagents used for the analysis were, carbon dioxide free distilled water, Methyl orange indicator, Sodium carbonate solution, 0.05 mol/l, HCl 0.02 M and Phenolphthalein indicator. For analysis 100 ml sample was taken in conical flask and 2-3 drops of phenolphthalein indicator were added. Determination of alkalinity was carried out by titration with standard acid-HC until the indicator pink colour vanished.

In case if there was no colour appeared after addition of phenolphthalein, the alkalinity of sample was recorded as zero. To measure the alkalinity of water sample with methyl orange, the sample was titrated with standard acid HCl 0.02 until the colour of sample changes to orange from yellow.

The total Alkalinity is calculated by using following formula

$$\text{Total alkalinity as } CaCO_3 \text{ (m.mol/l)} = \frac{1000 \times B \times C}{V}$$

Where;

B= ml of standard acid solution to reach the end point of methyl orange;

C= Concentration of acid in mol/l

V= ml of sample.

Used 100 ml of sample and 0.1 mol/l standard acid solutions, the numerical value of alkalinity is directly expressed in mol/l by the number of ml of titrant consumed. Three replicates were analysed, and alkalinity is measured in mg/l.

Determination of Hardness

The determination of hardness is an important characteristics of drinking water quality and help us to differentiate between soft and hard water. Usually the hardness of water samples was conducted through titration at room temperature. Hardness is measured through the EDTA Standard Method (1992).

For the process the reagents used in the analysis were; EDTA, buffer Inhibitor, Erichrome black T and distilled Water. Glassware were washed with washing acid (1:1HCL) and de-ionised water. In 100ml beaker, 10ml of water sample was taken and 20ml deionized water is added to the sample. Then 1 ml buffer inhibitor was added in the sample. Added 1ml of buffer inhibitor in the sample which increased the pH of the solution sufficiently. Further a small amount of EBT was also poured in solution which formed soluble chelates of calcium and magnesium ions and wine-red coloured was appeared.

The solution is titrated against EDTA (0.01M) from the burette. The EDTA solution is added slowly and sky-blue colour appeared. The burette reading was multiplied by 100 to record the hardness. The solution was then titrated against EDTA finally sky-blue colour appeared. The reading was multiplied with 100 to calculate the total hardness for water sample. Three replicates were analysed for each sample. The measurement unit for hardness of water is mg/l.

Determination of Carbonate (CO3)

To characterize the carbonate of the water sample was done through titrimetric method 2320 Standard Method (1992). The process used reagents like hydrochloric Acid (0.1N) and (0.02N), Sodium carbonate (0.05N) and Phenolphthalein. The water samples which had pH above 8.3 detected the presence of carbonate. For the analysis, 50 ml sample was taken in beaker and phenolphthalein indicator was added in water sample. Pink colour indicates presence of carbonates and without pink colour the sample was recorded as zero carbonate. In case of samples which turned pink indicated presence of carbonate as the pH is above 8.3. The water sample was titrated against standard solution (acid) until the solution became colourless. In the equation below the “R1” is the volume of acid used.

Concentration of carbonate mg/l= R1x20x2

Determination of Bicarbonate

The sources of bicarbonates in drinking water is mainly by natural process of weathering of the rocks. Their presence is dominated both in ground and surface water resources. Determination of bicarbonate allows estimation of alkalinity. The concentration of bicarbonate is mainly related to pH of water as these are easily soluble in water. Usually the concentration of bicarbonates in ground water remain less than 500 mg/l and has direct impact on alkalinity and hardness of water. For bicarbonates, WHO does not recommend any guiding value. Bicarbonates are measured through 2320

Standard Method (1992). The reagents used for analysis includes, hydrochloric acid (0.1N) and (0.02N) and sodium carbonate (0.05N)

10 ml sample was taken in flask and few drops of indicator was added and appearance of green colour confirmed the presence of bicarbonate. The solution was then titrated against 0.02 N HCl. Titration was continued until the colour of the solution changed to pink.

The bicarbonates concentration is calculated through formula

$$\text{Alkalinity, mg CaCO3/L} = \frac{A \times N \times 50000}{\text{ml sample}}$$

Where:

A indicate ml of standard acid

N indicate ml of normality of the standard acid

Determination of Magnesium (Mg) and Calcium (Ca)

Naturally Magnesium is found abundant in water resources on earth. It is commonly occurring element and the water resources which are in proximity of siliceous sand or granite have high concentration of magnesium per litre of water. Like Calcium Magnesium also contributing to hardness of the water and it can be controlled through ion exchange method. 2340-C, Standard titration Method (1992) was utilized for identification of Mg. Mg was calculated as difference between hardness while calcium as CaCO3.

Concentration of Mg (mg/l) = [total hardness (as CaCO3 mg/l)–Calcium hardness (as mg CaCO3/l) x 0.243].

The method is used for characterization of the quality of potable water and determination of Calcium helped to categorize hard and soft water. Water EDTA was added in water sample which has magnesium and calcium both, it first combined with calcium. Indicator is used for determination of calcium only, while Magnesium is majorly precipitated as hydroxide at high pH level.

The reagents used in the analysis include; Ethylenediaminetetraacetic acid (EDTA), NaOH (1M), Murexide Indicator and distilled Water. In a beaker, 10 ml sample and deionized water is added in solution, pH of solution was maintained through addition of NaoH and indicator Murexide is added in the solution which produced pink colour in solution. The solution was then titrated against EDTA and continued until purple colour appeared

The calcium concentration was calculated by multiply the EDTA with 40. The Magnesium of the sample was calculated by,

Mg= (Hardness-2.5x Ca) 0.243

During the procedure the pH of the solution was maintained at 12 and NaOH was used to maintain the desired pH of sample. Both magnesium and calcium were measured in mg/l.

Determination of Chlorides (Cl)

Water contain Chloride (Cl) ion, due to chemical composition of water the concentration of ions has considerable variations. Sometimes due to excess of cations of calcium and magnesium the chloride concentration become very high, but the water usually does not taste salty. The chloride concentration is usually affected by saline water and it was noticed that raw water has less chlorides compared to waste water. Determination of chlorides and assessment of their concentration is another important step to characterize the quality of water. The high concentration of chlorides indicates high level of pollution due to industrial waste or domestic sewage. Chlorides give salty taste to water sources.

Titration (silver nitrate) standards method was used for analysis of chlorides. Chloride was determined by using titration with standard silver nitrate and potassium chromate was used indicator. Silver chloride quantitatively precipitates before red silver chromate is formed. Reagents used during analysis are; Sodium chloride (0.0141N), Standard Silver Nitrate: (0.0141), Potassium chromate Indicator solution. In a neutral or slightly alkaline solution, potassium chromate can indicate the end point of the silver nitrate titration of chloride; silver chloride is precipitated quantitatively before red silver chromate is formed.

In a beaker 20 ml of water sample was taken and few drops of K2CrO4 was added to the solution and then titrated against 0.0141N AgNO3. The sample coloured changed to pinkish yellow. The chloride concentration was calculated through the formula;

$$\text{mg Cl -1/L} = \frac{(A - B) \times N \times 1000 \times 35.46}{\text{ml of sample}}$$

A = ml titration for sample

B = ml titration for blank

C = Normality of AgNO3

Determination of Sodium (Na) & Potassium (K)

Both Sodium and Potassium is abundant in nature and found in all the water resources. The concentration of sodium may vary in water from 1mg to 500mg/l. the concentration of potassium remained low in drinking water and usually remain below 20 mg/l. Emission photometric method was used for determination of sodium and potassium in water samples. Through Flame photometer the compound were thermally dissociated which excited the atom to higher energy level. When the atoms returned to ground state, they emitted radiation. The light emitted during the procedure is proportional to the concentration of water sample.

The reagents used in the analysis are; Na and K Multi Standard Stock Solution and Na and K Standard Solutions (by dilution). The detection limits of flame photometer for sodium and potassium is <0.2 mg/l. Instrument ignited and first select control was set, suction rate for distilled water was between 2-6ml/minute. Blank and standard solutions of various concentrations were aspirated and then water samples were aspirated to note the results. Blanks and standard were set, and three replicates were analysed for each sample and Sodium and potassium was measured in mg/l.

Determination of Sulfate (SO3)

Sulphate ions are abundant in the earth's crust. Their concentrations may vary in water depending upon the source of sulphate, usually industrial wastes constitute of high sulphur organic compounds. However drinking water contain sulphate in varying concentration from a few mg to hundreds of mg per litre. According to WHO water guidelines, the permissible limit of sulphate for domestic water use is 400 mg/l. The instrument used for analysis was UV-VIS Spectrophotometer (U-1100), HITACHI. Through the method the sulphate presence can be easily measured ranges between 0 to 70 mg/l. The reagents used in analysis are; Sulphate Buffer, Barium Chloride Crystals and Distilled water. Sulphate ions in the sample react with barium in the sulpha ver 4-sulfate reagent and form insoluble barium-sulphate turbidity. Spectrophotometer was used to measure barium sulphate absorbance. the turbidity formed by the solution is proportional to the sulphate level. For analysis, in a flask, 25 ml of deionized water was taken and sulfa ver 4 sulphate reagent powder was included in water. The solution was kept for 5 minutes. The solution was then taken in a reference cell to place it in holder of UV-VIS spectrophotometer, the wavelength of spectrophotometer is adjusted at 450 nm. For analysis the standard solutions of 5,10,20,30,40,50,60 and 70 mg/l sulphate were prepared.

And then contents of sulfa ver 4-sulfate reagent powder was added in solutions and after reaction period the absorbance for each standard solution. The results are then plotted in graph between concentration of the sulphate standard solution and their relative absorbance. Afterwards, the water samples were also analysed, and their absorbance results were then compared with graph and concentration of sulphate was recorded for water sample. The concentration of Sulphate is measured in mg/l in water samples and three replicates were analysed for each sample.

Determination of Nitrate (NO3)

Nitrogen is commonly found in water due to aerobic decomposition of organic matters. Nitrogen is the product of decomposition of nitrogenous compounds and Nitrate are oxidized from nitrogen and present in water resources. Indication of nitrates confirm that the water resources are contaminated with sewage. The range of measurement for Nitrate (N) in drinking waters falls between 0 to 4.5 mg/l. The excessive number of nitrates in the water is mainly due to agriculture activity and domestic and industrial waste. Fresh water usually does not contain high number of nitrates. The method employed for the determination of nitrate is Cadmium Reduction Method (HACH-8171) and instrument used for detection was Spectrophotometer.

In a beaker, a 25 ml of deionized water was taken and contents of 1 NitraVer 5-nitrate reagent were added. the beaker was set aside for reach period of 5 minutes. The solution is then taken from the beaker in a reference cell and then into the cell holder of spectrophotometer, the wavelength is adjusted at 400 nm. Standard nitrate (N) solutions of 0.2, 0.4, 0.6, 0.8, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5 and 4.0 mg/l were prepared. For each standard the absorbance was recorded and then absorbances of samples were also measured. The concentration of nitrate was determined through calibrated graph. Three replicates were analysed for each sample and Nitrate is measured in mg/l.

Determination of Fluoride (Fl)

Fluoride found in water naturally or due to anthropogenic activities. Usually fluoride concentration in drinking water is 1.0 mg/l in drinking water with no toxic effects. With enhanced fluoride concentration the fluorosis occurred. The range of analysis is about 0.0 to 2.00 mg/l. The method applied for determination of fluorides is SPANDS colorimetric method and instrument used for analyses was 8029, SPADNS (Hach) by spectrophotometer. The reagents used in the process is SPANDS solution and Distilled water. The method was based on the reaction between fluoride and a zirconium-dye lake. Fluoride reaction with the dye lake resulted in, dissociation into a colourless complex anion (ZrF6-2) and the dye. The colour of the solution become progressively lighter with increased fluoride concentration. Thus, bleaching the red colour is an amount proportional to the fluoride concentration. 10 ml deionized water was taken in 25 ml cuvet and 2 ml SPANDS solution was added in it. The solution was shaken and waited for reaction time of one minute. blank correction was made and then 10 ml water sample was taken and treated. The results were the concentration of fluorides, which were measured in mg/l and three replicates were analysed for each sample.

2.7.3. Heavy Metal Quality Analysis

Table 2.5 Water Quality Parameters and analytical methods used for toxic Heavy Metals

S. No	Parameter	Analytical Method	Instrument
1	Arsenic (As)	3114-B Hydride generation Atomic Absorption Spectrophotometry, standard Method, APHA, 2012	Atomic Absorption spectrophotometer (AAS) Vario 6& nov AA 300 (Analytic Jena Germany)
2	Chromium (Cr)	3114-B Flame Atomic Absorption Spectrophotometry, standard Method, APHA, 2012	Atomic Absorption spectrophotometer (AAS) Vario 6& nov AA 300 (Analytic Jena Germany)
3	Copper (Cu)	3114-B Flame Atomic Absorption Spectrophotometry, standard Method, APHA, 2012	Atomic Absorption spectrophotometer (AAS) Vario 6& nov AA 300 (Analytic Jena Germany)
4	Iron (Fe)	3114-B Flame Atomic Absorption Spectrophotometry, standard Method, APHA, 2012	Atomic Absorption spectrophotometer (AAS) Vario 6& nov AA 300 (Analytic Jena Germany)
5	Mercury (Hg)	3114-B Cold Vapour Atomic Absorption Spectrophotometry, standard Method, APHA, 2012	Atomic Absorption spectrophotometer (AAS) Vario 6& nov AA 300 (Analytic Jena Germany)
6	Lead (Pb)	3114-B Flame Atomic Absorption Spectrophotometry, standard Method, APHA, 2012	Atomic Absorption spectrophotometer (AAS) Vario 6& nov AA 300 (Analytic Jena Germany)

7	Zinc (Zn)	3114-B Flame Atomic Absorption Spectrophotometry, standard Method, APHA, 2012	Atomic Absorption spectrophotometer (AAS) Vario 6& nov AA 300 (Analytic Jena Germany)

Heavy metals are part of natural water resources and are usually not harmful within permissible limits but with the increase in concentration and long duration of exposure to these toxic metals have long lasting health impacts. Based on the toxicity of these metals, they are grouped in two categories; Group I include metals like Fe, Cu, Zn, the metals with undesirable health impacts and Group II include metals such as As, Cr, Hg, Pb metal with toxic health impacts (Muhammad et al., 2010).

The chemical analysis of water samples was carried out in PCRWR water quality testing laboratory by using state of art equipment. The instrument used for the analysis is Atomic Absorption spectrophotometer (AAS) Vario 6& nov AA 300 (Analytic Jena Germany). The apparatus is highly sensitive and capable to determine the small concentration of Arsenic, Copper, Chromium, lead, Zinc, Iron and Mercury which were analysed for the current research. This analytical method was used for analysis of wide range of hazardous chemicals (acids, bases, organic solvents, etc.) (Abdul et al., 2012).

For the analysis of Co, Cu, Zn, Fe, Cr, Pb, Hg and As, the radiation source used was hollow cathode lamps and flame atomic Absorption spectrophotometry was employed. For determination of As hydride generation system was attached to AAS while for determination of Hg cold vapour generation system was employed. The analysis of the water samples was conducted after standard procedure, the wavelength calibration was carried out through multielement standard solution with 50 ppm Potassium and 5 ppm of As, Cu, Pb, Hg, Zn (PCRWR, 2005).

Also, the calibration of instrument with multi-element standard solution of unknow concentration. During the procedure deionized water ($EC<0.3$ µS/cm) was used for the preparation of blank to be used in analysis. Nitric Acid (65%) was added to deionized water to maintain its concentration at 2 % (HNO3). For washing and calibration, the blank was used during the process (Khan et al. 2013).

To ensure the reliability and reducibility of the method and instrument of analysis the blank, standard and also pre-tested samples were used during course of analysis. And the frequency of quality check is after every ten samples. Analytical grades of Sulfuric acid, nitric acid, hydrochloric acid, hydrogen, peroxide, potassium iodide, sodium borohydride and stannous chloride were used during analysis (Khan et al. 2013).

Atomic Absorption Spectrophotometry is an analytical technique used in the laboratories to detect various metals and metalloids and to determine their concentration in water samples. The technique is simple and have ability to analyse more than 62 metals and metalloids. The technique is based on principle of absorption of radiations and were used for both qualitative and quantitative analysis and can measure concentration in ppm and ppb. The basic principal in AAS is that the concentration of metal is measured from absorbance of the radiation. The ground state atom is excited in gaseous state and absorb radiations in gaseous state. The absorbance of UV radiation transitions the atom in higher energy state (Muhammad et al., 2010).

The concentration of metal is usually determined through amount of radiation absorbed by the metal. The concentration of the metal is determined through the calibration curve. AAS was calibrated with standard. After calibration of the instrument, standard of known concentration was run. The technique used for atomization of the sample is flame atomization, in multiple steps the liquid is converted into gas and which is further broken down into free atoms. The atomization is the process, where the compound is further broken down into molecules and then in individual atoms.

In AAS the hollow cathode lamp was used as source of radiation, the hollow cathode lamp constitutes of tungsten anode and a hallow cylindrical cathode. They are sealed in glass tube filled with inert gas argon gas. For determination of each metal, a unique lamp was used for analysis. Air acetylene flame is used in flame atomizer. Another important part in atomic spectrophotometer is monochromator, which has ability to separate thousands of lines with specific wavelength. It helps the instrument to select the wavelength which can be absorbed by the sample and exclude all other wavelength. The selection of specific wavelength of the light allow the process of identification of selected metal in the sample in the presence of other elements (Tahir et al., 1996).

Another important component of AAS is detector, after monochromator the light is then directed to the detector for identification of the element. The detector is photomultiplier tube capable of converting light signal into electrical signal. The electrical signals are directly proportional to the light intensity. The electric signals then translated into data and displayed on readout or amplifier (Khan et al., 2013).

To determine the unknown metal in sample calibration curve is used. The instrument is calibrated with elements of known concentrations. The absorbance of each known solution was then measured, and a calibration curve of concentration verses absorbance was plotted. Then the sample was analysed in instrument, the absorbance of the solution is measured and then the concentration of the unknown element was measured through the calibration curve (PCRWR, 2005).

Preparation of Sample for AAS analysis

The sample containers were pre-washed in acid solution and rinsed with distilled water twice to ensure minimal interference. The water sample was preserved with 2 mL of concentrated nitric acid after collection, kept in an ice chest in the field and later stored in the refrigerator at 4 °C. The acidified water samples was neutralized and adjusted to a pH of 7. The water samples were treated with concentrated nitric acid following standard procedures of the American Public Health Association, filtered with 0.45-micron filters into 10 mL volumetric flasks and made up to the mark with deionized water. The concentrations of heavy metals in the filtrates were determined by flame atomic absorption spectrometry (PCRWR, 2005).

Preparation of standard and blank solution and calibration of Instrument

For the analysis of the heavy metal on AAS instrument, standard, blank solutions were used. Standard solution of U.S. PerkinElmer was used for the calibration of the AAS in PCRWR laboratory (Khan et al., 2013). The instrument and method are validated for linearity, range, accuracy, specificity, precision, detection limit, quantitation limit, and robustness and these analytical characteristics were applied for the standardized methods. The standards solution for all the six elements were prepared through dilution of 1000 mg/l certified standard solutions (Khan et al., 2013).

The apparatus used for detection of trace element for the study is atomic absorption spectrophotometer (AAS) Vario 6&novAA 300 (Analytic Jena Germany). Flame atomization Atomic Absorption Spectrophotometer was used for the qualitative determination trace elements such as Fe, Zn, Cu, Cr, Pb and hydride atomization was used for detection of Arsenic and cold vapour atomization was used for mercury. Special measures were taken to discourage contamination in samples during the collection process and soon after the collection and with acidification process the sample was preserved.

The detection wavelength is specific for each metal. The detection wavelength for As, Cr, Cu, Fe, Hg, Pb and Zn were 193.7nm, 267.716nm, 324.7nm, 510nm, 220.353nm and 213.9nm respectively. The stranded solution for the analysis were prepared by using commercially available lab grade stock solutions of 1000 mg/l (APHA, 2012). An air acetyl flame was used in the process.

Table 2.6 Heavy metal with specific absorption wavelength and detection limits

S. No	Element	Atomization method	Wavelength	Detection limits
1	As	Hydride Atomization	193.7nm	0.0001 mg/l
2	Hg	Hydride Atomization	546 nm	0.0001 mg/l
3	Pb	Flame Atomization	220.353nm	0.001 mg/l
4	Cu	Flame Atomization	324.7nm	0.001 mg/l
5	Cr	Flame Atomization	267.716nm	0.001 mg/l
6	Zn	Flame Atomization	213.9nm	0.001 mg/l
7	Fe	Flame Atomization	510 nm	0.01 mg/l

Determination of Copper (Cu)

Copper come from both industrial processes and leaking old worn-out water pipes, lead is usually found in water in less than 5 µg/l. For analysis of copper, 2ml of concentrated HNO3 was added to sample to acidify it to store in plastic container. The instrument used for the determination and analysis of Cut AAS Vario 6 Analytik Tena AG and standard procedure (APHA, 1992). The optical parameters were adjusted, and wavelength was at 324nm. The calibration was performed with number of standards of known concentration using the stock solution of 100 ppb.

The reagents used in the process of flame Atomic Absorption Spectrometric method are Methyl isobutyl ketone (MIBK), Diethyldithiocarbamate (DDC. Phthalate buffer. Dissolve 102 g of potassium biphthalate in 500 mL of deionized water, add 14 mL of 1M HCl and dilute to 1 litre with deionized water. Hydrochloric acid, HCl, concentrated. Sodium hydroxide, NaOH, 1M. The standard solution was prepared from the stock solutions. Standards containing 10, 25, 50, 75, and 100 µg/litre of each element was prepared. Working curve was prepared from extracted standard and blank to calculate concentration of Cu (APHA, 1992).

Determination of Lead (Pb)

Lead come from both industrial processes and combustion of sub-standard fuel common in various parts of the country. The water supply usually get lead from industrial effluents and old water supply pipes. For analysis of lead 2ml of concentrated HNO3 was added to sample to acidify it to store in plastic container. The instrument used for the determination and analysis of Pb is AAS Vario 6 Analytik Tena AG. The optical parameters were adjusted, and wavelength was at 217 nm. The temperature of instrument was set at 900 Co whereas atomization takes place at 1800 C (PCRWR, 2005)

The calibration was performed with number of standards of known concentration using the stock solution of 100 ppb or as required will be given. The reagents used in the process of flame Atomic Absorption Spectrometric method are Methyl isobutyl ketone (MIBK), Diethyldithiocarbamate (DDC. Phthalate buffer. Dissolve 102 g of potassium biphthalate in 500 mL of deionized water, add 14 mL of 1M HCl and dilute to 1 liter with deionized water. Hydrochloric acid, HCl, concentrated. Sodium hydroxide, NaOH, 1M. The standard solution was prepared from the stock solutions. Standards containing 10, 25, 50, 75, and 100 μg/liter of each element was prepared. Pb was determined immediately after its extraction to control loss. Working curve was prepared from extracted standard and blank to calculate concentration of Pb from these curves through standard procedure (APHA, 1992).

Determination of Zinc (Zn)

The major source of Zinc in water resources is water supplying pipes. Zinc is important metal and required for proper functioning, but its higher concentration can affect human body and cause diseases. For analysis of Zinc, 2ml of concentrated HNO3 was added to sample to acidify it to store in plastic container. The method used for the determination and analysis of Zinc is flame AAS and instrument used is AAS Vario 6 Analytik Tena AG. The optical parameters were adjusted, and wavelength was at 213.9 nm. The reagents used in the process is Methyl isobutyl ketone (MIBK), Diethyldithiocarbamate (DDC) Phthalate buffer. Dissolve 102 g of potassium biphthalate in 500 mL of deionized water, add 14 mL of 1M HCl and dilute to 1 liter with deionized water. Hydrochloric acid, HCl, concentrated. Sodium hydroxide, NaOH, 1M. The standard solution was prepared from the stock solutions. Standards containing 10, 25, 50, 75, and 100 μg/liter of each element was prepared. Zn was determined immediately after its extraction to control loss. Working curve was prepared from extracted standard and blank to calculate concentration of Zn from these curves.

Determination of Iron (Fe)

Fe is another metal found in abundance naturally. It also exists in small quantities in natural water systems. Usually in surface water the amount of iron is 1 mg/l as the normal pH of surface water is between 6 to 9. The water become objectionable due to formation of hydrated ferric oxide which produces orange strains and effect water supply system, laundry articles, utensils and plumbing fixture etc. it also gave water a yellowish colour and changes its taste. With change in taste, colour and odour the water become undesirable for human consumption. According to WHO, 0.3 mg/l is the highest level for Fe in water and 1.0 mg/l as the maximum permissible level in water intended for domestic use. To avoid and control oxidation of iron, 1.5 ml of concentrated nitric acid was added per litre of sample immediately after collection. The method used for the determination and analysis of iron is Flame AAS through instrument AAS Vario 6 Analytik Tena AG. The reagents used in the process of flame Atomic Absorption Spectrometric method are Methyl isobutyl ketone (MIBK), Diethyldithiocarbamate (DDC. Phthalate buffer. Dissolve 102 g of potassium biphthalate in 500 mL of deionized water, add 14 mL of 1M HCl and dilute to 1 litre with deionized water. Hydrochloric acid, HCl, concentrated. Sodium hydroxide, NaOH, 1M.

The standard solution was prepared from the stock solutions. Standards containing 10, 25, 50, 75, and 100 μg/liter of each element was prepared. Fe was determined immediately after its extraction to control loss (APHA, 1992). The spectrophotometer wavelength for Fe is 510 nm. The absorbance was also taken, and iron concentrations was determined through calibrated graph.

Determination of Chromium (Cr)

The hexavalent is one of the two form of Chromium which is a stable and exists usually in drinking water while the other stable form of chromium which rarely found in drinking water is chromium trivalent. The water samples collected from the field were then acidified with 1.5 ml concentration HNO3, this ensure control in losses of chromium. Hexavalent Chromium was detected in water samples through colorimetric method Standard Methods (APHA, 1992) and total chromium was measured through Flame Atomic absorption spectrophotometric method and the instrument used for analysis is AAS Vario 6 Analytik Tena AG. The optical parameters were adjusted, and wavelength was at 267.216 nm.

The reagents used in the process is Methyl isobutyl ketone (MIBK), Diethyldithiocarbamate (DDC. Phthalate buffer. Dissolve 102 g of potassium biphthalate in 500 mL of deionized water, add 14 mL of 1M HCl and dilute to 1 litre with deionized water. Hydrochloric acid, HCl, concentrated. Sodium hydroxide, NaOH, 1M. The standard solution was prepared from the stock solutions.

Standards containing 10, 25, 50, 75, and 100 µg/litre of each element was prepared. Cr was determined immediately after its extraction to control loss. Working curve was prepared from extracted standard and blank to calculate concentration of Cr through these curves (APHA, 1992). The resulted collected were displayed as mg/l.

Determination of Arsenic

Arsenic is found in both surface and ground water and weathering of the rock is major contributor of the natural presence of arsenic in nature. However, the human activities such as industrial activities and agricultural inputs- herbicides, insecticides contribute arsenic in various forms such as arsenite, arsenate and organic arsenicals. An important factor to consider is that both organic and inorganic arsenic has varying impact on environment and their impact also differ based on their composition (PCRWR, 2005) The chemical form of arsenic is determined by its source. Industrial discharge and insecticides are the sources of inorganic arsenic and organic arsenic is resulted from the biological action of inorganic arsenic and industrial discharges.

Hydride generation atomization of sample was done for the analysis if water sample to detect total inorganic Arsenic. The samples analysis was done on HS 55 Mercury/Hydride system, an accessory (AAS, Vario 6 Analytik Jena AG) used for detection of hydride forming element such as As. The reagents used in the process were argon gas with 99.99% purity, Sodium borohydride (98% purity), Sodium hydroxide, Hydrochloric Acid (Concentrated 37%) and arsenic standard (Muhammad et al., 2010). For calibration of the instrument, calibration standards for arsenic was prepared with concentrations (0,10,20,30,40,50 ppb) and (50,60,70,80,90,100 ppb).

Instrument was calibrated and calibration curve was drawn and adjusted. Sodium boro-hydride reagent was used as reducing agent for Arsenic analysis, the hydrogen was liberated from the sodium boro-hydride in this hydride technique, and during the process the As present in the sample reacted with sodium borohydride in acidic medium. The hydrogen ions liberated in the process further combined with metal ions and formed gaseous hydrides- Arsine gas (AsH3).

These hydrides were carried by a carrier gas- argon gas to the hot quartz cell where decomposition of the gaseous hydride occurred as a result of collision process releasing As atoms. The process of atomization of sample took at 950°C. The radiation (λ max 193.7 nm) came from Arsenic lamp passed through the quartz cell where these were absorbed by As atoms and this absorption was detected in detector and radiation was measured.

For the reaction process, 10ml water sample was taken and 1 ml of concentrated HCl was added in the sample beaker for analysis of Arsenic in the sample. The reaction process took two minutes before producing results. Each sample was analysed thrice. The resulted were displayed in ppm which was recorded in data sheet (Muhammad et al., 2010). The detection limit of this method is 0.1 ppb.

Determination of Mercury

Major source of Mercury the drinking water is through coal mining and industries. Hg is toxic metal and has devastating health impacts. Major sources of incineration of Coal which is common in mountainous region of the world. Another important contributor to mercury in the atmosphere and water is coal mining.

Mercury is non wetting liquid so it is usually analysed through Cold Vapour atomic absorption Spectrophotometry. Cold vapour generation system is used before analysis of samples on AAS instrument. The instrument used for analysis mercury in the lab was AAS Vario 6 Analytik Tena AG. The optical parameters were adjusted, and wavelength was 546 nm.

The reagents used in the process is Methyl isobutyl ketone (MIBK), Diethyldithiocarbamate (DDC. Phthalate buffer. Dissolve 102 g of potassium biphthalate in 500 ml deionized water, add 14 ml of 1M HCl and dilute to 1 litre with deionized water. Hydrochloric acid, HCl, concentrated. Sodium hydroxide, NaOH, 1M. The standard solution was prepared from the stock solutions. Standards containing 10, 25, 50, 75, and 100 μg/l of each element was prepared (Standard Method APHA, 1992).

Hg was determined immediately after its extraction to control loss. Working curve was prepared from extracted standard and blank to calculate concentration of Hg through these curves. The resulted collected were displayed as ppb/or mg/l. Due to its toxic characteristics the permissible limit of mercury set by WHO is .001mg/l

2.7.4 Microbiological Quality Analysis

Microbiological contamination has a lot of significance in the process of assessment of drinking water quality. Microbiological assessment was conducted to analyse the water quality of water sources. Various reliable analytical methods were used to identify and count microorganism colonies in water samples. Some of the detection techniques used during analysis of drinking water is given below;

Table 2.7 Water quality parameters and analytic methods used for Bacteriological Contamination

S. No	Parameter	Analytical Method	
1	Total Coliform (CFU/100 ml)	9222-B, C&D, Standard Methods APHA, 2012	Membrane Filtration Procedure /Technique
2	Fecal Coliform (CFU/100 ml)		
3	Escherichia Coliform (E. coli) (CFU/100 ml)		

Determination of Total Coliform, Fecal Coliform and E. *Coli*

For the determination of total coliform bacteria in water samples, membrane filtration (MF) Technique was used (Standard Method APHA, 1992). MF is most suitable technique for analysis of water samples; however, MF may be used in the analysis of sample from all stages of treatments and distributions and those sources of water having moderate turbidity.

Membrane filters are best for water sampling and suitable for the growth of bacteria colonies ((Abdul et al., 2012). The membrane is placed on a filter pad, which has been saturated with liquid medium, or it is placed on solid medium. The glassware used during the testing procure include Flasks, petri dish, sterile petri plates and sterile bottles (Collin and Lyne, 1985).

The instrument used in experiment are incubator, biosafety cabinets, autoclave oven, water bath, Grid-marked membrane filters, membrane filter assembly, colony counter etc. The culture media and reagents employed in the process are M-Endo agar LES, M-FC agar, Modified membrane-Thermotolerant and 70% ethanol (PCRWR, 2018).

Preparation of Media:

Media was prepared for detection of Coliforms, Fecal Coliforms and E. *Coli*. Dehydrated media was prepared and used following supplier's instructions. Three types of media were prepared for identification and estimation of Coliforms, Fecal coliforms and E. *Coli*. First the media was weighed in aluminium foil and respective quantity as per manufacturer's instruction for rehydration and then pH of the media was measured before pouring the medium to test tubes. M-Endo Agar and MFC media was heated till boiling whereas m-TEC media was sterilized in autoclave at 121 °C for 15-20 minutes (WHO, 2004).

For the preparation of L.E. S. Endo agar Medium, constituents of agar includes; yeast extract, 1.20 g, Trypticase 3.70 g, Thiopeptone, 3.70 g, Tryptose,7.50 g, Lactose, 9.40 g, Dipotassium hydrogen phosphate, 3.30 g, Potassium dihydrogen phosphate, 1.00 g, Sodium chloride, 3.70 g, Sodium deoxycholate, 0.10 g, Sodium lauryl sulphate, 0.05 g, Sodium sulphite, 1.60 g, Agar 15.0 g, distilled water,1 L, pH was7.2 (PCRWR, 2008).

In the preparation the constituents are then re-dehydrated in distilled water containing 20ml of 95% ethanol, heated to boiling, removed from heat and cooled to below 45 °C. Final pH was between 7.1 and 7.3 and it it was not exposed to direct sunlight (Standard Method APHA, 1992).

For the Preparation of MFC agar Medium the agar constitutes of yeast extract, 3.0 g, Tryptose, 10.0 g, Polypeptone, 5.0 g, Sodium chloride,5.0 g, Lactose, 12.5 g, Bile salts mixture, 1.5 g, Alinine blue, 0.1 g, Agar, 15.0 g, distilled water,1 L and pH 7.4. In preparation, the re-dehydrated in distilled water containing 10ml of 01% Rosalic acid in 0.2N NaOH, heated to boiling, and removed from heat and cooled to below 45 °C. Final pH was kept at 7.4. and it was stored at 2-10 °C (APHA, 1998)

The Preparation of Modified mTEC agar, the constituents of the agar include, yeast extract, 3.0 g, Protease peptone, 5.0 g, Lactose, 10.0 g, Sodium Chloride, 7.5 g, Dipotassium phosphate, 3.3 g, Monopotassium phosphate, 1.0 g, Sodium lauryl sulfate,0.2 g, Sodium desoxycholate, 0.1 g, Chromogen (5-bromo-6-chloro-3-indolyl-β-D-glucuronide), 0.5 g, Agar,15.0 and Reagent-grade water,1.0 L.

For the preparation the dry ingredients were added to 1 L of reagent-grade water and mixed it thoroughly and heated to dissolve it completely. Then it was Autoclaved at 12 °C for 15 minutes and cooled in a 50 °C water bath. The pH was adjusted to 7.3 with 1.0 N hydrochloric acid. The medium was then poured to 9 x 50 mm culture dishes to a 4-5 mm depth (approximately 4-6 mL) and allowed them to solidify. The culture dishes were stored in a refrigerator (Standard Method APHA, 1992).

For the water dilution water is dilated by using peptone, 1.0 g, Sodium chloride, 8.5 g, distilled water, 1000 ml and pH 7.0. In the preparation ingredients were dissolved in 1000 ml of deionized water the pH was adjusted to keep the pH 7.0 at 25 and then sterilization was done through autoclaving at121 °C for 15 min.

The dilatants were then poured in 9 ml capacity test tube. 95% Ethyl alcohol was used as sterilizing solution. Which constitute of absolute alcohol, 95 ml and 05ml distilled water. 70% Ethyl alcohol was also used as sterilizing solution, 70 ml absolute alcohol and 30 ml of distilled water. All sterilized media were stored in refrigerator at 4-8 °C and all the reagents are kept at 15-25 °C. Media quality control was done by using E-*Coli* and Staphylococcus aureus. Detail of culture used, and their expected results is given at Table A& B. (Standard Method APHA, 1992).

Table. 2.8 Cultures to be used in media quality control procedures:

Medium	Positive control	Negative control	Incubation condition
L.E.S. Endo Agar	*E. coli*	*S. aureus*	35 ºC for 24 hrs
MFC agar	*E. coli*	*S. aureus*	44.5 ºC for 24 hrs
m-TEC agar	*E. coli*	*S. aureus*	35 ºC for 2 hours and 44.5 ºC for 22 hrs

Table 2.9 Expected reactions of positive and negative controls

Medium	Positive control	Negative control
L. E. S. Endo Agar	Dark red colour colonies with metallic sheen	No Growth
M FC agar	Blue colour colonies	No Growth
m-TEC agar	Reddish Pink colonies	No Growth

The performance of sterility check was carried out through incubation of sterilized m-Endo agar, m-FC agar and m-TEC agar plates at 35 °C and 44.5°C for 24-48hrs. The growth of colonies was not observed which confirmed the agar is sterile (PCRWR, 2018).

The size of sample was governed by the expected bacterial density 100 to 500 ml was filtered as bacterial count was expected as high and suitable dilution of the sample were made. The apparatus and materials used in (MF) method include, the autoclave-able parts of membrane filtration assembly were carefully wrapped in aluminium foil and were autoclave at 121 °C (WHO, 2004).

Also, the membrane filters were placed in biological safety cabinet and sterilized under UV for 15-20 minutes. Before and after each sample, 70% ethanol was passed, then 90 % ethanol was passed. Finally, sterilized water was passed to wash away completely. When the media temperature was reached at 45 °C, it was poured in petri plates and then allowed to solidify (Collin and Lyne, 1985).

A sterile filter paper was placed over the porous plate of the filtration unit. Filtration was accompanied by passing the sample through the filter under the partial vacuum. Funnel was unlocked and removed immediately, and filter membrane was removed to place solid surface, L.E.S m-Endo agar for Coliforms, M-FC agar for Faecal Coliforms and E. coli for m-TEC with a rolling motion and avoided the entrapment of air (Standard Method APHA, 2012).

The filtration units were sterilized at the beginning of each filtration series. The plates were incubated (inverted) at 35 °C for 24 hours for Coliforms growth indication and at, 44.5 °C for 24 hours for fecal Coliforms (PCRWR, 2005). The colonies were reported in colony forming units per milli-litre (cfu/ml) which relate to original sample (WHO, 2004). The bacteria were then calculated through colonies formations. The typical coliform colony had a pink to dark red colour with metallic sheen in m-endo agar. Similarly, the E. *Coli* colonies were of blue colour in M-FC media. The target colonies on modified mTEC agar were red or magenta in colour after the incubation period (Standard Method APHA, 2012).

The resulted were expressed for Total Coliform, Fecal Coliform and E. Coli separately. Confirmed total coliforms were recorded as CFU per 100 ml of sample as determined by the membrane filtration method. Similarly, Faecal Coliforms were recorded as CFU per 100 ml of sample as determined by the membrane filtration method and lastly confirmed E-*Coli* were also recorded as CFU per 100 ml of sample as determined by the membrane filtration method (PCRWR, 2005).

2.7.5. National Drinking Water Quality Guidelines and Standards

Environmental protection Agency (EPA) Pakistan in consultation with Ministry of Health, National University of Science and Technology, PCRWR, WHO and UNICEF has drafted and finalized the National Standards for Drinking Water Quality (NSDWQ). Provincial governments and other key stakeholders were also involved in the process through consultative meetings and it was ensured that standards are align with international standers. EPA has notified the NSDWQ in the Gazette with S.R.O-1063(1)/2010 and are required to meet for drinking water quality. Provincial governments are also complying with these standards and included them in their drinking water polices.

The NSDWQ provides guidelines for drinking water quality for human use. To ensure enforcement of standards, Government of Pakistan has a dedicated body responsible for quality control and assurance- The Pakistan Standard and Quality Control Authority (PSQCA), the organization is responsible for standardization of quality standards. The basic purpose of provision of the standards is ensuring the provision of clean and safe drinking water to all the citizen of the country. For declaring water clean and safe multiple water quality parameters were considered to assess drinking water is suitable for human use considering its physical, chemical and microbiological requirements and permissible limits. (SDPI, 2017)

The country has not considered additional parameters like pesticides, phenolic compounds, sulphates and other hazardous aromatic hydrocarbons (PAHs), to national drinking water quality standards. There is needed to review national drinking water quality standards, especially for total hardness, lead, cadmium and arsenic which are higher than the WHO drinking water quality standards and might require revisions.

The alarming high levels of various toxic chemicals such as arsenic and fluoride are common concern related to drinking water. Limited use of purification technologies further aggregates the situation especially in rural areas of the country (Khwaja et al., 2011).

Table 2.10 Water Quality Permissible limits for Drinking water

S. No	Parameter	Unit	Permissible Limit -WHO	Permissible Limit NDWQS
1	Color	TCU	15	Colorless
2	Taste	-	Tasteless	Unobjectionable
3	Odor	-	Odorless	Unobjectionable
4	Temperature	-	-	-
5	pH	-	6.5-8.5	6.5-8.5
6	Hardness	mg/l	NGVS	500
7	Turbidity	NTU	5	<5
8	Alkalinity	mg/l	NGVS	NGVS
9	EC	µS/cm	NGVS	NGVS
10	TDS	mg/l	1000	1000
11	CO3	mg/l	NGVS	NGVS
12	Ca	mg/l	NGVS	NGVS
13	CO3	mg/l	NGVS	NGVS
14	Cl	mg/l	250	250
15	Fl	mg/l	1.5	1.5
16	Fe	mg/l	0.3	0.3
17	Mg	mg/l	NGVS	NGVS
18	NO3	mg/l	10	10
19	K	mg/l	NGVS	NGVS
20	Na	mg/l	200	NGVS
21	SO3	mg/l	250	NGVS
22	As	mg/l	0.01	0.01
23	Cr	mg/l	0.05	0.05
24	Cu	Mg/l	2.0	2.0
25	Hg	mg/l	0.006	0.001
26	Pb	mg/l	≤0.01	≤0.05
27	Zn	mg/l	2.0	5.0
28	Total Coliform	CFU/100ml	0	0
29	Fecal Coliform	CFU/100ml	0	0
30	Escherichia Coliform (E. coli)	CFU/100ml	0	0

CHAPTER 3

RESULTS AND DISCUSSION

The drinking water quality of District Mansehra was assessed by testing water samples from multiple sources and locations. The water samples were collected from 18 major settlements of the district from multiple water sources such as spring, dug well, Bore Hole, water supply schemes and tube wells (Ahmed et al., 2017). Both surface and ground water used for various needs such as drinking water, cooking and sanitation needs, beside agricultural activities (Bibi et al., 2010). The water quality testing parameters i.e. physical, chemical and biological were tested in the water quality testing laboratory of PCRWR.

The physical characteristics, color, taste, odor, temperature, pH, EC, TDS, and the inorganic parameters were tested (Bibi et al., 2010). The chemical parameters analyzed included; carbonates, bicarbonates, Chlorides, Sulphate, Calcium, Magnesium, hardness, Potassium, Alkalinity, Sodium and Nitrate. Heavy metals and trace elements were also tested in water samples which included; Arsenic, Iron, Lead, Copper, Chromium, Mercury. The water samples had been analyzed for biological parameters such as Total Coliform, Fecal Coliform and E. coli (Khan et al.,2012). The result of the analysis was matched with WHO and GoP water quality guidelines and standards.

From 18 major towns of District Mansehra, total 56 drinking water samples were collected from various water supply sources as shown in table 3.1.

Table 3.1 Types of Sources and Number of Samples collected for Analysis

S. No	Sources	No of Samples
1	Spring Water	18
2	Tap Water	18
3	Bore Hole Water	08
4	Dug Well Water	09
5	Tube Well Water	3
	Total	56

Physical, chemical and bacteriological examination showed that out of 56 water samples of different sources, 54 (96%) samples were beyond permissible limits of NDWQS, and hence, unsafe for drinking. Most of the samples i.e. 49 (87%) were unsafe due to bacterial contamination. Iron was second highest contaminant found in 30 (54%) samples. The details of samples beyond permissible limit is mentioned in table 3.2.

Table 3.2 Types and number of samples beyond permissible limits

Number of Samples Beyond Permissible Limits of NDWQS											
Source	**TDS (mg/l)**	**Hardness (mg/l)**	**Iron(mg/l)**	**Nitrate(mg /l)**	**Turbidity (NTU)**	**Total Coliform (CFU)**	**Fecal Coliform (CFU)**	**E. Coli (CFU)**	**Safe**	**Unsaf e**	**Total**
Dug Well (n=9)	0	3	6	5	0	9	9	9	0	9	9
Bore Hole (n=8)	3	2	5	6	2	4	4	4	2	6	8
Tap (n=18)	0	0	7	4	1	18	18	18	0	18	18
Spring (n=18)	0	1	9	0	4	18	18	18	0	18	18
Tube Well (n=3)	0	1	3	2	0	0	0	0	0	3	3
Total	**3**	**7**	**30**	**17**	**8**	**49**	**49**	**49**	**2**	**54**	**56**

3.1. Bacteriological Contamination

For the analysis of microbiological contamination in water, 56 water samples were taken from multiple locations of district Mansehra of Khyber Pakhtunkhwa province. Samples were taken from major towns and from multiple water sources, both from surface and ground water. (Ahmed et al., 2017). Majority of the drinking water samples collected from Mansehra, Balakot, Batta Kandi, Besal, Burwae, Dadai, Darband, Gari Habibullah, Gittidas, Jabori, Jared, Kaghan, Kaawai, Naran, Oghi, Phulra, Shehr Garh and Shinkiari were showing presence of microorganism except 6 samples.

Out of 56 samples collected from spring, well, distribution network, stream and tap water collected from 18 sites of District Mansehra, 50 were found positive for total coliforms, faecal coliform and E. *Coli* (Ahmed et al, 2017). 90 % of the drinking water of the district is biologically affected and unsafe for drinking as shown in the table 3.3.

Table 3.3 Bacteriological contaminations in various water sources

S. No	Locations	Sources	Total Coliform 0 CFU/ml	Fecal Coliform 0 CFU/ml	E. *Coli* 0 CFU/ml	Safe/ Unsafe
1	Balakot	Spring	22	8	2	Unsafe
2	Balakot	Dug Well	48	8	4	Unsafe
3	Balakot	Tap	38	30	16	Unsafe
4	Balakot	Bore Hole	25	6	2	Unsafe
5	Batta Kundi	Spring	49	34	22	Unsafe
6	Batta Kundi	Tap	30	40	30	Unsafe
7	Besal	Spring	64	42	22	Unsafe
8	Besal	Tap	75	39	25	Unsafe
9	Burwae	Spring	72	18	6	Unsafe
10	Burwae	Tap	90	25	15	Unsafe
11	Dadai	Spring	32	16	10	Unsafe
12	Dadai	Tap	50	20	25	Unsafe
13	Darband	Dug Well	38	22	10	Unsafe
14	Darband	Bore Hole	58	10	8	Unsafe
15	Darband	Spring	82	16	10	Unsafe
16	Darband	Tap	78	46	12	Unsafe

17	Gari Habibullah	Spring	40	26	18	Unsafe
18	Gari Habibullah	Dug Well	52	22	16	Unsafe
19	Gari Habibullah	Bore Hole	69	28	12	Unsafe
20	Gari Habibullah	Tap	42	12	8	Unsafe
21	Gittidas	Spring	49	36	20	Unsafe
22	Gittidas	Tap	56	40	18	Unsafe
23	Jabori	Spring	44	24	10	Unsafe
24	Jabori	Tap	42	12	10	Unsafe
25	Jabori	Dug Well	62	10	6	Unsafe
26	Jared	Spring	45	24	14	Unsafe
27	Jared	Tap	40	30	14	Unsafe
28	Kaghan	Spring	48	18	8	Unsafe
29	Kaghan	Tap	36	12	10	Unsafe
30	Kawai	Spring	52	12	8	Unsafe
31	Kawai	Tap	59	8	10	Unsafe
32	Mansehra	Tap	32	18	10	Unsafe
33	Mansehra	Bore Hole	58	44	14	Unsafe
34	Mansehra	Dug Well	24	10	8	Unsafe
35	Mansehra	Spring	38	16	10	Unsafe
36	Mansehra	Tube Well	0	0	0	Safe
37	Naran	Spring	56	30	18	Unsafe
38	Naran	Tap	52	12	4	Unsafe
39	Oghi	Dug Well	74	8	4	Unsafe
40	Oghi	Bore Hole	0	0	0	Safe
41	Oghi	Spring	55	18	10	Unsafe
42	Oghi	Tub Well	0	0	0	Safe
43	Oghi	Tap	62	40	8	Unsafe
44	Phulra	Dug Well	62	12	10	Unsafe
45	Phulra	Bore Hole	0	0	0	Safe
46	Phulra	Spring	40	12	8	Unsafe
47	Phulra	Tap	48	20	14	Unsafe
48	Sher Garh	Dug Well	42	32	12	Unsafe
49	Sher Garh	Spring	30	8	6	Unsafe
50	Sher Garh	Tap	50	16	12	Unsafe

51	Sher Garh	Bore Hole	39	12	9	Unsafe
52	Shinkiari	Dug Well	78	32	16	Unsafe
53	Shinkiari	Bore Hole	0	0	0	Safe
54	Shinkiari	Spring	85	22	12	Unsafe
55	Shinkiari	Tap	48	20	10	Unsafe
56	Shinkiari	Tub Well	0	0	0	Safe

Only 11 % of the water samples were found without any bacteriological presence and fit for drinking. Total 06 samples found safe for drinking include, tube well water of Mansehra, Shinkari, Oghi and Bore hole water of Ogi, Sher Garh and Phulra. 100 % of the water samples collected from sources like spring, dug well, distribution network and tap water were positive of total coliforms, faecal coliform and E. *Coli*. Deep ground water source of tube well and three bore holes were found safe. The tube well water was found safe and has no contamination (PCRWR, 2005).

The presence of E. *Coli* and coliform indicates the poor sanitary conditions and mixing of sewerage water with drinking water lines (Khan et al., 2012). It is evident from the data that majority of population is drinking water mixed with sewerage water and there is limited awareness about issues related with open defecation. The wastewater disposal system does not in most of the areas of district Mansehra (Ahmed et al., 2017).

There are less chances of contamination in ground water especially tube wells which is at the depth of 120-150 feet. The water transported through piping system is more vulnerable to contamination, as both drinking water and sewerage line run parallel in urban areas of the district (PCRWR, 2005). Majority of the population in the study area use water from dug wells for drinking and wells are usually open without proper cover and prone to contamination. Similarly, septic tank found near the well also contaminate dug wells. Open defecation practices are also prevalent in the area further increase risk of presence of bacteria in drinking water (Ahmed at al., 2017).

Total coliform bacteria are the major causes of digestive problems and water borne diseases such as nausea, diarrhoea, dysentery, Cholera, typhoid (Emmanuel et al., 2009). Microbiological presence in drinking water has serious health implications for locals, and the diseases like, vomiting, cholera, skin diseases jaundice are very common (Hussain et al., 2011).

3.2.1. Contamination in Spring

Spring water is the main source of drinking water for the residents of district Mansehra (Khan et al., 2013) and samples of spring water were collected from all 18 sites were found microbiological contamination (Ahmed et al, 2017). 100 % of the spring water samples collected from Balakot, Batta Kandi, Besal, Burwae, Dadai, Darband, Gari Habibullah, Gittidas, Jabori, Jared, Kaghan, Kaawai, Manshera, Naran, Oghi, Phulra, Shehr Garh and Shinkiari were showing significant presence of coliforms and fecal coliforms. Highest number of total coliforms were found in spring water samples of Shinkiari District, Darband district, Burwae district, Besal.

The total coliform in Naran, Oghi ranging from 85 to 50 CFU/ml. However, all other sites showed presence of total coliforms ranging from 50 to 20 CFU/mll All other samples had presence of Fecal coliforms ranging from 8-22 CFU/ml, respectively. Highest number of *E. coli* was present in the samples of Besal and Batta Kundi sites with 22 CFU/ml and Gittidas with 20 CFU/ml. Other samples also showed presence of E. *Coli* in the range of 2 to 18 CFU/ml. All the spring water of the district is unsafe and not for drinking (Ahmed et. al, 2017).

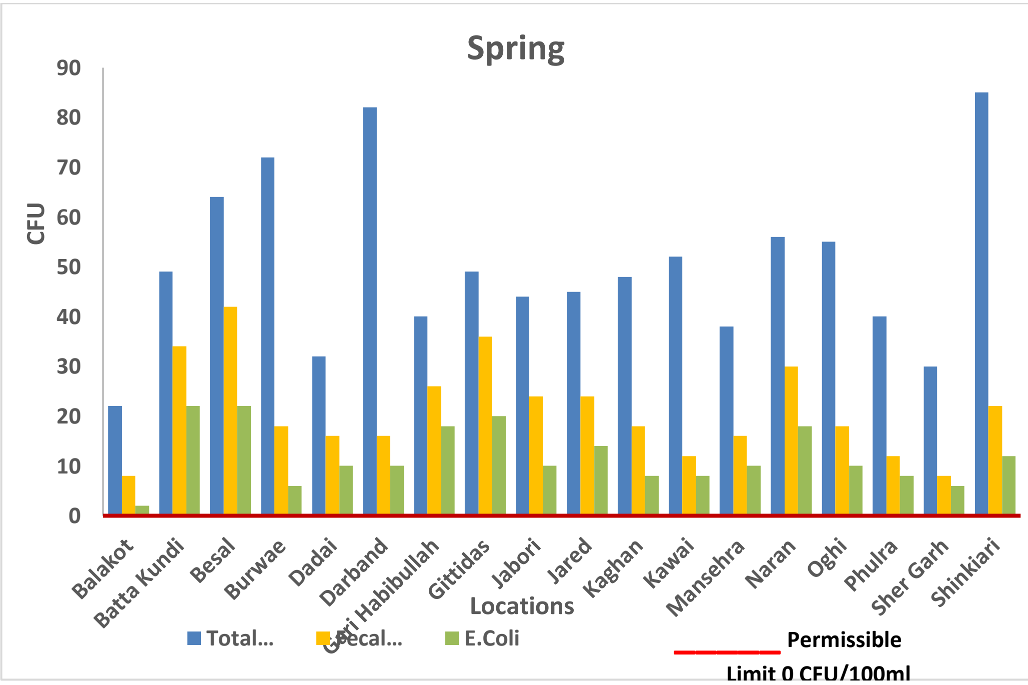

Figure 3.1 Bacteriological contamination in Spring Water of District Mansehra

The most definite presence of fecal contamination is indicated by fecal coliforms and *E. coli* that is also included in fecal coliform group of bacteria (PCRWR, 2005). Results obtained depicts the presence of fecal coliforms in all samples hinting toward high level of fecal contamination of spring water thus a serious threat to human health (InamUllah, 2014). Highest number was recorded in the spring water samples of Besal with 42 CFU/ml, followed by Gittidas with 36 CFU/ml and Betta Kundi 34 CFU/mL.

Mansehra is mountainous district and majority of population relay on spring water considering it safer and fit for drinking (Ahmed et al., 2017). Spring are open sources of water and close to animal pastures and rain and other water runoff bring animals faces to surrounding water sources (Aziz Ullah et al., 2011). The inhabitants of the area are dependent on Spring for their drinking needs.

The results paint a dismal picture of Fecal contamination in spring water samples. Lakes, rivers surface water is more exposed to bacteriological contamination (Aziz, 2005) which are the major sources of drinking water Mansehra District. The health issues related with drinking the biologically impacted water is gastrointestinal problems, urinary tract infections and diarrhoea and dysentery (Sher et al, 2010; Aziz, 2005).

3.2.2. Contamination in Tap

Tap water collected from 18 sites of the district Balakot, Batta Kandi, Besal, Burwae, Dadai, Darband, Gari Habibullah, Gittidas, Jabori, Jared, Kaghan, Kaawai, Manshera, Naran, Oghi, Phulra, Shehr Garh and Shinkiari were found contaminated with total coliforms, fecal coliforms and *E. coli* as shown in figure. 100% of the samples collected from tap were positive of microbiological contamination (Anwar et al., 2010). Tap water available at homes come from two sources, tube well and spring, the water is supplied through network of pipes and sometimes taken from far long areas. (PCRWR, 2005).

Water samples from the 18 sites result showed the presence of total coliforms with highest being in the Burwae, Darband, Besal and Oghi area with 90, 78, 75, 62 CFU/ml of coliforms. All other locations had the presence of coliforms ranging from 35 to 59 CFU/ml. Furthermore, fecal contamination was also spotted in all samples with highest in Darband 46 CFU/ml, Gittidas 40 CFU/ml, Oghi 40 CFU/ml and Batta Kundi 40 CFU/ml and lowest in in Kawai 8 CFU/mL.

Highest concentration of *E. coli* was present in Betta Kundi with 30 CFU/ml, Besal 25 CFU/ml, Dadai 25 CFU/ml. All other samples were also contaminated with *E. Coli* with the range of 4 to 16 CFU/ml. Thus, all the 18 tap water samples analysed were found unfit for drinking and unsafe for human consumption due to alarming level of coliforms and E. *Coli* (Aziz, 2005).

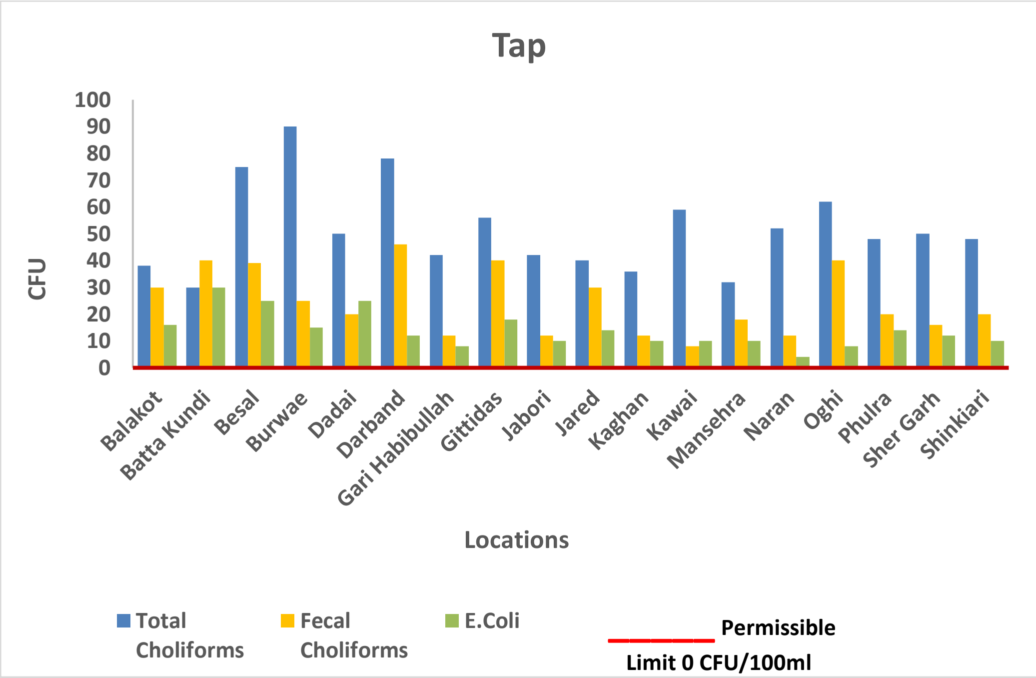

Figure 3.2 Bacteriological contamination in Tap water of District Mansehra

The presence of E. Coli and coliform refer to the poor health and hygiene conditions and mixing drinking water with grey water (Azizullah et al., 2011). It was also found that large proportion of the populations is drinking contaminated water without any filtration despite the fact that waste disposal system is inefficient and poor in various urban and rural settings of the district (Ahmed et al., 2017).

Presence of total coliforms is not considered harmful generally because of presence of its abundance in soil and organic matter, however, presence of fecal coliforms and E. coli is an obvious indication of fecal contamination in water that is unsafe for consumption without treatment. The water borne diseases like typhoid, nausea, cholera is common in the area (Sher et al., 2010).

3.2.3. Contamination in Dug Well

Dug well water collected from 09 different locations Balakot, Darband, Gari Habibullah, Jabori, Manshera, Oghi, Phulra, Shehr Garh and Shinkiari were analyzed for the presence total coliform, fecal coliform and E. coli (Ahmed et al., 2017).

There are two main sources of drinking water in the hilly areas of Kawai, Jared, Kaghan, Naran, Besal, Dadai, Gittitas, battakundi and Burwae, spring and tap water (Ahmed et al., 2017). 100 % of the Dug well samples collected from 9 different location were found positive for total coliform, fecal coliform and E. coli (Khan et al., 2013).

Highest number of total coliforms were found in dug well water samples of Shinkari town around 78 CFU/ml, with 32 CFU/ml of fecal coliform and 16 CFU/mL of *E. coli* bacteria. Sher Garh District also had 32 CFU/ml of fecal coliforms and 12 CFU/ml of *E. coli* bacteria that indicates significant fecal contamination in dug well water. Whereas, Oghi, Jabori, Phulra, Gari Habibullah, Balakot, Darband and Mansehra has total coliform presence of 74, 62, 62, 52, 48, 38 and 24 CFU/ml, respectively. In general, the coliform and E. *Coli* exceeds the WHO standard limit of 0 CFU per 100 ml of water set by WHO (Khan et al., 2013).

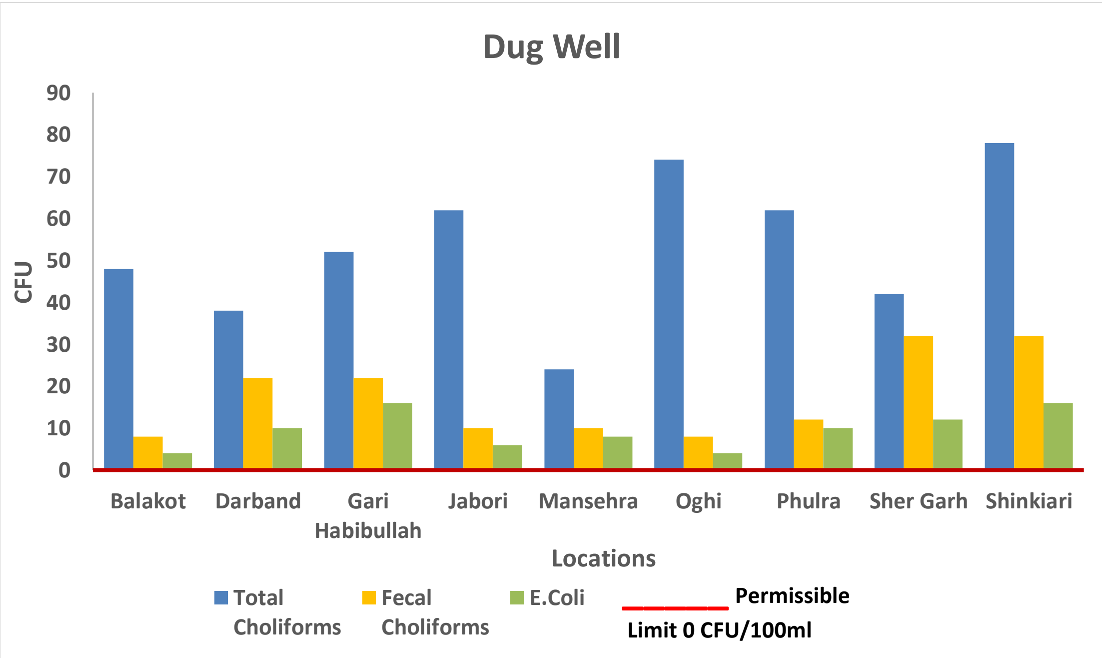

Figure 3.3 Bacteriological contamination in Dug Well of District Mansehra

The high level of Coliforms bacteria indicate seepage from septic tanks, poor sewage and waste disposal system and other health and hygiene conditions of the population (Khan et al., 2013). 100 % of the sample contamination in dug well is showing limited awareness about health and hygiene, safe disposal of waste and non-availability of purification technologies (Ahmed at al., 2017) are present naturally in soil, organic matter and faecal products of humans and animals.

However, presence of faecal coliform indicates the fecal contamination in water. *E. coli* is definite proof of fecal contamination. Additionally, presence of fecal coliforms and E. coli in all samples confirm fecal contamination that renders water unsafe for human consumption (PCRWR, 2018).

3.2.4. Contamination in Bore Hole

Bore hole has become a popular source of drinking water in Mansehra, the depth of the bore hole in the district varies due to landscape of the area and water table (Khan et al., 2012). Both kind of bore holes are common in district, one with the manual hand pump and other with electric motor used for pumping of water from the ground (NDMA, 2008). Most of the urban house hold in the district is dependent upon motorized pumps for pumping of fresh water from the ground (PCRWR, 2008).

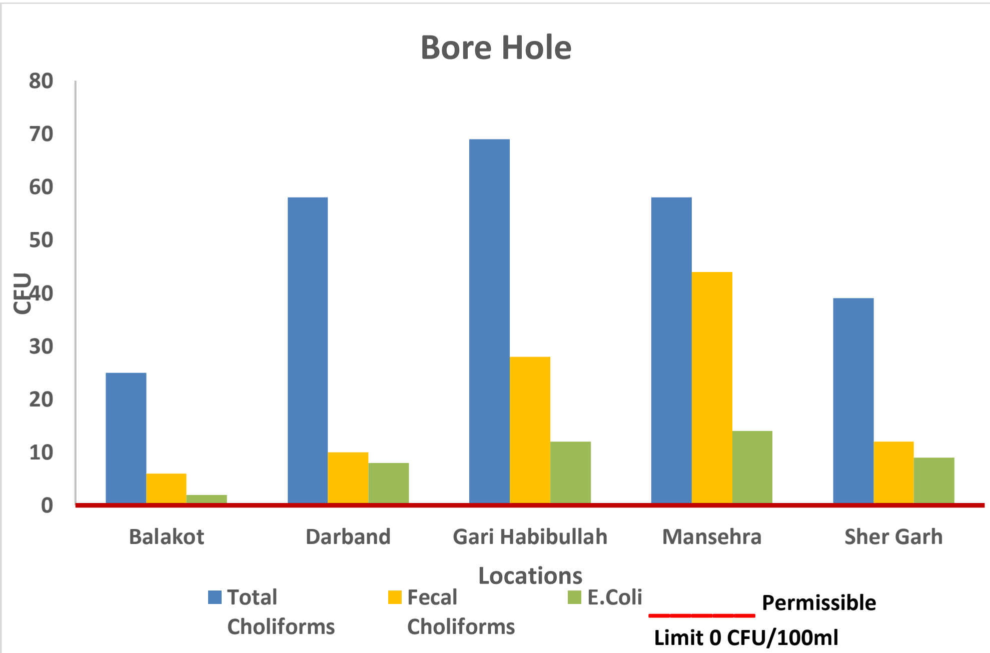

Figure 3.4 Bacteriological contamination in Bore Holes of District Mansehra

Bore hole water samples were collected from 8 sites of District Mansehra, Balakot, Darband, Gari Habibullah, Manshera, Oghi, Phulra, Shehr Garh and Shinkiari. The microbiological analysis of water samples showed that water of Balakot, Darband, Gari Habibullah and Mansehra have alarming number coliforms, fecal coliforms and *E. Coli*.

Highest number of coliforms were spotted from Gari Habibullah 69 CFU/ml, followed by Manshera city 58 CFU/ml, Darband 58 CFU/ml, Balakot 25 CFU/ml. Moreover, fecal coliforms were highest in Manshera (44 CFU/ml), Gari Habibullah (28 CFU/ml), Darband (8 CFU/ml), Balakot (6 CFU/ml). E. coli was also detected in Manshera 14 CFU/ml, Gari Habibullah 12 CFU/ml, Darband 8 CFU/ml, Balakot 2 CFU/ml.

It was found that the drinking water of bore hole of Oghi, Phulra and Shinkari were within the permissible limits of WHO that is 0 no of bacteria in 100 ml of water sample. The situation of bore water is different compared to spring, tap and dug well. From bore holes 62.5 % of samples were found with contamination compared to spring, dug and tap water where 100 % of the samples were positive for coliforms and E. Coli. 37.5 % of the samples from bore hole were found within safe limit and water is safe for human consumption.

Presence of fecal coliforms and *E. Coli* render the water is unsafe and contaminated. The main factor behind the contamination in bore hole is rainfall runoff and prevalent sanitary conditions in the areas (Anwar et al., 2010). Similarly, the water distribution pipes were rusted and vulnerable to contamination due to defective joints and mixing of water from septic tanks to ground water especially in the areas of shallow water sources. (Azizullah, et al. 2011).

Microbiological contamination is serious threat for residents of the district drinking water from bore hole considering it safe and fit for drinking (Anwar et al., 2010). The bacterial presencw in the water is causing endemic diarrhoea (Soomro et al., 2011). Water related diseases like typhoid, cholera, typhoid, hepatitis, cryptosporidiosis and guinea worm infections are due to poor quality of water and (Aziz Ullah et al. 2011).

3.2.5. Contamination in Tube Well

There are only few tube wells in district Mansehra, majority of population is dependent upon shallow water sources (NDMA, 2008). Most of the tube well in Mansehra is providing water for agriculture and used for irrigation purposes. There are only three locations in Mansehra, that is Mansehra city, Shinkari town and Oghi where tube wells were found and used for drinking purposes (NDMA, 2008).

In district Mansehra there is limited availability of tube wells so the only available tube wells from where the samples collected were Shinkari, Oghi and Mansehra. The analysis of tube well water showed that water is free from any type of coliforms, fecal coliforms and *E. coli* contamination. The tube well water source of district is matching with WHO water gridline of 0 percent presence of total coliform, Faecal Coliform and E. Coli and found to be safe source of clean drinking water with respect to microbiological contamination (Ahmed et al., 2017) Therefore, it can be concluded that the tube well water is safer among samples taken from bore hole, spring, dug well and tap water.

The water from tube well is less prone compared with shallow water sources, the tube wells are deeper than bore holes. There are slim chances of rainwater runoff and waste water seepage (PCRWR, 2010). Community awareness about safe and clean drinking water resources is limited in the district and tube wells were majorly used for agriculture purposes and communities still prefer to use spring water (Ahmed et al., 2017).

As shown in the figure 90 % of the drinking water samples of the district Mansehra were found positive for bacteriological presence thus making water unfit for human consumption. (Azizullah et al., 2011). Only 10 % of the water samples are providing clean and safe drinking water to district residents. All the 18 sites shown in the fig have high level of total Coliform, Fecal Coliform and E. *Coli* presence effecting drinking water quality.

Large number of populations of District is dependent upon spring and dug well water and surface water has more tendency for microbial contamination compared to ground water sources, which are not popular in mountainous areas (PCRWR, 2005). 100 % of the spring, dug well and tape water was unsafe and not suitable for drinking and have ability to cause multiple water borne diseases (Soomro et al., 2011).

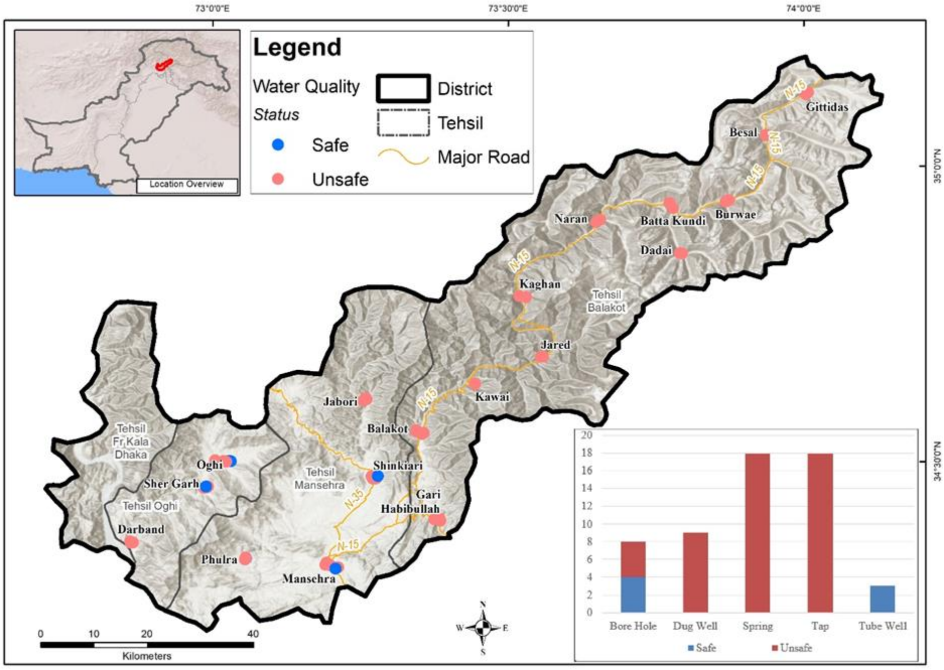

Figure 3.5 Water Quality Status of various water sources of District Mansehra

3.2. Aesthetic Aspects

The drinking water samples collected from multiple sources of drinking water were further tested for aesthetic parameters, the aesthetic aspects include; color, taste, odor and temperature. Mainly this aesthetics do not have direct health impacts but still they are important for water quality testing (Khan et al. 2013).

Taste and odor of the water is noticeable problem. 100 % of the samples tested for colour taste and odor were found non objectionable. Although there are no guiding values for aesthetic parameters still, they are important and for drinking purposes water need to be tasteless and colorless and should not have any foul odor. People uses surface water of streams and spring for various domestic and commercial purposes (Ali et al., 2019).

The test confirmed that the drinking water collected from 18 sites Balakot, Batta Kandi, Besal, Burwae, Dadai, Darband, Gari Habibullah, Gittidas, Jabori, Jared, Kaghan, Kaawai, Manshera, Naran, Oghi, Phulra, Shehr Garh and Shinkiari were tasteless, odorless and colorless having good aesthetic properties and within permissible limits of WHO and EPA (Hashmi et al.2009).

Similarly, the temperature noted at time of collection of water samples from multiple locations ranges between 7.1◦C to 11◦C. For temperature EPA does not provide any guiding limits however WHO water quality guidelines consider water with temperature of maximum 12◦C safe for drinking (Tahir et al., 1996). Most of the samples of district Mansehra were below the safe limits. Temperature has critical role in growth of microorganisms, providing suitable grounds for bacteriological contamination (Ramteke et al., 1992). Moreover, temperature has direct impact on dissolved oxygen with is an important indicator for aquatic animals (Tahir et al., 1996).

3.3. Physcio- Chemical Aspects

The physical and chemical parameters of the drinking water of District Mansehra was tested in water quality testing laboratory of PCRWR in Islamabad. The drinking water samples collected from multiple sources of drinking water were further tested for physio- chemical aspects (Shah et al., 2012).

The samples analyzed were collected from Balakot, Batta Kandi, Besal, Burwae, Dadai, Darband, Gari Habibullah, Gittidas, Jabori, Jared, Kaghan, Kaawai, Manshera, Naran, Oghi, Phulra, Shehr Garh and Shinkiari. The physical parameters tested include; TDS, pH, EC, Alk, Turbidity and hardness (PCRWR, 2018). The details of water samples for these parameters is shown in below table 3.1.

Table 3.4 Physico-Chemical parameters results of drinking water samples

S. No	**Locations**	**Sources**	**pH**	**Electric Conductivity**	**Alkalinity**
			6.5-8.5	**NGVS µS/cm**	**500 mg/L**
1	Balakot	Spring	6.9	426	102
2	Balakot	Dug Well	7.2	636	202
3	Balakot	Tap	7.1	170	62
4	Balakot	Bore Hole	7	519	103
5	Batta Kundi	Spring	8	387	147
6	Batta Kundi	Tap	8	380	150
7	Besal	Spring	7.9	428	142
8	Besal	Tap	8.0	430	145
9	Burwae	Spring	7.2	7407	127
10	Burwae	Tap	7.9	7502	120
11	Dadai	Spring	7.2	518	140
12	Dadai	Tap	7.2	520	140
13	Darband	Dug Well	7.2	1314	498
14	Darband	Bore Hole	7.6	975	402
15	Darband	Spring	7.8	360	152
16	Darband	Tap	7.6	300	135
17	Gari Habibullah	Spring	7.8	369	122
18	Gari Habibullah	Dug Well	7.2	248	87

19	Gari Habibullah	Bore Hole	7.6	276	112
20	Gari Habibullah	Tap	7.3	158	62
21	Gittidas	Spring	7.4	428	122
22	Gittidas	Tap	7.0	435	110
23	Jabori	Spring	8.0	377	152
24	Jabori	Tap	8.1	321	152
25	Jabori	Dug Well	7.6	529	222
26	Jared	Spring	8.2	421	162
27	Jared	Tap	8.0	430	150
28	Kaghan	Spring	7.6	1281	252
29	Kaghan	Tap	7.4	645	152
30	Kawai	Spring	8.2	301	92
31	Kawai	Tap	8	335	76
32	Mansehra	Tap	8.1	880	287
33	Mansehra	Bore Hole	7.2	1363	322
34	Mansehra	Dug Well	7.5	1103	302
35	Mansehra	Spring	7.5	220	82
36	Mansehra	Tube Well	7	200	70
37	Naran	Spring	7.3	520	202
38	Naran	Tap	7.6	520	122
39	Oghi	Dug Well	7.6	1093	372
40	Oghi	Bore Hole	7.4	1820	402
41	Oghi	Spring	7.7	358	152
42	Oghi	Tub Well	7.1	1950	105
43	Oghi	Tap	7.5	1381	352
44	Phulra	Dug Well	7.2	1035	202
45	Phulra	Bore Hole	7.4	1075	302
46	Phulra	Spring	7.3	219	82
47	Phulra	Tap	7.5	596	86
48	Sher Garh	Dug Well	7.2	214	302
49	Sher Garh	Spring	7.9	365	132
50	Sher Garh	Tap	8.1	181	82
51	Sher Garh	Bore Hole	7.6	255	42
52	Shinkiari	Dug Well	7.4	193	72
53	Shinkiari	Bore Holee	7.5	670	222
54	Shinkiari	Spring	7.2	173	52
55	Shinkiari	Tap	7.9	668	252
56	Shinkiari	Tube Well	7.3	926	50

3.3.1. pH

The water samples tested for pH were found within safe limit. The pH of 100 % of samples was within the safe zone and ranges from 6.5.-8.5. The pH of drinking water samples of the district ranges from 6.9- 8.2. The maximum pH was recorded in the spring water of Kawai area, lowest pH was confirmed in the spring of Balakot town.

Similarly, 20 % of the samples have pH value above 8 which include tap and spring of Batta kundi, Jabori, Jared and Kawai and tap water of Mansehra and Sher Garh. 2 % of the water samples have pH at 7 that is tube well water of Mansehra city and bore hole of Balakot. However, the pH value of the remaining 73 % samples were between 8-6.9 as shown in table. In drinking water quality, the pH is an important parameter and indicates acidity or alkalinity of water and it usually changes in different seasons (Zeb et al. 2011). Drinking water samples of District Mansehra is mildly acidic with maximum acidic water of Balakot spring which is 6.9. pH of water is usually acidic in summers due to acidic nature of soil and moreover higher pH can be attributed to presence of carbonates and bicarbonates of calcium and magnesium in water. Natural weathering and geology are also affecting pH of the water sources. (Zeb et al., 2011).

3.3.2. Alkalinity

Alkalinity was analysed in drinking water of Balakot, Batta Kandi, Besal, Burwae, Dadai, Darband, Gari Habibullah, Gittidas, Jabori, Jared, Kaghan, Kaawai, Manshera, Naran, Oghi, Phulra, Shehr Garh and Shinkiari ares of District Mansehra. WHO Standards provide values of alkalinity in term of TDS of 500 mg/l (Mohsin et al., 2013). 100 % of the drinking water of Mansehra were found within permissible limit.

The Alkalinity of the drinking water of Mansehra district ranges from 50mg/l to 498 mg/l. Maximum value was recorded in Darband dug well 498 mg/l, followed by bore hole of Darband and Oghi 402 mg/l and minimum level of 50 mg/l was observed in tube well water of Shinkari area. It was found that the ground water of dug well, bore hole and tube well were more alkaline compared to surface water sources.

Rainfall runoff and domestic waste water seepage might cause higher level of alkalinity in ground water (Hashmi et al., 2009). Moderate concentration of water is critical in mostly water supply networks to control effects of acidity of water, higher alkaline water may impact water quality, but all the water samples are within WHO safe limit of 500 mg/l and have no health consequences (Mohsin et al., 2013)

3.3.3. EC

EC value of drinking water of district Mansehra varies from 170 μS/cm -7502 μS/cm, the highest value of 7502 μS/cm was recorded in tape water of Burwae area followed 7407μS/cm in the spring of Burwae. The minimum EC was confirmed in 170 μS/cm followed by spring water of Shinkari town 173 μS/cm area.

There is direct relationship between EC and TDS and presence of the dissolved salts such as sodium, calcium and magnesium, bicarbonate and chloride increase the EC of the drinking water (Hashmi et al., 2009). The EC of drinking water is usually high with dissolved ionic species. The high level of EC in Burwea water can be attributed to natural process of mineralization and weathering of the rocks (Muhammad et al., 2010).

There is need for further investigation to find reason for high value. The EC value of water with limited anthropogenic activities seems high because the area is remote and away from industrial activity but Burwea receive large influx of tourists in summer, a potential contributor to the EC of water resources (Hashim et al, 2009). There is no guiding value for EC by WHO.

3.3.4. Turbidity

For the Analysis of turbidity, Water samples collected from Balakot, Batta Kandi, Besal, Burwae, Dadai, Darband, Gari Habibullah, Gittidas, Jabori, Jared, Kaghan, Kaawai, Manshera, Naran, Oghi, Phulra, Shehr Garh and Shinkiari were tested to see the turbidity. WHO guiding range for turbidity of the drinking water is 5 nephelometric turbidity units (NTU) (Hashmi et al., 2009). The turbidity values of drinking water samples varied from 1 NTU to 22 NTU. In 12 % of the samples, turbidity values exceed permissible limits and 88 % of the water samples were found safe for drinking.

Table 3.5 Turbidity Concentration in drinking water samples of District Mansehra

S. No	Location	Spring	Tap	Bore Hole	Dug Well	Tube Well
1	Balakot	3	3	8	2	0
2	Batta Kundi	2	2	0	0	0
3	Besal	1	1	0	0	0
4	Burwae	1	1	0	0	0
5	Dadai	4	3	0	0	0
6	Darband	2	1	1	3	0
7	Garhi Habib Ullah	1	3	22	3	0
8	Gittidas	2	3	0	0	0
9	Jabori	6	1	0	2	0
10	Jared	11	11	0	0	0
11	Kaghan	1	3	0	0	0
12	Kawai	1	2	0	0	0
13	Mansehra	13	4	2	3	2
14	Naran	3	3	0	0	0
15	Oghi	3	2	2	4	2
16	Phulra	3	2	3	1	0
17	Sher Garh	3	2	3	2	0
18	Shinkari	7	3	2	2	1

The water samples of Ghari Habib ullah, Mansehra, Jared and Balakot, Jabori, Jared and Manseh were observed with abnormal turbidity values ranges from 8 and 22 NTU. Bore hole water of Garhi Habibullah was showing maximum turbidity of 22 NTU followed by 13 NTU in Mansehra spring, 11NTU in Jared spring and tape, 8NTU in bore water collected from Balakot. Moreover, turbidity of water samples collected from springs of Jabori and Shinkari were also found higher compared to the normal range of 5 NTU.

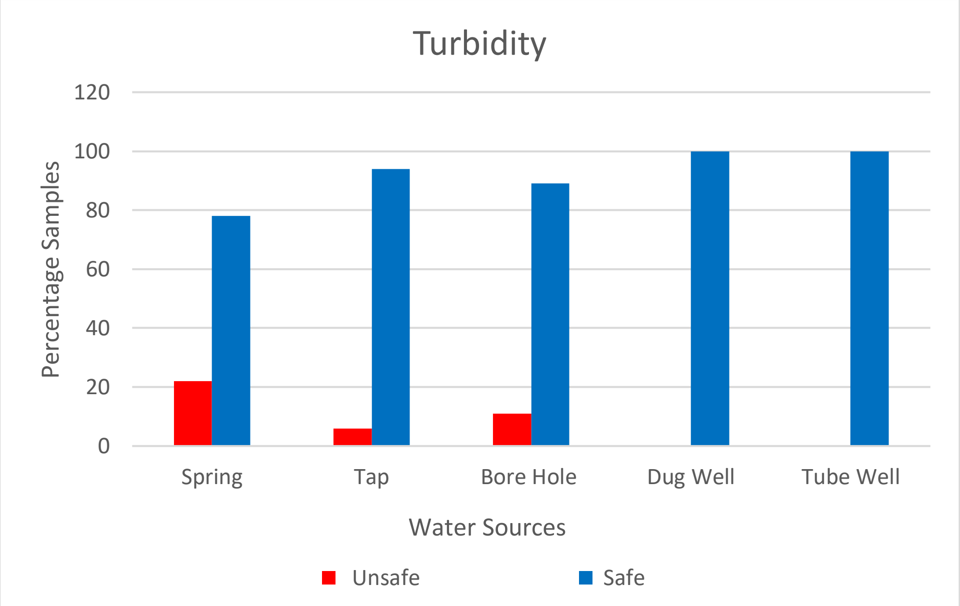

Fig 3.6 Turbidity in various water sources of District Mansehra

It is evident from the data that the spring water samples are more turbid followed by bore hole samples. Dug well and Tube well samples have shown considerably low turbidity concentration but some of the tap water were also found turbid. It was found that 22 % of the spring, 6 % Tap water & 11 % Bore Hole water samples were Unsafe for drinking.

The turbidity seems common problem in the district and it has direct link with microbiological contamination in the water (Hashmi et al., 2009). The chances of microbiological contamination increase with high values of pH, temperature and turbidity, all these factors provide suitable environment for the growth of microorganisms. (Hassan et al., 1983).

Deterioration in drinking water quality due to turbidity and iron concentration due to poor condition of pipes promote microbiological growth (PCRWR, 2005). During the months of summer with increase temperature and pH, turbidity and reduction in water supply provides favourable conditions for the growth of coliform bacteria (Hashmi et al., 2009).

3.3.5. Total Hardness

Drinking water samples collected from Balakot, Batta Kandi, Besal, Burwae, Dadai, Darband, Gari Habibullah, Gittidas, Jabori, Jared, Kaghan, Kaawai, Manshera, Naran, Oghi, Phulra, Shehr Garh and Shinkiari were tested for hardness to compare them with WHO desirable limits of 500mg/L of hardness (Mohsin et al., 2013). Overall high levels of hardness were found in water of district Mansehra. The hardness of drinking water ranges from 50mg/l to 602mg/l.

The highest concentration of 602 mgl/l was observed in spring water of Kaghan areas, followed by Darband dug well, 552 mg/l, Mansehra city bore hole 522 mg/l, Sher Garh dug well 515, mg/l, Mansehra Dug Well 508 mg/l and Oghi bore hole, 502 mg/l respectively. Hardness is an important characteristics of water quality which have impact of taste of the water and in conjunction with other contaminants cause diseases. The higher concentration of hardness in drinking water is making water unfit for drinking and other domestic use (Hashmi et al., 2009).

Table 3.6 Total hardness Concentration in drinking water samples of District Mansehra

S. No	Location	Spring	Tap	Bore Hole	Dug Well	Tube Well
1	Balakot	192	82	50	302	0
2	Batta Kundi	182	182	0	0	0
3	Besal	212	188	0	0	0
4	Burwae	182	180	0	0	0
5	Dadai	242	242	0	0	0
6	Darband	132	430	452	552	0
7	Garhi Habib Ullah	162	62	112	102	0
8	Gittidas	202	210	0	0	0
9	Jabori	172	152	0	222	0
10	Jared	162	162	0	0	0
11	Kaghan	602	302	0	0	0
12	Kawai	142	142	0	0	0
13	Mansehra	82	302	522	508	503
14	Naran	202	252	0	0	0
15	Oghi	152	402	502	402	403
16	Phulra	82	398	452	342	0
17	Sher Garh	132	72	332	515	0
18	Shinkari	72	272	292	92	220

The lowest hardness values were recorded in bore hole of Balakot region. 89 % of the water samples of district Mansehra were found within safe limits of WHO and 11 % were showing higher level of hardness as shown in figure. However, the results presented in table is showing relatively high hardness values which is due to soil condition because industries are not common in Mansehra District (Tahir et al., 1996). 25 % of the water samples were showing hardness of above 400 mg/l which is on higher side.

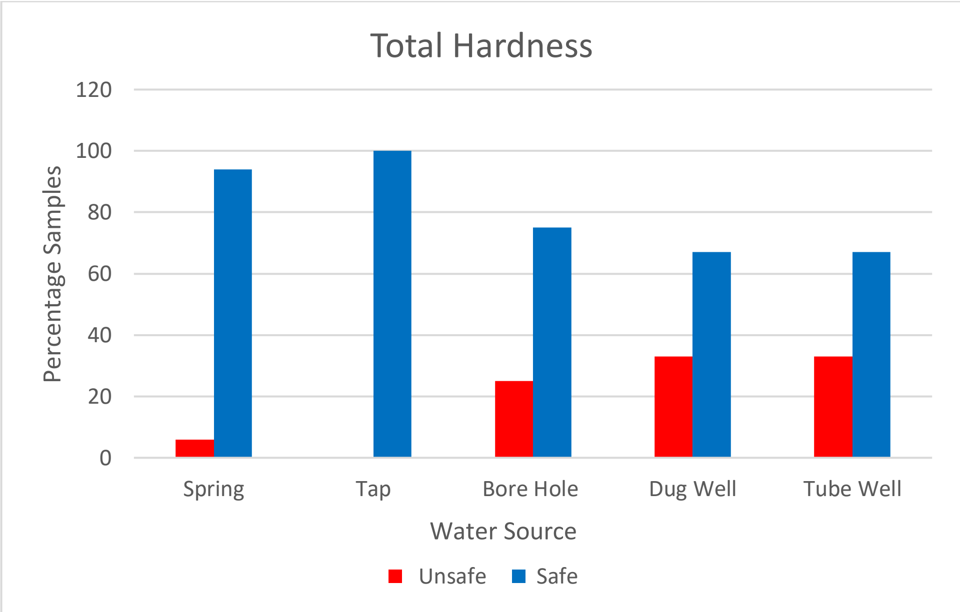

Fig 3.7 Total hardness in various water sources of District Mansehra

The study data showed highest hardness in Dug well and Tube well samples followed by bore hole samples. Tap water samples were found safe because of low concentration of hardness in tap water. High Hardness concentration was observed in various springs of the districts. It was evident from the research that 6 % Spring, 25 % Bore hole and 33 % Dug well and Tube well water samples are unsafe for human consumption. Hardness is mainly characterized by mineral contents found in the water which does not have direct health impact and samples found under the permissible limit of WHO were safe for drinking and not harmful for local communities (Mohsin et al., 2013).

Hardness is important characteristic from its domestic application and can cause damage to house hold items. Marble industries are common in various parts of the district and waste water from these industries are full of calcium and other minerals which contaminate clean drinking water (Zeb et al., 2013). The hardness of water may alter the taste of drinking water and can cause gastro-intestinal problems. (Mohsin et al., 2013).

3.3.6. TDS

TDS is a term for total dissolved solids in a water sample. It is an indicator for testing the quality of water samples. The principal constituents are usually calcium, magnesium, sodium, potassium cations, carbonate, hydrogen carbonate, chloride, sulphate, and nitrate anions which usually gives water unwanted taste (Mohsin et al., 2013).

The water samples from Balakot, Batta Kandi, Besal, Burwae, Dadai, Darband, Gari Habibullah, Gittidas, Jabori, Jared, Kaghan, Kaawai, Manshera, Naran, Oghi, Phulra, Shehr Garh and Shinkiari were analysed to record presence of TDS.

Table 3.7 TDS level in drinking water samples of District Mansehra

S. No	Location	Spring	Tap	Bore Hole	Dug Well	Tube Well
1	Balakot	234	94	55	350	0
2	Batta Kundi	213	215	0	0	0
3	Besal	235	255	0	0	0
4	Burwae	224	220	0	0	0
5	Dadai	285	270	0	0	0
6	Darband	198	190	536	7	0
7	Garhi Habib Ullah	203	87	152	136	0
8	Gittidas	235	233	0	0	0
9	Jabori	207	177	0	291	0
10	Jared	2	3	0	0	0
11	Kaghan	705	355	0	0	0
12	Kawai	166	160	0	0	0
13	Mansehra	121	484	8	607	870
14	Naran	286	286	0	0	0
15	Oghi	197	760	1092	601	854
16	Phulra	120	580	1110	269	0
17	Sher Garh	2	100	120	118	0
18	Shinkari	95	367	1030	106	530

TDS in Mansehra district were ranges 2 mg/l -1110 mg/l. There is still a debate among researcher on negative impacts of TDS exceeding permissible limits of WHO,1000 mg/l (Mohsin et al., 1013). Maximum level of TDS was confirmed in drinking water of bore holes of Phulra 1110 mg/l, followed by Oghi bore hole 1092 mg/l and Shinkari 1030 mg/l. Lowest TDS was recorded in Spring of Jared area. Only 10 % of the water samples were above the permissible limits and 90 % of the water is safe and within permissible limits of WHO and TDS do not have direct impact on human health so remaining samples are safe. (Mohsin et al.,2013).

Although TDS were not as hazardous for health, but high concentration of TDS may indicate presence of heavy metals in water (Hashmi et al., 2009). The high level of TDS can be attributed to mixing of pollutants in drinking water due by the residents of the area, which include mixing of sewerage, clothes washing and garbage dumping in ground and surface water (Zeb et al., 2013)

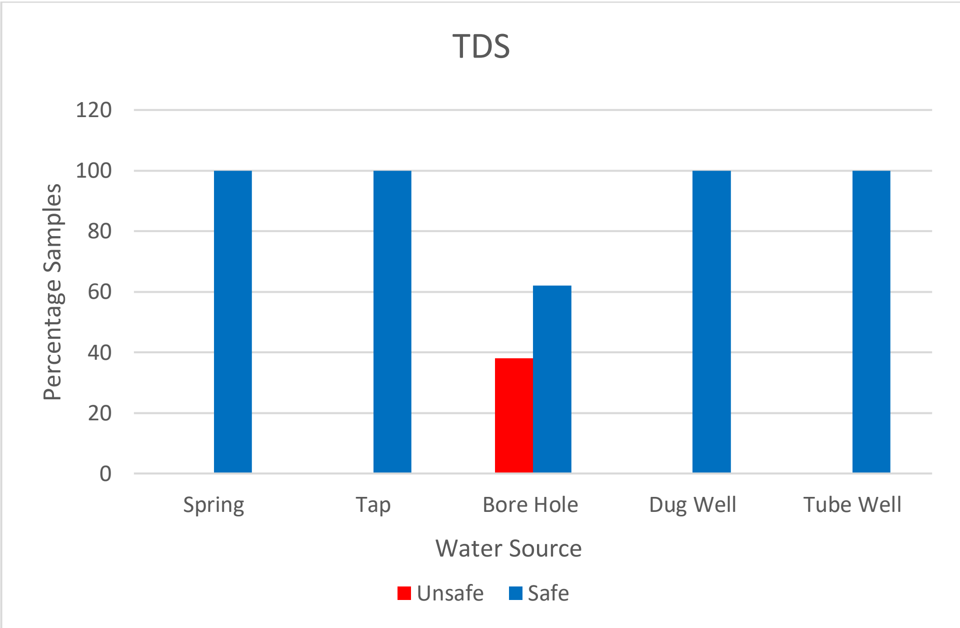

Fig 3.8 TDS in various water sources of District Mansehra

Looking at the data of TDS concentration, it is observed that only bore holes were showing higher values. All other sources of water are within the permissible limits and safe for human consumption. 100 % of the tape water, spring, tube well and dug well were found safe only 38 % of bore holes were above the safe limits of WHO.

Other Chemical parameters were also analyzed in drinking water samples which includes CO3, Cl, SO3, Mg, Ca, Na, K, NO3. The results were further compared with permissible limits of WHO and NDWQS of Pakistan (PCRWR, 2010). Water samples collected from different sites of District Mansehra such as Balakot, Batta Kandi, Besal, Burwae, Dadai, Darband, Gari Habibullah, Gittidas, Jabori, Jared, Kaghan, Kaawai, Manshera, Naran, Oghi, Phulra, Shehr Garh and Shinkiari were tested and results are presented in the table 3.2.

Table 3.8 Chemical Parameters level in drinking water samples of District Mansehra

S. No	**Location**	**Sources**	**Bicarbonates**	**Calcium**	**Carbonates**	**Magnesium**
			NGVS mg/L	**200 mg/L**	**NGVS mg/L**	**150 mg/L**
1	Balakot	Spring	102	21	BDL	34
2	Balakot	Dug Well	202	97	BDL	14
3	Balakot	Tap	62	21	BDL	7
4	Balakot	Bore Hole	103	56	BDL	14
5	Batta Kundi	Spring	147	41	BDL	19
6	Batta Kundi	Tap	150	40	BDL	19
7	Besal	Spring	142	65	BDL	12
8	Besal	Tap	145	65	BDL	12
9	Burwae	Spring	127	61	BDL	7
10	Burwae	Tap	120	61	BDL	7
11	Dadai	Spring	140	41	BDL	34
12	Dadai	Tap	140	55	BDL	40
13	Darband	Dug Well	152	165	BDL	34
14	Darband	Bore Hole	402	161	BDL	12
15	Darband	Spring	152	41	BDL	7
16	Darband	Tap	135	130	BDL	12
17	Gari Habibullah	Spring	122	53	BDL	7
18	Gari Habibullah	Dug Well	87	33	BDL	5
19	Gari Habibullah	Bore Hole	112	33	BDL	7
20	Gari Habibullah	Tap	62	21	BDL	2
21	Gittidas	Spring	122	21	BDL	36
22	Gittidas	Tap	110	25	BDL	40
23	Jabori	Spring	152	13	BDL	34
24	Jabori	Tap	152	41	BDL	12
25	Jabori	Dug Well	222	57	BDL	19
26	Jared	Spring	162	37	BDL	17

27	Jared	Tap	150	37	BDL	17
28	Kaghan	Spring	252	181	BDL	36
29	Kaghan	Tap	152	93	BDL	17
30	Kawai	Spring	112	37	BDL	12
31	Kawai	Tap	76	37	BDL	12
32	Mansehra	Tap	287	81	BDL	24
33	Mansehra	Bore Hole	322	193	BDL	10
34	Mansehra	Dug Well	302	89	BDL	65
35	Mansehra	Spring	82	21	BDL	7
36	Mansehra	Tube Well	70	192	BDL	75
37	Naran	Spring	202	57	BDL	14
38	Naran	Tap	122	81	BDL	12
39	Oghi	Dug Well	372	97	BDL	39
40	Oghi	Bore Hole	402	193	BDL	5
41	Oghi	Spring	152	41	BDL	12
42	Oghi	Tube Well	105	187	BDL	15
43	Oghi	Tap	352	91	BDL	42
44	Phulra	Dug Well	202	121	BDL	10
45	Phulra	Bore Hole	302	161	BDL	12
46	Phulra	Spring	82	21	BDL	7
47	Phulra	Tap	86	132	BDL	11
48	Sher Garh	Dug Well	302	149	BDL	27
49	Sher Garh	Spring	132	13	BDL	24
50	Sher Garh	Tap	82	21	BDL	5
51	Sher Garh	Bore Hole	42	21	BDL	29
52	Shinkiari	Dug Well	72	29	BDL	5
53	Shinkiari	Bore Hole	222	93	BDL	14
54	Shinkiari	Spring	52	17	BDL	7
55	Shinkiari	Tap	252	97	BDL	7
56	Shinkiari	Tube Well	50	83	BDL	9

3.3.7. Carbonates and Bicarbonates

Drinking water samples were tested from Balakot, Batta Kandi, Besal, Burwae, Dadai, Darband, Gari Habibullah, Gittidas, Jabori, Jared, Kaghan, Kaawai, Manshera, Naran, Oghi, Phulra, Shehr Garh and Shinkiari. There is no guiding value for carbonates and bicarbonates by EPA, however the safe limits given by WHO for carbonates was below 500 mg/l (Mohsin et al., 2013).

All the drinking water samples were found within permissible limits. Water samples were showing standard values for carbonates and bicarbonates thus confirming water safe for drinking (PCRWR. 2005). Bicarbonates are found in most of the water bodies and impacting hardness and alkalinity of the drinking water. Bicarbonates cause hardness due to their soluble nature and hardness further effects caused by bicarbonates causes stomach issues in h and because of their soluble nature causing hardness (Mohsin et al., 2013).

3.3.8. Calcium (Ca)

Drinking water samples were collected from Balakot, Batta Kandi, Besal, Burwae, Dadai, Darband, Gari Habibullah, Gittidas, Jabori, Jared, Kaghan, Kaawai, Manshera, Naran, Oghi, Phulra, Shehr Garh and Shinkiari to test for Ca presence. The standard value for Ca provided by WHO is 75 mg/l compared to PSQCA permissible limit of 200 mg/l (Mohsin et al., 2013).

As shown in table the Ca concentration in drinking water of study area ranges from 220 mg/l – 17mg/l. Highest Ca concentration was confirmed in tube well water of Mansehra, 55mg/l followed by Tube well water of Oghi. In the areas of Mansehra and Oghi the Ca concentration exceeds the safe limits which can affect health issues of its residents (Mohsin et al. 2013) Other water samples with higher Ca concentration include Kaghan area spring water, darband dug well and bore hole, 181 mg/L, 165 mg/L and 161 mg/L respectively.

The minimum Ca was recorded in spring water of Shinkari. Additionally, 17 mg/L Ca was recorded in the samples of Balakot, Gittidas, Mansehra city and Sher Garh. In District Mansehra, 97 % of the samples were found within safe limits and 3 % of the samples were found above the permissible limit of 200 mg /L as shown in table.

3.3.9. Magnesium (mg)

Drinking water samples taken from Balakot, Batta Kandi, Besal, Burwae, Dadai, Darband, Gari Habibullah, Gittidas, Jabori, Jared, Kaghan, Kaawai, Manshera, Naran, Oghi, Phulra, Shehr Garh and Shinkiari were analysed for Mg presence and results are shown in table. The standard permissible value for Mg set by WHO is 150 mg/L (Mohsin et al., 2013).

It was found that 100 % of the samples tested from District Mansehra were within desirable standard of WHO. The Mg contents in drinking water of Mansehra varies from 75 mg/L – 2 mg/L. Highest Mg concentration was observed in tube well water of Mansehra city, followed by dug well Mansehra city, Oghi tap water and Dadai tap. The level of Mg found was 75mg/l, 65mg/l, 42mg/l and 40mg/l.

In all the sites the concentration of Mg was not exceeding the WHO safe limit and water is safe for human consumption (Zeb et al., 2011). The minimum Mg 2mg/l was recorded in Garhi Habib Ullah tap water which can affect health of the resident due to low level, as Mg is required for proper functioning of body organs (Mohsin et al., 2013). 100 % of the samples were found within permissible safe limits as shown in table 3.9.

Table 3.9 Chemical Parameters level in drinking water samples of District Mansehra

S. No	**Location**	**Sources**	**Chlorides**	**Potassium**	**Sodium**	**Sulphate**	**Fluoride**
			250 mg/L	**12 mg/L**	**200 mg/L**	**250 mg/L**	**1.50 mg/L**
1	Balakot	Spring	10	3.40	15	38	0.54
2	Balakot	Dug Well	21	5.30	26	59	0.39
3	Balakot	Tap	7	3.50	11	21	0.72
4	Balakot	Bore Hole	15	5,30	20	20	0.20
5	Batta Kundi	Spring	4	5.20	6	13	0.21
6	Batta Kundi	Tap	4	6.00	6	13	0.20
7	Besal	Spring	4	6.20	5	59	0.31
8	Besal	Tap	5	6.30	5	59	0.36
9	Burwae	Spring	2	4.30	7	59	0.24
10	Burwae	Tap	2	4.30	7	62	0.24
11	Dadai	Spring	6	5.60	6	128	0.29
12	Dadai	Tap	5	5.60	5	128	0.29
13	Darband	Dug Well	60	9.50	50	42	0.26
14	Darband	Bore Hole	26	2.40	18	24	0.32
15	Darband	Spring	10	3.00	28	16	0.24
16	Darband	Tap	15	2.45	30	24	0.32

17	Gari Habibullah	Spring	12	1.80	15	12	0.23
18	Gari Habibullah	Dug Well	8	2.60	12	10	0.29
19	Gari Habibullah	Bore Hole	7	3.90	14	8	0.58
20	Gari Habibullah	Tap	4	2.40	7	BDL	0.73
21	Gittidas	Spring	12	6.50	5	52	0.27
22	Gittidas	Tap	12	6.50	5	50	0.23
23	Jabori	Spring	12	7.40	6	21	0.14
24	Jabori	Tap	BDL	2.10	2	50	BDL
25	Jabori	Dug Well	12	6.9	11	27	0.12
26	Jared	Spring	8	1.70	19	19	0.24
27	Jared	Tap	8	1.70	18	21	0.22
28	Kaghan	Spring	7	3.60	23	150	1.11
29	Kaghan	Tap	4	3.90	5	180	0.38
30	Kawai	Spring	20	1.80	10	8	0.17
31	Kawai	Tap	20	1.81	11	9	0.17
32	Mansehra	Tap	43	2.70	40	36	0.43
33	Mansehra	Bore Hole	60	2.20	34	31	0.28
34	Mansehra	Dug Well	84	1.80	31	50	0.29
35	Mansehra	Spring	12	0.70	12	10	0.14
36	Mansehra	Tube Well	87	5.10	60	62	0.12
37	Naran	Spring	19	7.60	19	48	0.76
38	Naran	Tap	BDL	5.40	7	135	0.41
39	Oghi	Dug Well	101	2.40	59	32	0.11
40	Oghi	Bore Hole	144	5.90	130	80	0.55
41	Oghi	Spring	12	2.80	26	15	0.25

42	Oghi	Tube Well	180	7.10	160	89	0.90
43	Oghi	Tap	120	11.30	84	64	0.63
44	Phulra	Dug Well	72	5.00	27	39	0.23
45	Phulra	Bore Hole	72	2.40	50	30	0.30
46	Phulra	Spring	12	0.70	13	12	0.12
47	Phulra	Tap	61	4.50	45	30	0.41
48	Sher Garh	Dug Well	48	2.10	26	27	0.28
49	Sher Garh	Spring	12	2.80	26	16	0.23
50	Sher Garh	Tap	12	1.90	15	8	0.24
51	Sher Garh	Bore Hole	11	3.10	22	25	0.22
52	Shinkiari	Dug Well	BDL	1.90	4	19	0.39
53	Shinkiari	Bore Hole	24	3.40	17	27	0.23
54	Shinkiari	Spring	12	3.10	7	14	0.47
55	Shinkiari	Tap	24	1.80	17	21	0.34
56	Shinkiari	Tube Well	19	6.70	18	30	0.20

3.3.10. Sodium (Na)

Drinking water samples from various sites of District Mansehra such as Balakot, Batta Kandi, Besal, Burwae, Dadai, Darband, Gari Habibullah, Gittidas, Jabori, Jared, Kaghan, Kaawai, Manshera, Naran, Oghi, Phulra, Shehr Garh and Shinkiari were tested for Na presence and results are shown in table. The permissible limit for Na in the drinking water is 200 mg/l (WHO, 1984).

The Na concentration in drinking water of various locations of District Mansehra were found below the standard permissible limit of 200 mg/l. The Na contents in drinking water of Mansehra varies from 160 mg/L – 4 mg/l. Na in two drinking water samples were found above 100 mg/l, Oghi tube well water Na was recorded at 160 mg/L and Bore hole 130 mg/l. The minimum Na was observed in drinking water of Shinkari dug well which is 4 mg/l. 100 % of the samples tested from District Mansehra were found within safe limits with respect to Na, (Hashmi et al., 2013). High level of Na can cause multiple health issues such as hypertension, headache, high blood pressure and renal issues. (Mohsin et al., 2013). Low level of Na is also harmful for resident of Shinkari who are dependent on dug well water.

3.3. 11. Potassium (K)

Water samples collected from Balakot, Batta Kandi, Besal, Burwae, Dadai, Darband, Gari Habibullah, Gittidas, Jabori, Jared, Kaghan, Kaawai, Manshera, Naran, Oghi, Phulra, Shehr Garh and Shinkiari were analysed for the presence of K. The standard guiding value for K in drinking water is 12 mg/L (WHO, 1984).

Higher level of K was found in 3 samples of the district. The concentration of K in drinking water of various locations of District Mansehra were found below the standard permissible limit of 12 mg/l. The Na contents in drinking water of Mansehra varies from 162 mg/l – 0.7 mg/l. The maximum level of K, 162 mg/l was found in tube well of Oghi. Similarly Bore hole and Tap of Oghi were also contaminated with 84 mg/l and 50mg/l of K.

Low level of K 0.07mg/l was confirmed in spring water of Phulra and Mansehra towns. 95 % of the samples tested for K were found safe with 5 % showing high concentration of K making water unfit for drinking purposes (Mohsin et al. 2013).

3.3.12. Chloride (Cl)

Drinking water samples from various sites of District Mansehra such as Balakot, Batta Kandi, Besal, Burwae, Dadai, Darband, Gari Habibullah, Gittidas, Jabori, Jared, Kaghan, Kaawai, Manshera, Naran, Oghi, Phulra, Shehr Garh and Shinkiari were tested for Cl presence and results are shown in table. The permissible limit for chloride set by WHO and EPA of Pakistan is 250mg/L (Mohsin et al., 2013).

The Cl concentration in drinking water of various locations of District Mansehra were found below the standard permissible limits. The Cl contents in drinking water of Mansehra varies from 180 mg/l – 2 mg/l. 4 samples having chloride more than 100 were from Oghi area, the highest concentration was found in Tube well 180 mg/l followed by bore hole with concentration of 144 mg/l, tape, 120 mg/l and dug wellspring and tap water of Burwae area which is 2 mg/l. However, the samples of dug well of Shinkari, tap of Naran and Jabori have chloride below detection limit.

Moreover, Cl was found below detection limits in tape water of Jabori and Naran and dug well of Shinkari. The surface water has low level of Cl compared to ground water sources but was found that 100 % of the samples tested from District Mansehra were within permissible standard of WHO (Hashmi et al., 2013). Low level of Cl contents in drinking water does not have much health implications (Zeb et al., 2011).

3.3.13. Fluoride (Fl)

Water samples collected from Balakot, Batta Kandi, Besal, Burwae, Dadai, Darband, Gari Habibullah, Gittidas, Jabori, Jared, Kaghan, Kaawai, Manshera, Naran, Oghi, Phulra, Shehr Garh and Shinkiari were tested for Fl level and results are presented in table. The WHO standard value and Pak EPA for fluoride is 1.50 mg/l.

Fl level in drinking water of District Mansehra ranges from 1.11mg/L – 0.12 mg/l. Highest Fl concentration 1.11mg/L was recorded in spring water of kaghan area and lowest level was found in spring water of Phulra town. However, Fl was found below the detection limit in spring water of Jabori town. 100 % of the water samples tested from Mansehra were found within safe limits of WHO with respect to Fl and water is safe for human consumption (Zeb et al., 2011).

The high concentration of Fl in drinking water can cause tooth decay which is called fluorosis (Patil et al. 2013). High level of Fl in water bodies are due to multiple reasons such as, leaching of minerals, Industrial discharge and combustion of coal and use of fertilizers (Azizullah et al., 2011). Coal combustion and mining are common in various town of Mansehra and can contribute to high level of Fl in Mansehra.

3.3.14. Sulphate (SO4)

Water samples were collected from various sites of District Mansehra such as Balakot, Batta Kandi, Besal, Burwae, Dadai, Darband, Gari Habibullah, Gittidas, Jabori, Jared, Kaghan, Kaawai, Manshera, Naran, Oghi, Phulra, Shehr Garh and Shinkiari to analyse for Sulphate. The permissible limit for SO4 set by WHO drinking water guidelines and Pak EPA is 250 mg/l (Mohsin et al. 2013).

The SO4 concentration in drinking water of various locations of District Mansehra were ranges from 340 mg/l – 8 mg/l. 55 samples were found within the safe limits and one sample have high level of SO4. Spring water of Kaghan area was showing high level of SO3, 256 mg/l.

The lowest concentration was recorded in bore hole of Garhi Habibullah and tap of Sher Garh , 8 mg/l and the concentration was below detection limit in tape water of Garhi Habib ullah. The water samples of Kaghan, Dadai and Naran were found SO4 in the ranges of 128 mg/l- 180mg/l.

The high concentration of SO_4 in drinking water of Kaghan may affect the health of population dependent on sprig water for drinking purposes. (Mohsin et al., 2013). The high concentration of SO_4 in drinking water can be due to industrial and construction activities or mining and natural weathering of rocks or disposal of domestic waste in surface water (Azizullah et al., 2011).

3.3.15. Nitrate (NO_3)

Drinking water samples from various sites of District Mansehra such as Balakot, Batta Kandi, Besal, Burwae, Dadai, Darband, Gari Habibullah, Gittidas, Jabori, Jared, Kaghan, Kaawai, Manshera, Naran, Oghi, Phulra, Shehr Garh and Shinkiari were tested for NO_3 and the results have shown high level of NO_3 concentration as shown in the Fig.

The permissible limit for NO_3 set by WHO drinking water guidelines and EPA of Pakistan is 10 mg/l (Zeb et al., 2011), the drinking water above the permissible limit is unfit for drinking and other human consumption having potential for diseases.

Table 3.10 Nitrate Concentration (mg/l) in drinking water samples of District Mansehra

S. No	Location	Spring	Tap	Bore Hole	Dug Well	Tube Well
1	Balakot	3.20	1.70	7	10.90	0
2	Batta Kundi	2.30	2.30	11.00	0	0
3	Besal	1.09	1.10	1.41	0	0
4	Burwae	0.54	0.54	0	0	0
5	Dadai	1.58	1.98	0	0	0
6	Darband	0.05	6.10	0	5.13	0
7	Garhi Habib Ullah	4.76	1.36	0	1.16	0
8	Gittidas	1.49	1.59	0		0
9	Jabori	0.26	0.42	0	2	0
10	Jared	2.63	2.63	0	0	0
11	Kaghan	0.10	1.56	0	0	0
12	Kawai	1.66	1.68	0	0	0
13	Mansehra	2.33	10.20	43.00	26.00	9
14	Naran	1.28	1.04	0	0	0
15	Oghi	3.19	26.00	48.00	4.28	51.10
16	Phulra	2.35	26.00	27.00	25.00	0
17	Sher Garh	3.16	0.36	25.00	27.00	0
18	Shinkari	1.10	12.00	11.00	12.00	13.00

Nitrate concentration in drinking water of various locations of District Mansehra were ranges from 51mg/l – 0.05 mg/l. 21 % of the samples were found above permissible limits of WHO and 79 % samples were found within safe limits of EPA.

The highest concentration of NO3, 51mg/l was found in tube well water of Oghi area followed by 27 mg/l found in bore hole of Phulra and dug well of Shergarh. Similarly, the Tape water of Oghi and Phulra and dug well of Mansehra city were observed with 26 mg/l and bore hole of Sher Garh with 25 mg/l of NO3.

The water samples of Mansehra tap, Shinkari bore hole, tape and dug well ranges from 10mg/l-13mg/l. However, spring of Darband area was found with minimum level of 0.05 mg/l of NO3 and the metal presence is less in surface water compare to ground water (Hashmi et al., 2013).

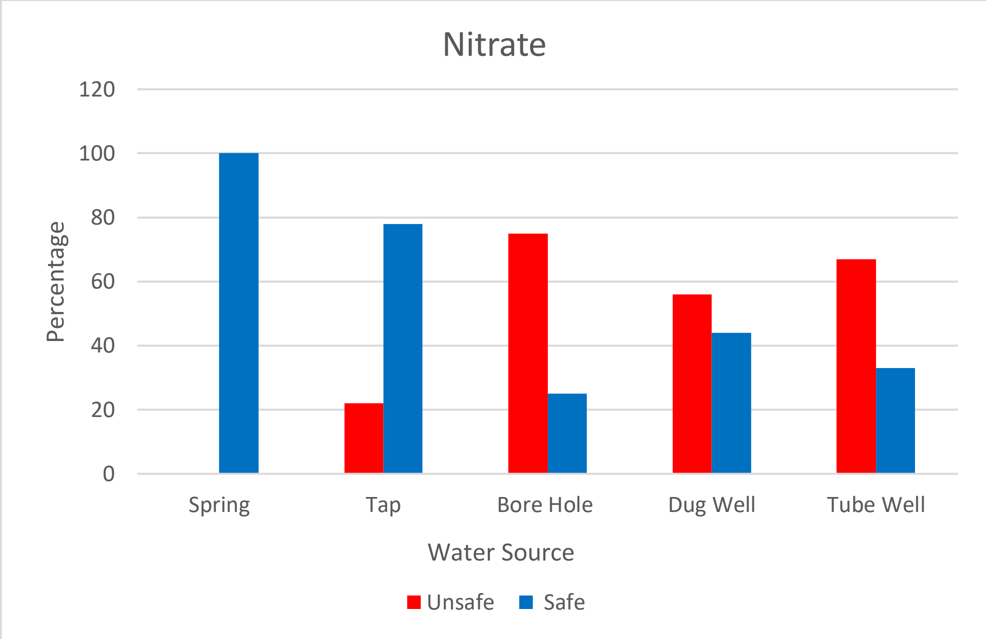

Fig 3.9 Nitrate Presence in various water sources of District Mansehra

Nitrate has disease causing characteristics and potential to cause blue baby syndrome if taken in higher amount (Mohsin et al., 2013). Other common health effects of nitrates include, respiratory tract infections, blood disorders, diabetes mellites (Azizullah et al., 2011) In the study area high level of NO3 contamination were found thus the residents have bigger threat compared to other water quality parameters. (Zeb et al., 2011). The nitrogen in drinking water in the study area is mainly due to agriculture activity and small-scale industries (Hashmi et al., 2009). The most common sources of nitrate concentration in drinking water is surface runoff from crop fields which brings fertilizers and pesticides to the drinking water sources (Zeb et al., 2013).

3.4 Heavy Metal

Heavy metals were analysed for the sample collected from Balakot, Batta Kandi, Besal, Burwae, Dadai, Darband, Gari Habibullah, Gittidas, Jabori, Jared, Kaghan, Kaawai, Manshera, Naran, Oghi, Phulra, Shehr Garh and Shinkiari. Tested heavy metals include As, Cr, Cu, Fe, Hg, Pb and Zn. The results found were compared with guiding vaµg/lues of WHO and NDWQS of Pakistan (PCRWR, 2010). Toxic metals such as As, Cr, Cu, Hg, Pb and Zn were found below permissible limits and even were below detection limits in most of the water samples. However, Fe was found in high concentration was observed in multiple drinking water sources of the district.

Total 56 samples were tested for HM and high level of Fe was found in 30 samples. The results were further compared with WHO and EPA permissible limits and

100 % of samples of As, Cu, Cr, Hg and Zn was found within safe limits and water is declared safe for drinking purposes. Industrial activities and mining processes produced huge amount of toxic heavy metals which can easily affect water bodies (Ali et al., 1996). The heavy metal contamination is not only limited to surface water sources but their seepage in the soil contaminate freshwater ground aquafer thus further complicating the water quality issues (Azizullah et al, 2011)

3.4.1. Iron (Fe)

Water sample taken from areas of Balakot, Batta Kandi, Besal, Burwae, Dadai, Darband, Gari Habibullah, Gittidas, Jabori, Jared, Kaghan, Kaawai, Manshera, Naran, Oghi, Phulra, Shehr Garh and Shinkiari were analysed for Fe. The results have shown high level of Fe concentration as shown in the Fig. The permissible limit for Fe sets by WHO drinking water guidelines is 0.30 mg/l (Khan et al., 2013).

Table 3.11 Iron Concentration (mg/l) in Drinking water samples of District Mansehra

S. No	Location	Spring	Tap	Bore Hole	Dug Well	Tube Well
1	Balakot	BDL	BDL	BDL	BDL	0
2	Batta Kundi	1.02	1.04	0	0	0
3	Besal	BDL	BDL	0	0	0
4	Burwae	BDL	BDL	0	0	0
5	Dadai	BDL	BDL	0	0	0
6	Darband	1.25	1.10	0.08	1.88	0
7	Garhi Habib Ullah	BDL	BDL	0.69	0.11	0
8	Gittidas	BDL	BDL	0	0	0
9	Jabori	0.63	BDL	0	0.80	0
10	Jared	BDL	BDL	0	0	0
11	Kaghan	BDL	BDL	0	0	0
12	Kawai	BDL	BDL	0	0	0
13	Mansehra	0.97	0.31	0.15	BDL	1.01
14	Naran	0.83	BDL	0	0	0
15	Oghi	0.95	1.18	0.80	0.85	1.20
16	Phulra	1.26	0.45	0.90	0.91	0
17	Sher Garh	1.41	1.31	1.22	0.44	0
18	Shinkari	1.18	1.28	1.32	0.82	1.30

The Fe concentration in drinking water of various locations of District Mansehra were ranges from 0.30 mg/l – 1.88 mg/l. The highest concentration of Fe 1.88 mg/l was recorded in dug well water of Darband area, followed by spring water of Sher garh 1.41 mg/l and minimum value of Fe 0.15 mg/l was recorded in bore hole of Mansehra city.

However, Fe was recorded below the detection limit in 19 samples of the Balakot, Burwae, Besal, Dadai, Garhi habibullah, Jared, Kaghan, Kawai and Naran, all these water samples have minimal quantity of the Fe and that's why found safe for human conzumption.

Higher concentration of Fe exceeding 1.01 mg/l was found in 16 samples. The sites with higher concentration include, Shinkari Sprig, tube well, tape and borehole 1.18 mg/l, 1.30 mg/l, 1.28mg/l and 1.32mg/l respectively. The level of Fe was also quite high in the area of Sher garh and found in the Spring 1.41mg/l, tap 1.31mg/l and Bore hole 1.22 mg/l. 1.20mg/l and 1.18 mg/l of Fe was confirmed in drinking water collected from tube well and tap water of Oghi areas.

Similarly, Tape water of Phulra and Tube well water of Mansera city were observed with high concentration of 1.01mg/L of Fe. Both spring water and tap water resource of Naran town was also showing Fe concentration of 1.02 mg/L and 1.04 mg/L. However, Darband area of District Mansehra was found with highest levels of Fe, dug well, 1.88 mg/L, 1.25mg/L and Tap 1.10 mg/L.

Although the low level of iron has many health complication and human body require right amount of iron for its functioning. Still there are low level of iron as common problem in under developed countries. In many areas of Mansehra and other districts of KP, high concentration of Fe was found thus confirming problems for human consumption.

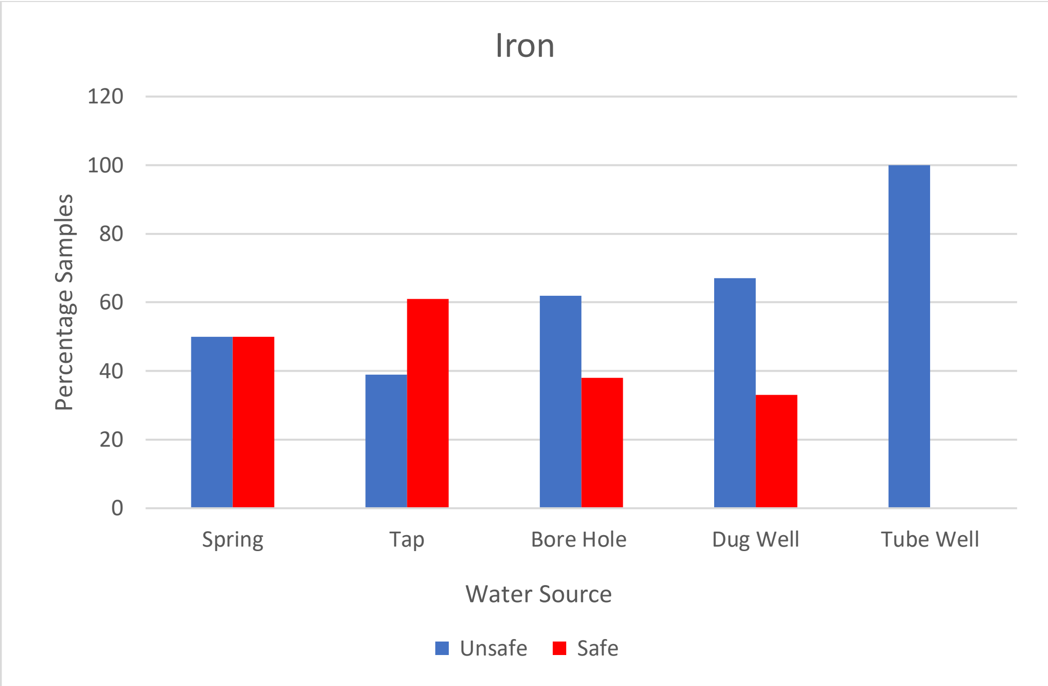

Fig 3.10 Iron Presence in various water sources of District Mansehra

Over 50 % of the samples tested for Fe was found above permissible limits of WHO and 34 % of the samples were not showing presence of Fe due to detection limitation of instrument, thus confirming 46 % of the drinking water samples were within safe limits of WHO and EPA (Hashmi et al., 2013).

Iron is naturally present in earth crust but usually its concentration is low in natural water resources. Its contamination in water make ferric precipitate making water aesthetically objectionable for drinking (Ali et al., 2019). It is not only objectionable for drinking; high concentration relates with human health implications.

Exposure of high concentration of Fe is toxic to human health and has potential to cause diseases of liver, muscles and gall bladder. The ingestion of Fe in drinking water can also cause Alzheimer type II and parkinsonism cognitive dysfunction (Farnendaz et al., 2013). Thesediseases were found common in the study area.

Toxic HM which are common in urban centers of the KP province were not found in most of the samples of District Mansehra. In few samples the metals were detected but their concentration was very low and often found undetectable as shown in table 3.12.

In the samples where the low concentration was recorded are from the areas where there is some mining activity. Another factor involved is usage of low-quality fuel often common in mountainous regions. Almost 100 % of the samples were considered within the safe limits of WHO and Pakistan EPA.

Table 3.12 Heavy Metal Concentration in various water samples of District Mansehra

S. No	Location	Sources	Arsenic	Chromium	Copper	Mercury	Lead	Zinc
			0.05 mg/L	0.05 mg/L	2.0 mg/L	0.001 mg/L	0.01 mg/L	3.0 mg/L
1	Balakot	Spring	BDL	BDL	BDL	BDL	BDL	0.59
2	Balakot	Dug Well	BDL	0.008	BDL	0.0008	0.002	BDL
3	Balakot	Tap	0.003	BDL	0.90	BDL	0.004	BDL
4	Balakot	Bore Hole	0.0015	BDL	0.32	BDL	BDL	0.54
5	Batta Kundi	Spring	BDL	BDL	BDL	BDL	BDL	BDL
6	Batta Kundi	Tap	BDL	BDL	0.46	BDL	BDL	BDL
7	Besal	Spring	BDL	BDL	BDL	BDL	BDL	BDL
8	Besal	Tap	BDL	BDL	BDL	BDL	BDL	BDL
9	Burwae	Spring	BDL	BDL	BDL	BDL	BDL	BDL
10	Burwae	Tap	BDL	BDL	BDL	BDL	BDL	BDL
11	Dadai	Spring	0.002	BDL	BDL	BDL	BDL	BDL
12	Dadai	Tap	0.002	BDL	BDL	BDL	BDL	BDL
13	Darband	Dug Well	0.0121	BDL	0.53	0.0005	0.007	0.08
14	Darband	Bore Hole	0.001	BDL	0.81	BDL	0.002	BDL
15	Darband	Spring	0.0009	BDL	0.88	BDL	BDL	BDL
16	Darband	Tap	0.0009	BDL	BDL	BDL	BDL	0.31
17	Gari	Spring	0.005	BDL	BDL	BDL	BDL	BDL
18	Gari	Dug Well	0.004	0.009	BDL	BDL	0.005	0.89
19	Gari	Bore Hole	0.0039	BDL	0.93	0.0007	0.008	BDL
20	Gari	Tap	0.008	BDL	1.06	BDL	BDL	0.89
21	Gittidas	Spring	BDL	BDL	BDL	BDL	BDL	BDL
22	Gittidas	Tap	BDL	BDL	BDL	BDL	BDL	BDL
23	Jabori	Spring	BDL	BDL	BDL	BDL	BDL	0.71
24	Jabori	Tap	BDL	BDL	0.67	BDL	0.009	0.71
25	Jabori	Dug Well	BDL	BDL	BDL	BDL	0.001	0.99
26	Jared	Spring	0.003	BDL	BDL	BDL	BDL	BDL
27	Jared	Tap	0.0027	BDL	BDL	BDL	0.008	BDL
28	Kaghan	Spring	BDL	0.007	BDL	BDL	BDL	BDL

29	Kaghan	Tap	BDL	BDL	0.73	BDL	BDL	0.24
30	Kawai	Spring	BDL	BDL	BDL	BDL	BDL	BDL
31	Kawai	Tap	0.0021	BDL	0.39	BDL	BDL	BDL
32	Mansehra	Tap	BDL	BDL	1.01	BDL	0.003	BDL
33	Mansehra	Bore Hole	0.001	BDL	0.53	BDL	0.005	BDL
34	Mansehra	Dug Well	0.0012	BDL	0.13	BDL	BDL	1.00
35	Mansehra	Spring	BDL	BDL	BDL	BDL	BDL	0.61
36	Mansehra	Tube Well	0.0036	0.008	BDL	BDL	BDL	0.42
37	Naran	Spring	BDL	BDL	BDL	BDL	BDL	BDL
38	Naran	Tap	0.005	0.007	0.33	BDL	0.001	BDL
39	Oghi	Dug Well	BDL	0.009	0.47	BDL	0.007	0.79
40	Oghi	Bore Hole	0.004	BDL	1.05	0.0007	BDL	BDL
41	Oghi	Spring	0.0015	0.005	BDL	BDL	BDL	0.49
42	Oghi	Tube Well	0.002	BDL	BDL	BDL	BDL	BDL
43	Oghi	Tap	0.002	BDL	0.51	BDL	0.003	BDL
44	Phulra	Dug Well	BDL	BDL	BDL	BDL	BDL	0.43
45	Phulra	Bore Hole	BDL	BDL	0.25	BDL	BDL	BDL
46	Phulra	Spring	BDL	BDL	BDL	BDL	BDL	BDL
47	Phulra	Tap	BDL	BDL	0.97	BDL	0.009	BDL
48	Sher Garh	Dug Well	BDL	0.006	0.28	BDL	BDL	BDL
49	Sher Garh	Spring	BDL	BDL	BDL	0.0009	BDL	BDL
50	Sher Garh	Tap	BDL	BDL	BDL	BDL	BDL	0.35
51	Sher Garh	Bore Hole	BDL	BDL	0.37	BDL	BDL	BDL
52	Shinkiari	Dug Well	0.0037	BDL	0.19	BDL	0.007	0.89
53	Shinkiari	Bore Hole	BDL	0.004	BDL	BDL	BDL	BDL
54	Shinkiari	Spring	0.003	BDL	BDL	BDL	BDL	BDL
55	Shinkiari	Tap	0.005	BDL	0.63	BDL	BDL	BDL
56	Shinkiari	Tube Well	0.002	BDL	BDL	BDL	BDL	0.59

3.4.2. Arsenic (As)

Water samples of Balakot, Batta Kandi, Besal, Burwae, Dadai, Darband, Gari Habibullah, Gittidas, Jabori, Jared, Kaghan, Kaawai, Manshera, Naran, Oghi, Phulra, Shehr Garh and Shinkiari were tested for As and results were shown in the table. The WHO standard value and NDWQS values for As is 50 mg/L

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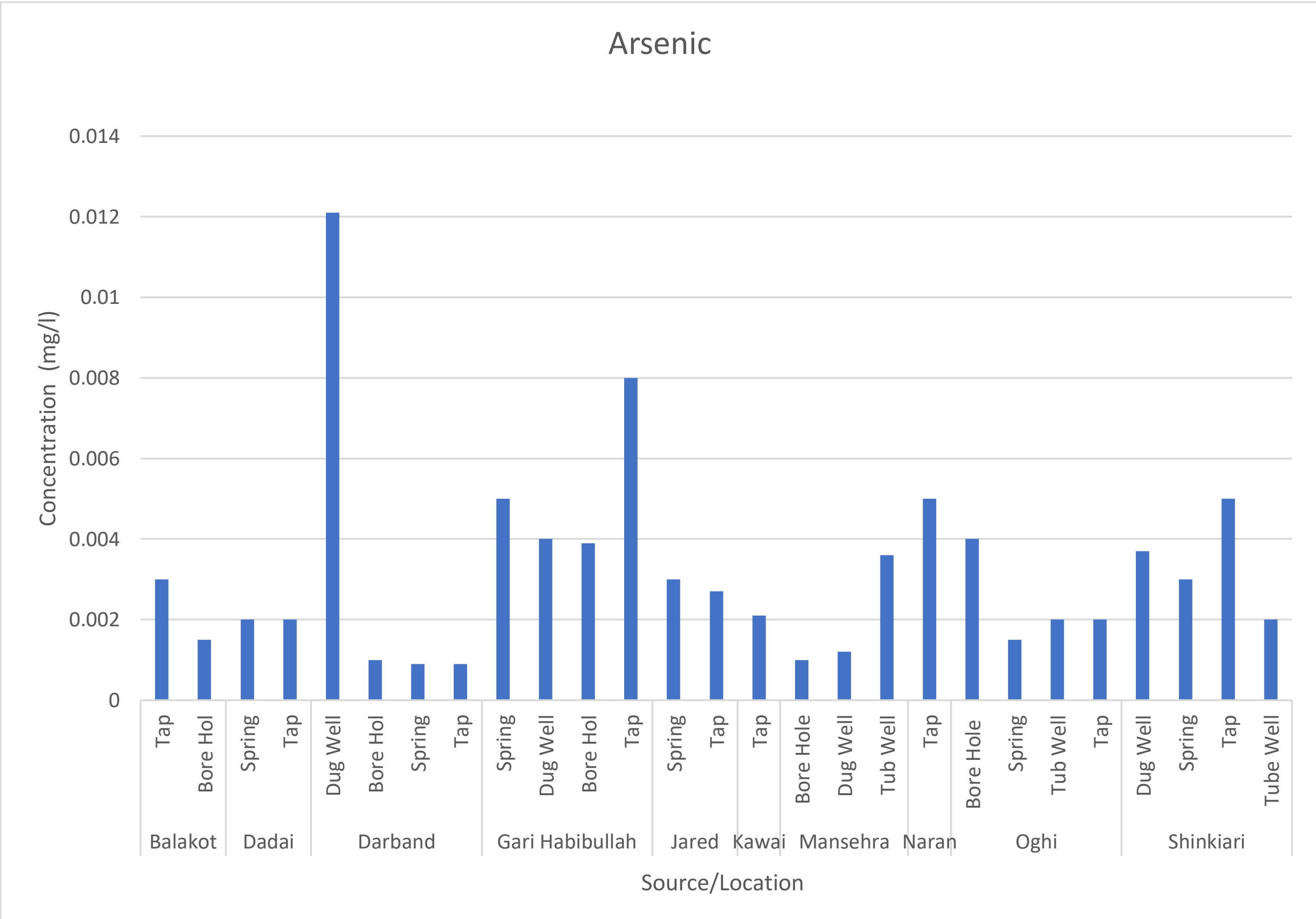

Fig 3.11 Concentration (mg/l) of As in various water sources of District Mansehra

As concentration in drinking water of District Mansehra ranges from 1.01 mg/l – 8.0 mg/l. Highest As concentration 8.0 mg/l was recorded tap water of Garhi Habibullah followed by tap water of shinkari and Naran 5.0 mg/l and bore hole of Oghi 4.0mg/L. The lowest concentration was reported in Mansehra bore hole water. However, As was found below the detection limit in 28 samples due to detection limitation of instrument.

The samples of BDL were from Balakot, Besal, Burwae, Gittidas, Jabori, Sher Garh, Phulra and Naran which can be attributed to limited industrial activity in these areas (Fernandez et al., 20113). 50 % of the samples were found with As but within safe limits of WHO and EPA, in the remaining 50 % samples As was not detected this making 100 % of the water samples safe for human consumption (Ali et al., 2011).

The high concentration of As in the drinking water has potential to cause deadly diseases like diabetes mellitus, hypertension, renal dysfunctions and failure respiratory infections and skin lesions (Fernandez et al., 2013). High level of As in ground water and surface water could be due to natural processes and anthropogenic activities.

Mining and percolation of minerals are the causes of As in ground water and industrial waste discharge in in water bodies are major contributor of As in surface water sources (Kavacar et al., 2008). With limited industrial growth in District Mansehra, and As was not reported in high concentration, the presence of As in the area is mainly due to natural processes (Fernandez et al., 2013).

3.4.3. Copper (Cu)

Drinking water samples collected from the areas of Balakot, Batta Kandi, Besal, Burwae, Dadai, Darband, Gari Habibullah, Gittidas, Jabori, Jared, Kaghan, Kauai, Mansehra, Naran, Oghi, Phulra, Shehr Garh and Shinkiari were further investigated for the presence of Cu. The results of Cu presence are shown in the table 3.10. The WHO and EPA allowable standards for Cu in drinking water is 2.0 mg/L (Azizullah et al., 2011).

Cu concentration in drinking water of the study area samples varies and ranges 0.13- mg/l – 1.06 mg/l. Highest Cu level of 1.06 mg/l was found in the tap water of Garhi habib ullah town followed by 1.05mg/l bore hole water of Oghi and 1.01mg/l of

Cu was found in Mansehra city tap water. The lowest concentration was noted in the dug well water of Mansehra city area.

However, detection limit of Cu remained below in 32 samples due to detection limitation of the instrument (Khan et al., 2013). The samples with BDL were from Balakot, Besal, Burwae, Gittidas, Dadai, Jabori, Kaghan, Naran, Shergarh and Shinkari areas.

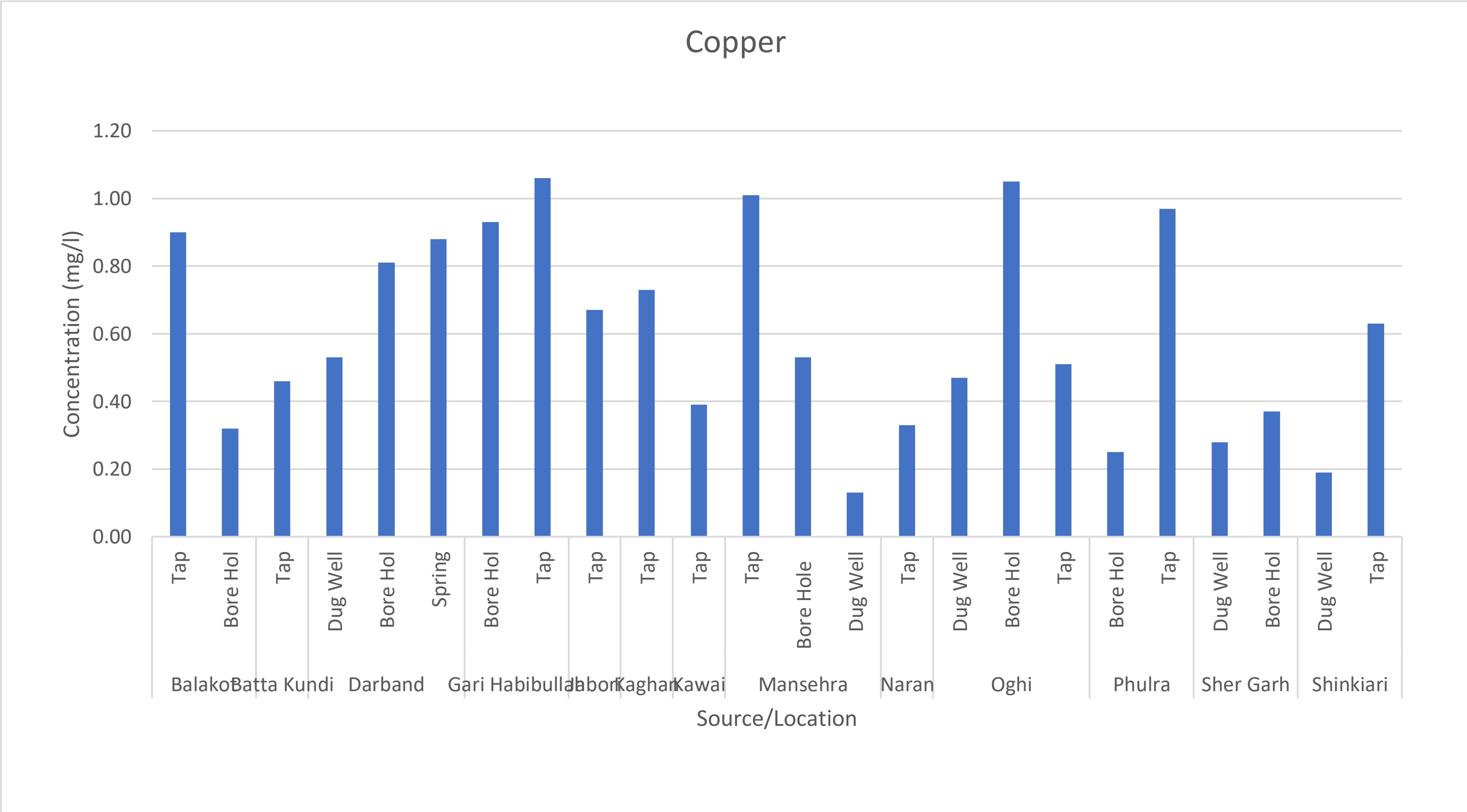

Fig 3.12 Concentration (mg/l) of Cu in various water sources of District Mansehra

The Cu concentration was recorded in 24 samples, but the level is in safe limits of WHO and EPA and in remaining 32 samples, Cu was found BDL. All 56 samples were within the range of safe limits and fir for human consumption. (Ali et al., 2019).

The high concentration of Cu is lethal for human being and it accumulates in body and cause Alzheimer type II and parkinsonism cognitive dysfunction lethal for human body and cause multiple diseases like and ataxia (Fernandez et al., 2013). Cu pollution in drinking water is mainly due to dumping of industrial and domestic waste in drinking water, mining and use of old copper pipes used for water distribution. The Cu concentration in District Mansehra was found within WHO standard limits (Patel et al., 2013).

3.4.4. Chromium (Cr)

Samples collected from sites of Balakot, Batta Kandi, Besal, Burwae, Dadai, Darband, Gari Habibullah, Gittidas, Jabori, Jared, Kaghan, Kauai, Mansehra, Naran, Oghi, Phulra, Shehr Garh and Shinkiari were further tested to record Cr concentration in drinking water. The WHO and NSDWQ permissible limit for Cr is 0.05 mg/ L (Fernandez et al., 2011).

Cr was found in 9 samples of the study area of Mansehra and the concentration ranges 0.009 mg/l – 0.004 mg/l. Highest Cr level of 0.004 was recorded in bore hole water of Shinkari region.

Similarly the concentration of Cr in Oghi spring water 0.006mg/l, Sher Garh dug well was 0.005 mg/l, Naran tap water 0.007 mg/l, Mansehra city tube well and balakot dug well 0.008 mg/l and minimal level 0.009 was observed in dug well water of Oghi and Garhi habib Ullah town.

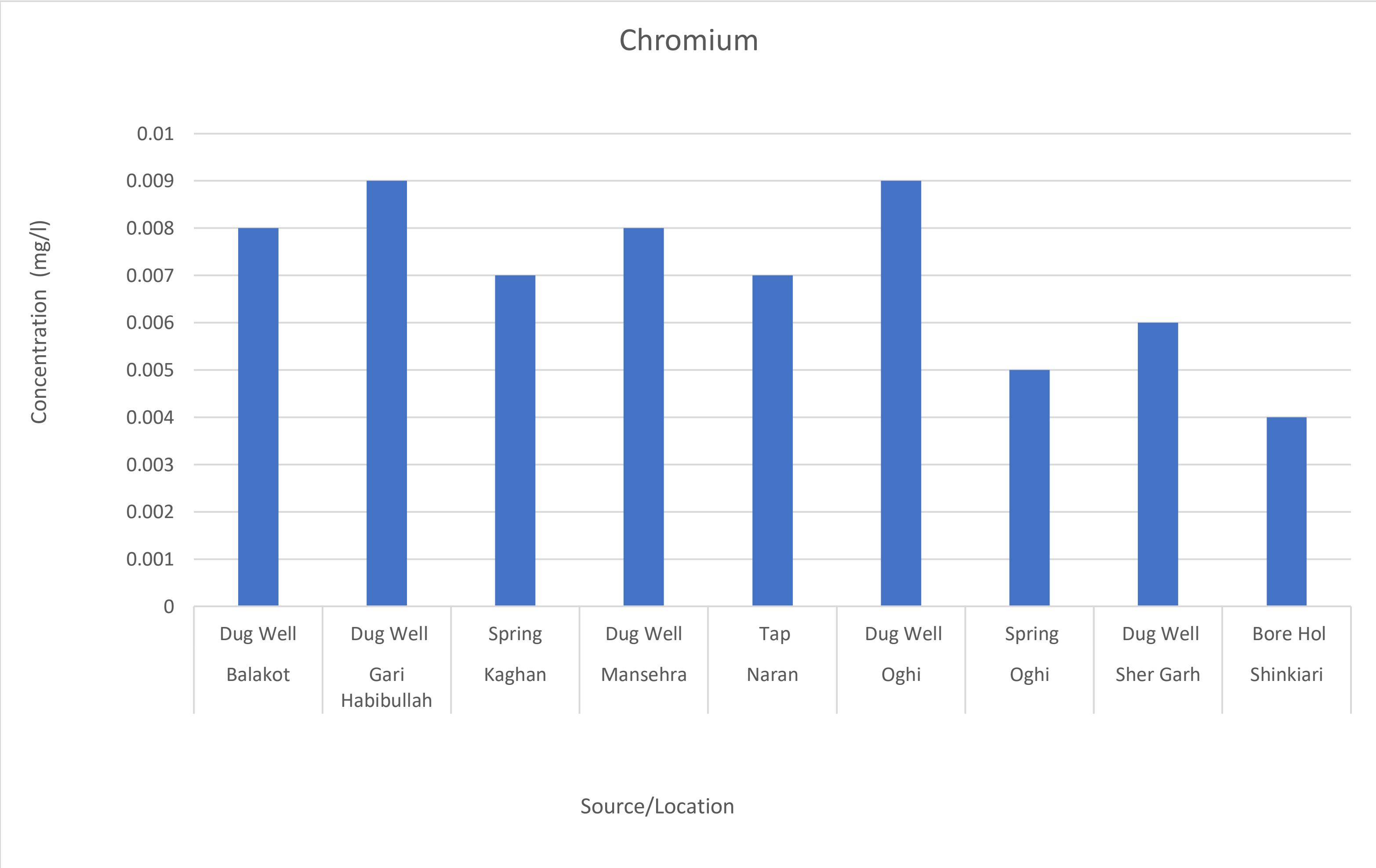

Fig 3.13 Concentration (mg/l) of Cr in various water sources of District Mansehra

Cr concentration detected in water samples of Oghi, Sher Garh, Shinkari, Balakot Naran and Mansehra and samples with BDL were from Besal, Burwae, Gittidas, Battakundi, Dadai, Jabori, Kaghan, Naran and Phulra areas. The Cu concentration was recorded in 16 % of the samples within permissible limits of WHO and EPA and 84 % of samples were BDL. All 100 % of the drinking water samples of district Mansehra was found safe with respect to Cr concentration. (Ali et al., 2019).

The high level of Cr in drinking water can be due to erosion of the parent rock or natural weathering of minerals or human induced mining processes and waste of paper or steel mills (Patel et al., 2013). In small quantities Cr can cause greater health complexities and various kinds of cancers.

It also effects human immune system and help in developing various types of allergies (Fernandez et al., 2013) The Cr concentration in water of District Mansehra can be due to erosion of natural rocks and its mixing with surface water commonly used for drinking. (Patel et al., 2013).

3.4.5. Lead (Pb)

Samples collected from sites of Balakot, Batta Kandi, Besal, Burwae, Dadai, Darband, Gari Habibullah, Gittidas, Jabori, Jared, Kaghan, Kauai, Mansehra, Naran, Oghi, Phulra, Shehr Garh and Shinkiari were tested to investigate concentration of Pb in drinking water sources. The WHO and NSDWQ permissible limit for Pb is 0.01 mg/l (Patil et al., 2013).

Pb was witnessed in 14 samples of the study area of Mansehra and the concentration ranges 0.009 mg/l – 0.002 mg/l. Highest Pb concentration 0.002mg/l recorded in the Dug well of Balkot and bore hole of Darband town, similarly lowest level 0.009 mg/l were found in Tap water of Jabori and Phulra towns.

Presence of Pb was also recorded in other locations of Mansehra, Balakot tap water 0.004mg/l, Darband dug well, 0.007mg/l, Garhi Habibullah bore hole 0.008mg/l and Jared tap 0.008 mg/l as shown in Table.

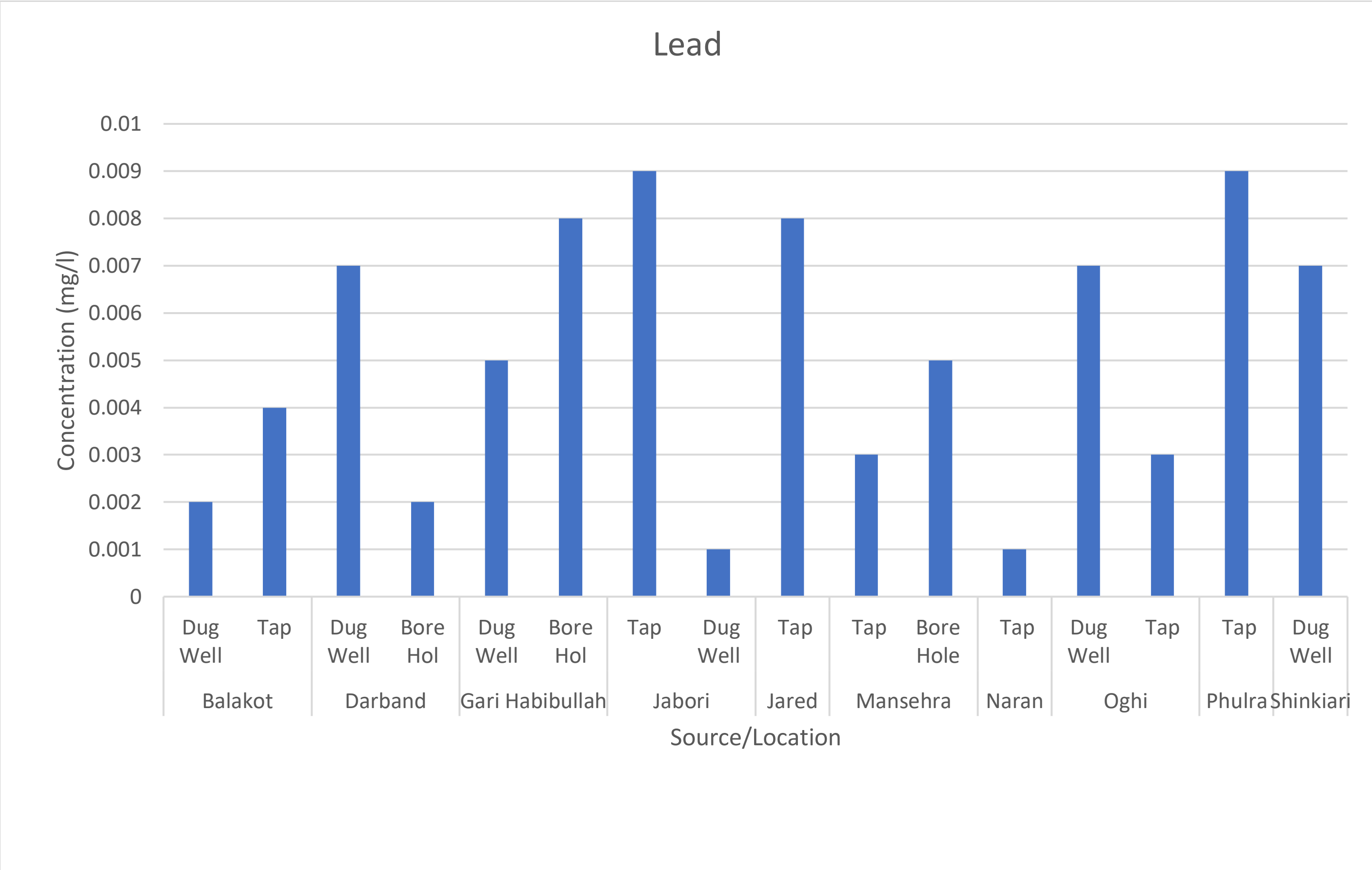

Fig 3.14 Concentration (mg/l) of Pb in various water sources of District Mansehra

Pb concentration detected in 14 water samples of Oghi, Sher Garh, Shinkari, Jared, Phulra,Balakot Garhi habib ullah and Darband. Pb was recorded BDL in 42 samples collected from sites of Besal, Burwae, Gittidas, Battakundi, Dadai, Jabori, Kaghan, Naran and Mansehra city areas.

The Pb concentration was witnessed in 25 % of the samples within permissible limits of WHO and EPA and 75 % of samples were BDL. All 100 % of the drinking water samples of district Mansehra was found safe with respect to Cr concentration. (Fernandez et al., 2013).

The high level of Pb has serious health implication especially for children effecting their growth and mental well-being. Pb in the drinking water cause serious damage to kidney and causing high blood pressure (Patil et al., 2013). The Pb pollution in drinking water in the study area can be due to atmospheric pollution caused due to leaded fuel common in mountainous region. The common sources of Pb in environment is corrosion of water distribution pipes, leaded petrol, paints and cosmetics products (Ali et al., 2019). However, no significant difference of Pb concentration was witnessed in WHO permissible limits and study area.

3.4.6. Mercury (Hg)

Drinking water samples collected from District Mansehra, Balakot, Batta Kandi, Besal, Burwae, Dadai, Darband, Gari Habibullah, Gittidas, Jabori, Jared, Kaghan, Kauai, Mansehra, Naran, Oghi, Phulra, Shehr Garh and Shinkiari were further analysed to detect the level of Hg concentration in water. The WHO and NSDWQ permissible limit for Hg is 0.001 mg/l (Fernandez et al., 2013).

Hg was found in 5 samples of the study area of Mansehra and the concentration ranges 0.0009 mg/l – 0.0005 mg/l. Highest level of Hg 0.0005mg/l was found in Darband Dug well followed by 0.0007mg/L in bore hole of Oghi and Garhi Habibullah. Similarly, Hg concentration was also witnessed in dug well water of Balakot 0.0008mg/l and Lowest Hg contents were observed in spring water of Sher Garh area of District Mansehra.

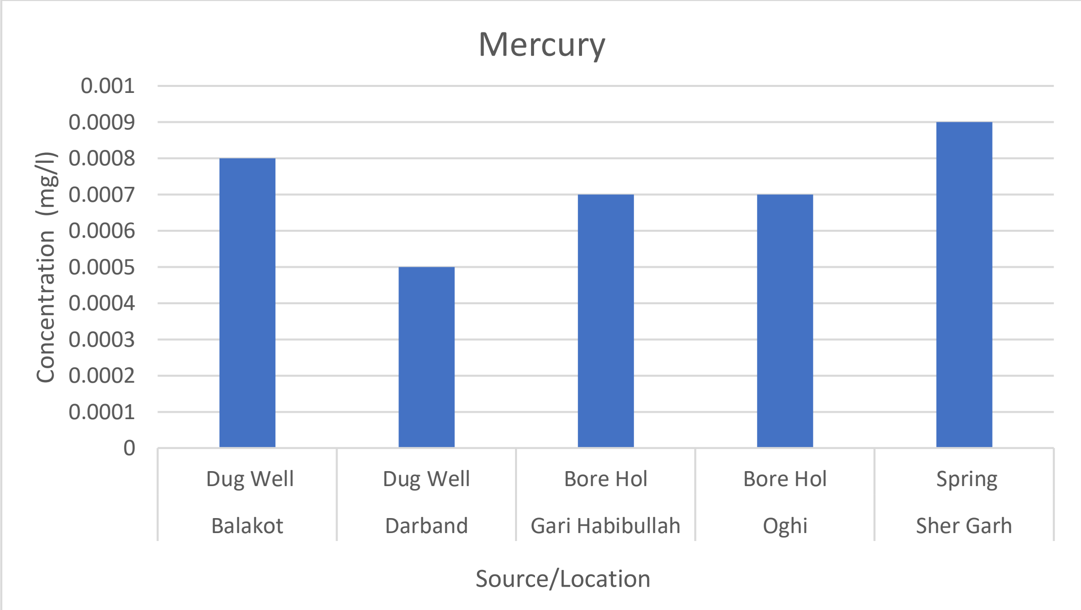

Fig 3.15 Concentration (mg/l) of Hg in various water sources of District Mansehra

Hg concentration was only recorded in 5 sites Oghi, Sher Garh, Darband, Garhi Habib Ullah and Balakot Naran and samples from 13 sites such as Besal, Burwae, Gittidas, Battakundi, Dadai, Jabori, Kaghan, Naran and P

hulra, Mansehra, Kawai and Jabori were showing Hg below the detectable limits. The Hg concentration was recorded in 09 % of the samples within permissible limits of WHO and EPA and 91 % of samples were BDL. All 100 % of the drinking water samples of district Mansehra was found safe with respect to Cr concentration. (Ali et al., 2019).

The high concentration of Hg in drinking water and has lethal consequences for human body and effecting its DNA. Hg in the drinking water cause serious damage to kidney and renal failure (Patil et al., 2013). Hg level in the environment are usually very low and it can be introduced to environment through both erosion from natural deposits and anthropogenic sources.

Moreover, industrial discharge and waste from refineries have high level of Hg but in the study area mining of coal can be the reason of Hg contamination (Patil et al., 2013) However no significant difference was recorded in Hg concentration of study area and WHO standard limits (Ali et al., 2019).

3.4.7. Zinc (Zn)

Water samples of Balakot, Batta Kandi, Besal, Burwae, Dadai, Darband, Gari Habibullah, Gittidas, Jabori, Jared, Kaghan, Kauai, Mansehra, Naran, Oghi, Phulra, Shehr Garh and Shinkiari were analysed to detect Zn presence. The WHO guiding limit for Zn is 3.0 mg/l and NDWQS standard value is 5.0 mg/l, which is slightly higher than WHO (Khan et al., 2013).

Zn concentration in drinking water of the study area samples varies and ranges 0.08- mg/l – 1.0mg/l. Highest Zn level of 1.0 mg/L was found in Dug wells of Jabori, Mansehra city and Garhi Habibullah and minimum concentration of 0.08 was observed in dug well of Darband town. However, detection limit of Zn remained below in 35 samples due to detection limitation of the instrument (Ali et Al., 2019).

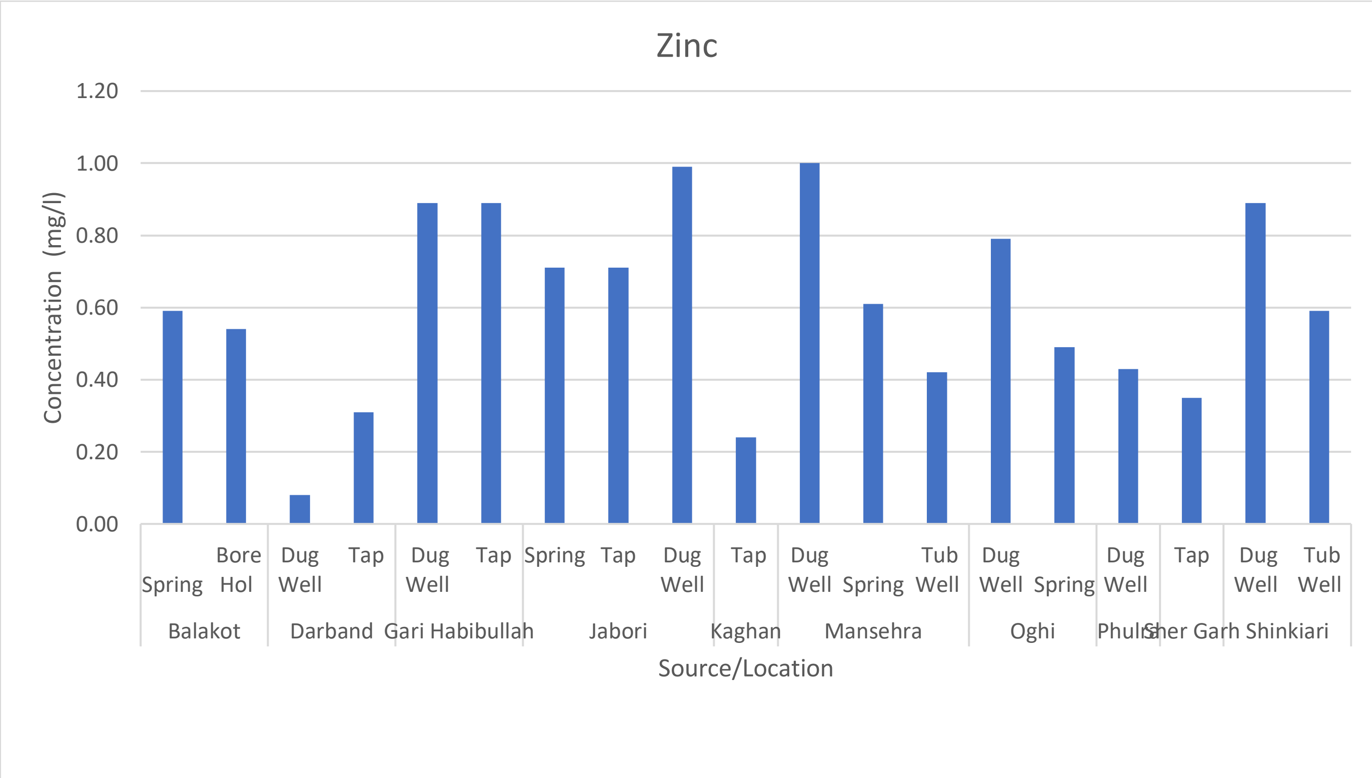

Fig 3.16 Concentration (mg/l) of Zn in various water sources of District Mansehra

The samples with BDL were from Balakot, Besal, Burwae, Gittidas, Dadai, Jared, Kaghan, Kawai, Shergarh, Sinkari, Oghi and Phulra. 37 % of the samples were found with Zn concentration but within safe limits of WHO and EPA, in the remaining 63 % samples, Zn contents were not detected this making 100 % of the water samples safe for drinking purposes (Ali et al., 2019).

The high concentration of Zn in the drinking water has potential to accumulate in liver, gills and muscles which can cause damage (Fernandez et al., 2013). Zn is common occurring element on earth and found in earth crust and mostly used in ceramics, paint batteries producing industries. Similarly drinking water supplied through water supply schemes were also contributing to Zn in drinking water (Patil et al., 2013) Moreover, no significant difference was recorded in Zn concentration of study area and WHO standard limits (Ali et al., 2019).

CONCLUSION

The district population is dependent mainly on shallow water sources such as springs, dug well and bore hole. Because of lack of proper sewerage system and poor sanitary conditions, significant level of bacteriological contamination was found in all the drinking sources except tube well water. Furthermore, alarming level of total Coliforms, fecal Coliforms and E. *Coli* was found above the permissible limits of WHO and NSDWQ.

Similarly, chemical contamination such as TDS, Hardness, Turbidity, Fe, NO3, SO4 was witnessed in both surface and ground water sources. Total Harness was observed in significant number of samples, high concentration of Fe was also a growing concern. However, HM contamination was found in limited number of samples and within safe limits.

18 samples collected from various towns of district Mansehra was found with high level of bacteriological contamination. 100 % of the spring water samples were observed with Total coliform, Faecal Coliform and E. *Coli* thus making water unsafe for human use. The high level of microbes is referring to poor sanitation conditions, open sewerage system and open defecation practices common in mountainous regions of Mansehra. Majority of the population in mountainous areas are dependent on spring water and alarming rate of bacteriological presence in water is serious threat.

Tap water samples were analyzed from both government and private water supply schemes and high level of Coliform and E. *Coli* was observed in 100 % of the samples due to damaged water supply lines, and dispute of service provider with the community.

In tap water, physico-chemical water quality parameters such as pH, EC, Alkalinity, turbidity, TDS, Na, K, SO4 and Toxic metals As, Cr, Cu, Zn, Hg and Pb were within the standard limits of the WHO standards except Nitrates, Hardness and Iron. Total 09 out of 18 tap samples were observed unsafe with respect to chemical composition. Like many other places in the country, the water supply system and sewage system lines are running parallel which is also a big source and risk of contamination.

Similarly, the supply schemes are dependent on spring water, and the water tanks are open and not maintained. Most of the supply schemes are in dismal shape and exposing water to more contamination. The existing government water supply schemes are not enough to fulfil the growing needs of the community, it only covers 30-40% population, and communities are using alternative private water sources.

Since these schemes are not well designed and mostly use sub-standard pipe which gets rust or broken very soon and are big source of both biological and chemical contamination. Secondly, water source collection tanks are far from communities – up in the hill so those are also not clean periodically which also settle biological contamination in the tank. One of the major sources of water contamination is open defecation among rural population which also contaminate surface water.

Bore hole are common source of drinking water and almost 80% of the households in Urban areas have individual borehole to fulfil their drinking water needs urban areas od district Mansehra where spring water availability is limited. Total 08 samples of bore hole were analyzed and bacteriological contamination was recorded in 06 samples similarly chemical contamination like TDS, Hardness, Turbidity, Fe, NO3 were found in 75 % of the samples. Heavy metals were not common in bore holes and found below the permissible limits. In district Mansehra the depth of bore hole usually varies from 80 -100 feet and the chances of mixing of water from septic tanks are drinking water is common. Dug well were found common in rural areas of the district. Total 09 dug well samples analyzed shown the presence of Total coliform, Faecal Coliform and E. *Coli,*100 % of the dug wells are unsafe for drinking purposes. Dug wells in the villages are not covered and more vulnerable to microbiological contamination. High level of Fe, NO3 and hardness was found in 6 samples of Dug well samples making water unsafe for human use.

Toxic metals such as As, Cu, Cr, Hg and Pb were within permissible limits. Dug wells are shallow source of water and more prone to pollution due to health and hygiene situation in rural areas. Also, sewage system in villages are not properly planned and open defecation is also common. Rainwater runoff further is also contributing factor in contamination in dug well water.

Tube well are not common source of drinking water , 3 samples were analysed for bacteriological and chemical analysis. Bacteriological contamination in the tube well was found in permissible limits and 100 % of the samples were safe. However, high level of Fe was observed in all samples, NO3 was found in 2 samples and hardness was also noted in one the tube well sample. In urban settlement of district Mansehra tube well water is used mainly for irrigation purpose. but less exposure of tube well water is due to its location- mostly away from major villages and depth of the tube well.

RECOMENDATIONS

Proper planning and management of sewerage and sanitation, especially in urban areas of the district is critical for provision of safe drinking water to bulk of the population. With increase urbanization, planning and installation of water supply pipes and sewage lines will help to control mixing of sewage with drinking water. There is dire need to operationalize the damaged water supply schemes and to arrange sustained budget allocation for its operations and maintenance. Damaged pipes and rusted fitting need replace on urgent bases.

Ground water extraction is an unregulated area in Pakistan and it is common in Mansehra, each house hold in urban center has a bore hole managed manually or motorized pump. Poor house planning is providing favorable environment for mixing of clean water with septic tanks. To control contamination, the septic tanks must have proper lining and should be constructed at least 50 feet from drinking water sources as per U.S. EPA guideline.

Public awareness campaign is critical to highlight harmful effects of contaminated drinking water and importance of better sanitation and hygiene. Low cost water filtration technologies should be promoted. Chlorination of water tanks should be ensured to control contamination in water pipes. For proper disinfection, the WHO recommended ≥ 0.5 mg/L of chlorine concentration is required.

Regular water quality monitoring and surveillance program should be designed to monitor drinking water of district Mansehra. As a standard practice chemical monitoring should be performed once a year while microbial quality on quarterly basis

There should be awareness raising in the communities for protection management of dug wells, wells should be covered to avoid entrance of rainwater and other containments. Similarly, communities should be informed about harmful effects of unsafe water and its health implications. The relevant water management bodies and institutions need to coordinate during planning for water supply systems. The governing water laws polices and quality standards should be implemented to control the gigantic issue of water pollution.

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