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Water Quality Status of Upper KPK and Northern Areas of Pakistan

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LIST OF ABBREVIATIONS

μS/cm	Micro Siemens Per Centimeter	MAC*	Maximum Acceptable Concentration
AAS	Atomic Absorption Spectrophotometer	MAC**	Maximum Allowable Concentration
ADB	Asian Development Bank	MAF	Million Acre Feet
AF	Acre Feet	MAR	Mardan
Alk	Alkalinity	Mg	Magnesium
As	Arsenic	mg/l	Milligram Per Liter
BDL	Below detectable Limit	MPL	Maximum Permissible Level
BOD	Biological Oxygen Demand	MPN	Most Probable Number
Ca	Calcium	N	Nitrate/Normal
Cl	Chloride	NO_3	Nitrate
CNS	Central Nervous System	NRSP	National Rural Support Program
C^o	Centigrade	NTU	Nephelometric Turbidity Unit(s)
CO_3	Carbonate	PO_4	Phosphate
COD	Chemical Oxygen Demand	Ppb	Parts Per Billion
Cr	Chromium	Ppm	Parts Per Million
DO	Dissolved Oxygen	PSI	Pakistan Standards Institution
E.Coli	Escherichia Coliform	PSQCA	Pakistan Standards & Quality Control Authority
EC	Electrical Conductivity/ European Community	PVC	Polyvinyl Chloride
EDTA	Ethylenediamine Tetraacetate Dehydrate	RO	Reverse Osmosis
EPA	Environmental Protection Agency	Sm^{-1}	Siemens Per Metre
F	Fluoride	SO_4	Sulphate
FDA	Food Development Authority	SPADNS	Sodium 2-(parasulfophenylazo) -1, 8-dihydroxy-3, 6-napthalene disulfonate
Fe	Iron	SW	Surface Water
Ft	Foot	TCU	True Color Unit
TW	Tube well	TDS	Total Dissolved Solids
OW	Open well	TMA	Tehsil Municipal Administration
DTW	Domestic tube well	TW	Tube well
Km	Kilometer	WAPDA	Water and Power Development Authority
HDL	Highest Desirable Level	WHO	World Health Organization
IWCP	Improved Water Conservation Practices for NWFP and Northern Areas of Pakistan	WRRC	Water Resources Research Centre
IBWA	International Bottled Water Association	WSS	Water Supply Scheme
JICA	Japanese International Cooperation Agency	M	Molar
K	Potassium	m	Meter

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Foreword

Water is essential for existence of life; it seems to be in abundance on the earth. Nevertheless, its 97.5% is saline, mostly in the form of oceans, seas and salty lakes etc, whereas the freshwater just makes 2.5%. A predominant quantity of freshwater (69.8%) is trapped as permanent snow covers, mountainous glaciers, soil moisture and swamps etc, 29.9% exists as groundwater of which about 50% is at an uneconomical pumping depth of 800 m. Therefore, the global renewable freshwater, comprising of precipitation and resultant streamflow merely becomes 0.3% of the freshwater or 0.02% of the global water, which is almost rejuvenated every year. Even then, these meagerly quantified freshwater resources of the world are sufficient to support more than five times the current global population, provided it is uniformly distributed amongst inhabitants. In contrast, the geographical distribution of freshwater is quite uneven ranging from more than 100,000 to less than 50 m^3 per capita per annum. The countries having low freshwater availability i.e. below 1700 m^3 are categorized as water stressed, while those less than 1000 m^3 are considered water scarce. The current per capita freshwater availability in Pakistan is around 1200 m^3 and is therefore categorized as a water stressed country. It is expected to be soon included among water scarce countries due to rapidly growing population.

Quality of water is of prime importance along with its availability, it is inextricably linked with water quantity as per assimilation principles of water resource management i.e. lesser the water quantity, the greater it is prone to contamination. Water quality has therefore become a major concern and fundamental cause of diseases in the last few decades in developing countries, leading to reduced life expectancy. The issue has been considered so serious that the theme for the World Water Day of 2010 has been chosen as, "Clean Water for a Healthy World".

The situation in Pakistan is rather worst where about 4 MAF (million acre-foot) of industrial and domestic wastewater is produced every year, of which merely 3% is got treated while the remaining is directly discharged into freshwater bodies. Similarly, in urban areas 60,000 tons of solid waste is generated daily, out of which 60% is got collected. All that is rapidly deteriorating the water quality in the already water stressed country. It has been reported that almost 40% of diseases in the country are water-borne and is taking a major chunk of the national health budget. Individualistically, people have to spend substantial portion of their income on fighting with these water-borne diseases which is further adding to the financial miseries of the poverty stricken citizens. Rising public and global concern over water quality has been sensitized by the planners and policy makers to make necessary arrangements for provision of safe water. However, planning and implementation of projects for provision of safe water could not be realized unless baseline survey data of water quality status is made available so that remedial measures could be devised accordingly by the responsible agencies. PCRWR took the initiative for the challenging job and launched numerous projects such as "National Water Quality Monitoring", "Rural Water Quality Monitoring" and "Arsenic Monitoring and Mitigation". The outcomes of those projects have led the government to launch mega projects such as "Provision of Safe Drinking Water" and "Clean Drinking Water for All".

Improved Water Conservation Practices (IWCP) is a project launched by the PCRWR exclusively for northern mountainous areas of NWFP and the entire Northern Areas (Gilgit-Baltastan) of Pakistan. These are remote, rugged and highly poverty stricken areas; therefore required special attention. The report pertains to water quality monitoring of the said area over the years 2004-06, highlights major contaminants and identifies hot spots of poor water quality. The report summarizes the findings of water quality survey, draw conclusions and gives recommendations for interventions to improve water quality of the surveyed area. The study will definitely be helpful for planners and policy makers for strategic move towards provision of safe drinking water for the area. I would like to appreciate efforts of the PCRWR scientists and supporting staff for carrying out this enormous task in highly rugged and remote areas for betterment of Pakistan, the future of which lies in water.

Dr. Muhammad Aslam Tahir
Chairman, PCRWR

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CHAPTER-1

INTRODUCTION

1.1 Background

Water is source of life and essential for survival of mankind on the earth. It is backbone of agriculture and ecological balance. Development of civilizations ever remained dependent on availability of reliable fresh water resources. Its quality and quantity are inextricably linked and are equally important. However, that very source and essential ingredient of life has now become a cause of multiple health hazards. Apart from geological origin, quality of water is also related to population density, extent of availability, human activities, industrial growth, and agricultural practices. The greater the population density, the more is water quality prone to degradation and deterioration. According to a UN study, while the world population is surging, the availability of freshwater is on the decline, and in the next two decades, many of the countries in South Asia, Middle East and Africa would face a crunch. While the water quantity is becoming scarce, its quality is deteriorating due to urbanization, industrialization, deforestation, land degradation, global warming, population increase and diversified domestic uses. As such, water quality issues are of prime concern followed by air pollution and solid waste management especially in developing countries.

Water contaminated with fecal bacteria, parasites and other microbes, causes about 6,000 deaths of adults and children every day. According to the World Health Organization, diarrheal disease accounts for an estimated 4.1% of the total daily global burden of diseases and is responsible for the deaths of about 1.8 million people every year. It was estimated that 88% of that burden is attributable to unsafe water supply, sanitation and hygiene, and children are most vulnerable especially in developing countries. The public health decision-makers in the developing countries are either not well aware of the gravity of the situation, or not equipped with feed back infrastructure and remedial measures. Even if they are, the lack of proper management and professionalism, together with financial constraints contributed significantly to the water-borne health risks.

In Pakistan, per capita water availability, which was more than 5000 m^3 half a century before has now fallen to about 1200 m^3, and as such it is rapidly entering into what are called water scarce countries. Increase in population density and decrease in water availability has become dual threat to water quality, and impact of which on public health is becoming significantly visible. It has been estimated that in Pakistan around 30% to 40% of all reported diseases and deaths are due to poor water quality. Moreover, the leading cause of deaths in infants and children up to 10 years age as well as mortality rate of 136 per 1,000 live births is reported owing to diarrhea, whereas every fifth citizen suffers from illness caused by polluted water. The situation in the North Western Frontier Province (NWFP) is rather worst due to being amongst the backward and poverty stricken areas.

1.2 North Western Frontier Province

The NWFP, which lies between latitude 31^{o} 40' to 36^{o} 57' N and longitude 69^{o} 19' to 74^{o} 70' E, mostly comprises mountainous terrain located in the lap of Hidukush and Hamalaya Ranges, the world's highest mountain ranges. The Hindukush range extends along its western border, whereas Hamalaya originates from its north eastern part. The southern boundary is formed by the east-west tending Safaid Koh Cherat range. The mighty Indus runs through its northern part and below Harripur forms its eastern boundary with Punjab. Geographical area of the province including FATA is 10.17 million hectares (NWFP 7.45 million hectares and FATA 2.72 million hectares). However FATA comprising seven agencies falls under administrative control of Federal Government. An Additional Chief Secretary stationed at FATA secretariat Peshawar coordinates its affairs between provincial and federal government. The NWFP with its capital at Peshawar comprises 24 districts, 48 tehsils and 986 union councils. The seven agencies of FATA comprise 43 tehsils. There is no local government system in FATA.

1.3 Physiography and Climate

The landscape of the province presents variety of physiographic features ranging from deserts in the south, fertile valleys in the middle and high altitude mountains in the north. There are great number of inter mountainous basins in the central and southern parts of the province. Some are no more than flat bottomed river valleys. Others, like Peshawar valley and the Bannu basin cover thousands of square kilometers. Most plains are crossed by one or more rivers, making it possible to irrigate some of the soils. Moreover plains are the sites with best ground water resources, for the coarse alluvial deposits make good aquifers.

Sharp variation in physiographic features and altitudinal difference create a diverse climate in the province. Therefore southern parts are arid and hot, whereas north is humid and cold. The northern mountains form a high altitude cold desert. Somewhat temperate climate prevails in the middle – the Peshawar valley. Average annual temperature varies between 5.9 ^{o}C in the north and 31.2 ^{o}C in the south. Snow fall is common at high altitudes and winter frosts in inter mountainous valleys. Kalam in district Swat is the coldest point where winter temperature frequently falls below zero. The average annual rainfall ranges between 363 mm in Peshawar to 1240 mm in Dir. Southern parts receive rather less rainfall. Major tributaries of the River Indus, which pass through NWFP, comprise the River Swat, Punjgor, Kabul, Kurram and Tochi etc. The River Kunhar is the only tributary that drains into the River Jehlum, which forms eastern boundary of NWFP.

1.4 Demography and Water Resources

Population of NWFP according to the 1998 census was 17.7 million, which has now escalated to 22 million by the year 2007. Population density accordingly is 288 persons per sq. km as compared with the national density of 193 persons per sq. km. In addition, 2.5 million Afghan refugees after the outbreak of war in 1979 have settled in NWFP. Population density wise, it is the second most thickly populated province of Pakistan, Punjab has the highest population density.

This increase in population will have direct impact on the water sector, which has to cater the increased domestic, industrial and agricultural demands. The quality of surface-water is already poor and is further deteriorating because the increased municipal, industrial, and agricultural uses have boosted up yield of waste water, which is disposed of unchecked and untreated into natural streams. Marble industry is rapidly growing along river banks and nullas and is adding into natural water bodies the substantial amount of mineral impurities such as salts of calcium, magnesium and sodium etc. Ground water is limited, and where available is being over exploited causing groundwater mining, which activate oxidation of otherwise inactive minerals resulting into mineralogical contamination or intrusion of contaminated water into otherwise fresh and sweet water aquifers. Water quality monitoring and information sharing is lacking, even though it is crucial to any water quality management program.

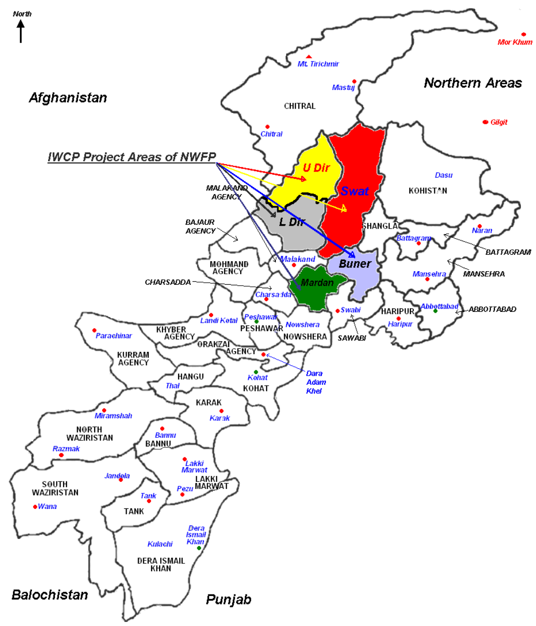


Figure 1: *IWCP Project Area of NWFP*

1.5 Northern Areas of Pakistan

Geography and Demography

As the name implies, Northern Areas are situated in the extreme north of Pakistan. It borders the Wakhan corridor of Afghanistan to the northwest, the Xingjian province of China to the northeast, the Indian held Kashmir to the east and southeast, the Azad Kashmir to the southeast and NWFP to the south and west. Most of the area comprises rugged mountains, the higher elevations having permanent snow cover and extensive glaciers. Northern Areas, having total geographical area of 72971 sq. km, are dominated with one of the most mountainous landscapes on earth, with an arm of the Hindu Kush to the south-west, the Himalaya to the south east, the Karakuram to the north-east and the Palmir range to the north-west. It is junction of the three highest mountain ranges in the world. More than half of the Northern Areas is located above 4500 meters and several of the snow covered highest peaks of the world are located therein – K2, Nanga Parbat and Raka Poshi are among the highest in the area.

According to the 1998 census, the population of the area was 0.88 million, which has now escalated to 1.5 million (2007), indicating population density of 20 persons per sq. km, of which only 10% is urban while the remaining is settled in rural areas. The population of the region is scattered in small valleys along the riverbanks among the high peaks of the Himalaya, Karakorum, and Hindu-kush mountain ranges.

Figure 2: Geographical Map of NAs

1.6 Climate and Water Resources

Climatic condition varies widely in Northern Areas, ranging from the monsoon-influenced moist temperate zone in the western Himalaya, to the arid and semi-arid cold desert in the north Karakuram and Hindu Kush. Below 3000 meters, precipitation is minimal, rarely exceeding 200 millimetres per annum. However there is strong gradient with altitude and at 6000 meters, an equivalent of 2000 millimetres per year falls as snow. The NAs contain the greatest area (22,000 sq. km) of perennial glaciers outside the polar regions and estimates are that as much as 28% of the region is glaciated; the area of winter snow cover reaches up to 30-40% (Ahmed and Joyia, 2001). There are more than 100 glaciers that are over 10 km in length and many go beyond 50 km. Hence glaciers and seasonal snow constitute a huge reservoir of freshwater in the area and contribute 60% to 80% waters of the River Indus, which with its several tributaries such as the River Gilgit, Hunza, Ishkoman, Yasim, and the River Shiok pass through it.

Ground water is almost non existent. Therefore, water supply in Northern Areas depends largely on surface water, which is conveyed through open channels and thus prone to contamination. Although official statistics exhibit that over 40 per cent of the Northern Areas rural population has access to piped water supplies, but many systems are out of order, and actual coverage may be as low as 20 per cent. The majority of the region has no proper water supply and the people are bound to consume raw water of springs, streams, khawars and nullas. That is adversely affecting health of the inhabitants and precious man-hours are wasted due to illness (IUCN 2003).

1.7 Water Quality Implications

Safe water is not only a vital health factor for life, but has also an important role in socio-economic development of population. The high death rate, sickness and poor standards of health are mostly due to unsafe water. Water quality is therefore crucial for the prevention of diseases and promotion of health of individuals and communities. In 1981, the 34th World Health Assembly in a resolution stressed that safe drinking water is a basic element of primary health care, which is the key to attainment of “Health for All”. PCRWR (1985) and WHO (1972-73) reported that after installation of new water supply pipes alone in 30 rural settlements of Japan, communicable intestinal diseases were reduced by 72% and that of trachoma by 64% while the infants and young children death rate fell by 52%. Similarly in Uttarpardesh (PCRWR, 1985) after carrying out improvements in water works, sewerage, and sanitation, the cholera caused death rate decreased by 74%, typhoid rate by 63.3%, and dysentery by 23%. Additionally, 10% productive time of each person, wasted due to water-related diseases, was also saved. WHO estimates exhibit that only in Asia some 500 million diarheal cases occur every year. These figures therefore reveal an alarming impact of unsafe water on public health, thus demanding an immediate attention.

1.8 Water Quality Monitoring of NWFP and Northern Areas

Previously, PCRWR collected data of surface and groundwater quality only in a few districts of NWFP, under "National Water Quality Monitoring Program". As such, no comprehensive data set became available on quality of drinking water pertaining to most parts of NWFP and the entire Northern Areas. Different organizations including Pakistan Council of Research in Water Resources (PCRWR), Water and Power Development Authority (WAPDA), Environmental Protection Agency (EPA) and some individual consultants also have conducted short-term water quality assessment studies, but that too pertains to a few districts only.

Pakistan Council of Research in Water Resources (PCRWR) therefore launched an exclusive project entitled "Improved Water Conservation Practices for NWFP and Northern Areas of Pakistan" on 1st July 2004. The program aims at, inter alia, undertaking water quality monitoring in mountainous areas comprising five northern districts of NWFP (Mardan, Bunner, Swat, Lower Dir, and Upper Dir) and entire NAs (Diamer, Gilgit, Ghizer, Skardu, and Ghanche).

1.9 Objectives

The general objective of water quality monitoring under the project "IWCP" is to provide the information on the level of pollution in the water resources of the project area. It is expected that this information would help in identifying the problem areas for initiating appropriate remedial measures. The specific objectives of the water quality monitoring under the project are:

- To monitor the surface and ground water quality of the mountainous areas, which so far remained more or less out of the water quality monitoring network.
- To provide a feed back to the consumers and policy makers for adopting precautionary measures well in time.
- To prepare national water quality map for researchers and planners for conserving the water quality in the upper tracts of the Indus Basin.

1.10 Scope of the Study

To tackle the alarming scenario of water quality concerns in Pakistan, several studies to monitor the drinking water quality have been carried out, but the remote, rugged and poverty stricken mountainous areas remained least monitored or almost neglected. After observing the gravity of the situation at national level, the Pakistan Council of Research in Water Resources (PCRWR) launched a project entitled "Improved Water Conservation Practices for NWFP and Northern Areas of Pakistan" on 1st July 2004. Water quality monitoring of the project area was one of the objectives of the project. The phase-I and phase-II of the program have been completed over the years 2004-05 and 2005-06. This report pertains to both the years of water quality monitoring. Analytical data has been incorporated and presented covering five districts (Mardan, Buner Swat, Upper Dir and Lower Dir) of NWFP and the entire Northern Areas of Pakistan (Gilgit, Skardu, Ghanche, Diamar and Ghizer).

The information regarding water quality problems/issues all over the districts would be available free of cost on Water Quality Website of PCRWR for researchers, policy makers, planners and citizens for utilization in preparation of development schemes on water supply, agriculture, livestock and fisheries *etc*.

1.11 Relationship of the Project to PCRWR

The PCRWR, with its headquarters at Islamabad, is a national research institution, which is mandated to conduct, organize, coordinate and promote research on all aspects of water resources including drinking water quality. The Council has five regional offices stationed at Lahore, Peshawar, Quetta, Bahawalpur, and Tandojam and 18 district water quality laboratories to address regional problems related with water resources and give feed back to policy makers. The central office at Islamabad has established National Water Quality Laboratory, which has secured accreditation of ISO 17025. Regional Water Quality Laboratories have also been set at all the regional offices. The regional laboratories have recently been strengthened with latest equipment and state of the art technology such as Atomic absorption spectrophotometers. All the laboratories are capable of carrying out analysis of parameters pertaining to issues of water quality assessment, water pollution, and environmental and waste water management. ISO accreditation of the regional laboratories is also being sought. PCRWR has so far undertaken numerous studies and facilitated different organizations including educational institutes in the area of water quality research. Recently PCRWR undertook a mega project of consultancy regarding water quality assessment survey of the sites for installation of water filtration plants at Union Council level all over the country under the project "Clean Drinking Water for All." Water supply schemes assessment survey all over the country is also being carried out by the organization under another project entitled "Provision of Safe Drinking Water."

CHAPTER-2

LITERATURE REVIEW

The water quality parameters being studied by WRRC, Peshawar, for Water Quality Monitoring in NWFP and Northern Areas of Pakistan under the project "Improved Water Conservation Practices for NWFP and Northern Areas of Pakistan" are reviewed in this chapter which are mainly focused on natural sources of contaminations and the health effects in respect of various Physical, Aesthetic, Chemical, Trace Elements and Microbiological parameters.

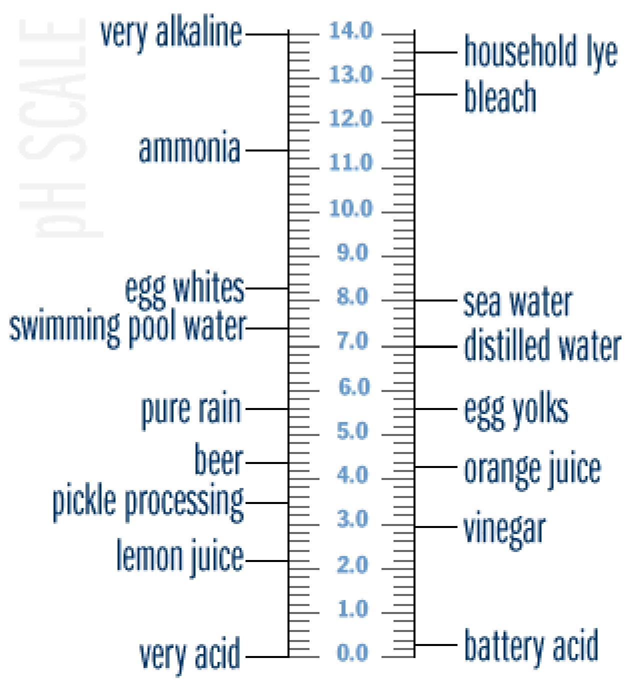
2.1 Natural Sources of Contaminations and its Health Effects

In under developed and developing countries of the world; most of transmissible diseases are water borne due to drinking of unsafe water which- cause morbidity and mortality. In developing countries, the mortality rate especially in the infants is very high. In Pakistan more than 1,100 children less than five years of age die everyday, about 600 of them are under one month of age. This means that in Pakistan an estimated 423,000 children under five years of age die every year. The most common causes of death amongst children under five, aside from newborns, are pneumonia and diarrhea. Simply ensuring clean drinking water, sanitation and hygienic practices for everyone can cut deaths by diarrhea by half and prevent the spread of disease (UNICEF). Unfortunately public and decision makers of the most developing world are not well aware of the gravity of the situation. In all developed countries drinking water quality is considered a very serious issue and improvement measures were taken about a century ago. For the evaluation of water pollution, water quality parameters are used for analytical purpose and also provision of safe drinking water to the citizens or public. The general public of these countries are aware of water quality impacts on human health, hence they are very conscience about it. For the reduction of pollution or improvement in quality of water used for human consumption depend on reliable analytical measurements of contaminants. So analytical water quality parameters are utmost important and are playing a key role for water pollution assessment. The prime objective of this chapter is to know about natural sources of contaminations, health effects and guideline values of some basic drinking water quality parameters.

2.2 Physical and Aesthetic Parameters

2.2.1 pH

The pH of a sample of water is a measure of the concentration of hydrogen ions. Mathematically it is the negative logarithm of the hydrogen ion (H^+) concentration and the term pH was derived from the manner in which the hydrogen ion concentration is calculated. The term implies that at higher pH, there are fewer free hydrogen ions and vice versa, and that a change of one pH unit reflects a tenfold change in the concentration of the hydrogen ions. The pH scale ranges from 0 to 14. A pH of 7 is considered to be neutral. Substances with pH less that 7, are acidic and those with greater than 7 are basic. The diagram below reflects pH of various common solutions and substances. The pH of most raw water sources lies within the range of 6.5-8.5. Chlorination tends to lower the pH, whereas water softening using the excess lime/soda ash process raises the pH level. A direct relationship between human health and pH of drinking water is difficult to ascertain because pH is also closely associated with other aspects of water quality. In so far as pH affects the various processes in water treatment that contribute to the removal of viruses, bacteria and other harmful organisms, it can be claimed that pH has an indirect effect on human health. WHO recommended guideline value for pH is 6.5-8.5, although it is recognized that some problems can arise within a distribution system with water having pH level below 7.0 because the pH of water determines the solubility of chemical constituents. In the case of heavy metals, the degree to which they are soluble determines their toxicity. Metals therefore tend to be more toxic at lower pH because they are more soluble. It has also been reported that drinking water at high pH level acquires bitter taste. The efficiency of coagulation and flocculation process is also markedly dependent on pH (Kahlown *et. al*. 2006).



2.2.2 Electrical Conductivity (EC) and Total Dissolved Salts (TDS)

Pure water free of ions is an excellent insulator, but even the deionized water is not free of ions. As water is a good solvent, it almost always has dissolved mineral salts in the form of ions. These ions make it to transmit electric current by the phenomenon what is known as ionic conduction. The electrical conductivity of water is therefore used as indirect measure of ionic activity of dissolved mineral salts. The electrical conductivity of aqeous solution depends on concentration of ions, their nature and temperature of measurement. The measurement at 25 ^{o}C are used as reference. The unit of electrical conductivity is Siemen per meter (S/m) but dS/m, or mS/cm, is commonly used for better covering the range of measurement in case of water. In dilute solutions, Total Dissolved salts (TDS) and electrical conductivity are reasonably comparable. The TDS of a water sample based on the measured EC value can be calculated using the following equation.

$$TDS\ (mg/l) = 640 \times EC\ (dS/m) = 640 \times EC\ (mS/cm)$$

The above relationship can applied EC rangeing from 0.5 to 5 dS/m (Kahlown and Khan 2002). It does not however apply to wastewater.

Total Dissolved Salts (TDS) consist mainly of carbonates, bicarbonates, chlorides, sulfates, phosphates, nitrates, calcium, magnesium, sodium, potassium, iron, manganese, and a few others. They do not include gases, colloids, sediment or other minerals found on the earth's surface. The dissolved minerals can produce an unpleasant taste or appearance and can contribute to scale deposits on pipe walls. There is no consensus on the negaetive, or otherwise, impacts on human health of TDS in excess of 1,000 mg/1.It has been reported elsewhere that excess TDS in drinking water may even have beneficial health effects. Extremely low TDS level may also be unacceptable owing to its flat insipid taste (Kahlown *et. al.* 2006). WHO however has recommended permissible range of 500 mg/l and admissible range of 1000 mg/l for drinking purpose.

2.2.3 Turbidity

Turbidity is the cloudiness or haziness of water caused by suspended individual particles that are generally invisible to the naked eye and do not settle down easily, or may be caused by growth of phytoplankton. In drinking water, the higher the turbidity level, the higher the risk that people may develop gastrointestinal diseases. This is especially problematic for immune-compromised people, because contaminants like viruses or bacteria can become attached to the suspended solids. The suspended solids interfere with water disinfection with chlorine because the particles act as shields for the virus and bacteria. Similarly, suspended solids can protect bacteria from ultraviolet (UV) sterilization of water. In case of filtration plants, higher turbidity also requires frequent replacement of filtration material. The turbidity is therefore a key parameter of water quality and is measured in terms of light absorbing or light scattering property of water. It is expressed by US Environmental Monitoring Standard unit what is called Nephelometric Turbidity Units (NTU). Public health services drinking water standards (1962) stated that turbidity excess of the guideline value of 5 NTU is generally unacceptable to consumers. In water supplied through pipe distribution system, presence of high turbidity at consumer end as compared to that at source may indicate on the way intrusion of contaminants or corrosion of pipes etc (Kahlown *et al*).

2.2.4 Colour

Clean water is supposed to be clear without any noticeable colour. Color of water may be characterized as true or apparent. The apparent blue color of water bodies is owing to selective absorption and scattering of light spectrum. The true colors in water may be due to suspended material, dissolved mineral salts such as ferric hydroxide and manganese, and dissolved organic substances such as humic acids, corrosive material, colored industrial waste or other substances from anthropogenic sources. Colour can also indicate the presence of certain runoff or discharges into the water. These colored impurities undermine aesthetic value of drinking water. As reviewed by Kahlown et al. (2006), Washington Administrative Code for Public Water Supplies has set a maximum limit of 15 color units for physical characteristics of water under use for drinking purpose. WHO (1996) recommended level is 15 TCU above which consumer complaints start arising because of unacceptable appearance.

2.2.5 Taste

Taste (or, more formally, gustation) is a form of direct chemoreception and is one of the traditional five senses. It refers to the ability to detect the flavor of substances such as food, certain minerals, and poisons. Traditionally identified taste sensations are: sweet, salty, sour, bitter, piquance (the sensation provided, among other things, by chili peppers) and savoriness (also known as umami). Taste is a sensory function of the central nervous system. The receptor cells for taste in humans are found on the surface of the tongue, along the soft palate, and in the epithelium of the pharynx and epiglottis (Wikipedia). As reviewed by Kahlown et al (2006), Taste threshold in distilled water for the major cations of drinking water i.e. calcium, magnesium, sodium and potassium have been reported to be approximately 100, 30,100 and 300 mg/l respectively (National Academy of Sciences, 1973).

2.2.6 Odor

Pure water is odorless. An odor in water is caused by one or more volatilized chemical compounds, generally at a very low concentration, that humans or other animals can sense. The most minimal concentration of a substance that can be detected by a human nose is termed as odor threshold value. Odors are also called smells, which are categorized both pleasant and unpleasant Pleasant odor are primarily used in food and cosmetic industry. In contrast, an unpleasant odor refers to malodor or stink. Kahlown *et. al.* (2006) reviewed that a great number of organic and some inorganic substances contribute to the odor of waters. The non-specific fishy, grassy and musty odors normally associated with biological growth tend to occur most frequently in warm surface water in the warmer months of the year. Odor in potable water is almost invariably indicative of some form of pollution of the water source, malfunction during distribution or water treatment. Chlorinated water may have some odor due to residual chlorine which is rather indicator of proper chlorination. Drinking water should however have no observable odor to any consumer (WHO, 1984).

2.3 Chemical Parameters

2.3.1 Alkalinity (Alk)

The Alkalinity may be defined as the capacities of some of its components to accept protons or to bind an equivalent amount of a strong acid (Kahlown et al 2006). It is therefore a measure of the ability of a solution to neutralize acids to the equivalence point of carbonate or bicarbonate and is equal to the stoichiometric sum of the bases in solution. In natural environment, carbonate alkalinity tends to make up most of the total alkalinity due to the common occurrence and dissolution of carbonate rocks and presence of carbon dioxide in the atmosphere. Other common natural components that can contribute to alkalinity include borate, hydroxide, phosphate, silicate, nitrate, dissolved ammonia, the conjugate bases of some organic acids and sulfide. Limestone is rich in carbonates, so waters flowing through limestone regions generally have high alkalinity — hence its good buffering capacity. Conversely, granite does not have minerals that contribute to alkalinity. Therefore, areas rich in granite have low alkalinity and poor buffering capacity. Alkalinity is sometimes incorrectly used interchangeably with basicity. For example, the pH of a solution can be lowered by the addition of CO_2 which will reduce the basicity; however, the alkalinity will remain unchanged. The common unit of alkalinity is m.Eq/L (milliequivalent per liter) but the other unit as ppm (parts per million) still prevails.

Alkalinity is not a pollutant. Its measurements are however used in the interpretation and control of water and waste water treatment processes. Raw domestic waste water has an alkalinity less than or slightly greater than that of the water supply. Jaffer et al. (1985), as reported by Kahlown et al (2006), gave the maximum permissible level/range of alkalinity as 50 to 500 mg/1 as CaCO3.

2.3.2 Bicarbonate (HCO_3)

The bicarbonate ion (hydrogenated-carbonate ion) is an anion with a charge of negative one with empirical formula HCO_3^- it is the conjugate acid of CO_3^{2-}. The weathering of rocks contributes to bicarbonate content in water as mostly these are soluble in water. However, their concentration in water depends on water pH and is generally less than 500 mg/l in groundwater. It is a principal alkaline constituent in almost all water sources, therefore influences hardness and alkalinity of water. Many types of bicarbonate are soluble in water at standard temperature and pressure, particularly sodium bicarbonate and magnesium bicarbonate; both of these substances contribute to total dissolved salts, a common parameter for assessing water quality. The flow of bicarbonate ions from weathered rocks by carbonic acid in rainwater is an important part of the carbon cycle.

Bicarbonate is vital component of the pH buffering system of the body (maintaining acid-base homeostasis) as 70%-75% of CO_2 of the body is converted into carbonic acid (H_2CO_3,) with carbonic acid as the central intermediate specie. Bicarbonate, in conjunction with water, hydrogen ions, and carbon dioxide forms this buffering system which is required to provide prompt resistance to drastic pH changes in the body. This is especially important for protecting tissues of the central nervous system and heart throb rate. Bicarbonate also serves in the digestive system. It raises the internal pH of the stomach, after highly acidic digestive juices have finished their digestion of food. Ammonium bicarbonate is used in digestive biscuit manufacture. The blood value of bicarbonate is one of several indicators of the state of acid-base physiology in the body. The parameter Standard bicarbonate concentration (SBC) is the measure of bicarbonate concentration in the blood. The major intake of bicarbonate into the human body is through drinking water, however, there is no guideline value set for concentration of bicarbonate in drinking water.

2.3.3 Carbonate (CO_3)

Carbonate is a salt of carbonic acid, characterized by the presence of the carbonate ion (CO_2^{-3}) which originates from dissolving of carbonate minerals. The carbonate minerals are extremely varied and ubiquitous in chemically-precipitated sedimentary rocks. The most common are calcium carbonate ($CaCO_3$ - the main constituent of limestone), mollusk shells, coral skeletons, dolomite, and siderite etc. A carbonate salt forms when a positively charged ion, attaches to the negatively charged oxygen atoms of the carbonate ion. Metal carbonates generally decompose on heating. Calcium carbonate, on burning in a lime kiln, liberates carbon dioxide through a process called calcination and leaves behind an oxide of calcium (CaO) which is known as quicklime. The most carbonate salts are insoluble in water at standard temperature and pressure with exceptions of sodium, potassium and ammonium carbonates including many uranium carbonates.

In aqueous solution, carbonate, bicarbonate, carbon dioxide, and carbonic acid exist together in a dynamic equilibrium. In strongly basic conditions, the carbonate ion predominates, while in weakly basic conditions, the bicarbonate ion is prevalent. In more acid conditions, aqueous carbon dioxide, is the main form, which, with water is in equilibrium with carbonic acid - the equilibrium lies strongly towards carbon dioxide. Thus sodium carbonate is basic; sodium bicarbonate is weakly basic, while carbon dioxide itself is a weak acid.

Carbonated water is formed by dissolving CO_2 in water under pressure. When the partial pressure of CO_2 is reduced, for example when a can of soda is opened, the equilibrium for each of the forms of carbonate (carbonate, bicarbonate, carbon dioxide, and carbonic acid) shifts until the concentration of CO_2 in the solution is equal to the solubility of CO_2 at that temperature and pressure.

2.3.4 Calcium (Ca)

Calcium is soft gray alkaline earth metal, and is the fifth most abundant element by mass in the Earth's crust as well as the fifth most abundant dissolved ion in seawater. Calcium is essential for living organisms, particularly in cell physiology and mineralization of bones and shells. It is the most abundant metal by mass in many animals. Approximately ninety-nine percent of the body's calcium is stored in the bones and teeth. The rest of the calcium in the body has other important uses, such as some exocytose, especially neurotransmitter release, muscle contraction and cardiac action. Long-term calcium deficiency can lead to rickets and poor blood clotting and in case of a menopausal woman, it can lead to osteoporosis, in which the bone deteriorates and there is an increased risk of fractures. While a lifelong deficit can affect bone and tooth formation, over-retention can cause hypercalcemia (elevated levels of calcium in the blood), impaired kidney function and decreased absorption of other minerals however, vitamin D is essential for absorption of calcium.

High calcium intakes or high calcium absorption were previously thought to contribute to the development of kidney stones however, this notion has been nullified by the latest research. However, in most studies strong co-relation have been found between cardiovascular diseases and exceeding calcium concentration. The presence of calcium in water supplies results from deposits of limestone, dolomite, calcite, gypsum and gypsiferous shale. The calcium minerals and compounds are not easily soluble in pure water, the presence of carbon dioxide readily increases their solubility and sources of water containing up to 100 mg/liter are fairly common in arid regions having pH above 7.0. WHO (1996) and PSI (1987) recommended 75 mg/l as permissible amount of calcium in drinking water, whereas PSQCA (2002) recommends 200 mg/l. However the body demand of an adult is 1000 mg/day.

2.3.5 Magnesium (Mg)

Magnesium is an alkaline earth metal and the eighth most abundant element in the Earth's crust by mass and is the third most abundant element dissolved in seawater. It is the 11th most abundant element by mass in the human body where 60% is in the skeleton, 39% intracellular (20% in skeletal muscle), and 1% extracellular. Its ions are essential to all living cells, where they play a major role in manipulating important biological polyphosphate compounds like ATP, DNA, and RNA. Hundreds of enzymes thus require magnesium ions in order to function. Magnesium is a common constituent of natural water. Michael (1981) found that magnesium and calcium both produce the property of hardness in water. Magnesium (Mg^{+2}) hardness is usually approximated at 33% of the total hardness of a particular water supply. Magnesium is found in many minerals, including dolomite, magnesite, and many types of clay. Acu-Cell (2003) had reported that about 19g of magnesium per 70kg human body weight is involved in the synthesis of protein as well as acts as co-factor in 300 enzymatic reactions. WHO recommends the maximum permissible limit for magnesium in water to be 150 mg/l.

2.3.6 Hardness

Hard water is water with high mineral contents. It primarily contains excessive calcium and magnesium metal cations, and sometimes other dissolved compounds such as bicarbonates and sulfates. Hard water is generally not harmful to one's health. The measurements of hardness can be obtained through a wet titration. Although water hardness usually measures only the total concentrations of calcium and magnesium (the two most prevalent, divalent metal ions), iron, aluminum, and manganese may also be present at elevated levels in some geographical locations. Iron in this case is important for, if present, it will be in its trivalent form. Water becomes hard during its movement through soil and rock; it dissolves small amounts of these naturally-occurring minerals and carries them into the groundwater. Hard water forms precipitates on boiling or when soap is added to it. Total hardness is expressed as mg/l of calcium carbonate because calcium and carbonate are the dominant ions in most hard waters. The following table gives the concentration of $CaCO_3$ dissolved in water by its degree of hardness.

Degree of Hardness	*mg/l as CaCO3*
Soft	0-60
Moderately Hard	60-120
Hard	120-180
Very Hard	Greater than 180

Bokina (1965) found increased incidence of urolithiasis due to hard water in the USSR where the local domestic tubewell contained 300-500 mg of calcium per liter. Guidelines for Canadian drinking water quality (1979) documented that there is no firm evidence that water hardness causes ill effects in man. Marier (1979) observed that there is a close association between death rates from strokes and the acidity of river derived drinking water. Since that time, a number of studies in various parts of the world have demonstrated that there is high statistically significant negative association between water hardness and cardiovascular disease. Very hard water can cause household pipes choking, scaling, incrustations on kitchen utensils and increasing soap consumption. Hard water can create both nuisance and economic burden to community. A hardness level of about 100 mg/l provides an acceptable balance between corrosion and the problems of incrustation, although, from drinking considerations 500 mg/1 is recommended as a guideline value.

2.3.7 Sodium (Na^+)

Sodium is a soft, silvery-white, highly reactive metal which does not occur naturally in elemental form on earth as it quickly oxidizes in air and is violently reactive with water, so it must be stored in an inert medium, such as liquid hydrocarbon. Sodium is present in abundance or in less quantity in natural waters. Seawater contains relatively high levels of sodium about 10 g/l (WHO, 1979). The sodium salts are highly soluble in water and found abundance in mineral deposits. Sodium is the principal cation (Na^+) in the extra-cellular fluid (ECF) and it has several physiological roles including maintaining acid-base balance, generating transmembrane gradients (which allow cells to take up nutrients) maintenance of ECF volume and osmotic pressure and in the electro-physiology of nerve and muscle cells (Healthnet, 2003). Acu-Cell (2003) reported that deficiency of sodium in the body may appear as mental apathy, low blood pressure, fatigue, depression, seizures, dehydration etc., whereas overdose can cause edema, hypertension, stroke, headaches, kidney damages, stomach problems and nausea. The co-relation of sodium intake with cardiovascular diseases and hypertension is so well established that such persons are advised to desist from sodium salts (sodium chloride). WHO (1984) reported that in most of the countries, the majority of water supplies contain less than 20 mg/l but in some countries sodium levels can exceed 250 mg/l. According to WHO (1979) water treatment chemicals such as sodium fluoride, sodiumsilico fluoride, sodium hydroxide, sodium carbonate, sodium bicarbonate and sodium hypochlorite can add significant amounts of Na (30 mg/l) in drinking water. WHO (1996) recommended the 200 mg/l to be the maximum permissible limit for drinking water.

2.3.8 Potassium (K^+)

Potassium is a soft silvery-white metallic alkali metal that oxidizes rapidly in air and is very reactive with water. Potassium in nature occurs only as ionic salt. As such, it is found dissolved in seawater, and as a part of many minerals. Potassium ion is necessary for the function of all living cells, and is thus present in all plant and animal tissues. It is found in especially high concentrations in plant cells and fruits.

Though potassium and sodium are chemically similar yet their functions in organisms are quite different, especially potassium content of drinking water varies greatly depending on its source and it tends to be larger in mineral and seawaters than ordinary tap water. However, on average the daily water consumption by adults, the K intake is less than 0.1% of their diet. Potassium abundance in drinking waters can reach upto 20 mg/l (APHA, et al., 1992). The potassium is very significant body mineral important to both cellular and electrical function. The total potassium in the body and blood serum varies from 4-5 mg/100 ml. An amount of 1600 to 3500 mg of potassium consumption per day has been recommended by Anderson & Young (2002). Potassium deficiency causes irregular and rapid heart beat, hypertension, muscle weakness, bladder weakness, kidney disease and asthma whereas over dose may appear as irregular/rapid heart beat, cystitis, bladder infection, ovarian cysts, and weakened immune system (Acu-Cell, 2003). An increased level of potassium in the blood is known as hyper-kalemia appears as reduced renal function, an abnormal breakdown of protein and severe infection (Aparna, 2001). WHO recommend the maximum permissible limit of potassium in drinking water as 12 mg/l.

2.3.9 Chloride (Cl^-)

Chloride is an anion mainly derived from dissociation of salts of hydrochloric acid such as NaCl, KCl and $CaCl_2$ originating from geological formations. It is also added through pollution with sewage, industrial waste, sea water or saline water intrusion. Surface water normally has low concentration of chlorides as compared to groundwater. Chloride is a chemical the human body needs for metabolism (the process of turning food into energy). It also helps keep the body's acid-base balance. The amount of chloride in the blood is carefully controlled by the kidneys. Chloride ions have important physiological roles. For instance, in the central nervous system, the inhibitory action of glycine and some of the action of GABA relies on the entry of Cl^- into specific neurons. Also, the chloride-bicarbonate exchanger biological transport protein relies on the chloride ion to increase the blood's capacity of carbon dioxide, in the form of the bicarbonate ion. The normal blood reference range of chloride for adults in most labs is 95 to 105 mili equivalents (m. Eq) per liter. The normal range may vary slightly from lab to lab. Normal ranges are usually shown next to your results in the lab report.

The major source of chloride for humans is table salt (NaCl) which is recommended to be 1 g per person per day for normal health. For children up to 18 years of age, a daily dietary intake of 45 mg chloride per kg of body weight is sufficient. The other major source of chloride for human body is drinking water. The salty taste produced by chloride depends on the chemical composition of water. The salty taste with chloride concentration of 250 mg/1 may be detectable in water containing sodium ions, but the taste may be absent in water containing 1000 mg/1 chloride when calcium and magnesium ions are predominant. High chloride content has a deleterious effect on metallic pipes and structures. WHO (1984) recommended 250 mg/1 as the maximum permissible value of chloride for drinking water (Kahlown et al 2006).

2.3.10 Sulphate (SO_4^-)

Sulfate (SO_4) is polyatomic anion mostly derived from the dissociation of the salts of sulphuric acid Na_2SO_4, Ca SO_4, K_2SO_4 etc and occurs in almost all natural water due to high solubility. Most sulfate compounds originate from the oxidation of sulfite ores, the presence of shales, and the existence of industrial wastes. Sulfate is one of the major dissolved constituents in rain, but one of the least toxic anions. The lethal dose for humans as potassium or zinc sulphate is 45 g. The reported minimum lethal dose of magnesium sulphate in mammals is 200 mg/kg. (Faust and Osman, 1983). The major physiological effects resulting from the ingestion of large quantities of sulphate are catharsis and gastrointestinal irritation (Mckee and Wolf, 1963). Water containing magnesium sulphate at levels above 1000 mg/L acts as a purgative in adults. Lower concentrations may affect bottle-fed infants and adults who have just been introduced to the water (Wikipedia). Sulphates can interfere with disinfection efficiency by scavenging residual chlorine in the distribution system (Arther, 1971). The presence of sulphate salts in drinking water could increase corrosion of mild steel in the delivery system (Larson 1971) Bacteria, which attack and reduce sulfates, causes hydrogen sulfide gas (H_2S) formation. No symptoms of sulphate deficiency have been reported in humans. No optimum dietary intake for inorganic sulphate has been suggested. Fingl (1980) reported the dehydration as a common side effect due to the ingestion of large amounts of magnesium or sodium sulphate. The taste threshold concentrations of sulphate salts are 250-500 mg/l for sodium sulphate, 250 to 900 mg/l for calcium sulphate and 400 to 600 mg/l for magnesium sulphate (NAS, 1977). WHO (1996) has set the sulphate level of 250 mg/l in drinking water above which consumer may feel problem in taste (Kahlown et al. 2006).

2.3.11 Nitrate (NO_3^-)

The nitrate is a polyatomic ion with molecular formula NO_3^- . Nitrogen trioxide is an alternative name for nitrate. It is one of the important diseases causing drinking water quality parameter. The major sources of Nitrate are nitrogen cycle, nitrogenous fertilizers, decay of organic matter, solid waste, domestic and industrial effluent etc. Nitrate is reduced to nitrite in the body. As early as 1940, it was recognized that consuming waters with high nitrate levels contributed to methemoglobinemia ("blue baby" syndrome). This condition, usually in infants, impairs the ability of blood to carry oxygen. Nitrate toxicities in humans occur through enterohepatic metabolism of nitrates to ammonia, with nitrite being an intermediate. Nitrites oxidize the iron atoms in hemoglobin from ferrous iron to ferric iron, rendering it unable to carry oxygen. This process can lead to generalized lack of oxygen in organ tissues and a dangerous condition called methaemoglobinaemia. Infants in particular are especially vulnerable to methaemoglobinaemia due to nitrate metabolizing triglycerides present at higher concentrations than at other stages of development. Furthermore, pregnant women are at greater risk as compared to other adults due to nitrate induced Methaemoglobinaemia. The disease can be treated with methylene blue, which reduces ferric iron in affected blood cells back to ferrous iron. Gastric cancer as cause of comparatively high mortality rate has been reported in China in the areas having high levels of nitrates and nitrites in drinking water as well as vegetables of the area. Maximum permissible limit for nitrate in drinking water, as per WHO Standard (1986), is 10 mg/1 (Kahlown *et. al.*, 2006).

2.4 Trace Elements

2.4.1 Arsenic (As)

Arsenic is a metalloid, present naturally in surface and ground water due to erosion of rocks. It is concentrated in shale, clays, phosphorites, coal, sedimentary iron and manganese ores. The chemical form of arsenic depends on its source. Arsenic is notoriously poisonous element and its toxicity depends on its chemical form. It is more commonly found as arsenide and in arsenate compounds. Arsenic and its compounds are used in pesticides, herbicides, insecticides and in various alloys. Aqueous arsenic in the form of arsenite, arsenate and organic arsenicals may result from mineral dissolution, industrial discharges or the application of herbicides.

The arsenic in the groundwater is predominantly of natural origin, and is released from the sediment into the groundwater owing to the anoxic conditions of the subsurface. Arsenic contamination of ground water has led to a massive epidemic of arsenic poisoning in Bangladesh. Many other countries such as Vietnam, Cambodia, China, Thailand and South East Asia have geological environments conducive to generation of high-arsenic groundwater. Arsenic has also been reported in the groundwaters of the several states of USA. PCRWR studies have revealed arsenic contamination in several districts of Southern Punjab and Central Sindh (Kahlown *et. al.* 2006). Presently 42 major incidents around the world have been reported on groundwater arsenic contamination. It is estimated that approximately 57 million people are drinking groundwater with arsenic concentrations elevated above the WHO standard of 10 ppb. Lamm *et. al.* (2006) after a study of cancer rates in Taiwan suggested that significant increases in cancer mortality appear only at levels above 150 parts per billion. Pakistan’s standard of Arsenic contamination is 50 ppb against WHO standard of 10 ppb.

Early evaluations of the removal of dissolved arsenic by drinking water treatment processes demonstrated that arsenic is very effectively removed by co-precipitation with either iron or aluminum oxides. The use of iron as a coagulant, in particular, was found to remove arsenic with efficiencies exceeding 90%. (O,Coner and Gulledge 1973). A methodology termed as Subterranean Arsenic Removal (ARS) Technology for in situe remediation of Arsenic has been introduced in West Bengal whereby arsenic is left as an insoluble form in the subterranean zone by recharging aerated water into the aquifer and thus developing an oxidation zone to support arsenic oxidizing micro-organisms (Wikipedia). Magnetic separations of arsenic at very low magnetic field gradient have been demonstrated in point-of-use water purification with high-surface-area and monodisperse magnetite (Fe_3O_4) nanocrystals (Yavuz et al. 2005). PCRWR has recently developed a low cost household Arsenic Removal Technology which has proved very effective.

2.4.2 Iron (Fe)

Iron is fourth most abundant element on the earth making up about 5% of its crust. It is essential to nearly all organisms. Iron in water occurs in the ferrous and ferric forms. The solubility in natural waters is dependent upon the pH and the oxidation-reduction potential. In reducing conditions; iron exists in the ferrous state. On exposure to air oxidized to the ferric form and with water hydrolyzes to insoluble hydrated ferric oxide that makes iron-laden waters objectionable. As concentrations increase visible orange/brown staining appears and any increase in concentrations may create conditions where complex insoluble oxides, hydroxides and carbonates of iron start precipitating out producing a semi-gelatinous and dense floc carpeting the river bed. Such conditions are very deleterious to most organisms and can cause serious damage in a river system. Iron in water can cause staining of laundry and porcelain, deposit a slimy coating on the piping.

In drinking water a concentration above 1 mg/l., a bittersweet astringent taste is detectable. It is an essential element in human nutrition and is contained in a number of biologically significant proteins as hemoglobin and cytochromes. Iron also promotes the growth of "iron bacteria" which derive their energy from the oxidation of ferrous iron to ferric iron. Iron deficiency can lead to anemia and fatigue. However, its distribution is heavily regulated in mammals, partly because it has a high potential for biological toxicity. The higher iron intake through drinking water/food may produce symptoms of anorexia, dizziness, nausea, vomiting, headache, weight loss, shortness of breath and possibly a graying color to the skin. Therefore iron supplements are not considered appropriate unless iron deficiency is diagnosed (Wikipedia). WHO (1996) have recommended the guideline value for iron in drinking water as 0.3 mg/l (Kahlown et al. 2006).

2.4.3 Fluoride (F)

Fluoride is the anion F^-, the reduced form of element fluorine. Compounds containing fluoride anions and in many cases those containing covalent bonds to fluorine are called fluorides. Fluorine containing compounds range from potent toxins such as sarin to life-saving pharmaceuticals (Wikipedia).Traces of fluorides occurrence are widespread in waters and higher concentrations are often associated with groundwater sources in areas where fluoride-bearing minerals are common. Edmunds and Smedley (1996) have found high fluoride concentrations in groundwater from calcium-poor aquifers and where exchange of sodium for calcium occurs. In areas that are rich in fluoride containing minerals e.g. flourapatite, the groundwater may contain up to 10 mg of fluoride per liter or even more (Bulusu et al, 1979). Most of the waters contain below 1 mg of fluoride per liter (WHO, 1970). Drinking water is typically the largest single contributor to the daily fluoride intake (WHO, 1986). However, this is not necessarily true in every case. Optimal concentrations are 1 mg/l, however, chronic ingestion greater than 1.5 mg/l (WHO guideline value) is linked with development of dental fluorosis and in extreme cases, skeleton fluorosis. Linkage of cancer to high doses of Fluoride have also been reported (Kahlown et al. 2006).

British Geological Survey (2003) has found that a minor concentration of fluoride in drinking water is beneficial due to having significant mitigating effect against dental cavities. Peterson and Lennon (2004) also reported that mild concentration of fluoride reduces tooth decay and cavities in both children and adults. Therefore, the developed countries, such as USA, UK, Canada and Australia etc, carry out water fluoridation, which is the controlled addition of fluoride to a public water supply. Fluoridation of water is, however, still controversial and many developed nations have abandoned it. A 1994 WHO expert committee suggested a level of fluoride from 0.5 to 1.0 mg/l depending on climate. Bottled water typically has unknown fluoride levels, and some domestic water filters remove some or all fluoride. (Hobson et al. 2007).

2.5 Biological Parameters

2.5.1 Total Coliforms

Coliforms are facultatively anaerobic rod-shaped Gram-negative non-spore forming organisms of Enterobacteriaceae family and are commonly used bacterial indicator of sanitary quality of foods and water. Coliforms are abundant in the feces of warm-blooded animals, but can also be found in the aquatic environment, in soil, on vegetation, in decaying matter, and can even grow in water distribution system. Total Coliforms include genera that originate in feces (Fecal Coliforms e.g. Escherichia) as well as genera not of fecal origin (non-Fecal Coliforms e.g. Enterobacter, Klebsiella, Citrobacter). However, total coliforms are an indicator of fecal contamination and subsequently of Escherichia coliform, which is an indicator microorganism for other pathogens, such as viruses, protozoa and many multicellular parasites that may be present in feces. Almost all surface waters have some form of bacteria, but ground water is normally free of that unless some sort of contaminated or wastewater gets intruded into it. Symptoms of exposure to the bacteria include, inter alia, abdominal cramps and diarrhea. For safe drinking water, WHO standard requires zero coliforms per 100 ml of water sample (Kahlown et al. 2006).

2.5.2 Fecal Coliforms

Fecal coliforms are sub set of total coliforms. They are capable of growth in the presence of bile salts or similar surface agents, oxidase negative, and produce acid and gas from lactose within 48 hours at 44 ± 0.5ºC. The presence of fecal coliforms in aquatic environment may indicate that the water has been contaminated with the fecal material of concern. It is considered an indicator of Escherichia coliform, which is further indicator microorganism for other fecal oriented pathogens. However, presence of fecal coliforms in water may not be directly harmful, and does not necessarily indicate the presence of feces. In general, increased levels of fecal coliforms provide a warning of failure in water safety from possible contamination with pathogens.

Fecal coliform bacteria can enter surface water bodies through several routs such as direct discharge of waste from mammals and birds, from agricultural and storm runoff and from municipal sewage. Their presence may also be the result of plant material, and paper mill effluent. Failing home septic systems can allow coliforms to flow into groundwater aquifers, drainage ditches and nearby surface water. Sewerage system that carry both sewage and storm water can cause intrusion of sewage into surface waters during high rainfall periods. Runoff from roads, parking lots, and yards can carry animal wastes to streams through storm sewers. Birds and waterfowl can elevate bacterial counts, especially in wetlands, lakes, ponds and rivers. Allowing livestock grazing near water bodies, spreading manures on fields, using sewage sludge biosolids and watering livestock in streams can all contribute to fecal coliforms contamination. Large quantities of fecal coliforms bacteria in water are not harmful according to some authorities, but may indicate a higher risk of pathogens being present in the water. Some waterborne pathogenic diseases that may coincide with fecal coliform contamination include ear infections, dysentery, typhoid, viral and bacterial gastroenteritis, and hepatitis A (Wikipedia, 2010).

2.5.3 Escherichia Coli (E.Coli)

Escherichia coliform are unicellular microorganisms, virtually always associated with fecal contamination of water. It appears as straight rods, single or in pairs forms, and can grow on simple nutrient media. It is the fecal coliform group of bacteria found in much higher concentration than other coliforms. Waite (1985) estimated that E. Coliform could be 95% of all coliforms found in human feces. Chiang (2003) found that Escherichia coli is a specific subset of thermotolerant coliform bacteria which possess the enzymes B-galactosidase, B-glucuronidase and hydrolyzes 4-methyl-umbelliferyl-B-D-glucuronidase. Sewage, treated effluents, all natural water which was subjected to recent fecal contamination from humans or wild animals will contain E. Coliform. Usually it cannot multiply in any natural water environment and is, therefore, used as specific indicator for fecal contamination (WHO, 1996). The presence of E. Coliform can cause diarrhea, nausea and other problems especially for infants, children and those with weak immune systems and may become fatal. An acute disease caused by E. Coliform is Hemorrhagic colitis which results in severe abdominal cramps, watery diarrhea, and lower intestinal bleeding; with occasional vomiting and fever. In severe cases, hemolytic uremic syndrome or renal failure can occur. E. Coliform is transmitted through fecal-oral ingestion of the bacteria by direct ingestion (i.e. drinking), primary contact recreation (i.e. swimming), or secondary contact (i.e. fishing). WHO standards require zero E. Coliform to be found per 100 ml of safe drinking water (Kahlown et al. 2006).

2.6 Causes of Water Pollution

2.6.1 Sanitation

Sanitation coverage in urban areas of Pakistan has been reported as 92% including 42% with sever connections. The coverage in rural areas was 41% including 6% with sewer connections. Situation is rather poor in NWFP and Northern Areas. Solid and liquid excreta are the major source of water pollution in the country and resultantly fundamental cause of widespread waterborne diseases (UNICEF & META-META 2009).

2.6.2 Masses and Institutional Awareness

Contaminated or even turbid water is consumed for drinking purpose in many rural areas of Pakistan. That exhibit lack of awareness among the general public about water quality related health risks. That awareness is lacking even at institutional level as per PCRWR (2006) survey reports indicate. The concerned agencies such as PHED restrict themselves to the execution of development schemes for provision of water without bothering whether, or not, it is safe. No doubt such institutions have their own water quality laboratories, but such laboratories are either not functional or ill equipped with required apparatus and manpower. Very often water supply operators are found not well acquainted with chlorination techniques and dosage. Water in many rural areas is found safe at source but poor water handling due to lack of aware ness renders it unsafe for drinking purpose. Widespread awareness campaign is required for improving the situation.

2.6.3 Leakage of Pipelines

The water at the source is usually safe if groundwater, or fit for human consumption if treated from surface water, but it gets contaminated and polluted in the transmission system when pipelines are tempered for illegal connections or when abandoned hydrants are not properly closed or left unattended. The old, rusted, substandard and exposed distribution pipelines can trigger holes and cracks in the network and pave the way for intrusion of sewage or polluted water.

2.6.4 Location of Pipelines

Drinking water supply lines are often laid close to, parallel and beneath the sewerage system or wastewater channels. That practice is very common especially in unplanned towns and localities. Resultantly, the seepage from sewerage system being towards lower level envelope the supply lines and intrude into it through holes, cracks or damaged parts especially when back pressure develops in the system. Under rationing of water compel consumers to pump water from supply lines which promotes development of back pressure and contaminated water intrusion. Personal experience has shown that at the time of installation of service supply lines, the consumers prefer to get the service line passed through wastewater disposal drains holes instead of drilling a new hole for the purpose. Any damage or leakage in the service line becomes a regular passage for easy access of bacterial contamination.

2.6.5 Clogging of Sewerage System

Uncollected or improperly disposed off municipal solid waste makes its way towards sewerage drains and manholes which, causes their choking. Very often sewerage serves the dual purpose of wastewater and storm water disposal and remains blocked due to poor maintenance and overloading resulting in overflows which gets mixed with natural water channels and municipal water works. In severe storm conditions, polluted water may enter into bore holes, open wells and domestic water tanks. Proper cleansing and disinfection after such events is seldom carried out. Solid waste and storm water disposal require due consideration right at the stage of planning and designing sewerage systems.

2.6.6 Growing of Field Crops and Vegetables

In the urban peripheries, farmers adjoining municipal disposal drains prefer to irrigate their agricultural fields with untreated wastewater due to its easy, reliable, free of cost availability and high fertility without awareness of health risks involved and long term soil degradation impact. Waste water is even used for fish farms. Kahlown et al (2006) carried out a case study of Faisalabad and found that crops grown and fish raised with municipal and industrial waste were highly contaminated with heavy metals. Soil fertility was also found degrading by irrigation with the wastewater. Crop production with wastewater without its primary treatment is restricted under United Nations Environmental Programme whereas less than one percent industries in Punjab are equipped with wastewater treatment facilities. The authors further reported that about 20 million hectares in 50 countries are being irrigated with raw or partially treated wastewater.

2.6.7 Groundwater Pollution

Groundwater is major source of drinking water in Pakistan and about 70% population relies on it for domestic purpose. However, over the last three decades, agriculture has become the major consumer of groundwater and strength of tubewells which was one lakh in 1970s has now gone above ten lakh. Out of total groundwater potential of about 63 BCM, an estimated amount of 50 BCM is being abstracted per annum (Kahlown and Majeed 2004). Industrial use of groundwater has also grown accordingly. However, groundwater development is largely un-managed and unmonitored activity in Pakistan. Resultantly serious threats are emerging such as groundwater mining, saline water ingression, secondary salinization and sodification and rising levels of arsenic and fluoride. Quality of groundwater is, therefore, under sever threat and major concern. In many urban areas and around industries, groundwater is polluted by wastewater, oil residuals and several heavy metal contaminants. Arsenic and fluoride problem is rising in many areas of Sindh and Punjab. The most widespread problem however is biological contamination leading to a high child mortality rate of 128 per 1000 (UNICEF & Meta-Meta).

CHAPTER-3

METHODOLOGY

The methodology adopted for water quality monitoring under the project "Improved Water conservation Practices for NWFP and Northern Areas of Pakistan" was more or less the same as designed by Kahlown et al (2006) in National Water Quality Monitoring Programme. It consisted of establishing a network for collection of water samples, monitoring stations, and sample size and details of analysis etc. A brief description of these components of methodology follows.

3.1 Grid Size and Number of Samples

Grid size was designed keeping in view population density, access, extent and ruggedness of the area. As such grid size increased from fine to coarse while moving from thickly populated lower district of NWFP to thinly populated and scattered districts of northern NWFP and Northern Areas of Pakistan. Accordingly a grid size of 16 km^2 for thickly populated district of Mardan, 100 and 169 km^2 for scattered districts of Swat, Bunner and Dir, and 225 km^2 for thinly populated, remote and rugged Northern Areas was adopted. Sampling points were chosen preferably those under regular public use. A minimum distance of 3 to 4 km was endeavored to maintain between the two sampling points. Sample ID for monitoring purpose was marked according to prescribed sequence to avoid amalgamation of collected samples. Following identifications as per prevailing practice were marked on samples collected for different analytical purposes from each of the selected sampling points:

1. A for bacterial analysis;
2. B for trace element analysis;
3. C for Nitrate (NO_3) analysis;
4. D for other water quality parameters;

The details regarding grid size and sampling points (number) are shown in Table 3.1.

1..1.1.1

1..1.1.2 Table 3.1: Details of Water Quality Monitoring Network

Sr. #	*District*	*District code*	*Grid size (Km^2)*	*Grid No.*	*No. of samples*	*No. of samples collected*
1.	Mardan	MAR	16	70	70	36
2.	Buner	BUN	100	34	34	33
3.	Swat	SWA	100	30	30	30
4.	Lower Dir	L.DIR	169	11	11	12
5.	Upper Dir	U.DIR	169	10	10	11
6.	Gilgit	GLT	225	36	18	14
7.	Skardu	SKD	225	22	22	14
8.	Ghanche	CHE	225	15	15	8
9.	Diamar	DIM	225	21	21	9
10.	Ghizer	GHR	225	24	24	8

3.2 Monitoring Area

The water quality monitoring program under the project (IWCP) covered five districts of NWFP and the entire Northern Areas. The details of the districts covered for sampling and corresponding grid size, number of grids, sampling code and number of samples collected are given in table 3.1. All samples were collected and data compiled by WRRC, Peshawar centre. Samples for the first year (2005) of monitoring were got analyzed from National Water Quality Laboratory, PCRWR, Islamabad as by then the Water Quality Laboratory at WRRC Peshawar was not yet commissioned. However analyses for the second year (2006) were carried out at Peshawar after duly commissioning the PCRWR Regional Water Quality Laboratory over there.

3.3 Sample Collection and Preservation

Water samples were collected for physical, chemical, bacteriological and for analysis of trace elements. Sampling was carried out in bottles of 0.5 to 1 liter capacity. Due care was taken that the sampling bottles are washed several times with clean water followed by washing with distilled water before collection of samples. The samples for bacterial analysis were collected in duly sterilized containers of 100 ml capacity. Nitric acid as preservative was used in sampling bottles for trace elements and similarly boric acid was used in sampling bottles for nitrates. These preservations were added in duly marked respective bottles well before sample collection. Furthermore, recommended practices and protocol were observed for sample collection in the field.

3.3.1 Tap Water

For collection of water samples, the un-rusted and undamaged taps were selected. The selected taps were duly washed, cleaned and allowed to run for a couple of minutes before carrying out sample collection.

Sample Collection from Tap

3.3.2 *Tube Well Water*

In case of tubewells, water samples were collected after running the tubewell for at least ten minutes so that the best representative sample of groundwater could be collected. Additional data of tube well location and depth to water table were also recorded.

Water Sample from Source (Tube Well)

3.3.3 Water from Distribution Network

Water samples from distribution network were collected both at source and at the consumer end for evaluating the impact of distribution network on water quality. Samples at source were from the point where there was least possibility of contamination in original quality at the source. The samples at consumer end were collected from the point the water was supposed to have passed enough time or distance in the system so that the functionality of the system could be evaluated.

Sample Collection from Distribution Network and Field Testing

3.3.4 Hand Pump/Open Well Water

Samples from hand pumps were collected after ensuring that water columns hanging in the suction pipe and strainer has adequately been pumped out. That was carried out adopting a usual practice of at least ten full strokes per foot length of the water column. The purpose was to get best representative sample without trace of corrosive material from pumping system.


Water Sample from the Hand Pump and Open Well

3.3.5 Stream Water

Samples from stream water were endeavored to be collected from cross sectional centeroid of the stream. Neither too wide nor too narrow stream section was selected to avoid floating material or stream turbulence. Sampling bottles were kept well above the stream bed to minimize chances of intrusion of bed material into the sampled water.


Sample Collection from Stream

3.3.6 Spring Water

Water samples from springs were also endeavored to collect from almost mid point of the cross section of the spring pond but not exactly over the point of turbulence.


Water sample collection from the spring

3.3.7 Microbiological Samples

For the microbiological contamination analysis, water samples were collected in duly sterilized clean plastic bottles. Sterilization of taps was carried out by flame. Due care was taken to avoid contamination during sampling or post sampling. Therefore sampling was avoided from taps which were damaged or leaking due to inadequate repair and maintenance for avoiding the risk of secondary contamination. Microbiological testing was carried out in the field for presence of coliform, and E. Coli bacteria using Colitag test kits.

Sample Taking for Microbiological Analysis

3.3.8. Type of Water Samples and Preservatives

As stated earlier, four categories of samples were collected comprising those for microbiological analysis, for trace elements, for nitrates, and for other chemical water quality parameters. Samples categories and preservatives used for each of the category are detailed hereunder.

- Type A – All sites – Sterilized sampling bottles for microbiological analysis;
- Type B – All sites – 2+10 ml/litre HNO_3 as preservative for trace elements;
- Type C – All sites – 1 ml/100 ml, 1 M Boric acid as preservative for Nitrate (N); and
- Type D – All sites – No preservative for other water quality parameters.

These types of samples pertain to single sampling point. Items required and things needed to do before proceeding on sampling has been well documented by Kahlown et al. (2006) which was followed for sampling.

3.4 Analytical Methods

The collected water samples were analyzed either in Water Quality Laboratory, Water Resources Research Centre, Peshawar, or in the National Water Quality Laboratory, PCRWR, Islamabad. The methods of analysis adopted for individual water quality parameters are summarized in table below, whereas the details of a few in the subsequent sections.

Table 3.2: Water Quality Parameters and Methods Used for Analysis

S. #	Parameters	Test Method
1	Alkalinity (m.mol/l as $CaCO_3$)	2320, Standard method (1992)
2	Bicarbonate	2320, Standard method (1992)
3	Calcium (mg/l)	3500-Ca-D, Standard Method (1992)
4	Carbonate (mg/l)	2320, Standard method (1992)
5	Chloride (mg/l)	Titration (Silver Nitrate), Standard Method (1992)
6	Conductivity (mS/cm)	E.C meter, Hach-44600-00, USA
7	Fluoride (mg/l)	8029, SPADNS Method (Hach) by Spectrophotometer
8	Hardness (mg/l)	EDTA Titration, Standard Method (1992)
9	Iron (mg/l)	TPTZ Method (Hach-8112) by Spectrophotometer
10	Magnesium (mg/l)	2340-C, Standard Method (1992)
11	Nitrate Nitrogen (mg/l)	Cd. Reduction (Hach-8171) by Spectrophotometer
12	pH at 25^{o}C	pH Meter, Hanna Instrument Model 8519, Italy
13	Potassium (mg/l)	Flame photometer PFP7, UK
14	Sodium (mg/l)	Flame photometer PFP7, UK
15	Sulfate (mg/l)	SulfaVer4 (Hach-8051) by Spectrophotometer
16	Total Coliform and E.Coli	ONPG and MUG-Colitag kits by CPI International, USA
17	TDS (mg/l)	2540C, Standard method (1992)
18	Turbidity (NTU)	Turbidity Meter, Lamotte, Model 2008, USA
19	Arsenic (mg/l)	AAS, varios Analytic AG,Germany

3.4.1 Alkalinity

1..1.2

1..1.3 Alkalinity can be measured by titrating a sample with a strong acid until all the buffering capacity of the aforementioned ions above the pH of bicarbonate or carbonate is consumed. This point is functionally set to pH 4.5. At this point, all the bases of interest have been protonated to the zero level species; hence they no longer cause alkalinity.

1..1.4

1..1.5 The method used for analysis of alkalinity parameter was 2320 Standard Method (1992). Chemicals used for the analysis included:

i. Carbon dioxide free distilled water;
ii. Sodium carbonate solution, 0.05 mol/l;
iii. HCl 0.02 M;
iv. Phenolphthalein indicator; and
v. Methyl orange indicator.

A 100 ml sample was mixed with 2-3 drops of phenolphthalein indicator in a conical flask. The alkalinity due to phenolphthalein was considered zero in case no color was produced after addition of few drops of phenolphthalein. In case of the otherwise, the phenolphthalein alkalinity of the sample was determined by titrating with standard acid (HCl 0.02 M) until the disappearance of pink color. The methyl orange alkalinity of the sample was determined by titrating with standard acid (HCl 0.02 M) until the color changes from yellow to orange. The total alkalinity as carbonates was calculated by:

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

where:

B = standard acid solution to reach the end point of methyl orange (ml);
C= Concentration of acid in mol/l; and
V= sample volume (ml).

Using 100 ml of sample and 0.1 mol/l standard acid solutions, the numerical value of alkalinity is directly expressed in m.mol/l by the volume (ml) of titrant consumed.

3.4.2 Arsenic

Atomic Absorption Spectrometer (Hydride Generation mode) was used for the analysis of arsenic in water samples. All samples were analyzed on HS 55 Mercury/Hydride system, an accessory (AAS, Vario 6 Analytic Jena AG) for the matrix free determination of the hydride forming elements such as As, Bi, Sb, Se, Sn and Te. The Hydride technique makes use of the fact that hydrogen liberated in the reaction of the weakly acidic sample solutions with sodium boro-hydride combines with metal ions to form gaseous hydrides. These are carried to the hot quartz cell by the carrier gas and decomposed by collision processes in a series of steps, until free As atoms were obtained. For the analysis of arsenic the Atomic Absorption Spectrophotometer (AAS Vario 6 Analytik Jena AG), Mercury/Hydride System HS55 (Analytik Jena AG), and Argon Gas with 99.99% purity were used. The following common reagents were used for the analysis;

i. Sodium borohydride ($NaBH_{4,}$ 98% purity)
ii. Sodium hydroxide, NaOH
iii. Hydrochloric Acid (Concentrated 37% HCl)
iv. Arsenic Standard (1007 mg/ml, As in 2% $HNO_{3,}$ BDH)

In order to make reducing solution (Reductant), 15 g sodium borohydride ($NaBH_4$) and 5 g of sodium hydroxide were dissolved in 500 ml distilled water. This reagent was used as reducing agent for Arsenic analysis. The HS 55 Mercury/Hydride system consisting of a basic unit and the cell unit was operated and controlled from PC. Basic unit consists of three accessories. These include batch module, single channel-peristaltic pump and gas valve box. The gas valve box supplied argon gas for scavenging and for transporting the metal hydrides to the system.

Pressure of the argon gas cylinder was adjusted at 3-5 bars. After attaining the necessary temperature (950 ^{o}C), reducing agent was fed by the peristaltic pump. A 10 ml sample was taken into reaction cell and 0.8 ml of concentrated HCl was dispensed into sample and reaction cell was adjusted properly at its place. Calibration standards of arsenic with concentrations (0, 10, 20, 30, 40, 50 ppb) and (50, 60, 70, 80, 90, 100 ppb) were prepared. New method of calibration was developed using these standards under the operation of software, and then the method developed was loaded for analysis of actual samples. HS 55 hydride system analyzes the water samples in the following sequences:

- Pre-wash time
- Reaction time
- Rewash time

The detection limit of this method is 0.1 ppb**.**

3.4.3 Bicarbonates

1..1.6 The method used for this analysis was 2320 Standard Method (1992).

1..1.7

1..1.8 The reagent used for the analysis included**:**

i. Methyl orange indicator; and
ii. Standard acid (HCl) 0.02 N.

A 50 ml sample was taken in a flask and added one drop of methyl orange. The sample was then titrated against the standard acid until its color changed from yellow to orange. The volume of the acid consumed was recorded as “R_2”. Concentration of Bicarbonate was determined using the expression:

Bicarbonate (mg/l) = R_2 x20-R_1x20x2

where:

R_1= Volume of acid used for phenolphthalein alkalinity.

CHAPTER-4

WATER QUALITY STANDARDS

The basic purpose of making guidelines or standards is to ensure safe drinking water to all citizens. The World Health Organization (WHO) has provided guidelines for drinking water, which are advisory in nature, and are based on scientific research and epidemiological findings. The values of various water quality parameters recommended by WHO are the general guidelines. That is why; different countries have established their own water quality standards to meet their national priorities taking in to account their economic, technical, social, cultural, and political requirements. The PCRWR and Pakistan Standard Institution (PSI) have already drafted drinking water quality standards; however, the enforcement of these standards is still pending. This matter needs to be addressed on top priority basis. The WHO guidelines and standards proposed by national agencies like PCRWR, Pakistan Standard Institution (PSI), International Bottled Water Association (IBWA), Food Development Authority (FDA), Environmental Protection Agency (EPA) and other countries are given in this chapter.

4.1 WHO Guidelines

1..1.8.1.1.1

1..1.8.1.1.2 A. Biological Qualities

Source/Organisms	*Guideline Value*
• All water intended for drinking (E. Coli or thermo tolerant Coliform bacteria) • Treated water entering the distribution system (E. Coli or thermo tolerant coliform and total coliform bacteria) • Treated water in the distribution system (E. Coli or thermo tolerant coliform and total coliform bacteria)	• Must not be detectable in any 100 ml sample • Must not be detectable in any 100 ml sample • In the case of large supplies, where sufficient samples are examined, must not be present in 95% of samples taken throughout any 12-month period.

B. Chemicals of Health Significance

Inorganic	*mg/l*	*Inorganic*	*mg/l*	*Inorganic*	*mg/l*
Antimony	0.005	Copper	2.000	Molybdenum	0.070
Arsenic	0.010	Cyanide	0.070	Nickel	
Barium	0.700	Fluoride	1.500	Nitrate(NO_3)	0.020
Boron	0.300	Lead	0.010	Nitrite(NO_2)	50.00
Cadmium	0.003	Manganese	0.500	Selenium	03.00
Chromium	0.050	Mercury	0.001		0.010

C. Other Parameters

Inorganic	*mg/l*	*Inorganic*	*mg/l*	*Inorganic*	*mg/l*
Colour	15 TCU	1,2 dichlorobenzene	1-10	Hardness, pH,	-
Taste, Odour.	-	1,4-dichlorobenzene	0.3-30	DO	
Turbidity	5 NTU	Dichlorobenzene	5-50	Hydrogen sulfide	0.05
Toluene	24-170	Synthetic detergents	-	Iron	0.3
Xylenes	20-1800	Aluminum	0.2	Manganese	0.1
Ethyl-benzene	2.4-200	Ammonia	1.5	Sodium	200
Styrene	4-2600	Chloride	250	Sulfate	250
Monochlorobenzene	10-120	Copper	1	TDS	1000
				Zinc	3

D. Disinfectants and Disinfectant by-Products

Name	*Value*	*Name*	*Value*
Chlorine chlorophenol	600-1000	2,4,6-trichlorophenol	2-300
2,4-dichlorophenol	0.3-40	2-chlorophenol	0.1-10

4.2 Standards Drafted by PCRWR

A. Biological Standards (Urban and Rural water supplies)

Categories	*Standards*
A. *Piped Water Supplies*	
A-1 Treated water entering the distribution system	
· Faecal Coliform	0/100 ml
· Coliform organisms	0/100 ml
A-2 Un-treated water entering the distribution system	
· Faecal Coliform	0/100 ml
· Coliform organisms	0/100 ml
A-3 Water in the distribution system	
· Faecal Coliform	0/100 ml
· Coliform organisms	0/100 ml
B. *Un-piped Water Supplies*	
· Faecal Coliform	0/100 ml
· Coliform Organisms	10/100 ml

1..1.8.1.2 B. Standards for Inorganic Health Related Constituents

Constituent	*Unit*	*HDL**	*MPL***	*Toxic Effects*
Fluoride	mg/l	1.000	1.500	Dental fluorosis in children, excessive concentrative may cause crippling skeletal fluorosis.
Nitrate (NO_3)	mg/l	45.000	45.000	Infantile methaemoglobinaemia.
Lead	mg/l	0.050	0.050	Children particularly susceptible to effects of lead on central nervous system
Mercury	mg/l	0.001	0.001	Neurological effects

* Highest Desirable Level. ** Maximum Permissible Level.

C. Other Parameters

Constituent	*Unit*	*HDL**	*MPL***	*Undesirable Effects*
Turbidity	NTU	2.5	5	Un-aesthetic, decrease in efficiency of disinfections
Colour	PCU	5	15	Un-aesthetic
Taste & Odour	-	Unobjectionable		Taste & Odour
TDS	mg/l	500	1500	Fault or salty taste, corrosion or instruction
Iron	mg/l	0.1	0.3	Taste, discoloration
Manganese	mg/l	0.05	0.5	Taste, discoloration
Magnesium	mg/l	30	150	Stomach disturbances
Copper	mg/1	0.05	1.5	Taste, corrosion of pipes and utensils taste
Zinc	mg/l	5	15.0	Taste
Sulfate	mg/l	200	400	Corrosion, Laxative effect
Chloride	mg/l	200	600	Taste, Corrosion
pH	-	7.0-8.5	6.5-9.2	Taste, Corrosion
Hardness	mg/l	200	500	Corrosion or scale formation
Phenolic substances	mg/l	0.001	0.002	Taste

* Highest Desirable Level. ** Maximum Permissible Level.

4.3 Pakistan Standard Institution

Drinking Water Quality Standards

A. Physical Requirements

S. #	*Characteristics*	*Unit*	*MAC**	*MAC***
1.	Turbidity	NTU	5	25
2.	Colour	TCU	5	50
3.	Taste & Odour	-	Unobjectionable	
4.	pH	-	7.0-8.5	³ 6.5- £ 9.2

B. Chemical Requirements

1.	Total Dissolved Salts	mg/l	1000	1500
2.	Chloride (Cl)	mg/l	200	600
3.	Sulfate (SO_4)	mg/l	200	400
4.	Nitrate (NO_3)	mg/l	-	45
5.	Total Hardness ($CaCO_3$)	mg/l	20	500
6.	Nitrite (NO_2)	mg/l	Nil	Nil
7.	Magnesium (Mg)	mg/l	500	1000
8.	Total Ammonia	mg/l	0.1	0.5
9.	Hydrogen Sulfide	mg/l	Undetectable odor	
10.	Fluoride (F)	mg/l	-	1.5
11.	Iron (Fe)	mg/l	0.3	1.0
12.	Zinc (Zn)	mg/l	5.0	15.0
13.	Manganese (Mn)	mg/l	0.1	0.5
14.	Copper (Cu)	mg/l	1.0	1.5
15.	Calcium (Ca)	mg/l	75	200
16.	Magnesium (Mg)	mg/l	50	150
17.	Phenolic Substances	mg/l	0.001	0.002
18.	Alkyl Benzyl Sulfates	mg/l	0.5	1.0
19.	Carbon Chloroform Extract	mg/l	0.2	0.5

C. Limits of Toxic Substances

1..1.8.1.2.1

1.	Arsenic (As)	mg/l	0.01	-
2.	Cadmium (Cd)	mg/l	0.01	-
3.	Chromium (Cr)	mg/l	0.05	-
4.	Cyanide (Cn)	mg/l	0.20	-
5.	Lead (Pb)	mg/l	0.05	-
6.	Selenium (Se)	mg/l	0.20	-
7.	Radionaclider	U_o/l	1000	-

D. Biological Requirements (Chemical Indicators of Pollution)

1.	Chemical Oxygen Demand (COD)	mg/l	10	-
2.	Biochemical Oxygen Demand (BOD)	mg/l	6	-
3.	Ammonia (NH_3)	mg/l	0.5	-
4.	Grease	mg/l	1	-

E. Limits for Biological Contaminants

Acceptable bacterial standards for potable water supplies:		
i)	Standard plate count (SPC)/mls	No more than 100
ii)	Presumptive test for Coliform	Negative
iii)	Most probable number (MPN)	< 101 subject to the frequency of opportunity for water analysis.

1..2 * Maximum Acceptable Concentration. ** Maximum Allowable Concentration.

4.4 International Bottled Water Association (IBWA) Standards

A. Chemical Quality

1..2.1 Characteristics	*1..2.2 Unit*	*1..2.3 Standard*	*1..2.4 Characteristics*	*1..2.5 Unit*	*1..2.6 Standard*
Arsenic (As)	mg/l	0.05	Mercury (Hg)	mg/l	0.001
Barium (Ba)	mg/l	1	Nitrate (NO_3)	mg/l	10
Cadmium (Cd)	mg/l	0.005	Nitrite (NO_2)	mg/l	1
Chromium (Cr)	mg/l	0.05	Selenium (Se)	mg/l	0.01
Chloride (Cl)	mg/l	250	Silver (Ag)	mg/l	0.025
Copper (Cu)	mg/l	1	Sulfate (SO_4)	mg/l	250
Cyanide (Cn)	mg/l	0.1	Phenolic	mg/l	0.001
Fluoride (F)	mg/l	4	PCB	mg/l	0.0005
Iron (Fe)	mg/l	0.3	TDS	mg/l	500
Lead (Pb)	mg/l	0.005	Zinc (Zn)	mg/l	5
Manganese (Mn)	mg/l	0.05	Turbidity	NTU	0.5

B. Biological Quality

Escherichia Coli	MPN/100 ml	Nil	Coliform	MPN/100 ml	Nil

4.5 Food Development Authority (FDA) Water Standards

1..2.7 Characteristics	*1..2.8 Unit*	*1..2.9 Standard*	1..2.10	*1..2.11 Characteristics*	*1..2.12 Unit*	*1..2.13 Standard*
Arsenic (As)	mg/l	0.05		Nitrate (NO_3)	mg/l	10
Barium (Ba)	mg/l	1		Selenium (Se)	mg/l	0.01
Cadmium (Cd)	mg/l	0.01		Silver (Ag)	mg/l	0.05
Chromium (Cr)	mg/l	0.05		Sulfate (SO_4)	mg/l	250
Chloride (Cl)	mg/l	250		Phenolic	mg/l	0.001
Copper (Cu)	mg/l	1		Ra 226 activity (pCi/l)	-	5
Iron (Fe)	mg/l	0.3		Total Beta activity (pCi/l)	-	8
Lead (Pb)	mg/l	0.05		TDS	mg/l	500
Manganese (Mn)	mg/l	0.05		Zinc (Zn)	mg/l	5
Mercury (Hg)	mg/l	0.002		Coliform (MPN/100 ml)		<2,20

4.6 National Environmental Quality Standards by EPA (Liquid Industrial Effluents)

Sr.#	*Parameter*	*Standards*
1.	Temperature	40 °C
2.	pH Value (acidicity/basicity)	6-10 pH
3.	5-day Biochemical Oxygen Demand (BOD) at 20^0C	80 mg/l
4.	Chemical Oxygen Demand (COD)	150 mg/l
5.	Total Suspended Solids	150 mg/l
6.	Total Dissolved Salts	3500 mg/l
7.	Grease and Oil	10 mg/l
8.	Phenolic Compounds (as phenol)	0.1 mg/l
9.	Chloride (as Cl)	1000 mg/l
10.	Fluoride (as F)	20 mg/l
11.	Cyanide (as Cn)	2 mg/l
12.	An-ionic detergents (as MBAS) [3]	20 mg/l
13.	Sulfate (SO_4)	600 mg/l
14.	Sulfide (S)	1.0 mg/l
15.	Ammonia (NH_3)	40 mg/l
16.	Pesticides, herbicides, fungicides and insecticides	6.15 mg/l
17.	Cadmium	0.1 mg/l
18.	Chromium (trivalent and hexavalent)	1.0 mg/l
19.	Copper	1.0 mg/l
20.	Lead	0.5 mg/l
21.	Mercury	0.01 mg/l
22.	Selenium	0.5 mg/l
23.	Nickel	1.0 mg/l
24.	Silver	1.0 mg/l
25.	Total Toxic Metals	2.0 mg/l
26.	Zinc	5.0 mg/l
27.	Arsenic	1.0 mg/l
28.	Barium	1.5 mg/l
29.	Iron	2.0 mg/l
30.	Manganese	1.5 mg/l

31.	Boron	6.0 mg/l
32.	Chlorine	1.0 mg/l

1..2.13.1.1.1 4.7 Indian Water Quality Standards

A. Physical and Chemical Standards

1..2.13.1.1.2

Sr. #.	Characteristics (mg/l)	Acceptable	Marginal	Sr. #.	Characteristics (mg/l)	Acceptable	Marginal
1	Turbidity (NTU)	2.5	10	7	Fluoride	1.0	1.5
2	Colour (TCU)	5	25	8	Nitrate (N)	45	45
3	Taste & Odour	Unobjectionable		9	Calcium	75	200
4	pH	7-8.5	6.5-9.2	10	Magnesium	30	150
5	TDS	500	1500	11	Iron	0.1	1.0

- The figures indicated under the column "*Acceptable*" are the limits up to which the water is generally acceptable to the consumers.
- Figures in excess of those mentioned under "acceptable" render water not acceptable, but still may be tolerated in absence of alternative and better source but up to the limits indicated under column "*Marginal*" above which the supply will have to be rejected.

B. Biological Standards

Water entering the distribution system should have a coliform count of zero in any sample of 100 ml.

- Water in the distribution system shall satisfy all the three criteria indicated below:
- E.Coli count in 100 ml of any sample should be zero;
- Coliform organisms no more than 10 per 100 ml shall be present in any sample; and
- Coliform organisms should not be detectable in 100 ml of any two consecutive samples or more than 50% of the samples collected for the year.
- Individual or small community supplies.
- E.Coli count should be zero in any sample of 100 ml and coliform organisms should not be more than 3 per 100 ml.

C. Virological Aspects

- A level of 0.5 mg/l of free chlorine residual for one hour is sufficient to inactivate virus, even in water that was originally polluted. This free chlorine residual is to be insisted in all disinfected supplies in areas suspected of endemicity of infectious hepatitis to take care of the safety of the supply from virus point of view, which incidentally takes care of the safety from the bacteriological point of view as well. For other areas 0.2 mg/l of free chlorine residual for half an hour should be insisted.
- The water quality standards developed and enforced by various countries are given below:

4.8 Water Quality Standards of Indonesia, Singapore, Malaysia, Thailand, Philippines and Brunei.

A. Chemical Quality

S. #	Substances	2.1 Unit	Indonesia	Singapore	Malaysia	Thailand	Philippines	Brunei
1	Arsenic (As)	mg/l	0.05	0.05	0.05	0.05	0.05	<0.003
2	Barium (Ba)	mg/l	-	1	-	1	-	<0.02
3	Borate (BO_3)	mg/l	-	0.03	30	-	-	0.2
4	Cadmium (Cd)	mg/l	0.1	0.01	0.01	0.005	0.01	<0.002
5	Chromium (Cr)	mg/l	-	0.05	0.05	0.05	0.05	<0.01
6	Chloride (Cl)	mg/l	250	0.05	-	250	-	-
7	Chlorine (Cl_2)	mg/l	-	-	1	1	-	-
8	Copper (Cu)	mg/l	0.5	-	-	0.1	1	<0.01
9	COD	mg/l	-	-	0.01	1	-	-
10	Cyanide (CN)	mg/l	0.05	0.01	2	-	0.01	-
11	Fluoride (F)	mg/l	1	2	-	-	2	0.09
12	Hardness ($CaCO_3$)	mg/l	170	-	-	100	-	-
13	Iodine (I)	mg/l	-	1	-	0.3	-	-
14	Iron (Fe)	mg/l	0.1	-	-	0.05	1	-
15	Lead (Pb)	mg/l	0.05	0.05	0.05	0.05	0.05	<0.01
16	Manganese (Mn)	mg/l	0.05	2	2	0.002	0.1	0.01
17	Mercury (Hg)	mg/l	0.001	1	0.001	-	0.001	<0.005
18	Mineral Oil	mg/l	-	ND	ND	-	-	-
19	Nitrate (NO_3)	mg/l	ND	45	45	4	45	<0.01
20	Nitrite (NO_2)	mg/l	ND	0.005	0.005	-	0.01	-
21	Organic Matter	mg/l	1	0.003	3	-	5	-
22	Selenium (Se)	mg/l	-	0.01	0.01	0.01	0.01	-
23	Silver (Ag)	mg/l	-	-	-	0.05	-	-
24	Surfactant	mg/l	-	ND	ND	-	2	-
25	Sulfide (S)	mg/l	ND	0.05	0.05	-	-	-
26	Sulphate (SO_4)	mg/l	200	-	-	250	-	-
27	Phenolic	mg/l	-	ND	ND	0.001	0.001	-
28	Ra 226 activity	pCi/l	-	30	-	-	-	-
29	Total Beta activity	pCi/l	-	1	-	-	-	-
30	TDS	mg/l	500	-	-	500	-	-
31	Zinc (Zn)	mg/l	-	-	5	5	5	-

B. Microbiological Quality

1	Total Plate Count/ml	CFU/ml	Max $1x10^4$	Max.$1x10^5$	-	-	-	-
2	Coliform(MPN/100 ml)	MPN/100ml	<2.20	0/250 ml	Max.10	<2,20	<2.20	Nil
3	Escherichia coli	MPN/100ml	0	0	0	Negative	-	Nil
4	Salmonella/100 ml	CFU/100ml	-	0	-	-	-	-
5	Staphylococcus Aureus/250 ml	CFU/250ml	-	0	-	-	-	-
6	Pseudomonas Aeruginosa/250 ml	CFU/250ml	0	0	-	-	-	-
7	Fecal Streptococci/20 ml	MPN/20ml	-	-	-	-	1/100	-

							ml	

4.9 Water Quality Standards of Vietnam, Japan, China, Hong Kong, Korea and Taiwan

A. Chemical Quality

2.1 Sr. #	*Substances*	*Unit*	*Vietnam*	*Japan*	*China*	*H. Kong*	*Korea*	*Taiwan*
1	Arsenic (As)	mg/l	0.05	<0.2	0.05	0.01	0.05	0.05
2	Ammonium (NH_4)	mg/l	-	<0.5	-	1.5	0.5	-
3	Barium (Ba)	mg/l	-	-	-	0.7	-	-
4	Borate (BO_3)	mg/l	10	-	-	0.3	-	-
5	Cadmium (Cd)	mg/l	0.01	<0.05	0.01	0.003	0.01	0.01
6	Chromium (Cr)	mg/l	-	<0.05	0.05	0.05	0.05	0.05
7	Chloride (Cl)	mg/l	-	<350	250	250	150	250
8	Chlorine (Cl_2)	mg/l	-	-	-	-	-	1
9	Copper (Cu)	mg/l	1	<0.05	1	2	1	0.01
10	COD	mg/l	-	-	-	-	-	0.8
11	Cyanide (Cn)	mg/l	0.01	<0.01	0.01	0.07	ND	-
12	Fluoride (F)	mg/l	2	<1.5	0.8	1.5	1	-
13	Hardness ($CaCO_3$)	mg/l	-	100-500	250	-	300	250
14	Iodine (I)	mg/l	-	-	-	-	-	0.3
15	Iron (Fe)	mg/l	-	<0.1	0.3	0.3	0.3	0.05
16	Lead (Pb)	mg/l	0.05	<0.1	0.05	0.01	0.1	0.05
17	Manganese (Mn)	mg/l	2	<0.1	0.05	0.5	0.3	0.001
18	Mercury (Hg)	mg/l	-	-	0.001	0.001	ND	-
19	Nitrate (NO_3)	mg/l	45	<5.0	10	50	10	10
20	Nitrite (NO_2)	mg/l	-	-	ND	3	-	ND
21	Organic Matter	mg/l	3	-	0.1	-	-	0.1
22	Selenium (Se)	mg/l	-	<0.05	0.01	0.01	0.01	0.01
23	Silver (Ag)	mg/l	0.01	-	0.05	-		0.05
24	Sulphate (SO_4)	mg/l	-	<250	250	250	200	250
25	Phenolic	mg/l	-	<0.001	-	-	0.005	-
26	Total Beta activity	pCi/l	-	-	-	1.0 Bq/I	-	-
27	TDS	mg/l	-	<1000	500	1000	-	500
28	Zinc (Zn)	mg/l	5	<5	5	3	1	5

B. Microbiological Quality

1	Total Plate Count/ml	CFU/ml	<10	-	100	-	<100	-
2	Coliform (MPN/100 ml)	MPN/100ml	-	<15.100	3	<2.2	0	-
3	Escherichia coli	MPN/100ml	2.2	-	-	-	-	0/100 ml

4.10 Water Quality Standards of Saudi Arabia, Guam, Australia, Argentina, Mexico and Canada

A. Chemical Quality

Sr.#	Substances	Unit	S. Arabia	Guam	Australia	Argentina	Mexico	Canada
1	Arsenic (As)	mg/l	0.05	0.05	0.05	0.05	0.05	0.025
2	Ammonium (NH_4)	mg/l	-	-	-	0.2	0.5	-
3	Barium (Ba)	mg/l	1	1	1	-	0.7	1
4	Borate (BO_3)	mg/l	-	-	30	-	-	5
5	Cadmium (Cd)	mg/l	0.01	0.01	0.005	0.01	0.005	0.005
6	Chromium (Cr)	mg/l	0.05	0.05	0.05	0.05	-	0.05
7	Chloride (Cl)	mg/l	250	250	-	350	250	-
8	Chlorine (Cl_2)	mg/l	-	-	0.01	0.5	0.1	-
9	Copper (Cu)	pCi/l	1	1	1	2	1	-
10	COD	mg/l		-	3	-	-	-
11	Cyanide (Cn)	mg/l	0.05	-	0.1	0.10	-	0.2
12	Fluoride (F)	mg/l	-	-	1.5	2	2	-
13	Iron (Fe)	mg/l	0.3	0.3	-	2	0.3	-
14	Lead (Pb)	mg/l	0.05	0.05	-	0.05	0.02	0.01
15	Manganese (Mn)	mg/l	0.05	0.05	2	0.1	0.05	-
16	Mercury (Hg)	mg/l	-	0.002	0.001	0.001	0.001	0.001
17	Nitrate (NO_3)	mg/l	-	10	45	45	10	45
18	Nitrite (NO_2)	mg/l	-	-	0.01	0.1	-	3.2
19	Selenium (Se)	mg/l	-	0.01	0.01	-	0.05	0.01
20	Silver (Ag)	pCi/l	0.05	0.05	-	0.05	-	-
21	Surfactant	mg/l	-	-	-	-	0.5	-
22	Sulfide (S)	mg/l	-	-	0.05	-	-	-
23	Sulphate (SO_4)	mg/l	250	250	-	500	250	-
24	Phenolic	mg/l	0.001	0.001	-	-	0.001	-
25	Ra 226 activity	pCi/l	3	5	1	-	-	-
26	Total Beta activity	pCi/l	-	8	-	-	-	-
27	TDS	mg/l	-	500	-	1500	500	-
28	Zinc (Zn)	mg/l	5	5	5	5	3	-

B. Microbiological Quality

1	Total Plate Count/ml	CFU/ml	-	-	<1	500	100	100
2	Coliform (MPN/100 ml)	MPN/100ml	-	<2.20	Max.10	3	<2	-
3	Escherichia coli	MPN/100ml	-	-	-	Negative	-	0
4	Pseudomonas Aeruginosa/250 ml	CFU/250ml	-	-	-	Negative	-	0

CHAPTER-5

RESULTS & DISCUSSIONS

This chapter is pertaining to the results and discussion of IWCP Water Quality Monitoring Program conducted over the years 2004-05 and 2005-06. The IWCP is a project of PCRWR, covering water quality monitoring program in five northern districts of NWFP and the entire Northern Areas. The five districts of NWFP include: Mardan, Bunner, Swat, Lower Dir and Upper Dir, and the Northern Areas comprising districts of Gilgit, Skardu, Ghanche, Diamar and Ghizer. The sampling water sources locations in all the districts were selected from where the people get water largely for drinking purpose. During 2004-05, altogether 186 locations from ten districts were selected for water sampling, while in 2005-06 total 181 locations from the ten districts were chosen for water sampling. Hence a total of 367 Nos. of water samples were collected for water quality testing during the two years from five northern districts of NWFP and Northern Areas of Pakistan. Number of water samples collected from each of the districts of NWFP and NAs are given in Table 5.1 and 5.2 respectively**.**

Table 5.1: No. of Samples Collected from Five Districts of Northern NWFP

S. No.	*Name of district*	*No. of samples collected 2004-2005*	*No. of samples collected 2005-2006*	*Total No. of samples of both the years*
1	Mardan	51	36	87
2	Bunner	31	33	64
3	Swat	30	30	60
4	Lower Dir	11	12	23
5	Upper Dir	10	11	21
	Total No. of samples	**133**	**122**	**255**

Table 5.2: No. of Samples Collected from Five Districts of Northern Areas.

S. No.	*Name of district*	*No. of samples collected 2004-2005*	*No. of samples collected 2005-2006*	*Total No. of samples of both the years*
1	Gilgit	14	14	28
2	Skardu	14	14	28
3	Ghanche	08	09	17
4	Diamar	09	14	23
5	Ghizer	08	08	16
Total No. of samples		**53**	**59**	**112**

Distribution of water sources from where the samples were collected in each district are given in Table 5.3 and 5.4. These water sources mostly include groundwater, surface water, community and public water supply schemes, hand pumps, open wells and springs etc. The major water sources available in Mardan and Bunner districts are domestic wells, in Swat and Lower Dir are tube wells, while in Upper Dir the major water sources are springs.

Table 5.3: Distribution of Samples Across Water Sources Among the Northern Districts of NWFP

S. No.	District	Tube well		Open well		Domestic tube well		Spring		Hand pump		Tap (WSS)		Surface water	
		2004-05	2005-06	2004-05	2005-06	2004-05	2005-06	2004-05	2005-06	2004-05	2005-06	2004-05	2005-06	2004-05	2005-06
1.	Mardan	03	09	-	06	30	16	04	02	02	02	12	01	-	-
2.	Bunner	01	02	-	02	13	16	07	04	-	03	01	03	09	03
3.	Swat	11	12	01	01	02	03	08	08	-	02	03	04	05	-
4.	Dir Lower	06	06	-	-	02	04	01	02	-	-	02	0	-	-
5.	Dir Upper	-	-	-	-	-	-	04	08	-	-	05	03	01	-
Total		21	29	01	09	47	39	24	24	02	07	23	11	15	03

Glacier and snow deposits are the principal sources of all water in the Northern Areas. The melted water enters streams, which subsequently feed man-made channel -Kuhls- that bring water into the settlements for agriculture, livestock and domestic requirements.

Surface water based water supply schemes are constructed in most parts of the Northern Areas except in Diamer where surface water is directly consumed. According to Muneeba et al. (1994) most villages use the same channel for irrigation and domestic use. In some villages the people go up the channel to get water for drinking since they realize that water passing through the village can be contaminated. This has a basis in fact since most of the channels are open and wastewater from homes and feces can flow into them, plus clothes and domestic utensils are also washed in these channels.

Table 5.4: Distribution of Samples Across Water Sources in all the Districts of Northern Areas

S. No.	District	Domestic tube well		Spring		Tape (WSS based On surface water)		Surface water	
		2004-05	2005-06	2004-05	2005-06	2004-05	2005-06	2004-05	2005-06
1.	Gilgit	-	-	01	-	09	09	04	05
2.	Skardu	-	-	-	-	10	12	04	02
3.	Ghanche	-	01	01	01	01	03	06	04
4.	Diamar	-	01	-	01	-	02	09	10
5.	Ghizer	-	-	01	01	04	04	03	03
Total		-	02	03	3	24	30	26	24

Water quality analytical parameters evaluated in the water samples of the aforementioned areas can be divided into following three categories,

1. **Physical and Aesthetic Parameters:**

   Parameters evaluated under the name physical and aesthetic include qualitative and quantitative examination of pH, Electrical Conductivity (EC), Turbidity, Colour, Taste and Odour.

2. **Chemical Parameters:**

   These include Bicarbonate (HCO_3), Carbonate (CO_3), Nitrate (NO_3), Sulphate (SO_4), Hardness, Calcium (Ca), Alkalinity (Alk), Magnesium (Mg), Potassium (K), Sodium

(Na), Chloride (Cl^-), Total dissolved salts (TDS), Arsenic (As), Fluoride (F), Iron (Fe) and trace elements.

3. **Biological Parameters:**

   Evaluation of bacteriological or microbiological parameters depicts qualitative examination of Protozoan/Microbes present in water which are the potential carriers of various types of health hazards.

All the analyzed parameters were compared with permissible limits given by PSI reproduced in Table 4.3, to evaluate as “Safe” or “Unsafe” for drinking purpose. Before presenting the results of each district, a brief of the geography, demography, climate, water resources and land use statistics is given so that the results could be seen and discussed in the context and prospective of these indicators as they may have direct impact on ecology and water quality of the area.

5.1 Mardan

The district lies at the longitude 71^o 48’ to 72 ^{o} 52’ E and latitude 34^o 05’ to 34^o 32’ N. Average altitude of the district is 750 m. Geographical map of the district is given in Figure-5.1. As is evident from the Figure, Malakand and Bunner are its northern neighbours, district Charsadda falls in the west, while Swabi and Nowshera form its eastern and southern boundaries respectively. Geographical area of the district is 1632 sq. km and its population according to 1998 census was 1.46 million and population density of 895 persons per sq. km which now has escalated to 1.93 million in 2007. As such the current population density becomes 1180 persons per sq. km.

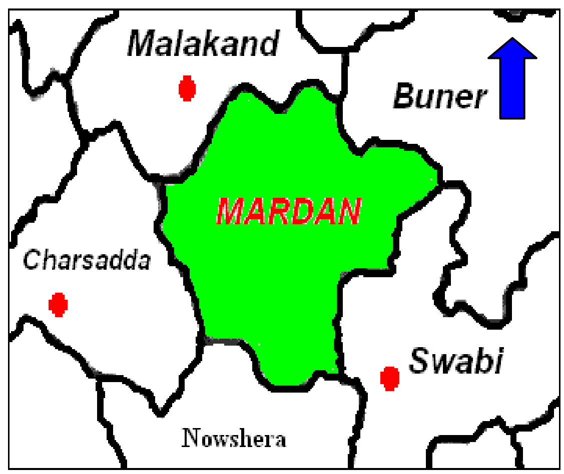


Figure 5.1: Geographical Map of District Mardan

Climatically Mardan can be divided into two sharp zones, south-eastern part and north-western part. South-eastern part falls under the climatic range of semi arid subtropical continental low land where annual rainfall is 340 mm, most of which (up to 60%) occurs in winter. Maximum temperature is 41^{o}C in summer and minimum winter temperature is 4.5 ^{o}C. The north-western part lies in the climatic range of sub-humid sub-tropical continental low land, annual rainfall ranges from 500 to 1000 mm. Land use statistics of the district are given in Table 5.5

Table 5.5: Land Use Statistics of the District Mardan

Land utilization	*Area in (000) hectares*	*Percentage of geographical area*	*Percentage of reported area*
Geographical Area	163	-	-
Reported Area	163	100	-
Cultivated	113	69	69
Irrigated area	80	49	49
Cropped area	126	77	77
Uncultivated area	49	30	30
Culturable waste	3	2	2
Forest area	8	5	5
Not available for cultivation	38	23	23
Cropping intensity:	112.2%		
Land use intensity:	97.2%		

Altogether 51 samples were collected in 2004-05 and 36 samples in 2005-06 from various sources in the entire district. Sources of these samples are given in Table 5.6, which indicates that domestic pump, and WSS tube wells are the common sources from where the public fulfil its domestic water requirements, whereas at some places spring water is also used. Due to availability of ground water at shallow depth and of acceptable quality, surface/river water consumption for domestic purposes is not in practice in the district.

Table 5.6: Types of water Sources and Number of Samples Taken thereof in Mardan (2004-06)

Source	*No of samples*		*Source*	*No. of samples*		*Total No. of samples*	
	2004-05	*2005-06*		*2004-05*	*2005-06*	*2004-05*	*2005-06*
Tube well	08	09	Open well	-	06	51	36
Domestic tube well	30	16	Spring	04	02		
Tap (WSS)	07	01	Hand pump	02	-		

Analytical results of the samples are presented in the Table 5.7 and graphical representation is given in Figure 5.2, which exhibit that major contaminants in the area are bacteria, calcium, nitrate and fluoride. Analytical results of the water samples collected during the year 2004-05 show that 88% water samples were microbiologically polluted, 14% of the water samples have turbidity beyond permissible limit of WHO standard, 18% have slightly more concentration of NO_3 against 10 mg/l acceptable level of WHO, 10% samples have higher concentration of Sodium (Na), 16% samples exceed in respect of calcium value, whereas 2% samples were identified possessing higher levels of chloride and hardness compared with international permissible water quality standards. Fluoride and TDS were found beyond permissible range in 6% and 4% samples respectively. On the overall basis, 92% samples were found to be unsafe for drinking purpose with respect to the either tested parameters.

However out of 36 samples tested in 2005-06, 67% were biologically contaminated, followed by 15% samples having calcium excess of permissible limit. Each of fluoride and nitrate was found having concentration beyond permissible limits only in 3 % samples. On the overall basis, 80% samples were detected as unsafe against only 20% samples which were found safe. Combined results of 2004-5 and 2005-6 indicate 87% samples unsafe and only the remaining 13 % samples safe for drinking purpose as shown in Figure 5.3.

Table 5.7: Water Quality Parameters Found Having Impermissible Values in Water Samples Collected From District Mardan (2004-06)

S. No.	*Parameters*	*No. of unfit samples out of total 51 (2004-05)*	*No. of unfit samples out of total 36 (2005-06)*	*Percentage*		*Overall %age 2004-06*
				2004-05	*2005-06*	
1	Bact. Cont.	45	24	88	67	79
2	Calcium (Ca)	8	5	16	15	15
3	Fluoride (F)	3	1	6	3	5
4	Nitrate (NO_3)	9	1	18	3	11
5	Total Dissolved Salts (TDS)	2	0	4	0	2
6	Chloride (Cl)	1	0	2	0	1
7	Sodium (Na)	5	0	10	0	6
8	Hardness	1	0	2	0	1
9	Turbidity	7	0	14	0	8

Mardan is one of the most populated areas and population wise the second largest district of NWFP. Overall geographical area is comparatively small and of which most of the area is fertile and cultivated. Cropping intensity in Mardan, which falls in Peshawar valley, is 112% as given in Table 5.5, which is amongst the highest in the country. Water table is shallow and ground water exploitation is common. The leakage within the distribution network and the location of drinking water sources being close to septic tanks etc. together with shallow water table seem common reasons of contaminants intrusions into the water source and water supply network. At the same time, high population density and high cropping intensity necessitate use of nitrate fertilizers, which also appears to be the source feeding high concentration of nitrate and hence bacteria that are major contaminants getting intruded into the supply network. Low literacy level (36.45%) and poor economic condition of the area are apparent reasons of lack of awareness, poor hygienic conditions and improper maintenance, which are certainly adding to contaminants yield and intrusion.

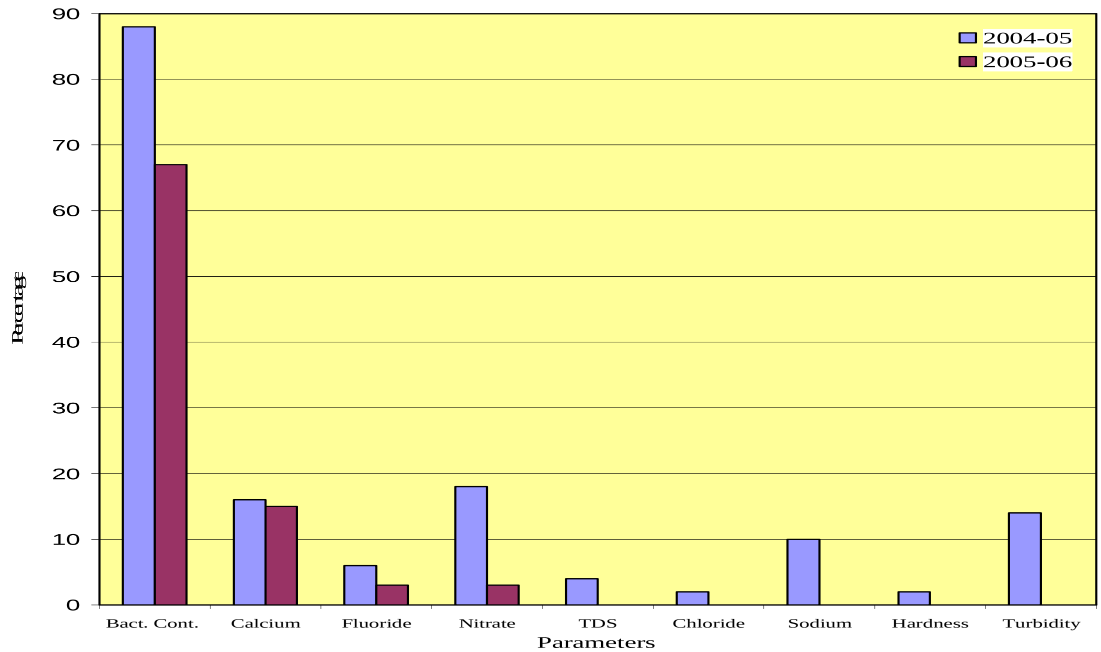


Figure 5.2: Percentage of Samples Having Impermissible Values for different parameters in District Mardan

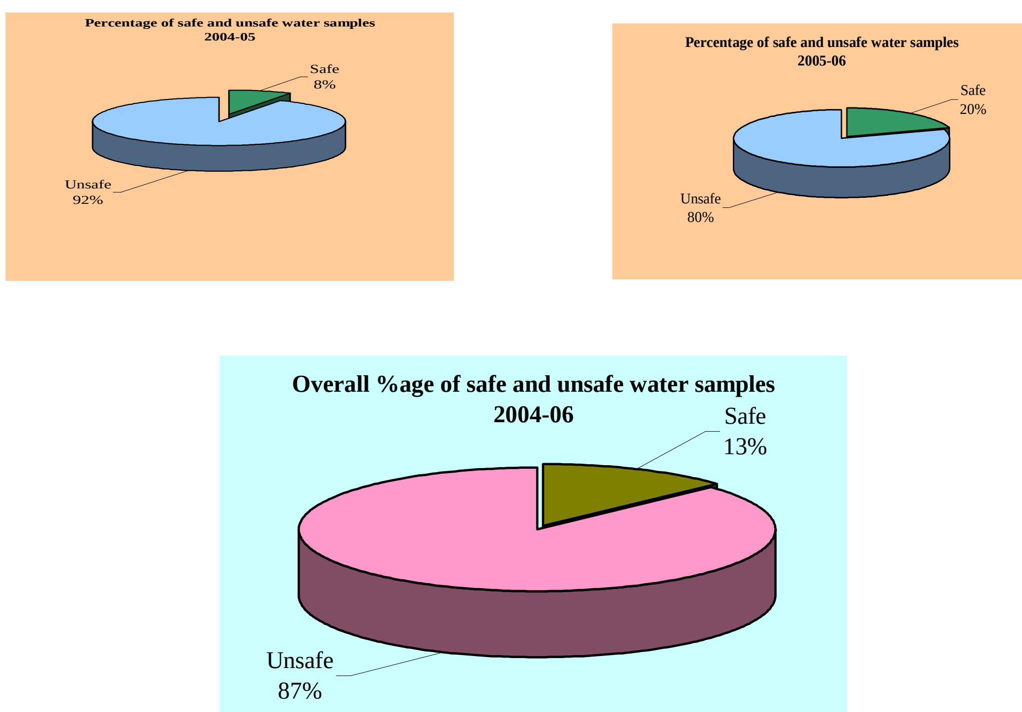


Figure 5.3: Graphical Presentation of Safe and Un-Safe Water Sources in District Mardan.

5.2 Buner

The district lies at the longitude 72° 30' to 72° 40' E and latitude 34° 08' to 34° 29' N. Average altitude of the district is 1500 m. As is evident from the geographical map given in Figure-5.4, that district Swat and Shangla are its northern neighbours, district Mardan lies towards its west, while district Mansehra and Swabi form its eastern and southern boundaries respectively.

Figure 5.4: Geographical Map of District Bunner

Geographical area of the district is 1865 sq. km. According to 1998 census, its population was 0.51 million with population density of 271 persons per sq. km which now has escalated to 0.73 million in 2007. As such the current population density becomes 393 persons per sq. km.

Climatically Bunner falls in sub humid and subtropical continental high land where average annual rainfall ranges from 750 mm to 1000 mm. Bunner is comparatively colder than district Mardan. Maximum temperature is 38°C in summer and minimum winter temperature is 2°C. Land use statistics of the district are given in Table 5.9.

Table 5.8: Land Use Statistics of the District Bunner

Land utilization	*Area in (000) hectares*	*Percentage of geographical area*	*Percentage of reported area*
Geographical area	186	-	-
Reported area	172	92	-
Cultivated	55	30	32
Irrigated area	16	9	9
Cropped area	100	54	58
Uncultivated area	117	63	68
Culturable waste	6	3	3
Forest area	41	22	24
Not available for cultivation	70	38	41
Cropping intensity:	181%		
Land use intensity:	91%		

In district Buner, altogether 64 locations were selected for water sampling during the two years (2004-06) keeping in view the source where most of the population consume water for drinking purpose. Sources of these samples are given in the Table 5.9 which indicates that domestic pump, and water supply schemes based on springs are the common sources from where the public fulfil their domestic water requirements. Whereas at some hilly terrain surface water is also used as ground water exploration is not possible in those areas of the district.

Table 5.9: Types of Water Sources and Number of Samples Collected from District Buner

Source	*No. of samples*		*Source*	*No. of samples*		*Total No of samples*	
	2004-05	*2005-06*		*2004-05*	*2005-06*	*2004-05*	*2005-06*
Tube well	01	02	Surface water	09	03	31	33
Domestic tube well	13	16	Spring	07	04		
			Open well	-	02		
Tap (WSS)	01	03	Hand pump	-	03		

Water quality results of the samples are presented in Table 5.10 and graphical representation is given in Figure-5.5, which exhibit that major contaminants in the area are bacteria, calcium, hardness and turbidity. Processing and compilation of water quality data revealed that out of total 64 samples (2004-06), 86% samples were found unfit for human consumption either chemically or biologically as shown in Figure 5.6. Out of 31 samples collected during the year 2004-05, 71% samples were found contaminated biologically; 19% samples had turbidity higher than the admissible range; 3% with high level of , calcium, sodium and hardness, 13% samples had high concentration of Nitrate, whereas 6% samples were found with objectionable muddy colour. On the overall basis, 84% samples were found as unsafe either biologically or chemically against the survey of the year 2004-05.

Whereas 33 samples were collected from district Bunner during the next year 2005-06, on the overall basis 88% samples were found contaminated either chemically or biologically as in Figure 5.6. However 70% samples were found contaminated biologically; 27% samples had turbidity higher than the admissible range; 12% with high level of hardness, 30% samples had high concentration of Calcium (Ca), 3% samples had high concentration of Nitrate, whereas 6% samples were found having excessive concentrations of Potassium, Total Dissolved Salts (TDS) or with objectionable muddy colour.

Table 5.10: Water Quality Parameters Found Having Values Beyond Permissible Limits in Water Samples Collected from District Buner (2004-06)

Sr. No.	*Parameters*	*No. of unfit samples out of total 31 (2004-05)*	*No. of unfit samples out of total 33 (2005-06)*	*Percentage*		*Overall %age 2004-06*
				2004-05	*2005-06*	
1	Bact. Cont.	22	23	71	70	70
2	Turbidity	6	9	19	27	23
3	Color	2	2	6	6	6
4	Nitrate (NO_3)	4	1	13	3	8
5	TDS	1	2	3	6	5
6	Calcium (Ca)	1	10	3	30	17
7	Sodium (Na)	1	0	3	0	2
8	Hardness	1	4	3	12	8
9	Potassium	0	2	0	6	3

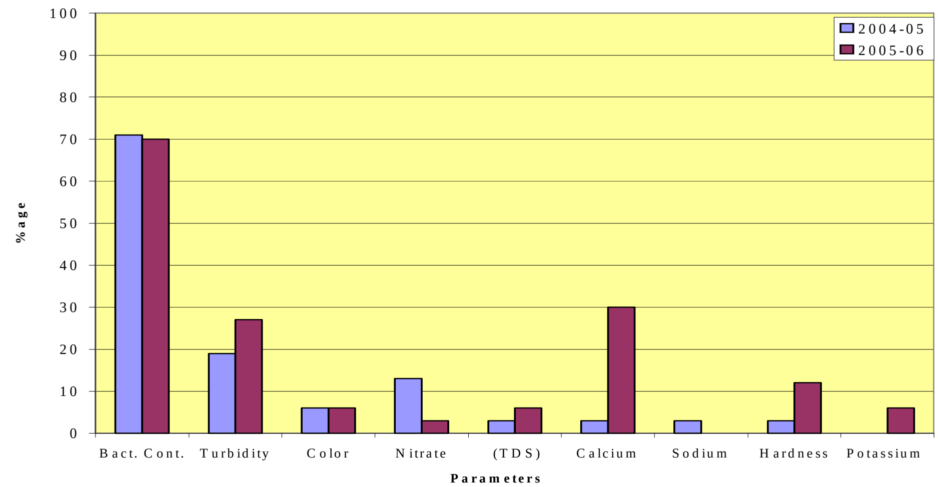


Figure 5.5: Percentage of Samples Having Impermissible Values in District Buner

Buner is one of the thinly populated district of NWFP, where almost entire population is rural and population density is comparatively low. Almost the entire district is mountainous. Out of total 0.17 million hectares reported area, 9% of land is irrigated. Cropping intensity in Bunner, which falls in Swat valley, is 181%, which is amongst the highest in the country. Generally ground water aquifer is deep. Due to scattered population, water supply schemes in the area are not well planned and well maintained, that combined with low literacy ratio (23%), poor hygienic condition and lack of awareness seem the probable reasons of bacteriological contamination. At the same time scattered population and high cropping intensity necessitate use of nitrate fertilizers, which also appear to be source feeding high concentration of bacteria and nitrate which, are major contaminants getting intruded into water resources. Marble stone cutting is an important industry of the district which seems to be the cause of high concentration of calcium & hardness. Low literacy level and poor economic condition of the area are apparent reasons of lack of awareness, poor hygienic conditions and improper maintenance, which are certainly adding to contaminants yield and intrusion.

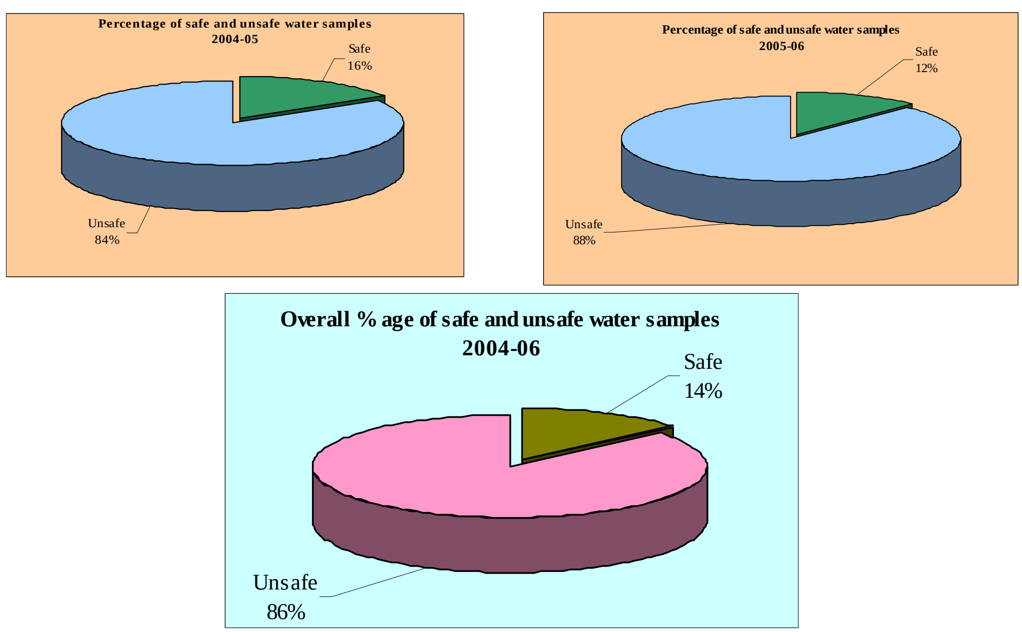


Figure 5.6: Graphical Presentation of Safe and Un-Safe Water Sources in District Bunner

5.3 Swat

District Swat lies at the longitude 71° 19' to 72° 35' E and latitude 34° 40' to 35° 20' N. Average altitude of the district is 1500 m. Geographical map of the district is given in Figure-5.7. As is evident from the Figure, Chitral and Northern Areas are its northern neighbours, Kohistan and Dir lies on its east and west side respectively, while Bunner and Shangla form its southern and eastern boundaries respectively. Geographical area of the district is 5337 sq. km and its population according to 1998 census was 1.26 million which now has escalated to 1.74 million in 2007. As such the current population density becomes 326 persons per sq. km.

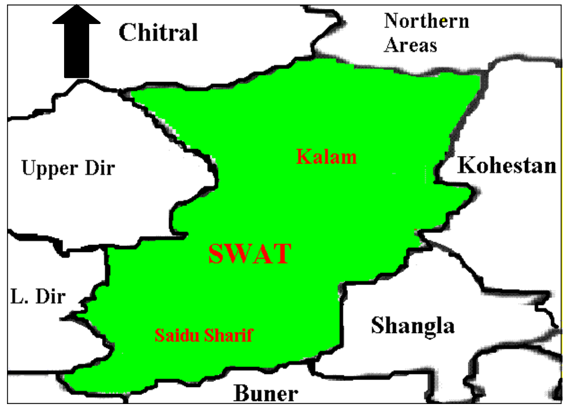


Figure 5.7: Geographical Map of District Swat

Climatically Swat lies in sub-humid-subtropical continental highland. Average annual rain fall in district Swat is about 800 mm. Maximum temperatures is 35°C in summer, while minimum winter temperature is 3°C in south-western part. North eastern part (Kalam area) is much colder where temperature in winter frequently falls below zero. Winter snow fall is common in that area and melting of seasonal snow pack feeds river Swat from April to July. Land use statistics of the district are given in the Table 5.11

Table 5.11: Land Use Statistics of the District Swat

Land utilization	*Area in (000) hectares*	*Percentage of geographical area*	*Percentage of reported area*
Geographical area	534	-	-
Reported area	506	95	-
Cultivated	96	18	19
Irrigated area	90	17	18
Cropped area	185	35	37
Uncultivated area	401	75	79
Culturable waste	80	15	16
Forest area	135	25	27
Not available for cultivation	194	36	38
Cropping intensity:	193%		
Land use intensity:	54%		

Altogether 30 samples were collected each year (2004-06) from various sources in the entire district. Sources of these samples are given in Table5.12, which indicates that tube wells and springs are the common sources used for domestic water requirements. Most of the rural population is scattered in mountainous areas and use water from domestic water supply schemes based on springs. Due to availability of ground water at affordable depth and of adequate quality, surface water consumption for domestic purposes is not normally in practice in south-western part of the district. However in north-eastern Swat, spring or surface water is commonly used.

Table 5.12: Types of Water Sources and Number of Samples Taken Thereof in Swat

Source	*No. of samples*		*Source*	*No. of samples*		*Total No. of samples*	
	2004-05	*2005-06*		*2004-05*	*2005-06*	*2004-05*	*2005-06*
Tube well	11	12	Open well	01	01	30	30
Domestic tube well	02	03	Spring	08	08		
			Surface water	05	-		
Tap (WSS)	03	04	Hand pump	-	02		

Analytical results (Annexure-03-a) of the samples are presented in Table 5.13 and graphical representation is given in Figure 5.8, which exhibit that major contaminants in the area are bacteria, calcium, nitrate and turbidity. Out of 30 samples collected during 2004-05, 73% were biologically contaminated, followed by 17% samples having nitrate excess of permissible limit. Ten percent of samples were found having turbidity and calcium beyond the permissible limits. Each of hardness and potassium was found having value beyond permissible limits only in 3 % samples. On the overall basis, 77% samples were detected as unsafe against only 23% samples which were found safe during 2004-5 as depicted in Figure 5.9.

During the year 2005-06, altogether 30 samples were collected from various sources in the entire district. It is evident from the analysis reports (Annexure-03-b) that 77% samples were biologically contaminated, followed by 20% samples having calcium and nitrate excess of permissible limit. Turbidity was found in excess in 10% of samples. Each of hardness and colour was found having value beyond permissible limits only in 3 % samples. On the overall basis, 87% samples were detected as unsafe against only13% samples which were found safe pertaining to the year as shown in Figure 5.9.

Table 5.13: Water Quality Parameters Found Having Impermissible Values in Water Samples Collected From District Swat (2004-06)

Sr. No.	*Parameters*	*No. of unfit samples out of total 30 (2004-05)*	*No. of unfit samples out of total 30 (2005-06)*	*Percentage*		*Overall %age 2004-06*
				2004-05	*2005-06*	
1	Bact. Cont.	22	23	73	77	75
2	Nitrate (NO_3)	5	6	17	20	18
3	Calcium (Ca)	3	6	10	20	15
4	Hardness	1	1	3	3	3
5	Turbidity	3	3	10	10	10
6	Colour	0	1	0	3	2
7	Potassium	1	0	3	0	2

Swat is one of the famous tourist resort and population wise third largest district in NWFP. Overall geographical area is comparatively large and of which only 18% is cultivated. Water Table is at moderate depth in inter mountainous valleys where tube well is the main source of water. Population is scattered in most of hilly areas where domestic water supply schemes are installed on springs having no regular employees for their maintenance. Water supply lines at places are damaged or punctured allowing intrusion of pollutants, which is the main cause of poor water quality condition. Similarly spring water is also distributed unplanned locally with out due care of the schemes.

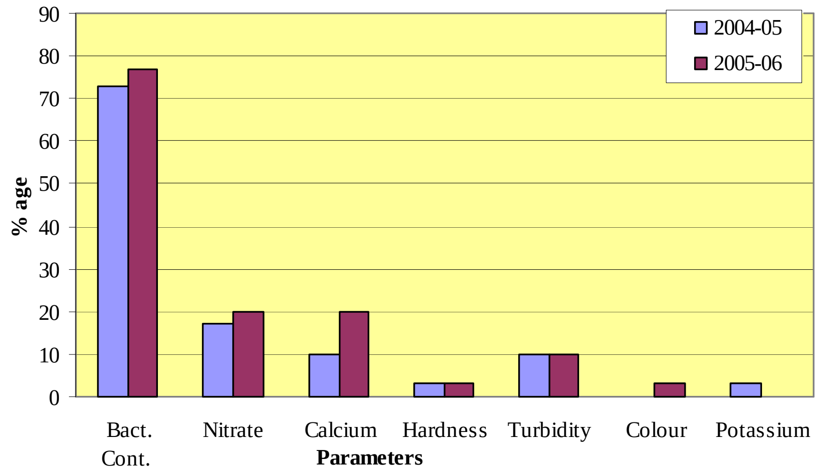


Figure 5.8: Percentage of Samples Having Impermissible Values in District Swat

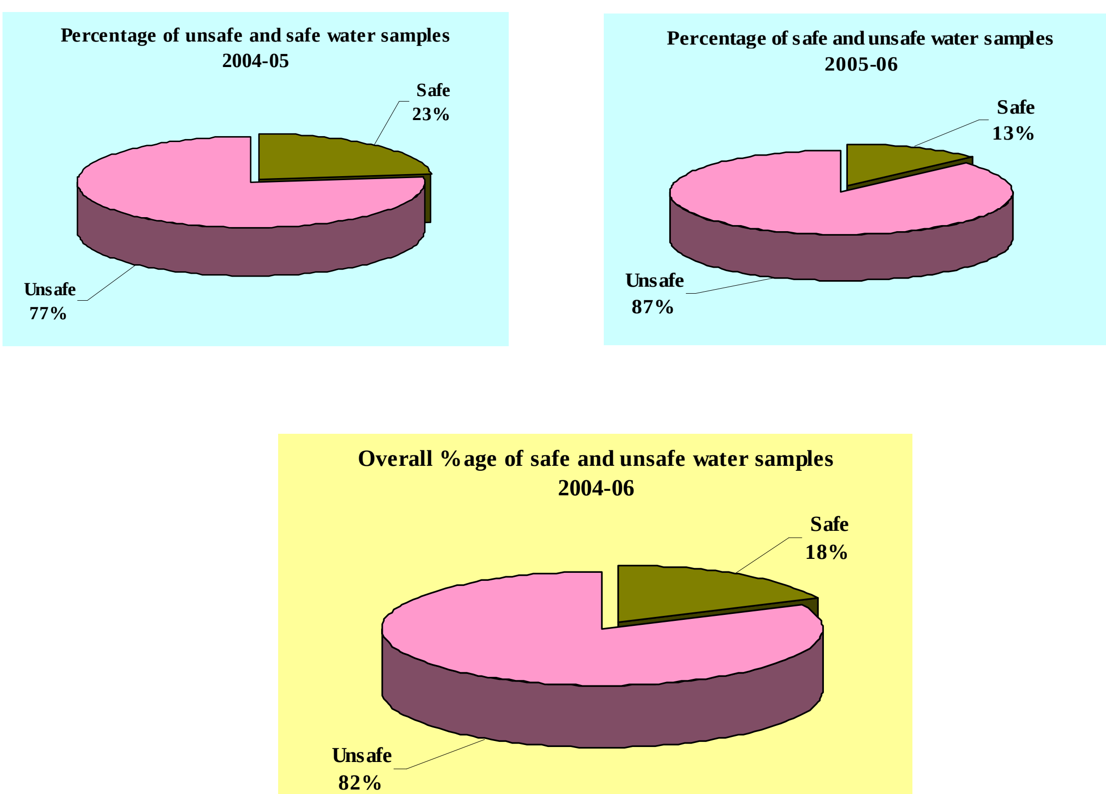


Figure 5.9: Graphical Presentation of Safe and Un-Safe Water Sources in District Swat.

5.4 Dir (Lower)

The district lies at the longitude 71° 47' to 72° 05' E and latitude 33° 59' to 34° 58' N. Average altitude of the district is 1800 m. Geographical map of the district is given in Figure-5.10, which shows that Malakand and Bajaur agency forms its southern and south-western boundaries, district Swat and Upper Dir are its north-eastern and northern districts respectively, whereas a small part of its western boundary forms Durand line with Afghanistan. Geographical area of the district is 1583 sq. km and its population according to 1998 census was 0.72 million, which now has escalated to 1 million in 2007. As such the current population density becomes 631 persons per sq. km.

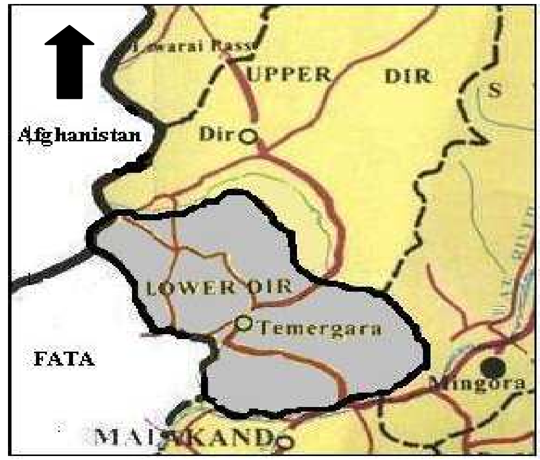


Figure 5.10: Geographical map of district Dir Lower

Climatically Lower Dir falls under the climatic range of sub humid subtropical continental highland, where annual rainfall is up to 875 mm, 60% of which falls in late summer. Maximum temperature is in the range of 32-38 °C in summer, while average minimum winter temperature is 3 °C. Land use statistics of the district Dir Lower are given in the Table 5.14.

Table 5.14: Land Use Statistics of the District Dir Lower

Land utilization	*Area in (000) hectares*	*Percentage of geographical area*	*Percentage of reported area*
Geographical area	158	-	-
Reported area	142	90	-
Cultivated	45	71	79
Irrigated area	41	50	56
Cropped area	54	80	89
Uncultivated area	49	31	35
Culturable waste	1	0.6	0.7
Forest area	8	5	6
Not available for cultivation	39	25	27
Cropping intensity:	120%		
Land use intensity:	98%		

Altogether 23 samples, 11 samples in 2004-05 and 12 samples in 2005-06, were collected during the two years from different sources in the entire district. Sources of these samples are given in Table5.15, which shows that domestic pump and tube wells are the common sources from where the public fulfil their domestic water requirements, whereas at some places spring water is also used. Due to availability of ground water at shallow depth and of acceptable quality, surface water consumption for domestic purposes is not normally in practice in the district.

Table 5.15: Types of Water Sources and Number of Samples Taken Thereof in Dir Lower

Source	No. of samples		Source	No. of samples		Total No. of samples	
	2004-05	2005-06		2004-05	2005-06	2004-05	2005-06
Tube well	06	06	Tap (WSS)	02	0	11	12
Domestic tube well	02	04	Spring	01	02		

Analytical results of the samples are presented in Table 5.16, which is graphically represented in Figure 5.11. The data revealed that major contaminants in the area are bacteria, nitrate and calcium. Out of 11 samples collected in 2004-05, all were biologically contaminated, followed by 54% samples having nitrate excess of permissible limit. Iron was found having concentration beyond permissible limits in 18 % samples. One out of 11 samples (9%) was found having calcium concentration beyond permissible limits.

Over the year 2005-06, all the 12 samples (100%) were found biologically contaminated, followed by 33% samples having calcium excess of permissible limit. Each of turbidity and nitrate was found having concentration beyond permissible limits only in 8 % samples.

Table 5.16: Water Quality Parameters Found Having Impermissible Values in Water Samples Collected From District Dir Lower (2004-06)

S. No.	Parameters	No. of unfit samples out of total 11 (2004-05)	No. of unfit samples out of total 12 (2005-06)	Percentage		Overall %age 2004-06
				2004-05	2005-06	
1	Bact. Cont.	11	12	100	100	100
2	Calcium (Ca)	1	4	9	33	22
3	Iron (Fe)	2	0	18	0	9
4	Nitrate (NO_3)	6	1	54	8	30
5	Turbidity	0	1	0	8	4

Lower Dir is one of the districts of the province having much scattered population. Out of 0.16 million hectares area, 71% is cultivated. Water table is at affordable depth and ground water exploitation is common. High cropping intensity (120%) necessitate use of fertilizers, which appear to be source feeding high concentration of bacteria and nitrate, which are major contaminants getting intruded into supply network. Reason of high concentration of calcium appears geological strata of the district. Low literacy level (30%) and poor economic condition of the area are apparent reasons of lack of awareness, poor hygienic conditions and improper maintenance, which are certainly adding to contaminants yield and intrusion.

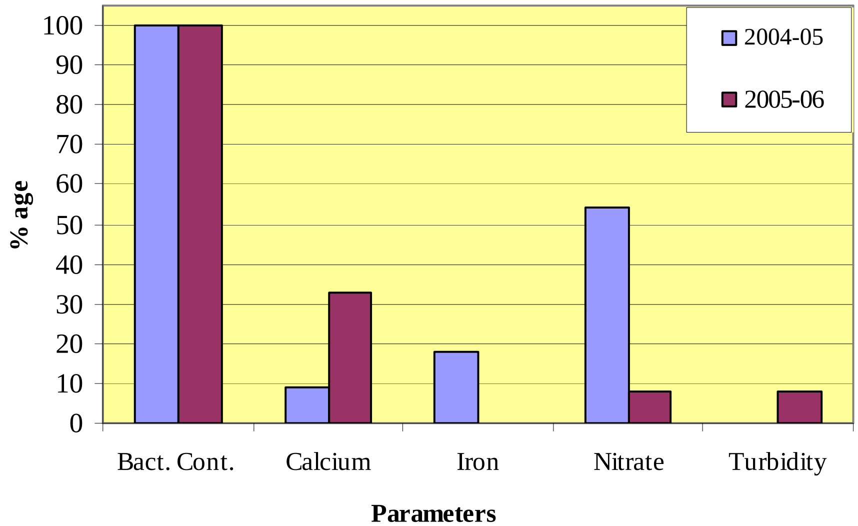


Figure 5.11: Percentage of Samples Having Impermissible Values in District Dir Lower

5.5 Dir (Upper)

The district is one of the remote northern districts of the NWFP which lies at longitude 71^{o} 00' to 72 ^{o} 07' E and latitude 34^{o} 20' to 34^{o} 24' N. Average altitude of the district is 1800 m. Geographical map of the district is given in Figure-5.12, which shows that district Dir (U) lying on Afghanistan boarder. District Chitral and Swat form its north-western and north-eastern boundaries respectively, whereas Dir Lower makes its southern boundary. Its total geographical area is 3699 sq. km with rugged mountainous topography

Figure 5.12: Geographical Map of District Dir (Upper)

Population of the district according to 1998 census was 0.58 million and population density 156 person per sq. km, which have now increased to 0.75 million 2007 with population density 203 person per sq. km. Upper Dir falls under the climatic range of sub humid subtropical continental highland, where annual rainfall is up to 875 mm, 60% of which falls in late summer. Maximum temperature in summer is 32-38 ^{o}C while minimum winter temperature is 3 ^{o}C. Land use statistics of the district is summarized in Table 5.17.

Table 5.17: Land Utilization Statistics Among Various Sectors of District Dir Upper

Land utilization	*Area in (000) hectares*	*Percentage of geographical area*	*Percentage of Reported area*
Geographical Area	370		
Reported Area	127	34	
Cultivated	42	11	33
Irrigated area	22	6	17
Cropped area	49	13	39
Uncultivated area	85	23	67
Culturable waste	0.6	0.2	0.5
Forest area	80	22	63
Not available for cultivation	51	14	40
Cropping intensity:	118%		
Land use intensity:	98%		

Dir Upper has hard and rugged mountainous terrain. Most of the population is scattered, where well-planned water distribution infrastructure is not normally possible. Poor economic condition, low literacy ratio (21%) and rugged mountainous topography persuade the people to use easily available spring water sources.

Altogether 21 water samples, ten in 2004-05 and 11 in 2005-06, were collected from different sources in the entire district. Sources of these samples are given in Table 5.18, which indicates that springs are the common sources from where the public fulfil their domestic water requirements, whereas at some places water supply schemes are also in use.

Table 5.18: Distribution of the Water Sources in District Upper Dir

Source	*No. of samples*		*Total No. of samples*	
	2004-05	*2005-06*	*2004-05*	*2005-06*
Tube well	05	03	10	11
Spring	04	08		
Surface water	01	-		

Analytical results of the samples are presented in Table 5.19 and are graphically represented in Figure-13, which exhibit that major contaminants in the district are bacteria, nitrate and turbidity. In 2004-05 out of 10 water sources, 80% were found biologically contaminated. Data processing revealed that all the water samples were contaminated biologically; 40% samples were either turbid or with high concentration of nitrate.

While over the year 2005-06, out of 11 water sources, none was supplying safe drinking water. Data processing revealed that all the water samples were contaminated biologically; 9% (1 sample) were either turbid or with high concentration of calcium and 27% samples had excess of nitrate.

Table 5.19: Water Quality Parameters Found Having Values Beyond Permissible Limits in Water Samples Collected from District Dir Upper 2004-06

S. No.	*Parameters*	*No. of unfit samples out of total 10 (2004-05)*	*No. of unfit samples out of total 11 (2005-06)*	*Percentage*		*Overall %age 2004-06*
				2004-05	*2005-06*	
1	Bact. Cont.	8	11	80	100	90
2	Calcium (Ca)	0	1	0	9	5
3	Nitrate (NO_3)	4	3	40	27	33
4	Turbidity	4	1	40	9	24

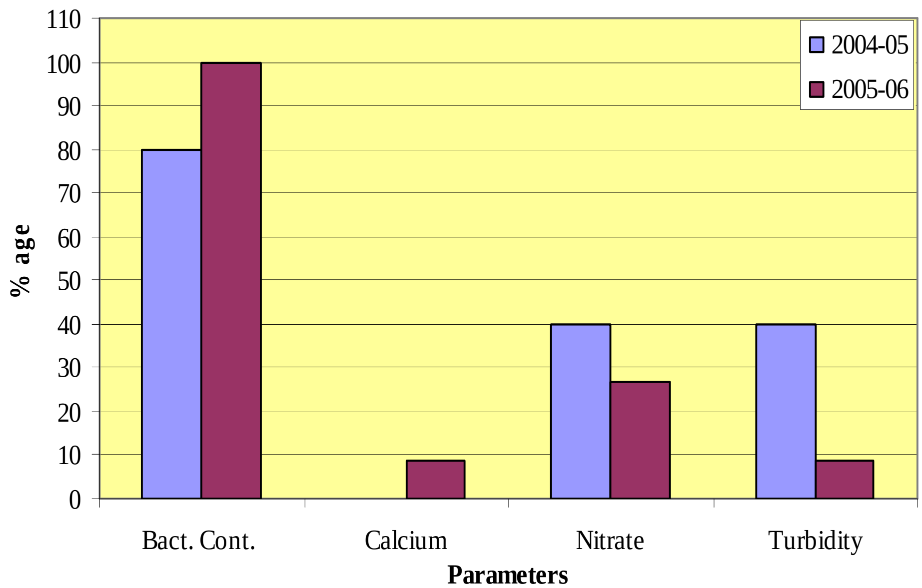


Figure 5.13: Percentage of Samples Having Impermissible Values in District Dir Upper

The deteriorated microbiological water quality in district Dir (U) seems due to poorly maintained water supply schemes. Population is scattered and people mostly consume water directly from springs which being open are prone to contamination. Water supply schemes if exist have no regular employees for their maintenance. Leaked and contaminated water was found accumulated around the leakage points, hence further deteriorating the supply. Lack of awareness and poor hygienic condition in such a rugged and remote area are other reasons of highest level of contamination.

Gilgit

Gilgit, the administrative capital of NAs, is an important city on ancient silk route, which is a famous passage from China to other countries of the world, lies at the longitude 74^o 17' to 76^o 50' E and latitude 35^o 55' to 36^o 32' N. Average altitude of the district is 1700 m. Geographical map of the district is given in Figure 5.14, which indicate that China and Afghanistan makes its northern and northern-east boundaries, district Ghizer lies towards its west, while district Skardu and Diamer makes its southern boundary. Geographical area of the district is 21300 sq. km. According to 1998 census, population of the district was 0.24 million and population density 11 person per sq. km. Maximum summer temperature is 33 ^{o}C whereas the minimum goes down to 16 ^{o}C, while maximum winter temperature is 28 ^{o}C and a minimum of -11 ^{o}C.

Figure 5.14: Geographical Map of District Gilgit

Altogether 28 samples were collected from different sources in the entire district during two years 2004-06. Sources of these samples are given in Table 5.20, which shows that direct surface water and water supply schemes (based on surface water) are the common sources from where public fulfil their domestic water requirements. Due to rugged topography and rocky underground strata, exploring of ground water is difficult and therefore ground water consumption for domestic purposes is not normally in practice in the district.

Table 5.20: Types of Water Sources and Number of Samples Collected from District Gilgit (2004-06)

Source	*No. of samples*		*Total No. of samples*	
	2004-05	*2005-06*	*2004-05*	*2005-06*
Surface water	04	05	14	14
Spring	01	-		
Water supply scheme	09	09		

Analytical results of the samples are presented in Table 5.21 and graphical representation is given in Figure 5.15, which exhibit that major contaminants in the area are bacteriological contamination, turbidity and color. Out of 14 samples collected during 2004-05, 57% samples show objectionable colour, taste and turbidity followed by 7% samples having potassium excess of permissible limit, while biologically all the samples were found contaminated (see annexure-06-a). In the following year (2005-06), the same 14 No. of samples were collected, analytical results of which show that, 29% samples have objectionable colour and taste, followed by 50% samples having turbidity excess of permissible limit, while biologically all the samples were found contaminated (see annexure-06-b).

Table 5.21: Water Quality Parameters Having Impermissible Values in Water Samples Collected from District Gilgit (2004-06)

Sr. No.	*Parameters*	*No. of unfit samples out of total 14 (2004-05)*	*No. of unfit samples out of total 14 (2005-06)*	*Percentage*		*Overall %age 2004-06*
				2004-05	*2005-06*	
1	Bact. Cont.	14	14	100	100	100
2	Turbidity	8	7	57	50	54
3	Color	8	4	57	29	43
4	Taste	8	4	57	29	43
5	Potassium	1	0	7	0	4

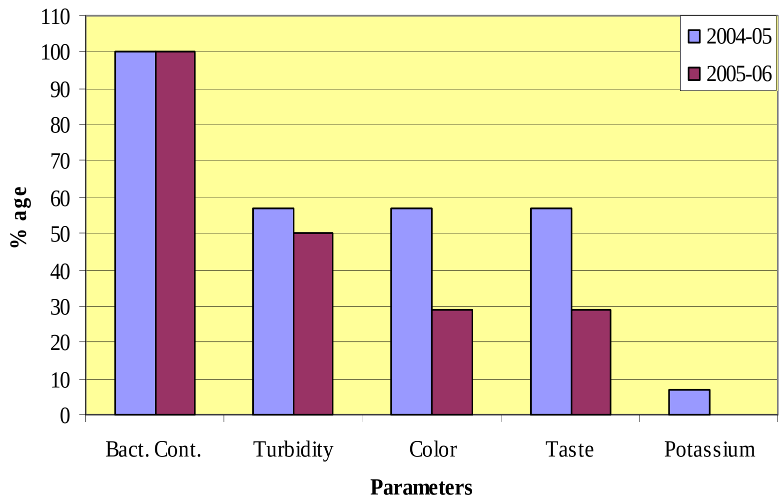


Figure 5.15: Percentage of Samples Having Impermissible Values in District Gilgit (2004-06)

Glacier and snow deposits are the principal sources of water in the district. Groundwater use for domestic purpose is not common except in some low lying settlements in Gilgit town, where people draw water from shallow wells. People depend mainly on their irrigation channels for the supply of water for domestic consumption. Water from these channels is stored in small pits, which is generally reserved for drinking and cooking purposes. The supply during winter is reduced due to minimal snow and glacier melt, which affect water quality of stored water. In summer months, the pit water is replenished more frequently, but turbulent flow and frequent landslides in the district induce high turbidity and muddy colour into the water. It was also noted that the contamination levels in the delivery systems were comparatively lower during the winter season. The important factor affecting the water quality is the human and the animal activities in the surrounding of the water delivery system. Water pits also contribute to the contamination primarily due to inappropriate location and lack of proper disposal of animal and human waste especially in rainy season.

Skardu

Skardu is the capital of Baltistan, lying at longitude 75º38’24” E and latitude 35º17’31” N, is situated at an altitude of 2438 meters above sea level in the lap of the great peaks of the Karakuram mountain range. Geographical map of the district is given in Figure 5.16, which indicates that it borders district Gilgit and the Xinjiang autonomous region of China to the north and northwest respectively, the district Ghanche to the east, the Indian held Kashmir to the southeast, the district Diamer to the west.

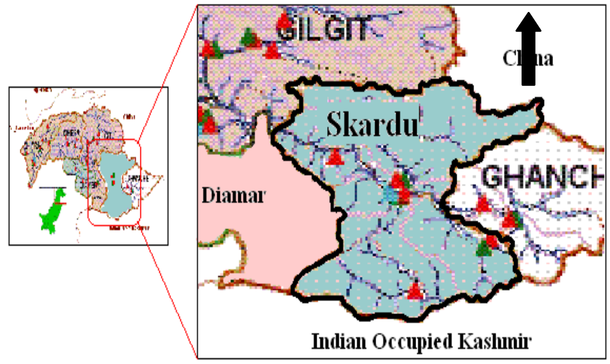


Figure 5.16: Geographical Map of District Skardu

Most of the area consists of rugged mountains, the higher elevation remaining snow covered throughout the year. Geographical area of the district is 18000 sq. km. Climate of the district during summer is moderate (maximum 27 ^{o}C) due its high altitude mountain setting, which also block monsoon. Winter temperature can drop to -10 ^{o}C. Population of the district, according to the 1998 census, was 0.21 million and population density 12 persons per sq. km. Satpara Tso, Katzura Tso, Phooq Tso are the important lakes of the district. Skardu is the district where Indus River enters the NAs from the Indian occupied Kashmir.

Water quality survey was conducted in 2004-05 and 2005-06. Altogether 28 samples were collected from various sources in the entire district. Sources of these samples are given in Table 5.26, which indicates that surface water either directly or in the form supply schemes are the principal sources of drinking water in the district. Due to unavailability of groundwater at shallow depth and of acceptable quality, groundwater consumption for domestic purposes is not in practice in the district.

Table 5.22: Types of Water Sources and Number of Samples Collected from District Skardu

Source	*No of samples*		*Total No. of samples*	
	2004-05	*2005-06*	*2004-05*	*2005-06*
Surface water	04	02	14	14
Water supply scheme	10	12		

Analytical results of the samples are presented in the Table 5.23 and graphical representation is given in Figure 5.17, which exhibits that major contaminants in the area are bacteria, calcium, turbidity, taste and fluoride. Out of 14 samples collected during 2004-05, it was found that all of the sample were biologically contaminated, 64% samples were found having turbidity excess of permissible limit, followed by 50% samples having objectionable color, 14% samples show objectionable taste, while one sample out of 14 found having fluoride concentration beyond permissible level. On the overall basis, one or more parameter(s) were found falling in the range of non-acceptable guideline values, Annexure-07-a.

Over the year 2005-06, 14 samples were collected. Out of 14 samples, 86% were biologically contaminated, followed by 28% samples having turbidity excess of permissible limit. Each of fluoride, taste and colour was found having concentration beyond permissible limits only in 3 samples (21%), (annexure-07-a).

Table 5.23: Water Quality Parameters Found Having Values Beyond Permissible Limits in Water Samples Collected from District Skardu (2004-06)

Sr. No.	*Parameters*	*No. of unfit samples out of total 14 (2004-05)*	*No. of unfit samples out of total 14 (2005-06)*	*Percentage*		*Overall %age*
				2004-05	**2005-06**	*2004-06*
1	Bact. Cont.	14	12	100	86	93
2	Turbidity	9	4	64	28	46
3	Color	7	3	50	21	36
4	Taste	2	3	14	21	18
5	Fluoride	1	3	7	21	14

Glacier and snow deposits are the principal sources of all water in the district. People depend mainly on their irrigation channels for the supply of water for domestic purpose. Water from these channels is stored into small pits, which is generally reserved for drinking and cooking purposes. The supply during winter is reduced due to minimal snow and glacier melt, which affects water quality of stored water. In summer months, the pit water is replenished more frequently, but turbulent flow and frequent landslides in the district induce high turbidity and muddy colour into the water. Water pits also contribute to the contamination primarily due to inappropriate location, improper protection, cleaning and maintenance, and lack of proper disposal of animal and human waste especially in rainy season. It was also noted that the contamination levels in the delivery systems were comparatively lower during the winter season probably due to the environment less conducive to bacterial growth. The important factor affecting the water quality is the human and the animal activities in the surrounding of the water delivery system.

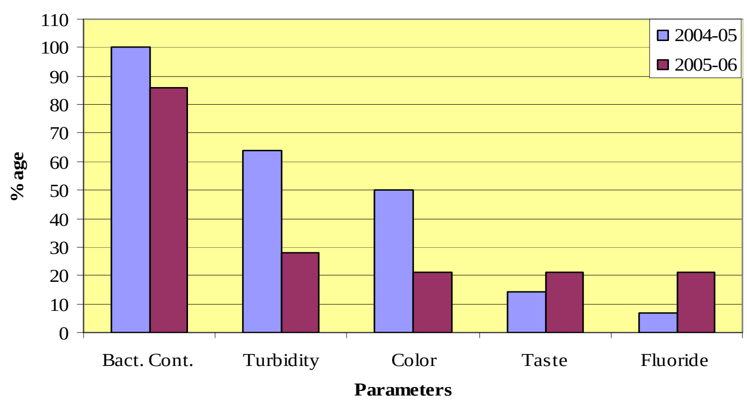
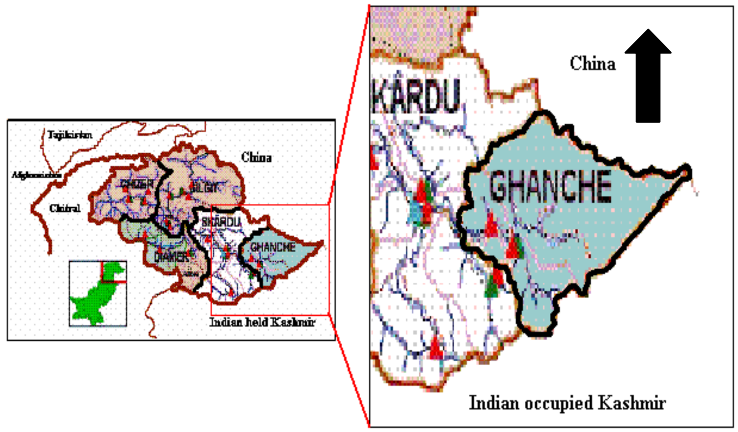


Figure 5.17: Percentage of samples having impermissible values in district Skardu

Ghanche

Ghanche district is the easternmost district of the Northern Areas of Pakistan. Average altitude of the district is 1454 m. Geographical map of the district is given in Figure 5.18, which indicates that to its northeast is China, to the north and northwest is Skardu district, to its west is Astore district and to its south is the Indian held Sate of Jammu and Kashmir.



The line of control along the eastern most region of Ghanche district cuts through the Siachen Glacier. This is the coldest district within Pakistan with winter temperature reaching below -20 ^{o}C. Geographical area of the district is 9400 sq. km. According to 1998 population census, population of the district was 88366, indicating population density of 9 person per sq. km.

Agriculture production is based essentially on irrigation, with water supply from the streams and rivers that are fed by snow melt from areas high in the mountain ranges. The area falls just outside the monsoon rainfall system, in a partial rain shadow area, and receives an annual precipitation of 100 to 500 mm, mainly as snow during the winter months. The average household has more than 6 members, 1.5 acres of farmland, of which 60% is suitable for annual crops.

From Ghanche district, altogether 17 samples were collected during the two years, keeping in view the source where most of the population consume water for drinking purpose. Sources of these samples are given in the Table 5.24, which indicates that surface water directly or in water supply schemes are common sources from where public fulfil their domestic water requirements.

Table 5.24: Types of Water Sources and Number of Samples Collected from District Ghanche (2004-06)

Source	*No. of samples*		*Total No. of samples*	
	2004-05	*2005-06*	*2004-05*	*2005-06*
Surface water	6	4	08	09
Spring	1	1		
Water supply scheme	1	3		
Domestic tube well	0	1		

Water quality results of the samples are presented in Table 5.25 and graphical representation is given in Figure-5.19, which exhibit that major contaminants in the area are bacteria, taste, colour and turbidity. Out of the 8 samples collected in the year 2004-05, none of the source was found safe for drinking purpose. After processing the analytical data it was found that all the samples were found contaminated biologically. Turbidity was found beyond permissible level in 50% samples while 25% samples were found having objectionable colour and taste (annexure-10-a).

Processing and compilation of water quality data of samples collected during 2005-06, revealed that all the samples were unfit for human consumption. Out of 9 samples, 44% samples had turbidity higher than the admissible range; 11% (one sample) was found having objectionable taste and muddy colour. All the samples were found microbiologically contaminated (annexure-10-b).

Table 5.25: Water Quality Parameters Found Having Values Beyond Permissible Limits in Water Samples Collected from District Ghanche (2004-06)

Sr. No.	*Parameters*	*No. of unfit samples out of total 8 (2004-05)*	*No. of unfit samples out of total 9 (2005-06)*	*Percentage*		*Overall %age 2004-06*
				2004-05	*2005-06*	
1	Bact. Cont.	8	9	100	100	100
2	Turbidity	4	4	50	44	47
3	Color	2	1	25	11	18
4	Taste	2	1	25	11	18

Ground water exploitation is uncommon in the district due to rocky strata and deep water aquifer. Glaciers and seasonal snow deposits are the principal source of surface water in the district. Snow melt and seasonal torrential rain result in land sliding and resultant increase in turbidity of water. Normally water flows in open channels and pipeline system is seldom laid. Nearby inhabitants fetch water for domestic consumption from the channel and activities like washing are carried out along the channel bank. Due to lack of proper drainage system, wastewater as well as grey water from households is directly drained into nearby small water rills and ultimately to water channels, which contaminate the water body. Therefore, intruding wastes are the causes of high microbiological contamination

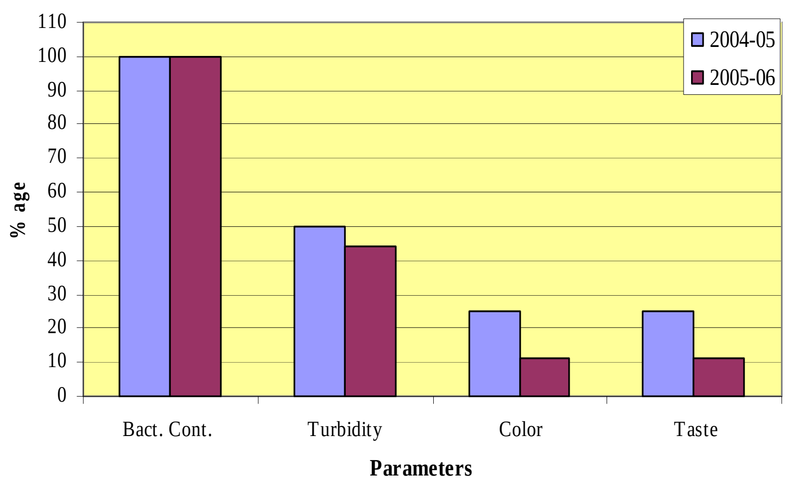


Figure 5.19: Percentage of Samples Having Impermissible Values in District Ghanche

Diamer

Diamer district was divided into Diamer and Astore districts in 2004. The Diamer district is bounded by Astore district in the east, NWFP in the south / south west (separated by Babusar Pass or Babusar Top), Ghizer district in the north / northwest and Gilgit district in the north / north east. Geographical map of the district is given in Figure 5.20. Diamer valley has a moderate climate during summer. In winter it receives snow up to 6 inches in the main valleys and up to 5 feet on the mountains. Geographical area of the district is 142861 sq. km.

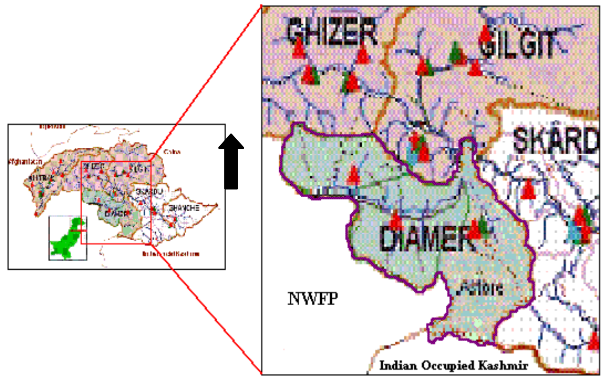


Figure 5.20: Geographical Map of District Diamer

Total population of the district according to the 1998 population census was 0.2 million with population density of 1.4 persons per sq. km - the lowest in the area. Water quality survey was conducted during two years 2004-06; altogether 23 samples were collected from different locations covering major residential areas of the district. Sources of the samples are given in Table 5.26

Table 5.26: Types of Water Sources and Number of Samples Collected from District Diamer (2004-06)

Source	*No. of samples*		*Total No. of samples*	
	2004-05	*2005-06*	*2004-05*	*2005-06*
Surface water	09	10	09	14
Spring	-	01		
Water supply scheme	-	02		
Domestic tube well	-	01		

In 2004-05 water samples were collected from 9 locations covering the major residential areas of the district. Being a mountainous area all sources were surface water and altogether all the sources were found biologically contaminated.

Similarly in 2005-06, all the 14 sources were found microbiologically contaminated, 50% samples had turbidity values beyond permissible limits, 14% samples showed excessive fluoride value than the highest desirable and 7% samples were found having calcium beyond permissible limits and objectionable color. The information regarding percentage of samples contaminated beyond permissible limits of different water quality parameters are given in Table 5.27, whereas water quality status of district Diamer is graphically represented in Figure 5.21.

Table 5.27: Water Quality Parameters Found Having Values Beyond Permissible Limits in Water Samples Collected from District Diamer (2004-06)

Sr. No.	*Parameters*	*No. of unfit samples out of total 9 (2004-05)*	*No. of unfit samples out of total 14 (2005-06)*	*Percentage*		*Overall %age 2004-06*
				2004-05	*2005-06*	
1	Bact. Cont.	09	14	100	100	100
2	Calcium	0	1	0	7	4
3	Fluoride	0	2	0	14	8
4	Turbidity	0	7	0	50	30
5	Color	0	1	0	7	4

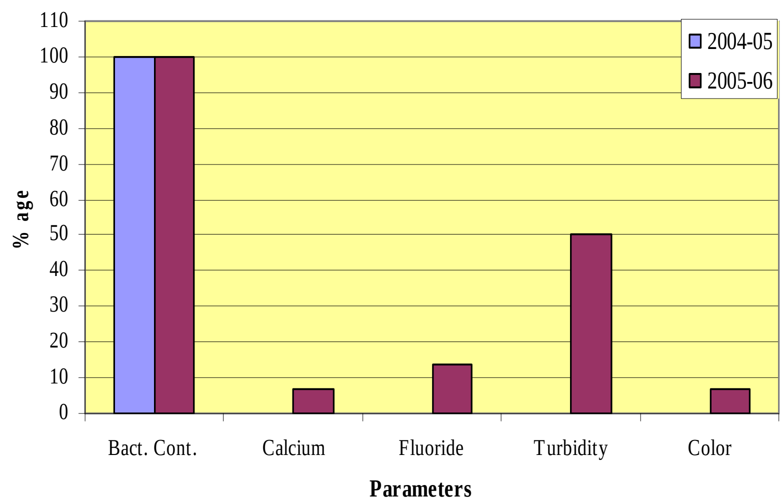


Figure 5.21: Percentage of Samples Having Impermissible Values in District Diamer

Ghizer

District Ghizer lies at the longitude 73º45'29" E and latitude 36º10'36" N. Geographical map of the district is given in Figure 5.22, which shows that Ghizer district lies in north-west part of the Northern Areas of Pakistan. It joins with Wakhan strip on its north-west and China on its north most corner. On its west, there is Chitral district of NWFP; and towards east is situated Gilgit. Diamer and district Swat of NWFP are on its south. Population of the district according to 1998 census was 0.12 million. Total geographical area of the district is 9635 sq. km. with population density of 13 persons per sq. km

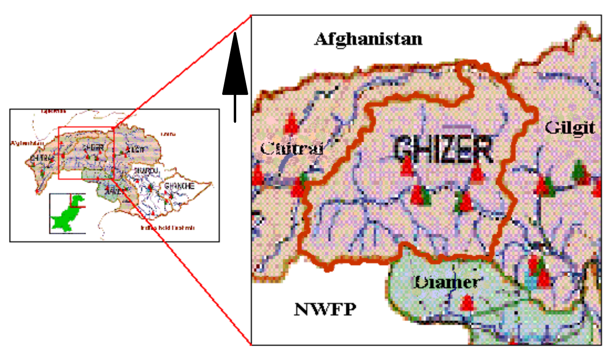


Figure 5.22: Geographical Map of District Ghizer

Altogether sixteen water samples were collected from entire district during the years 2004-06, sources of which are given in Table 5.28. It is evident that surface water, either directly or through water supply schemes, is the main source of water consumption for domestic requirements in the district.

Table 5.28: Types of Water Sources and Number of Samples Collected from District Ghizer (2004-06)

Source	*No. of samples*		*Total No. of samples*	
	2004-05	*2005-06*	*2004-05*	*2005-06*
Surface water	3	3	08	08
Spring	1	1		
Water supply scheme	4	4		

In 2004-05 water samples were collected from 8 locations covering the major parts of the district. Out of the 8 locations no source was found satisfactory for supplying potable and safe drinking water as all were found biologically contaminated and 25% samples had high turbidity compared to WHO guide line values (annexure-10-b). However in 2005-06 same locations were re-sampled to ascertain the water quality of the area. Again all the samples were found contaminated biologically, 14% samples showed turbidity beyond permissible limit and objectionable colour and taste (annexure-10-b). The information regarding percentage of samples contaminated beyond permissible limits of different water quality parameters are given in Table 5.29, whereas water quality status of district Ghizer is graphically represented in Figure5.23.

Table 5.29: Water Quality Parameters Found Having Values Beyond Permissible Limits in Water Samples Collected From District Ghizer (2004-06)

Sr. No.	*Parameters*	*No. of unfit samples out of total 8 (2004-05)*	*No. of unfit samples out of total 8 (2005-06)*	*Percentage*		*Overall %age 2004-06*
				2004-05	*2005-06*	
1	Bact. Cont.	8	8	100	100	100
2	Turbidity	2	1	25	14	19
3	Color	0	1	0	14	6
4	Taste	0	1	0	14	6

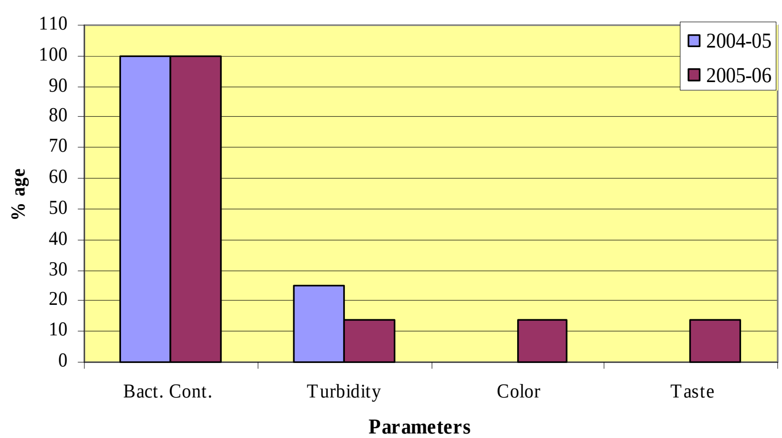


Figure 5.23: Percentage of Samples Having Impermissible Values in District Ghizer

In the district Ghizer, water channels which bring water for irrigation also serve for supply of water for domestic purpose (Muneeba *et al.* 1994). These channels are open and prone to contamination with feces and wastewater from residential area. In addition to that, clothes and domestic utensils are also washed in the same channels. To overcome uncertain and scare availability of water, pits are used for storage of water. The storage in pits facilitates removal of turbidity, but poor maintenance and cleaning of pits seems promoting bacterial contamination, the major cause of unsafe water in the area.

Overall Water Quality Situations in NWFP and Northern Areas

Over the years 2004-06, altogether 367 water samples were collected from five northern districts of NWFP and the entire Northern Areas of Pakistan. Out of 367 water samples, 186 were collected in 2004-05 and remaining 181 were sampled in 2005-06. Type of water source, number of samples taken thereof and percentage are given in table 5.30 and 5.31 for the years 2004-05 and 2005-06 respectively.

Table 5.30: Type of Source and Number of Samples Taken from All over the 10 Districts during 2004-05

Source	*Number of samples*	*Percentage*
Tube well	21	11
Domestic tube well	47	25
Tap (WSS)	47	25
Hand pump	02	1
Open well	01	1
Spring	27	15
Surface water	41	22
Total	**186**	

Table 5.31: Type of Source and Number of Samples Taken from All over the 10 Districts during 2005-06

Source	*Number of samples*	*Percentage*
Tube well	29	16
Domestic tube well	41	23
Tap (WSS)	41	23
Hand pump	07	4
Open well	09	5
Spring	27	15
Surface water	27	15
Total	**181**	

Overall situation regarding the type of water source, number of samples taken thereof during the two years in the project area is presented in table 5.32 and graphical representation is given in Figure 5.24, which exhibit that domestic tube well and public water supply schemes are the major sources of drinking water in the project area followed by surface water, springs and tube wells.

Table 5.32 Overall Types of Source and Number of Samples Taken from All Over 10 Districts during 2004-06

Source	*Number of samples*	*Percentage*
Tube well	50	14
Domestic tube well	88	24
Tap (WSS)	88	24
Hand pump	9	2
Open well	10	3
Spring	54	15
Surface water	68	19
Total	**367**	

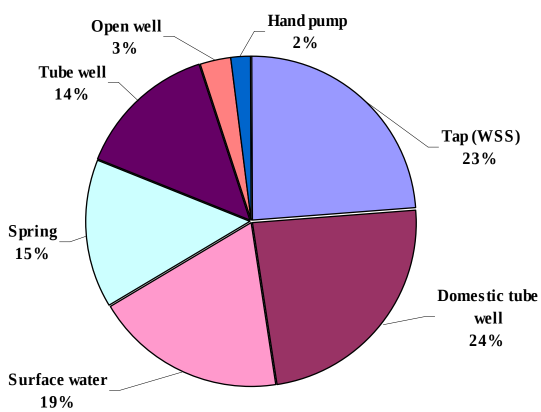


Figure 5.24: Overall Percentage of Sources Sampled during 2004-06

Number and percentage of safe and unsafe water sources either biologically or chemically are enumerated in table 5.33 which show the existence of biological contamination in all the 10 districts together with summary of contaminants.

Table 5.33: Overall Water Quality Situation of 10 Districts and Causes of Contamination (2004-06)

Sr. No.	District	Total No. of samples	Safe samples		Unsafe samples		Major causes of contamination
			No.	%age	No.	%age	
NWFP							
1	Mardan	87	18	21	69	79	Bacteriological, F, Ca, turbidity and NO_3
2	Bunner	64	19	30	45	70	Bacteriological, turbidity, Ca, hardness and TDS
3	Swat	60	15	25	45	75	Bacteriological, Ca, turbidity and NO_3
4	Dir (L)	23	0	0	23	100	Bacteriological Ca, iron and NO_3
5	Dir (U)	21	2	10	19	90	Bacteriological, turbidity and NO_3
Sub Total		**255**	**54**	**21**	**201**	**79**	Bacteriological, (Ca), NO_3 and turbidity
NORTHERN AREAS							
1	Gilgit	28	0	0	28	100	Bacteriological, turbidity, taste and color
2	Skardu	28	2	0	26	93	Bacteriological, turbidity, taste color and fluoride
3	Ghanche	17	0	0	17	100	Bacteriological turbidity, taste and color
4	Diamer	23	0	0	23	100	Bacteriological, turbidity and fluoride
5	Ghizer	16	0	0	16	100	Bacteriological and turbidity
Sub Total		**112**	**2**	**2**	**110**	**98**	Bacteriological, turbidity and fluoride
Grand Total		**367**	**21**	**12**	**160**	**88**	Bacteriological, turbidity and taste

Data analysis has also exhibited the fact that four water quality parameters i.e. Bacteria, Nitrate, Fluoride, and Turbidity are found more problematic than the rest of the physico-chemical parameters as presented graphically in figure 5.25.

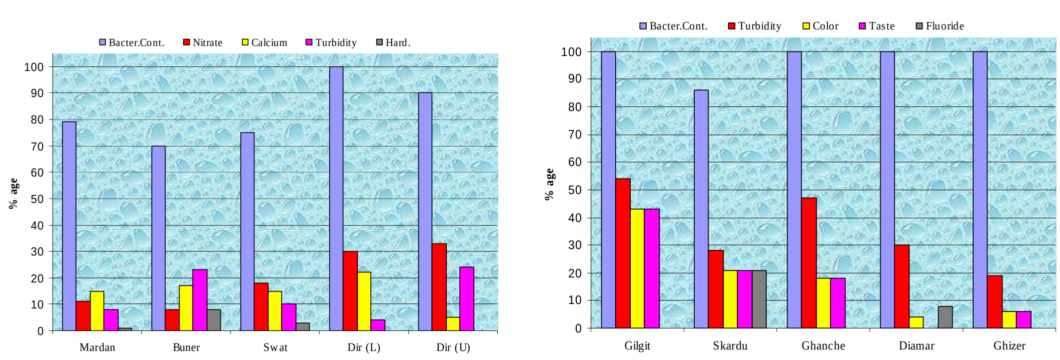


Figure 5.25: %age of Unfit Water Samples against Different Water Quality Parameters (2004-06)

On the other hand highest percentage of unsafe water sources was found in Dir (U), Dir Lower, Gilgit, Ghanche, Diamer and Ghizer where none of the source was found safe for drinking purpose mostly due to bacteriological contamination or chemical contaminations as indicated in figure 5.26

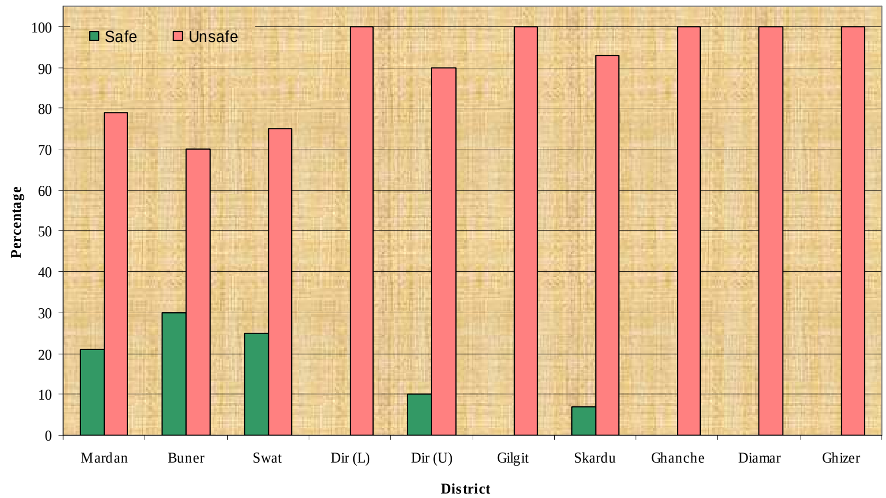


Figure 5.26: Overall Water Quality Situation in NWFP and Northern Areas (2004-06)

Summing up the complete information generated from this monitoring make us to conclude that only 14 % out of 181 water sources were "Safe" and the rest of the 86 % were "Unsafe" as shown below in figure 5.27. Parameter wise summaries of contaminants in all the surveyed districts are also given in tables 3.34 and 3.35 for NWFP and Northern Areas respectively.

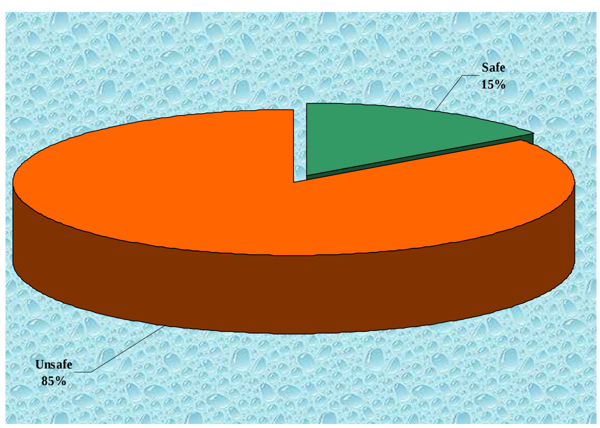


Figure 5.27: Water Quality Status of NWFP and Northern Areas of Pakistan (2004-06)

Table 5.34: Summary of Over All Water Samples Collected the Five Districts of NWFP and Status of Contaminants

Sr No.	*District*	*Total No. of Samples*	*Bacteria*		*Turbidity*		*Nitrate*		*Fluoride*		*Calcium*		*TDS*		*Hardness*		*Chloride*		*Sodium*		*Unsafe Samples*	
			No of unfit samples	*% age*	*No of unfit samples*	*% age*	*No of unfit samples*	*% age*	*No of unfit samples*	*% age*	*No of unfit samples*	*% age*	*No of unfit samples*	*% age*	*No of unfit samples*	*% age*	*No of unfit samples*	*% age*	*No of unfit samples*	*% age*	*No of unfit samples*	*% age*
1	Mardan	87	69	79	7	8	10	11	4	5	13	15	2	2	1	1	1	1	5	6	76	87
2	Bunner	64	45	70	15	23	5	8	*	*	11	17	3	5	5	8	-	-	1	2	51	80
3	Swat	60	45	75	6	10	11	18	*	*	9	15	*	*	2	3	*	*	*	*	49	82
4	Dir (L)	23	23	100	1	4	7	30	*	*	5	22	*	*	*	*	*	*	*	*	23	100
5	Dir (U)	21	19	90	5	24	7	33	*	*	1	5	*	*	*	*	*	*	*	*	21	100
Sub Total		**255**																				

Table 5.35: Summary of Over All Water Samples Collected from Entire Northern Areas and Status of Contaminants.

Sr No.	*District*	*Total No. of Samples*	*Bacteria*		*Turbidity*		*Nitrate*		*Fluoride*		*Calcium*		*TDS*		*Potassium*		*Colour*		*Taste*		*Unsafe Samples*	
			No of unfit samples	*% age*	*No of unfit samples*	*% age*	*No of unfit samples*	*% age*	*No of unfit samples*	*% age*	*No of unfit samples*	*% age*	*No of unfit samples*	*% age*	*No of unfit samples*	*% age*	*No of unfit samples*	*% age*	*No of unfit samples*	*% age*	*No of unfit samples*	*% age*
1	Gilgit	28	28	100	15	54	*	*	*	*	*	*	*	*	1	4	12	43	12	43	28	100
2	Skardu	28	26	93	13	46	*	*	4	14	*	*	*	*	*	*	10	36	5	18	26	93
3	Ghanche	17	17	100	8	47	*	*	*	*	*	*	*	*	*	*	3	18	3	18	17	100
4	Diamer	23	23	100	7	30	*	*	2	8	1	4	*	*	*	*	1	4	*	*	23	100
5	Ghizer	16	16	100	3	19	*	*	*	*	*	*	*	*	*	*	1	6	1	6	16	100
Sub Total		**112**																				
Grand Total		**367**																				

CHAPTER-6

FINDINGS, CONCLUSIONS & RECOMMENDATIONS

6.4 Findings

The water sources in all the districts were selected from where the people were getting water mainly for drinking purpose. The water samples for analysis were collected from altogether 181 different water sources (locations). Based on the survey, water quality status of the project area and findings thereof are summarized as below:

1. Bacteriological contamination (83% of samples) and Turbidity (20% of samples) are major problems of the area followed by minor percentage of Nitrate (2%), and Fluoride (1% of samples).
2. Bacteriological contamination in the water sources of project area was lowest in southern foothill plain district of Mardan where it was 67% of samples, but increased to 100% in mountainous districts of Dir Lower, Dir Upper, Gilgit, Ghanche, Diamar and Ghizer.
3. After bacterial contamination, turbidity was the major contaminant both in NWFP and Northern Areas. The range of samples having turbidity beyond permissible limits in NWFP varied from 8% to 23%, whereas the same varied from 19% to 54% in Northern Areas.
4. Significant percentage of samples was found having colour and taste (6% to 43% of samples) beyond admissible limits in Northern Areas. The highest percentage was found in Gilgit. These parameters were found within admissible limits in all the five surveyed districts of NWFP.
5. Nitrate contamination was found only in the five district of NWFP where percentage of samples contaminated with it was highest in Dir Upper (33%) followed by Dir Lower (30%), Swat (18%), Mardan (11%) and Bunner (8%). Nitrate contamination was not detected anywhere in Northern Areas.
6. Similar to Nitrates, calcium beyond admissible limits was found only in the surveyed five districts of NWFP where its concentration was found 22%, 17%,, 15%, 15% and 5% in Dir Lower, Bunner, Mardan, Swat and Dir Upper respectively.. The same was not found in Northern Areas except 45 samples of Diamer.
7. In all the 10 districts, out of 181 water sources, no water source was found having arsenic beyond permissible limits.
8. In NWFP, Fluoride contamination was detected only in 3% samples of Mardan, whereas in Northern Areas the same was found in 14% samples of Skardu and 8% samples of Diamer only.

9. The survey findings revealed that 80% to 100% water sources were unsafe for drinking purpose in NWFP and 93% to 100% were in Northern Areas. Major problem in the entire surveyed area was microbiological contamination resulting from water pollution, turbidity due to use of surface water and poor sanitary and hygienic conditions.

6.2 Conclusions:

1. Chemical water quality of the five northern mountainous districts of NWF and Northern Areas were found generally good.
2. Nitrate contamination was found in all the five districts of NWFP which seems to be due to high relief of the area causing high runoff, more erosion of top soil bringing with it agricultural fertilizers into surface water bodies, which still remain a substantial source of potable water.
3. Colour and taste were found the problematic esthetical parameters in the drinking water sources of Northern Areas. The reason was obviously the complete dependence, one way or the other, on surface water sources in the entire Northern Areas of Pakistan.
4. Biological contamination was the fundamental reason of rendering the water unsafe in almost all the mountainous districts of NWFP and the entire Northern Areas of Pakistan. That seems to be due to unprotected water sources, poor cleanliness and hygienic conditions, poor water handling, poverty, low literacy rate and lack of awareness.

6.3 Recommendations

Following recommendations are made based on the survey carried pertaining to the project area, and experience gained thereof and from earlier national level studies carried out by PCRWR:

1. Chemical quality of water is quiet fit in most parts of the surveyed area, but almost all the water sources have become biologically contaminated due to increased level of pollution, poor sanitary and hygienic conditions, and improper water handling. An intensive awareness campaign may, therefore, be launched especially in remote and poverty stricken areas to improve the situation.
2. Strict legislation and its implementation may be carried for protection of water bodies and relevant agencies must be strengthened accordingly to improve the water governance.
3. Water supply agencies should not restrict themselves to merely provision of water but provision of safe water must be ensured. For that water safety plan for each water supply scheme or consumer source must be devised and implemented.
4. In mountainous areas, water supply agencies restrict themselves to construction of community water supply tanks or construction of tubwell. Fetching supply from the source remains the responsibility of consumer which is carried out with poor

material and workmanship. The relevant agencies should ensure the permission for laying self managed service lines only with material of standard specifications and workmanship for avoiding contamination during transmission.

5. Small water supply schemes should be implemented with due participation of the consumers for ensuring after construction operation, maintenance and repair. Water rations and water tariff of safe water be implemented to generate finance for efficient operation and maintenance of the schemes.

6. Comprehensive plans should be made and implemented to meet the human needs of safe drinking water and to prevent the occurrence of all water-borne and water related diseases.

7. Protection of upstream surface water bodies may be given special emphasis as contamination of upstream water bodies have widespread water quality implications both for upstream and downstream consumers.

8. Growing urbanization and resultant price hike of urban residential plots has compelled the public for making best use of available urban land. That has developed a culture of construction of basement. Sewerage facility is difficult for basements and therefore ground sink wells for disposal of sewage are constructed. That is highly objectionable practice and must be curbed to avoid contamination of ground water.

9. Municipal as well as industrial waste must be disposed of after due treatment according to the prevailing regulation.

10. Uncollected solid waste is major source of blockage of surface drains which inundate the residential areas during heavy rainstorms and results in contamination of community water sources. Therefore collection and proper disposal of solid waste must be improved.

11. Basic health, environment and hygienic education must be a mandatory part of curriculum especially at school level. That should also include development of local level water safety plan.

12. Rapidly expanding poultry farms along the river banks are a major threat to the bacteriological contamination of water sources in upstream mountainous reaches of surface water bodies, because in those areas such activities remain confined only to the valleys falling along the river banks due to unavailability of other easily accessible lands.

13. High erosion rate due to high relief and terraced farming coupled with substantial annual precipitation bring agricultural fertilizers down to the surface water bodies. Controlled and well managed application of fertilizers is therefore required to be practiced in such areas.

14. Sand filters for removing sand and silt particles and appropriate treatment for microbiological disinfection of surface water diverted, or pumped, for drinking purpose may be introduced to improve the quality of water consumed by the community.

15. Improving the conveyance of water in the Kuhl (Channels) system constructed for supply of water for drinking purposes by avoiding entry of sanitary and agricultural effluents and other wastes may be ensured.
16. Water quality monitoring should not remain responsibility of only the supply agencies, rather a third party monitoring and evaluation must be obligatory for ensuring provision of safe drinking water.
17. Economical and simple technologies, such as those developed by PCRWR, for water purification at household level should be introduced on war footing. This may initially be subsidized by the government.

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