GIS Analysis of Water Quality Data from Shigar Town, District Skardu, Baltistan, Pakistan

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ABBREVIATIONS

AA	Atomic Absorption method
AKCSP	Aga Khan Cultural Services for Pakistan
Alk	Alkalinity
APHA	American Public Health Association
CDWQ	Canadian Drinking Water Quality
CL	Clear
col.	colonies
CSIRO	Commonwealth Science and Industry Research Organization
DFBMD	Division of Foodborne Bacterial and Mycotic Diseases
EC	Electrical Conductivity
EC	European Commission guidelines
EPA	Environmental Protection Agency
ESRI	Environmental Systems Research Institute
FAO	Food and Agricultural Organization
HC	Hyemorrhagic Colitis
IUCN	International Union for Conservation of Nature and Natural Resources
KVA	Kilo Volts Ampere
MaxCL	Maximum Contaminant Level
NTU	Nephelometric Turbidity Units
Obj.	Objectionable
PAN	PANchromatic
PCRWR	Pakistan Council of Research in Water Resources
PSI	Pakistan Standards Institute
PSQCA	Pakistan Standards and Quality Control Authority
SAP	Social Action Programme
SDWF	Safe Drinking Water Foundation
STHIS	Shigar Town Health Information System
TDS	Total Dissolved Solids

UNEP	United Nation Environment Program
UO	UnObjectionable
USDI	United States Dental Institute
USEPA	United States Environmental Protection Agency
WASEP	Water and Sanitaion Extention Program
WP	Water Pit
WQI	Water Quality Index
WQS	Water Quality Support
WSS	Water Supply System

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ABSTRACT

Water quality is a major factor that influences the human health and environment of an area. Northern areas of Pakistan, especially Shigar town, which is located 30 km north-east of Skardu, suffers water quality issues. This study investigates the quality of water in Shigar town with respect to its physical, chemical and microbiological parameters. Surface water in Shigar town is used for agricultural and domestic purposes. There are three categories of water distribution system in Shigar town: (a) water supply system (b) conventional water channels and (c) water pits, commonly used in winter season. The source of water supply system is assumed to be naturally free from contaminations but it gets contaminated as a result of human activities within the inhabited area. The factors that degrade the quality of water in Shigar town are (a) lack of proper sanitation system, (b) poor maintenance of water supply network and (c) surface runoff due to rain. After preliminarily analysis, all chemical and physical parameters of water quality were within the permissible limits of WHO (World Health Organization) drinking water standards. However bacteriological parameters, such as total coliforms and thermotolerant faecel coliforms, exceed the permissible limit set by WHO. Selected medical data of Shigar health center showed that about 35% of all patients suffer from gastroenteritis. The thermotolerant faecel coliform bacteria are known to cause gastroenteritis in human beings. The water quality trends in terms of microbiological parameters were analyzed on seasonally basis using spatial datasets and GIS techniques. Further, the number of victims and sources that contribute to the contamination in water distribution systems were analyzed. It was observed that the microbiological contaminations in water supply system were least severe as compared to the microbiological contaminations in water channels and water pits. Water pits were found to be at the highest risk of bacterial contaminations. The water channels within the settlements were more contaminated as compared to the agricultural and open land. Water quality in Shigar town was outlined through GIS analysis into no risk zone, low risk zone, intermediate risk zone, high risk zone and very high risk zone. In terms of water supply network, the areas closer to the source of water supply system had fewer contaminations as compared to the areas away from the source. It was also observed that the entire study area lies in very high risk contamination zone of water quality in terms of water pits.

CHAPETR 1

INTRODUCTION

Water is lifeblood of the environment, essential to the survival of all living things, plants, animals and human beings. It is estimated that about 70% of the earth is covered with water, and 97% of that, is part of the salty oceans. Remaining 3% is the fresh water out of which, less than 1% of fresh water is usable (Kahlown and Tahir, 2006). The fresh water sources include rivers, lakes, and ground water. Quality of water has a lot of impact on the health of human beings and animals. Each year, more that 2.2 million people, mostly children under five, die from problem associated with lack of water and sanitation. In developing countries, about 80% of illnesses are linked to poor water and sanitation conditions. In any one of the time, half of the world's hospital beds are occupied by patients suffering from water borne diseases. By 2015, the international community hopes to reduce by half the proportion of people who are unable to reach, or afford safe drinking water. More than 6000 children die every day from disease associated with lack of access of safe drinking water, in-adequate sanitation and poor hygiene (EC, 2000).

Water is essential for life. Being universal solvent, it is highly prone to contamination by bacteria, viruses, protozoa, pathogens, helminthes parasite, toxic organic & inorganic compounds. Such contaminated water affects the user to various diseases like diarrhea, dysentery, typhoid, cholera, and hepatitis etc (Waheed and Kausar, 1987).

1.1 OVERVIEW OF STUDY AREA

Shigar valley is located 30 km north-east of district Skardu Baltistan, in Northern Area of Pakistan. The valley comprises of nine union councils with population of 45000 persons (IUCN, 2007). The Area of Interest for this study is Shigar town (two union councils) ranges from 75º42´33.04´´ E to 75º45´59.25.00´´ E and Latitude values range from 35º21´56.00´´ N to 35º27´04.74´´ N. The altitude varies from nearly 7000 feet (Shigar river bed) to 8500 feet (mountain peak near Shigar Fort) above mean sea level. Shigar town is governed by two union councils. The two union councils are Marapi and Markunja. Marapi union council has 8 hamlets (villages) and Markunja union council consist of 16 hamlets. The population of Shigar town is approximately 10000 persons (IUCN, 2007). The total area of Shigar town is nearly 15 km^2. Valley is internationally well-known, especially among mountaineers, because it offers one of the access to K-2, highest peak of Pakistan and 2nd highest peak in the world. Shigar River flows through the Shigar valley from north to south. Shigar town is one of the most important town of Shigar valley. Water level in Shigar River comes to its peak in summer (June, July and August) due to snow and glaciers melts. The River water is not used for irrigation and other purposes directly because the slope of Shigar town is greater than that of the River bed. People use stream water directly for drinking, domestic and irrigation purposes. The source of surface water is Shigar stream (other than spring water) that enters from eastside of the Shigar town. It carries snow melt water and spring water that is also used for power generation in Shigar town. The power house of Shigar town generates approximate 500 KVA powers that fulfill the electricity requirements of the Shigar town.

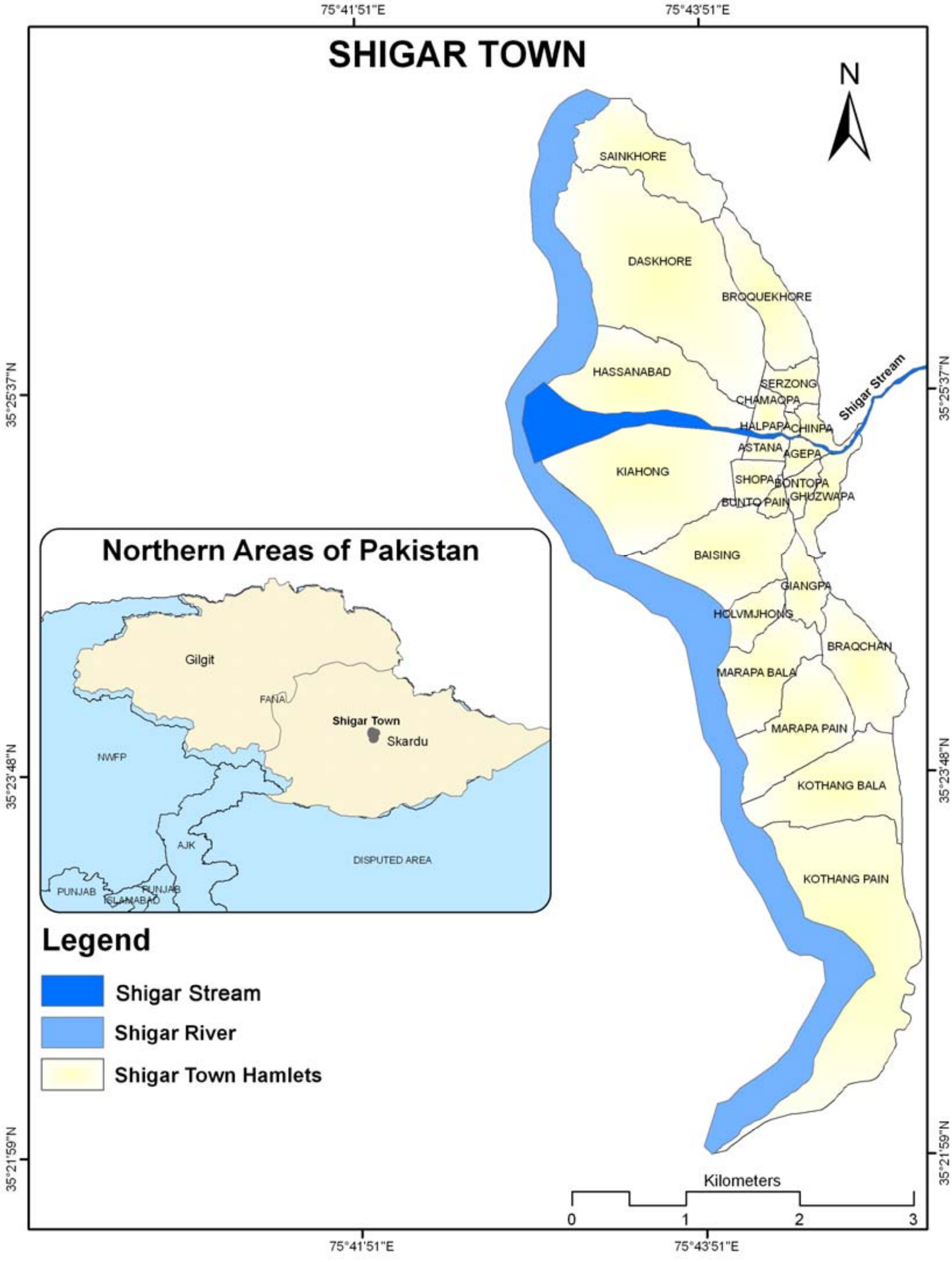

Figure 1.1: Location map of Shigar

There are a number of manmade (used for irrigation and domestic purpose) water channels that initiate from Shigar stream and carry water into the various parts of the Shigar through small tributaries. These water channels are categorized into main channels, sub-channels and tributaries by the community of Shigar town. Shigar stream is considered the main source of water in Shigar town. The surrounding area is mountainous, while Shigar town is built on an alluvial fan, with some plane area, which is used for agricultural purposes. Wheat, potato and barley are the most common summer season crops. There is no harvesting in winter due to severe cold. There are a number of apricot farms in Shigar town. Other fruit farms include almond, plum and apple trees.

The temperature of area changes -20 degree centigrade to 25 degree centigrade in winter and summer season respectively. Snow starts melting in the start of February and continues to melt until August. Due to change in temperature, the water level in Shigar stream goes on peak in June, July and August.

1.2 OBJECTIVES OF THE STUDY

i. To identify the potential zones of poor water quality.

ii. To evaluate the availability and source of safe quality drinking water.

iv. To develop water information system to help the Shigar town Management Society in making informed decisions on the landuse and water distribution for domestic, agricultural and other uses.

v. To design the standalone health information system for Shigar town

1.3 SOURCES OF DRINKING WATER IN SHIGAR TOWN

The major sources of drinking water in Shigar town are, Shigar stream and spring water. Stream water is used for drinking and domestic use in different ways. The stream water is collected into water tanks before entering the Shigar town and then distributed to whole of the Shigar town through water pipelines (both above surface and sub-surface). Water supply network is not installed at household level and is limited to street level and some community places. There are a number of non-governmental organizations also installing water supply network in Shigar town. Aga Khan Cultural Services for Pakistan (AKCSP) has installed water supply network in Agepa, Serzong and Shigar fort. Water and Sanitation Extension Program (WASEP) has installed their water supply network in Kothang Bala and Marapi Bala. The Table 1.1 shows the number of water taps in each hamlet of Shigar town.

Table 1.1 Water supply network in Shigar town

Hamlet_Name	No. of water taps	Hamlet_Name	No. of water taps	Hamlet_Name	No. of water taps
Agepa	47	Chinpa	61	Kothang Bala	8
Astana	4	Dashkhore	18	Kothang Pain	72
Biasing	14	Ghuzwapa	11	Marapi bala	17
Bantopa	8	Gianpa	20	Marapi Pain	18
Braqchan	11	Halpapa	6	Sainkhore	7
Broquekhore	6	Hassanabad	8	Serzong	23
Bunto Pian	4	Holvmjhong	9	Shopa	4
Chamaqpa	8	Kiahong	14		

(Source: Field Survey)

The water discharge in most of the water taps is not sufficient for the public requirements. There are some water taps that have water discharge of one litre per five to ten minutes especially in remote area (or areas away form the source). Most of the people use surface water directly for drinking and domestic purposes especially in winter, when whole of the town is covered by snow. People store channel water into water pits and use for drinking and domestic purposes.

1.4 FACTORS AFFECTING THE WATER QUALITY

Water of sufficient quality to serve as drinking water is termed as “potable water” whether it is used for drinking or not (WWF, 2007). Although the sources of water are utilized for drinking purpose by humans, some contain disease vectors (pathogens) or contain some unacceptable levels of dissolved contaminants and cause health problems if they do not meet the drinking water quality guidelines. Water that is free from pathogens is called safe water (WHO, 2004). All the chemical parameters of water quality in Shigar town, are within the acceptable limit given by WHO. In terms of color and turbidity, there are some samples found objectionable for drinking but in term of bacterial contamination (total coliform and thermotolerant faecel coliform) maximum samples were found beyond the safe limit set by WHO. There are a number of physical, chemical and biological factors that affect the quality of water are mentioned below.

1.4.1 Water Quality Parameters

1.4.1.1 Physical & Aesthetic Parameters

pH, Electrical Conductivity, Turbidity, Color, Taste and Odor are considered the most common physical parameters of water quality.

1.4.1.2 Chemical Parameters

Alkalinity (Alk), Bicarbonate (HCO_3), Calcium (Ca), Carbonate (CO_3), Chloride (Cl), Hardness, Magnesium (Mg), Sodium (Na), Potassium (K), Sulfate (SO_4), Nitrate (NO_3), Total Dissolved Solids (TDS), Arsenic (As), Copper (Cu), Fluoride (F), Iron (Fe) and Lead (Pb) are the chemical parameters of water quality that are mostly considered for study of water quality.

1.4.1.3 Biological Parameters

There are a number of bacterial indicators such as Total coliforms, Thermotolerant faecel coliforms ,Escherichia coli, Faecal streptococci (enterococci), Total bacteria (microscopic), Viable bacteria (microscopic), Heterotrophic bacteria, Aerobic spore-forming bacteria, Somatic coliphages, F specific, Bacteroides, Clostridium perfringens, Enteric viruses , Giardia cysts (WHO, 1997). Total Coliforms and Thermotolerant faecal coliforms (E-coli) are the basic biological parameters of water quality that are considered in this study.

1.5 WATER QUALITY ASSESSMENT WITH GIS

Advance Technology, Geographical Information System (GIS) increases the decision support and visualization capabilities. GIS is a valuable tool to analyze existing water quality data. Most published definitions of “Geographical Information Systems” refer to both data and operations, “a system for input, storage, manipulation, analysis and output of geographical referenced information”. In turn, geographically referenced information can define fairly as information linked to specific location on the earth’s surface. In the past many monitoring programs have been characterized as “data rich but information poor”, because the existing data was not used effectively. This study treats this shortcoming of the past as the challenge for the future, and strengthens the spatial content of the water quality data. The preparation of data for GIS software and analysis on monitoring data, are the most important steps in the assessment of water quality and seasonal comparison of water quality in Shigar town.

The purpose of GIS analysis over the water quality data in Shigar town was to:

i. Map water quality zones in the study area into arbitrarily defined categories of No risk, Low risk, Intermediate risk, High risk, Very high risk zones of water quality. These categories are defined, considering the domestic uses of the water in the Shigar town.
ii. Map to identify the spread of specific type of water borne diseases in specific area. i.e. excess amount of coliform cause Gastrointitis
iii. Estimate the percentage of people, using descent quality drinking water in Shigar town.

An attempt has been made to describe water conditions on a specific (sampling) point or over larger areas (e.g. water supply systems, water channels, water pits). This difference of location, on which the data/information is being collected, is sometimes referred to as the micro and macro-locations of monitoring systems (Ward *et al*., 1990).

1.5.1 Availability of Acceptable Quality Drinking Water

People of Shigar town use surface water for agricultural, domestic and other uses. There are three categories of water distribution system in Shigar town: (a) water supply system, installed by Aga Khan Cultural Services for Pakistan, local government and Water And Sanitation Extension Program, with a proper system of filtration tanks and pipelines (both above surface and subsurface). Water supply network is not installed on house level. There is limited number of water taps installed in each hamlet as shown in Table 1.1; (b) manmade water channel system, conventional water distribution system commonly practiced in northern areas of Pakistan over alluvial fans, maintained by local residents and members of town management society of Shigar; (c) water pits system, maintained due to the freezing cold temperature during winter season, by local residents. It is assumed that, the water supply system is only source of acceptable quality drinking water available in Shigar town. In this study, GIS tool is also used to identify the availability of good quality drinking water in Shigar town.

1.6 HEALTH INFORMATION SYSTEM IN THE LIGHT OF GIS

A health information system is used to identify the disease patterns through basic mathematical and statistical operations over the health data. The purpose of Health Information System for Shigar town is only to assist decision makers. In order to assist decision makers, the information should be in a clear and easy to understand. This is done because the maps of health data are usually much quicker to interpret and understand than other forms of presenting the same data, such as written descriptions, tables or even graphs. If a map enables a decision maker to grasp the real disease situation in a moment, the result will be better and decision will be more informed. The purpose of health information system is to manage and incorporate the data collected from Shigar Health Center. Ultimately, the purpose of much of the information gathered is to assist in decision making process. Decisions may be improved by the provision of better information. However improving the quality of information provided to decision makers will only improve their decisions. There are numerous examples of poor decision-making due to lack of good information or non-understanding of the spatial component of disease distribution.

CHAPTER 2

REVIEW OF LITREATURE

Water is an essential component for human survival. Unfortunately, while Pakistan is blessed with adequate surface and groundwater resources, rapid population growth, urbanization and unsustainable water consumption practices have placed immense pressure on maintaining the quality as well as the quantity of water resources in Pakistan. Deterioration in the water quality and contamination induced in lakes, Rivers and groundwater aquifers, has resulted in increased waterborne diseases and other health impacts. A recent study of 11 cities of Punjab shows an excess amount of arsenic and fluoride concentrations in the water supply systems of six cities; Multan, Bhawalpur, Shaikhupura, Kasur, Gujranwala, and Lahore. Over 2 million people in these cities are drinking unsafe water, some with a high arsenic concentration (PCRWR, 2004). The quality of water supplies in many cities of Pakistan is deteriorating fast. The primary source of these supplies is groundwater. As a result, one hundred million cases of diarrhea are being registered for treatment in hospitals of Pakistan each year (WHO, 1972-73). A survey conducted by PCRWR (Tahir *et al*., 1994) showed that 81,996 cases of water related diseases were registered in Basic Health Units of Rawalpindi Division alone. According to United Nations Children's Fund (UNICEF), 20 to 40% beds are occupied in the hospitals of Pakistan by patients suffering from water related diseases. Diseases such as cholera, typhoid, dysentery, hepatitis and guinea worm infections are about 80% (including diseases due to sanitation problem) of all diseases and are responsible for 33% of deaths (Tahir *et al*., 1994).

In developing countries, mortality rate due to drinking of poor quality water especially in infants, is very high (Kahlown *et al*., 2006). In the rural areas of central and southern Pakistan, 60% of the population has access to clean water. This figure drops significantly in northern area of Pakistan, where only 16% of the population has access to clean drinking water (SAP, 2007).

2.1 WATER POLLUTION

Water pollution is the presence in water of harmful or objectionable material in sufficient quantity to measurably degrade water quality (WHO, 1996). Water contamination is the unintended presence, or introduction of contaminats into water. Pollution can take the form of chemical substances, or energy, such as noise, heat, or light energy. As the word "Pollution" is the introduction of contaminants into an environment that causes instability, disorder, harm or discomfort to the physical systems or living organisms they are in. Pollutants, the elements of pollution, can be foreign substances, or manmade, or naturally occurring; when naturally occurring, they are considered contaminants when they exceed natural levels. Pollution is often classed as point source or non-point source pollution (USEPA, 2005). This study focused on water pollution only in Shigar town and elements of water pollutions. Natural phenomena such as volcanoes, algae bloom, storms, and earthquakes also cause major changes in water quality and the ecological status of water. Water pollution has many causes and characteristics. The primary sources of water pollution are generally grouped into two categories based on their point of origin. Point-source pollution refers to contaminants that enter a waterway through a discrete "point source". Examples of this category include discharges from a wastewater treatment plant, outfalls from a factory, leaking underground tanks and water pipes, etc. Non-point source pollution refers to contaminations that do not originate from a single discrete source. Non-point source pollution is often a cumulative effect of small amounts of contaminants gathered from a large area. Nutrient runoff in storm water from sheet flow over an agricultural field, or metals, faecel contaminants and hydrocarbons from an area with high impervious surfaces and vehicular traffic are examples of non-point source pollution. In case of area like Shigar town where there is only non-point source of water pollution is effective. As point sources have been effectively regulated, greater attention has come to be placed on non-point source contributions, especially in rapidly urbanizing or developing areas. The specific contaminants leading to pollution in water include a wide spectrum of chemicals, pathogens, and physical or sensory changes (USEPA, 2005).

2.2 DESCRIPTION OF WATER CONTAMINANTS

There are a number of water contaminants, differentiated to Microbiological, physical and chemical parameters of water. These contaminants can cause a number of diseases in human beings such as Anaemia, Arsenicosis, Campylobacteriosis, Cholera, Diarrhea, Drowning, Fluorosis, Trachoma etc. The most commonly occurring contaminants and their effect on human beings, are discussed below in the light of different studies.

2.2.1 Microbiological Parameters

Microbiological parameters are the most important in water quality consideration due to their affects on human beings and animals.

2.2.1.1 Total Coliform Organisms

The coliform organisms are the most commonly measured indicators for water quality. Total coliforms, a particular group of waterborne microbiological contaminants, are the most common indicator organism applied to drinking water. Total coliforms are defined as “gram negative bacteria”, which ferment lactose at 37º, with the production of acid gas and aldehyde within 24 – 48 hours (Chiang, 2003). Under suitable conditions they can be active in the presence of organic materials. Some coliforms are associated with plant waste or may be common inhabitants in soil or surface water. WHO drinking guidelines require zero number of coliforms to be found per 100 ml water. According to Pakistan water quality standards, quantity of total coliforms should be zero in 250 ml of water.

2.2.1.2 Thermotolerant faecel coliform (E.Coli)

Thermotolerant faecel coliform bacteria are a large and diverse group of bacteria. Some kinds of E. coli can cause diarrhea, while others cause urinary tract infections, respiratory illness, pneumonia, and other illnesses. Still other kinds of E. coli are used as markers for water contamination. Very young children and the elderly are more likely to develop severe illness and Hemolytic Uremic Syndrome (HUS) than others, but even healthy older children and young adults can become seriously ill (DFBMD, 2005). The presence of E .coli in water samples is considered to be closely associated with recent faecal contaminations. During the rainfall and water runoff from inhabited areas, E. coli may get washed into surface water where they can survive. Usually E. coli can not multiply in any natural water environment and they are therefore, used as specific indicator for fecal contamination (WHO, 1996). The presence of E. coli can cause diarrhea, Gastroenteritis, nausea and other problems especially for infants, children and those with weak immune systems. Hemorrhagic Colitis (HC, a type of gastroenteritis) is the acute disease caused by E. coli (Kahlown et al., 2006). If E. coli is present in even a single number may found in any sample of 100 ml of water, then it is likely that the water has recent sewage or animal waste contamination and may contain different types of disease causing organisms (WHO, 1996).

2.2.2 Physical Parameters

Physical parameters that are commonly found in water are: turbidity, taste, odour, temperature, colour, pH value, electrical conductivity etc. Physical contamination analyzed to assess physical characteristic on the spot using appropriate test equipment and personnel sense.

2.2.2.1 Turbidity

Turbidity is an expression of light scattering and light absorbing properties of water (USEPA, 2005). The turbidity excess of guidelines value is 5 NTU (Nephelometric Turbidity Units) maximum that is generally un-objectionable to consumers (WHO, 1997). The excessive amount of turbidity can protect micro-organisms from the effect of disinfection that stimulate the growth of bacteria in the water. Human activities that disturb land, such as construction, can lead to high sediment levels entering water bodies during rain storms, due to storm water runoff, and create turbid conditions. Urbanized area contribute large amounts of turbidity to nearby water bodies, through storm water pollution from paved surfaces such as roads, bridges and parking lots. This is especially problematic for immune-compromised people, because contaminants like viruses or bacteria can become attached to the suspended solid.

Turbidity is important in both, acceptability and selecting water treatment processes for drinking water. As a concerned with collecting physical data of sample locations of Shigar town water bodies, it was to assess the level of turbidity to identify the factors, which influence the capacity of water bodies due to sedimentation of sand and silt deposits in the sources. Turbidity in water is caused by the presence of suspended matter, such as clay, silt and organic particles. Naturally surface water from the catchment areas of high altitude mountainous areas with gravity flow of high velocity may carry suspended sediments to the stream/lake.

2.2.2.2 Taste

The combined perception of substances detected by the senses of taste and smell is often called taste (WHO, 1997). Generally the taste buds in the oral cavity, specifically detect inorganic compound metals such as magnesium, calcium, sodium, copper, iron and zinc present in water. The taste of drinking water must be unobjectionable (WHO, 2004).

2.2.2.3 Odor

Water odor is mainly due to the presence of excess number of organic and some inorganic substances (WHO, 1997). Some odors are indicative of increased biological activity and decomposition of vegetable matter. Moreover the water remains fresh in stream by continuous charging with fresh surface or spring water and discharging outflow downstream that resulted to avoid any causes of odor. The drinkable water must be unobjectionable for human consumption in terms of odor (WHO, 2004).

2.2.2.4 Temperature

The temperature of water should be un-objectionable for drinking purposes (WHO, 1997). In this regard no standards available for drinking water by WHO or at national level. However PCRWR and Pakistan Standard Institute (PSI) recommend it as unobjectionable for the consumers.

2.2.2.5 pH

A measurement of the degree of how acidic or alkaline the water supply is based on a scale of 0 - 14. The pH reading of 7.0 is considered neutral. Below 7 is considered acidic and above 7 is considered as alkaline (WHO, 2003). There can be many causes of acidic water including acid rain (high carbon dioxide), acid source absorbing atmospheric carbon dioxide and from decaying vegetations in water. Excessive levels of alkalinity can produce a soda taste and have drying effect on the skin because of the tendency to remove normal skin oils. Water with more acidic or alkaline pH will tend to be corrosives. This corrosive water helps to dissolve metals such as lead, copper, brass, and zinc in plumbing pipelines and carrying in water to the water appliances such as washing machines, water heater and plumbing fixture. United States Environmental Protection Agency (USEPA) recommends contaminant level of pH is 6.5 to 8.5. WHO guideline (1984) also recommended the guidelines value of pH 6.5-8.5. Higher the pH value in drinking water acquire a bitter taste (EPA, 1997).

2.2.2.6 Color

Color of drinking water may be due to the presence of colored organic substances usually humus, metals such as iron and manganese and colored industrial wastes (WHO, 1984). The transparency or color of the drinking water must be un-objectionable. The acceptable level of drinking water color is up to 5 NTU and PSI recommended it up to 25 NTU (Kahlown *et al.*, 2006).

2.2.2.7 Electrical Conductivity

Electrical Conductivity is a numerical expression of the ability of an aqueous solution, to carry an electric current. The ability depends upon the presence of ions, their total concentration, mobility, and also on their temperature. The determination of electrical conductivity provides a rapid and convenient means of estimating the concentration of electrolytes (salts) in water. Solutions that are more organic are good conductor (WHO, 1979).

2.2.3 Chemical Parameters

The chemical parameters that are mostly found in water bodies are as, Dissolved Oxygen (DO), Total Dissolved Solids (TDS), Hardness, Calcium (Ca), Bicarbonates (HCO_3), Nitrate (NO_3), Phosphate (PO_4), Potassium (K), Magnesium (Mg), Sodium (Na), Sulfate (SO_4), Alkalinity (Alk), Chloride (Cl), Iron (Fe) and Fluorides (F) and heavy metals like Arsenic (As), Lead (Pb), Chromium (Cr), Copper (Cu) (*Kahlown et al.,* 2006). The occurrence and health significance of these selected chemical parameters and recommended standards for human consumption are described below:

2.2.3.1 Nitrates

Nitrate is a very important water quality parameter from the health point of view. Nitrate (NO_3) and nitrite (NO_2) are inorganic forms of nitrogen in the environment. Nitrates along with ammonia are forms of nitrogen, used by plants. Nitrates and nitrites are formed through the oxidation of ammonia by nitrifying bacteria, known as nitrification. In turn, they are converted into other nitrogen forms by de-nitrification and plant uptake. Thereof the nitrogen rarely limits the growth of plants as dosage and phosphorus. Nitrates are normally present in natural water and waste water. Nitrates enter water supplies from the breakdown of natural vegetation, the use of chemical fertilizers and from the oxidation of nitrogenous compounds in sewages materials and industrial wastes. Drinking waters containing excessive amounts of nitrates can cause methaemoglobinaemia and death (U.S EPA, 1977). The Maximum Contamination Level (MCL) recommended for nitrate and nitrites is 10 mg/l (WHO, 1984).

2.2.3.2 Total Dissolved Solids

Total dissolved solids comprise inorganic salts (calcium, magnesium, potassium, sodium, bicarbonates, chlorides and s). TDS in drinking water originate from natural sources, sewerage, urban runoff and industrial waste water. Concentrations of TDS in water vary considerably in different geological regions owing to difference in the solubility of minerals. TDS is linked to taste, hardness, and corrosive properties. There is no evidence of physiological effects having TDS level in excess of 1000 mg/l (Dufor, 1972). However for use of agricultural irrigation the value of TDS acceptable between 450 to 2000 mg/l (FAO, 2005).

2.2.3.3 Hardness

Hard water is a common water quality problem that relates to the amount of dissolved minerals present in water. As water moves through the ground, rock and soil, it carries minerals along the way. The primary mineral substances that are found in water as hardness are calcium and magnesium (Michael, 1982). These minerals are not found in nature in elemental form but found in water as chlorides, carbonates and bicarbonates. Hardness reduces a soap or detergent ability to dissolve. Therefore more soap will be required in hard water. It can cause the reduction in water flow through pipes and make heating less. The degree of hardness is equivalent to calcium carbonate concentration named as soft (0-60 mg/l), medium hard (60-120 mg/l), hard (120-180 mg/l) and very hard (>180 mg/l) (Kahlown, 2006). There is no firm evidence that water hardness causes ill effect in human (CDWQ, 1991).

2.2.3.4 Sulfate

Sulfate is widely distributed in nature and may be present in natural water in concentration ranging from a few to several thousands milligrams per litre. Mine drainage waste contributes high in the form of pyrite oxidation. Sodium and magnesium exert a cathartic action and should not be present in drinking water. The amount of sulfate also detected in, with a reasonable value under the acceptable limit of drinking water standards. The recommended value of sulfate in drinking water is 250 mg/l, above which consumer may feel problem in taste (WHO, 1996).

2.2.3.5 Bicarbonates

Bicarbonates are dominant in both surface and ground water. The weathering of rock contributes to the formation of bicarbonates in water. Most of bicarbonates are soluble in water and concentration related to the pH scale. Bicarbonate also influences the alkalinity and hardness of water.

2.2.3.6 Magnesium

Magnesium is common constituent of water. Magnesium and calcium both produce the property of hardness in water (Michael, 1981). About 19 kg of magnesium per 70 kg human body weight is involved in the synthesis of protein as well as act as co-factor in 300 enzymatic reactions (Acu-Cell, 2003).

2.2.3.7 Alkalinity

Alkalinity is defined as “the capacity of some of its components to accept proton i.e. to bind an equivalent amount of strong acid. The maximum permissible level of alkalinity is 50 mg/l to 500 mg/l as $CaCO_3$ (Jeffer *et al*., 1985).

2.2.3.8 Sodium

Sea water contain relatively high levels of sodium about 10 g of sodium per litre (WHO, 1979).The deficiency of sodium in human body may appear as mental apathy, low blood pressure, fatigue, depression, seizures, dehydration etc.(Acu-Cell, 2003). In most of the countries, the majority of water supplies contain less than 20 mg of sodium per litre (WHO, 1979).

2.2.3.9 Iron

In water, Iron found as divalent and trivalent (ferrous and ferric) form. Iron deficiency in body cause anemia and symptoms of fatigue appeared. The recommended quantity of iron in drinking water is as 0.3 mg/l (WHO, 1996).

2.2.3.10 Fluoride

Drinking water is typically the largest single contributor to the daily fluoride (F) intake (WHO, 1986). Low concentration of fluoride cause the teeth problem and high doses have been linked to cancer disease. Recommended value of lead is 1.5 mg/l (WHO, 1986).

2.2.4 Trace and Ultra Trace Elements

2.2.4.1 Arsenic

Arsenic is distributed through out the earth's crust. Arsenic is an important drinking water contaminant. Arsenic is introduced into drinking water sources primarily from the naturally occurring minerals. Arsenic in drinking water is a significant cause of bad health effects. It is one of the few substances shown to cause cancer in human through consumption of drinking water. The new born babies and people with suppressed immunity are at greater risk of arsenic poisoning (USDI, 2001). WHO recommends the MCL of arsenic as 0.01 mg/l where as PSI recommends the quantity of arsenic to 0.05 mg/l in drinking water.

2.2.4.2 Lead

Lead is widely distributed all over the world in the form of its sulfide. The levels of lead in drinking water, however, can be much higher owing to use of lead service pipes running from the street to a dwelling, from lead plumbing or lead lined storage tanks. Lead in high doses has been recognized for centuries as a cumulative general metabolic poison. Lead taken internally in any of its forms is highly toxic. The effects are usually felt after it has accumulated in the body over a period of time. The symptoms of lead poisoning are weakness, constipation, colic, palsy, and often a paralysis of the wrists and ankles and in the case of children, behavioral changes. SDWF (2003) had given the possible chronic health effects as brain and nerve damage, digestive disturbance, blood disorders and hypertension. Maximum Contaminant Level (MCL) recommended quantity of lead is 1.3 mg/l for drinking water (USEPA, 1986). Guideline value of lead given by WHO, is 0.01mg/l (WHO, 2004).

2.2.4.3 Chromium

The harmful effects of waterborne chromium in human are associated with hexavalent chromium, and trivalent chromium, which is practically non-toxic. Chromium metal and chromium (III) compounds are not usually considered health hazards, chromium is an essential trace mineral. However, hexavalent chromium (chromium VI) compounds can be toxic if inhaled. Most chromium (VI) compounds are irritating to eyes, skin and mucous membranes. Chronic exposure to chromium (VI) compounds can cause permanent eye injury unless properly treated. The maximum allowable concentration of chromium (VI) in drinking water is 0.05 mg/l (WHO, 2001).

2.2.4.4 Copper

Copper is found throughout the world in basaltic lava, but the largest known deposit is in the Andean Mountains of Chile, in the form of porphyry copper. Severe gastrointestinal irritation and possible necrotic action changes in the liver and kidneys could occur. Copper in water has an unpleasant, astringent taste. The taste threshold is above 5.0 mg/l.

2.3 GUIDELINES AND STANDARDS FOR QUALITY DRINKING WATER IN PAKISTAN COMPARISON WITH WHO

As all the water quality parameters are needed for living things while in specific quantity. WHO has provided guidelines for drinking water parameters as shown below:

Table 2.1 Limits for drinking water quality parameters

PROPERTIES/ PARAMETERS	GUIDELINE/STANDARD VALUES FOR PAKISTAN	WHO STANDARDS
Physical		
Color	<= 15 TCU	<= 15 TCU
Taste	Non Objectionable/Acceptable	Non Objectionable/Acceptable
Odor	Non Objectionable/Acceptable	Non Objectionable/Acceptable
Temperature	Acceptable	Acceptable
Turbidity	< 10 NTU	< 10 NTU
TDS	< 1000	< 1000
pH	6.5 - 8.5	6.5 - 8.5
Chemical		
Essential Inorganic	***mg/litre***	***mg/litre***
Aluminum (Al)	0.01 - 0.2	0.2
Antimony (Sb)	0.005	0.02
Arsenic (As)	0.01 - 0.05	0.01
Barium (Ba)	0.7 - 2.0	0.7
Boron (B)	0.3 - 0.5	0.5
Cadmium (Cd)	0.003 - 0.01	0.003
Chloride (Cl)	250 - 400	250
Chromium (Cr)	0.05 - 0.1	0.05
Copper (Cu)	1 - 2	2
Toxic Inorganic	***mg/litre***	***mg/litre***
Cyanide (CN)	0.05 - 0.1	0.07
Fluoride (F)	1.5 - 4.0	1.5
Lead (Pb)	0.01 - 0.05	0.01
Manganese (Mn)	0.2 - 0.5	0.01
Mercury (Hg)	0.001 - 0.002	0.01
Nickel (Ni)	0.02 - 0.1	0.02
Nitrate (NO_3)	50 (as NO_3^-)	50
Nitrite (NO_2)	3 (as NO_2^-)	3
Selenium (Se)	0.01	0.01
Total Dissolved Solids	1000	1000
Zinc (Zn)	2.0 - 5.0	3
Bacterial		
Escherichia Coli	Must not detectable in 100 ml sample	Must not detectable in 250 ml sample

Total Coliform	Must not detectable in 100 ml sample	Must not detectable in 250 ml sample

Source: *Finalized Under Collaborative Sponsorship of World Health Organization (WHO) an. Government of Pakistan, Ministry of Health, Health Services Academy (2005)*

2.4 SPATIAL RELATIONSHIP OF WATER QUALITY DATA

It is estimated about 250,000 child's death occur each year in Pakistan due to waterborne diseases (WWF, 2007). Proper water supply system and good quality sanitation network decrease the microbiological contamination in water. It is 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 death rate for infants and young children fell by 52% (WHO 1972-73).Water Quality is an important and sensitive issue in Shigar town, which needs to be addressed in a very systematic approach, encompassing all the water quality related issues. GIS provides an ideal platform for supporting a wide range of analysis on the basis of geographic data. Association of GIS with spatial analysis is impeded by various factors and has been more successful in some fields that having spatial content in data (Haslett *et al*., 1990). The efficiency of the results depends upon the accuracy of appropriate data. Therefore, the study in GIS is necessary for decision making and keeping the public to know about the quality of water. One of the strength of Geographical Information System (GIS) has the capability to handle multiple layers of information through common georeferencing (Noel Cressie, 1999). It is confirmed that simply generating good data is not enough to meet the objectives. Therefore in water management and policy making, there is an increasing need for assessment methodologies for diagnosis and prognosis purposes, in which an integrated water system approach is considered (Witmer, 1995). The data must be processed and presented in a manner of easy understanding of the spatial and temporal pattern. In the light of GIS, this study is mainly focused on spatial analysis on water quality data to find out the trends in water contaminants, the number of victims and sources that contribute the contaminations in water distribution systems.

The PCRWR launched a program "National Water Quality Monitoring Program" in Pakistan on 17th March 2001. The aim of the program was undertaking water quality monitoring in 21 major cities, six rivers and 11 storage reservoirs, canal, drains and natural lakes. Different organizations including PCRWR, Water and Power Development Authority (WAPDA), Environmental Protection Agency (EPA) and some individual consultants had conducted short-term studies on water quality assessment of a few cities of Pakistan but not used the strength of GIS in water quality monitoring. As water quality monitored on a single point, therefore it needs to estimate the trend in contaminant's concentration and indicate the factors that degrade the quality of water.

The whole system of water quality monitoring is aimed at the generation of reliable data, i.e. data that accurately reflects the actual status of the variables which influence the water quality. GIS is specifically designed to relate data to geographical locations and produce it in the form of maps also. A water quality monitoring programme can be superimposed in different aspects. For example, data of water quality such as chemical variables can be overlaid with data of human settlement to view the impact of water quality over the population. GIS has the ability to integrate layers of spatial information and to uncover possible relationships rather obscure. The process of transforming one layer of spatial information to match a second layer is called registration (Nelson *et al*., 1999). Producing meaningful information from raw data normally requires an initial statistical analysis of the data, i.e. to determine the magnitudes of variables, their variability, any time trends, graphical representation of data. It is also necessary to be able to give some indication of the "confidence" the user may have in the statistical outputs (UNEP and WHO, 1996). Some of the organizations are working to find out the water quality by use of Water Quality Index (WQI) methods. Use of WQI simplifies the presentation of results of an investigation related to a water body, as it summarizes in one value or concept a series of parameters analyzed. Water Quality Indices are considered very useful to transmit information concerning water quality to the public (Zandbergen and Hall, 1998).

2.5 SPATIAL ANALYSIS ON DISEASE DATA

Another important role of GIS is administration and planning, representing the "management" role of a GIS. Health information system develops a program for data visualization, which incorporates not only the spatial but also the temporal distribution of disease (Goodchild, *et al*., 1999). In order to mount such a response, quick access to all the relevant information is needed. To minimize the effects of disease outbreaks, a rapid effective response is required. If the spatial component of disease distribution is incorporated through a GIS, the examination of geographical location as a factor in disease occurrence is possible. In health information systems, a computer program uses knowledge of spatial relationships between villages, and multiple linked data sources to provide all the key information required to mount an effective response, within a matter of seconds (Hoff, and Geldreich, 1981).

CHAPTER 3

MATERIALS AND METHODS

The details of the datasets and general methodology adopted for spatial analysis on water quality data of Shigar town is as under:

3.1 DATA COLLECTION AND SOURCES

3.1.1 Data Acquired form IUCN

i. Water quality data of autumn, winter and spring seasons of water supply network, water channels and water pits.

ii. QuickBird Satellite image with 0.6m resolution of study area.

iii. Hamlet level population data of the Shigar town

iv. Socio-economic data of Shigar town

Table 3.1 Availability of water quality seasonal data (microbiological)

Season	Water Distribution System Data		
	Water Supply System	Water Channel	Water Pits
Autumn	Available	Available	Available
Winter	Available	Not available	Not available
Spring	Available	Available	Not available
Summer	Not available	Not available	Not available

3.1.2 Data Acquired During Field Survey

i. Water network/channel (locations and route) data during field survey (30-03-2008—10-04-2008).

ii. Water taps location data collected of Shigar town with handheld GPS, for the availability of good quality water in Shigar town.

iii. Verification of location of water sample locations (water quality data) with the help of handheld GPS (Garmin, 76 cs, 10-15 m accuracy).

3.1.3 Data Acquired from Shigar Health Center

i. Medical data (patient history) of one year (01-03-2007—31-03-2008).

3.2 DATA PRE-PROCESSING AND PREPARATION

Data collected from different sources including field survey was not in valid format for GIS analysis in ArcGIS. Thus there was need of some preprocessing steps to make it feasible/usable for GIS software. The water quality data was in raw excel format so it was needed to convert into shape file format for further GIS analysis.

3.2.1 Base Image

The image collected of study area was, in Panchromatic (High ground) and multi spectral (high spectral) resolution. Image bands were merged by using resolution merge functionality of ERDAS Imagine software, to get a single image of high ground and high spectral resolution. Image collected from IUCN, covers about 62 Km^2 area, including Shigar town.

Table 3.2: QuickBird image specifications

Image	Description	Abbreviations	Resolution	Bandwidth (micrometers)
Black & White	Panchromatic	PAN	0.6m	0.45 – 0.90
Color	Band 1 (Blue)	VIS B	2.4m	0.45 – 0.52
	Band 2 (Green)	VIS G	2.4m	0.52 – 0.60
	Band 3 (Red)	VIS R	2.4m	0.63 – 0.69
	Band 4 (Near Infrared)	NIR	2.4m	0.76 – 0.90

The methodology flow diagram of the study work is as given below. The methodology of whole study is named as A, B, C D on the basis of sub-objectives of the study work.

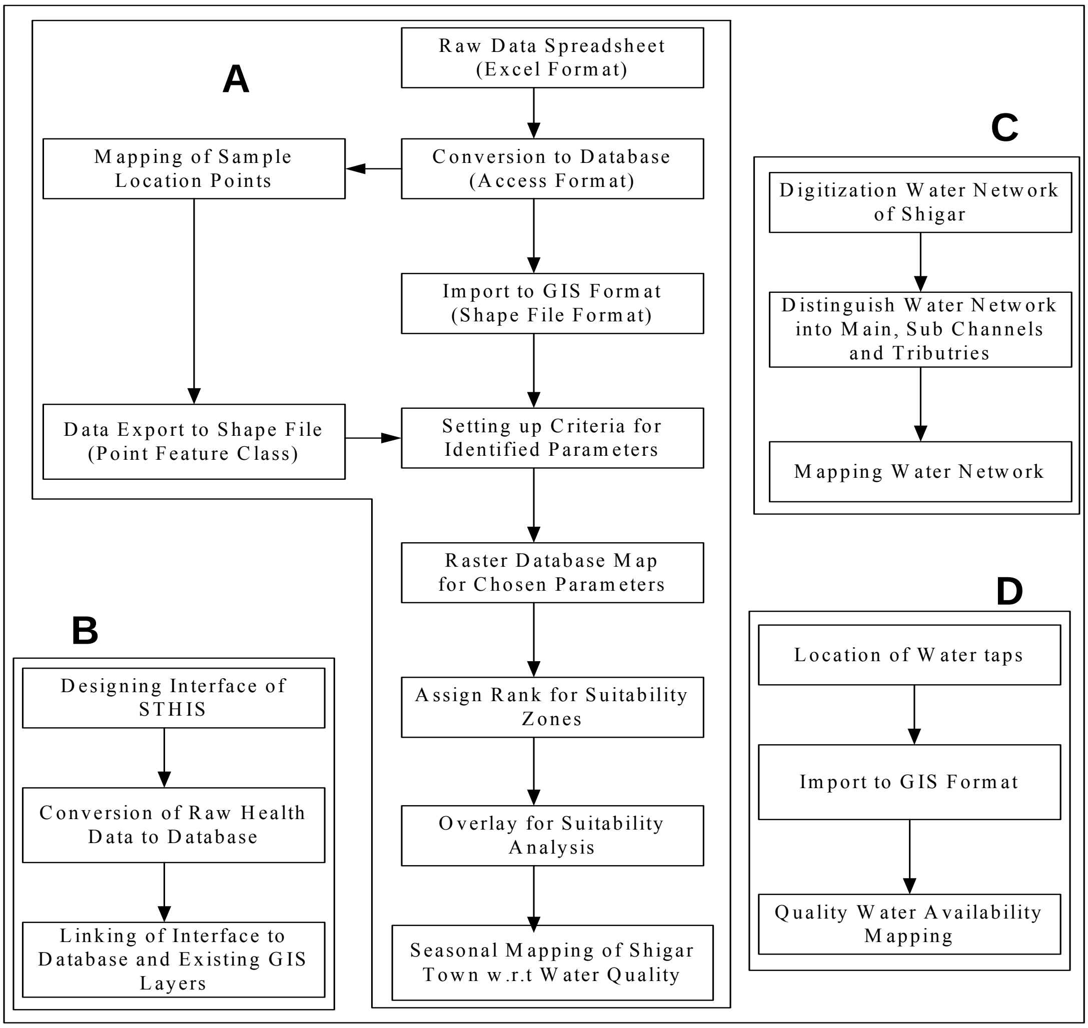

Figure 3.1: Mythologies

(A) Methodology for Identification of the potential zones of poor water quality

(B): Methodology for Shigar Town Health Information System

(C): Methodology for mapping of water network of Shigar town

(D): Methodology for quality water availability in Shigar town

3.2.3 Classification of Study Area

Shigar town is classified into Irrigated Land, Built-in area, Gardens and Water bodies. The purpose of image classification is to compare the results obtained by classification methods given in ERDAS Imagine with the work done by field survey for the mapping of water channels in Shigar town. It is hard to classify the built-in area by classification methods because the spectral signature of top of buildings in study area matches with the spectral signature of cliffs so built-in area has been classified visually from the high resolution QuickBird image.

3.3 WATER QUALITY DATA PREPARATION

Water quality data collected from IUCN, verified (sample locations) on field using handheld GPS for making the data usable and to enhance the accuracy of results. Data verified on the basis of given ground locations along with co-ordinates of sample points. Data collected was in raw excel format. This raw data is converted into database format with all its characteristics. Database converted into ESRI (shapefile) format for mapping of sample points on study area map.

3.3.1 Digitization

The water channels and water taps location data, collected from field survey using handheld GPS digitized over the map of study area, using AutoCAD map 2000. The water channels and water taps (water supply system) also digitized over the QuickBird image on the basis of reference survey data. The digitized data exported to ESRI format for further GIS analysis for mapping of surface water network (water channels) of Shigar town. The built-in area of Shigar town also digitized. The purpose to digitize the built-in area is to find out the relationship of population of Shigar town with the water quality zones.

3.4 SPATIAL ANALYSIS OF WATER QUALITY DATA

The entire chemical and most of the physical parameters are found with-in the affordable limit set by WHO. Therefore all the GIS analysis performed over the microbiological indicators of water quality. The data have the bacterial contamination in terms of total-coliforms and E-coli (Thermotolerant faecel coliforms). Total coliform is the combination of thermotolerant faecel coliform (E. coli) bacteria and number of other faecel coliform. In this study the thermotolerant coliform bacteria subtracted from total coliform bacteria, to find out the concentration of other coliform bacteria. Water quality zones of thermotolerant faecel coliform (E.Coli) is distributed into different zones of drinking water quality as criteria set by WHO, defined in Table 3.3. Each drinking water quality zone assigned a different color. The above process of water quality zone distribution is repeated for water supply network, water channels and water pits for autumn, winter and spring seasons. Water quality data is point data of different locations of study area. The point data is converted into surface for the preparation of water quality zones. IDW (Inverse Distance Weighted) technique is used for the preparation of water quality zones. IDW interpolation technique applied over the water quality parameters (Thermotolerant fecal coliforms, other coliforms) for all above mentioned three seasons.

Table 3.3 Classification of thermotolerant faecel contaminants (WHO)

Count per 100ml	Category	Color code	Remarks
0	A	Blue	No risk
Not Drinkable but with different classes			
1-10	B	Green	Low risk
10-100	C	Yellow	Intermediate risk
100-1000	D	Orange	high risk
>1000	E	Red	very high risk

(Source: WHO, 1997)

Water quality zones are categories from A to E alphabetically shows the relative quality of water from good to worse respectively. Concentration of other bacteria (other than thermotolerant faecel coliforms) in Shigar town is also studied in the light of GIS in the same way as thermotolerant faecel coliform water quality zones. There is no criterion given by WHO for the distribution of other faecel coliforms into different zones on the basis of water contaminants. The criteria is self defined and given below in Table 3.4. The purpose water quality zone distribution of other coliforms is only to see the concentration of faecel coliform other than thermotolerant faecel coliform in the Shigar town. The coliforms other than thermotolerant faecel coliforms may have pathogens (A pathogen, infectious agent, or more commonly germ, is a biological agent that causes disease or illness to its host).

Table 3.4 Classification criteria of other faecel coliforms

Count per 100ml	Category	Color Code
0	A	Blue
1-10	B	Green
10-100	C	Yellow
100-1000	D	Orange
>1000	E	Red

3.4.1 Relation of Population with Water Quality Zones

The Hamlet level population data of Shigar town, is compared with the water quality zones, prepared for each water distribution system (water supply system, water channel and water pits). The population effected by each classified water quality zone for all three seasons (autumn, winter and spring), is calculated according to the criteria mentioned below:

i. Digitization of built up area of Shigar town
ii. Calculation of unit area (Area of each house)
iii. Total built-up area lies in each water quality zone
iv. Average population of each house
v. Population lies in each water quality zone

3.4.2 Criteria for Acceptable Quality Drinking Water Availability

The location data of water supply system network (water taps location) is used to access the availability and access of water supply system in Shigar town. The location of water taps compared with the built-in area of Shigar town on the basis of distance as shown in Table 3.5 below:

Table 3.5 Water taps accessibility criteria

Class Name	Criteria (distance away from houses or settlements)
Easily Accessible	<20m
Hardly Accessible	20 m to 50 m
Not Accessible	>50 m

3.5 DISEASE DATA PROCESSING

Medical data is collected from Shigar health center is in the form of pictures (scanned pages of hospital patient's record). The collected data has been converted into database format from scanned pages of hospital's record, using Microsoft MS Access. Disease data has been embedded with the Shigar town hamlet boundaries layer to see the geographical distribution of patients for specific type of disease in Shigar town. An application named as "Shigar Town Health Information System (STHIS)" is designed in MapObject 2.3 with user friendly interface and connected to Geodatabase (diseases data). The application is capable of visualizing the patient's disease data of Shigar town with respect to location. Application includes some basic functionalities such as a diseases occured in one year (March 3007 to March 2008), retrieval of disease data graphically and some basic statistical functions. Visual basic 6.0 is used to make the application platform (GIS software) independent.

CHAPTER 4

RESULTS AND DISCUSSION

The results of overall test parameters are compared with WHO drinking water guideline values. Thermotolerant faecel coliforms (pathogens causes waterborne diseases) and other coliforms (all coliforms other that thermotolerant faecel coliforms) are analyzed in GIS for the preparation of water quality zones on the basis of contaminant value. In this study main focus is thermotolerant faecel coliform because these coliforms are harmful for human beings and cause to increase the quantity of waterborne diseases. Concentrations of other coliform bacteria are also studied and analyzed in GIS but the resultant maps of coliforms other than thermotolerant are shown in appendix only. Water quality is studied for autumn, winter and spring seasons respectively. There are three surface water distribution systems (i) water supply system (WSS), (ii) water channels (W-CH) and (iii) water pits (WP) in Shigar town. The results are discussed below started from autumn season to spring season for each water distribution system.

4.1 AUTUMN WATER QUALITY RESULTS

4.1.1 Water Supply System

The point data of 31 samples is collected of water supply system network, used for preparation of water quality zones in Shigar town by using GIS. There is no such pattern of gradual increase or decrease in microbiological contaminants found in water supply system network. There is heavy increase seen on different points that indicate the pipe leakage or pipe burst around the sample location. E.Coli ranges in water supply network, from 0 to 8 colonies and total coliform ranges from 0 to 48 colonies per 100 ml of water as shown in figure 4.1. In all the graphs total coliform and E.Coli present in 100 ml of water are shown vertically and sample codes are horizontally.

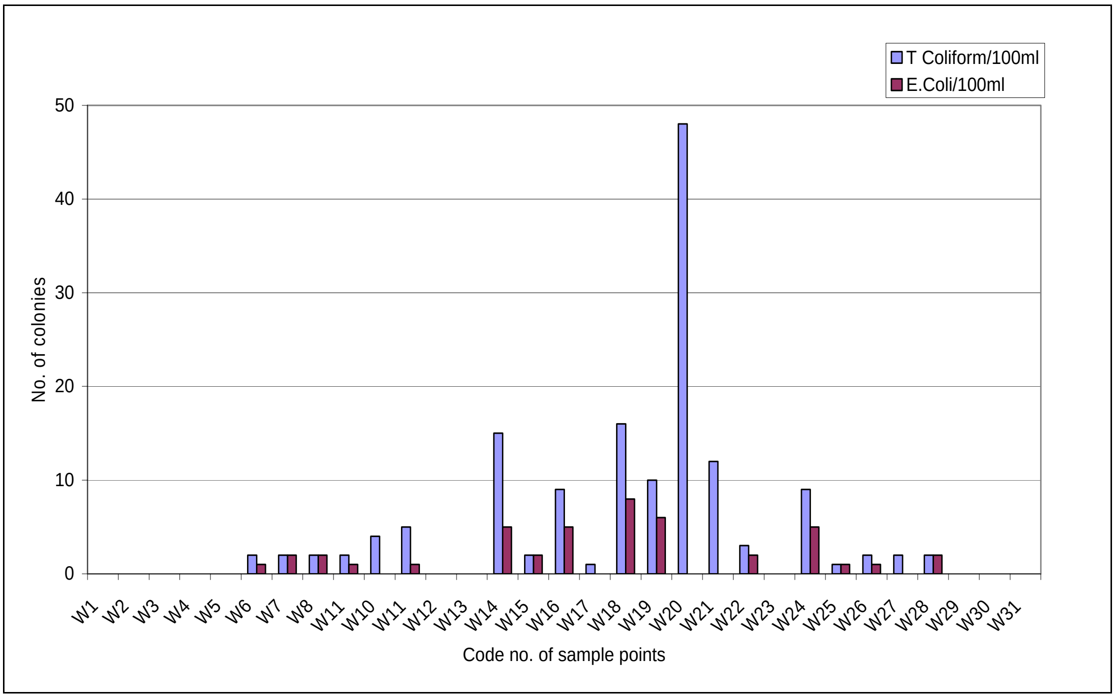

Figure 4.1: Autumn microbiological contamination (WSS)

About 68% samples go beyond the permissible limit given by WHO guidelines for drinking water. Water quality is studied for thermotolerant faecel coliforms and other faecel coliforms. The results of water quality zones prepared on the basis of thermotolerant faecel coliforms are shown below in figure 4.1.

Table 4.1: Percentage microbiological contaminations in WSS (Autumn)

Parameter	Total no. of samples	No. of samples beyond permissible limit	%age
Thermotolerant faecel coliforms	31	14	45
Total coliforms	31	21	68

Coliforms other than thermotolerant faecel coliforms are also treated in GIS to see the concentration of other faecel coliforms. The concentration of other faecel coliform bacteria found in water of water supply network, is distributed into five categories A, B, C, D and E on the basis of colonies of bacteria presents in per 100 ml of water as discussed in chapter 3.

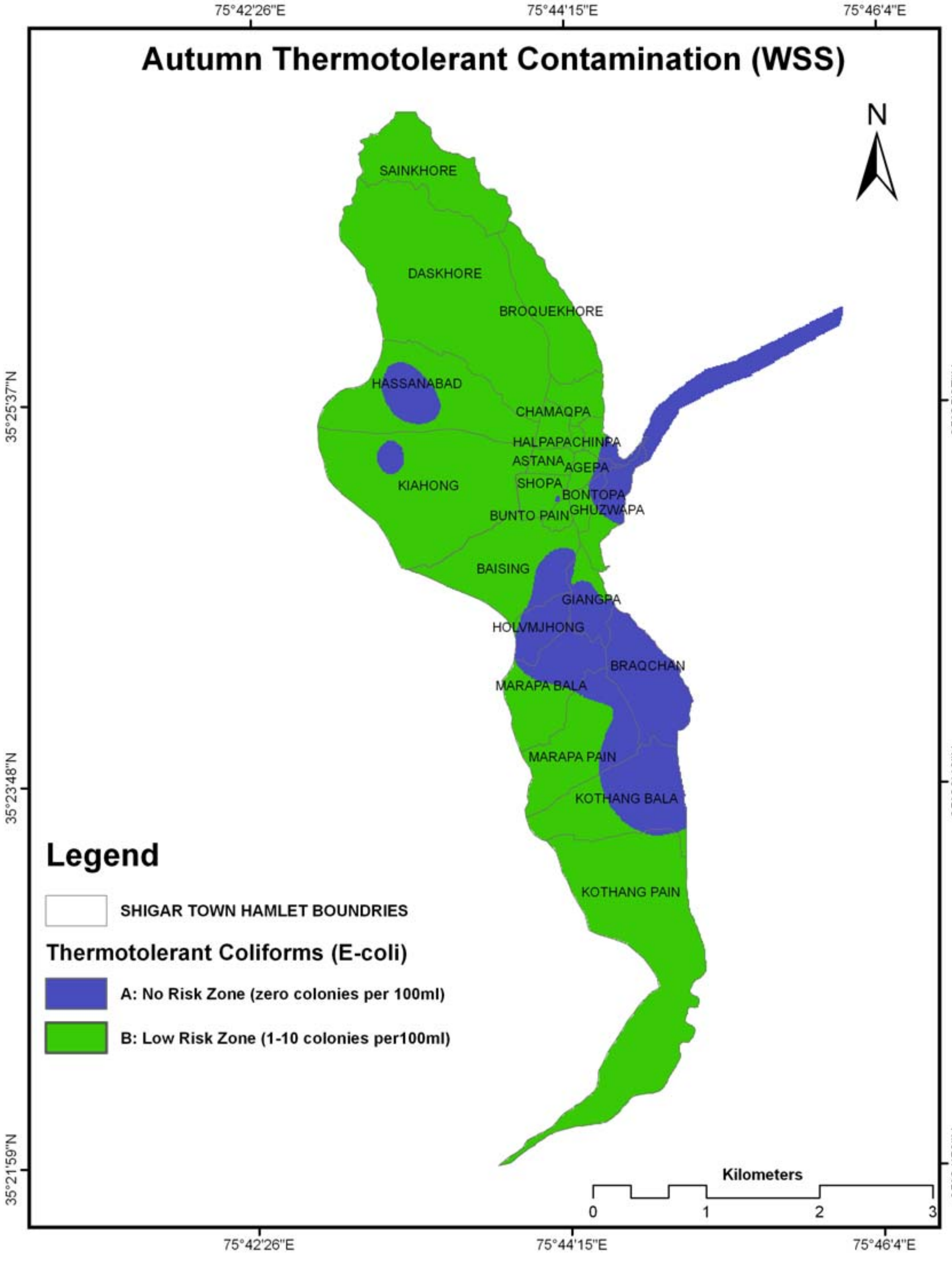

Figure 4.2 Autumn water quality zones (WSS)

Table 4.2 below shows the relationship of water contamination zones (Thermotolerant faecel coliforms) of autumn season with the population of Shigar town with respect to water supply network.

Table 4.2: Population in water supply system's contamination zones (Autumn)

Water Quality Zone	Category	Contaminant Ranges	%age Population
No Risk Zone	A	Zero colonies per 100 ml	14
Low Risk Zone	B	1-10 colonies per 100 ml	86

4.1.2 Water Channels

Out of 24 samples, there is only one sample found without microbiological contamination (The water sample taken from the intake of stream). Resultant map after analysis in ArcGIS shows that, there are more contaminants with-in the human settlements as compared to agricultural and open land. When channel comes out from human settlements, the contaminant level starts decreasing gradually. This shows that all the contaminations are caused as a result of human activity with-in the Shigar town. The factors participating in the contamination of water channels are household waste, animal waste and poor sanitation system. Thermotolerant faecel coliform found in water channels, ranges from 0 to 16,000 colonies and total coliform ranges from 0 to 24,000 colonies per 100 ml of water. This shows that the channel water is highly contaminated and not safe for drinking purposes. Water quality data of water channels is treated in GIS for the preparation of water contamination zones of channel water. Table 4.3 shows the percentages of contaminated samples of channel water in autumn season that exceed the permissible limit of drinking water given by WHO.

Table 4.3: Percentage microbiological contaminations in water channels (Autumn)

S.#	Parameter		Total no. of samples	No. of samples beyond permissible limit	%age
1	Themotolerant faecel coliform	cfu/100ml	24	22	92
2	Total coliform	cfu/100ml	24	23	96

Figure 4.3 shows the comparison of contaminants of each sample in water channel in autumn season. Contamination value of E.Coli and total coliform is shown in graph vertically and sample code horizontally in figure 4.3.

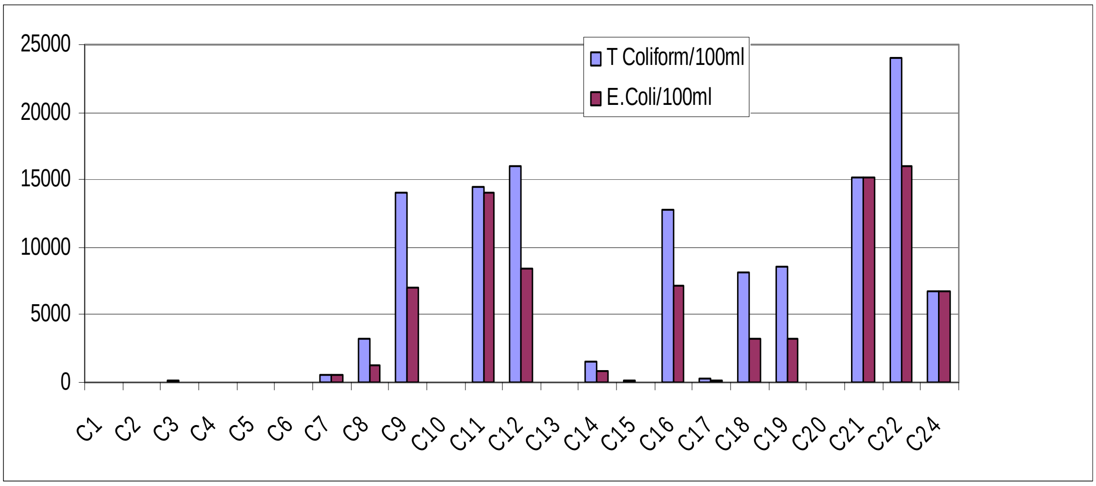

Figure 4.3: Autumn microbiological contaminations (W-CH)

When the results of water contamination zones of water channels are compared with the population of Shigar town, it gives the total population within each contamination zone as shown in Table 4.4.

Table 4.4: Population in water channel's contamination zones (autumn)

Water Quality Zone	Category	Contaminant Ranges	%age Population
Intermediate Risk Zone	C	<100 colonies per 100ml	2
High Risk Zone	D	100-1000 colonies per 100ml	8
Very High Risk Zone	E	>1000 colonies per 100 ml	90

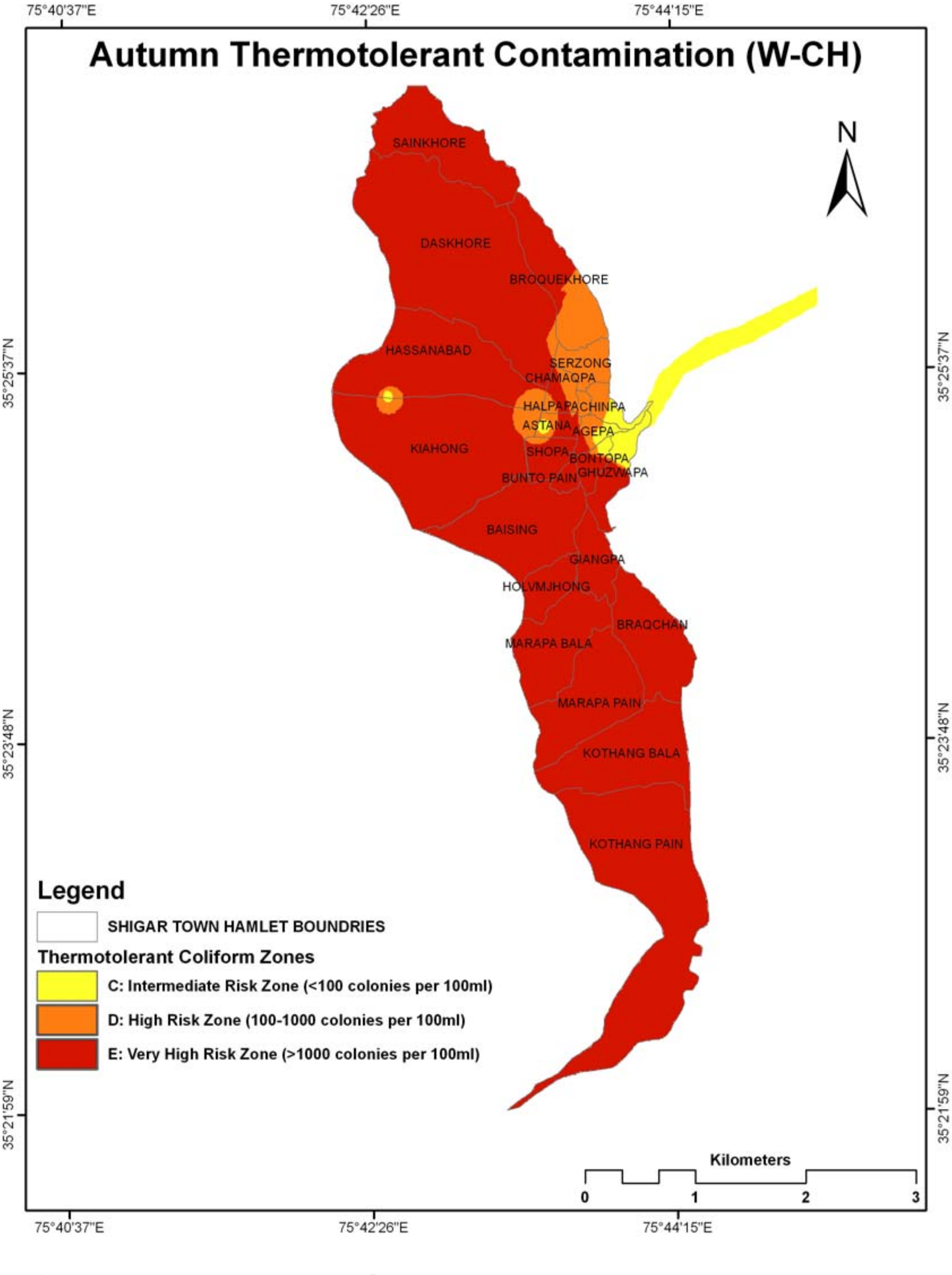

Figure 4.4 Autumn water quality zones (W-CH)

4.1.3 Water Pits

There are only 7 samples collected to study the quality of pit water. Due to non availability of geographical co-ordinates, 3 samples were discarded from the results. Thermotolerant faecel coliform ranges from 3,600 to 41,200 colonies and total coliform ranges from 9,200 to 41,200 colonies per 100 ml of water. The detail is as in Table 4.5 below.

Table 4.5: Percentage microbiological contaminations in water pits (Autumn)

S.#	Parameter		Total no. of samples	No. of samples beyond permissible limit	%age
1	Thermotolerant faecel coliform	cfu/100ml	4	4	100
2	total coliform	cfu/100ml	4	4	100

Figure 4.5 shows the graphical representation in microbiological water contaminants values of samples collected from water pits in Shigar town.

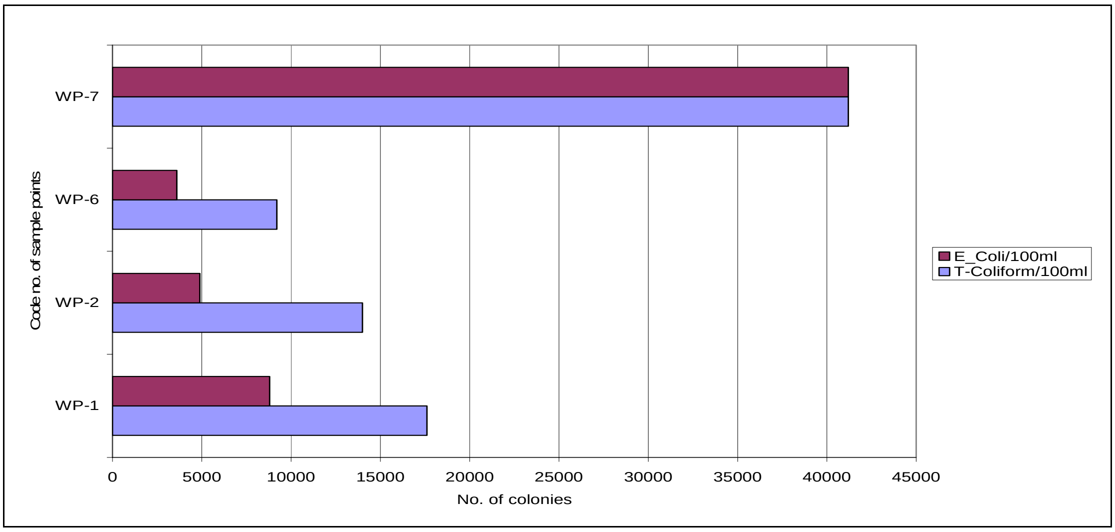

Figure 4.5: Autumn microbiological contamination (WP)

It is found that the pit water is not suitable for drinking. There is maximum contamination found in water pits as compared to the contamination in water supply system and channel water. Whole study area lies in very high risk zone of water quality under the WHO drinking water guidelines.

4.2 WINTER WATER QUALITY RESULTS

4.2.1 Water Supply System

In total, the data of 44 samples was collected of the water quality of WSS in winter season. The data was treated in GIS for distribution of water quality zones of water supply system in winter season. Maximum sample locations are same as it was in autumn season. Only one sample (intake of water supply network) is without any fecal contamination. This step gives the strength to idea that the source of water supply system is free from contaminations. There are 98% samples in winter season that are contaminated in terms of microbiological contaminations. Thermotolerant faecel coliform ranges from 0 to 47 colonies and total coliform ranges from 0 to 47 colonies per 100 ml of water. The detail of water contamination of winter season in water supply networks is shows graphically below in figure 4.6.

Table 4.6: Percentage microbiological contaminations in water supply system (Winter)

S.#	Parameter		Total no. of samples	No. of samples beyond permissible limit	%age
1	Thermotolerant faecel coliform	cfu/100ml	44	43	98
2	Total coliform	cfu/100ml	44	43	98

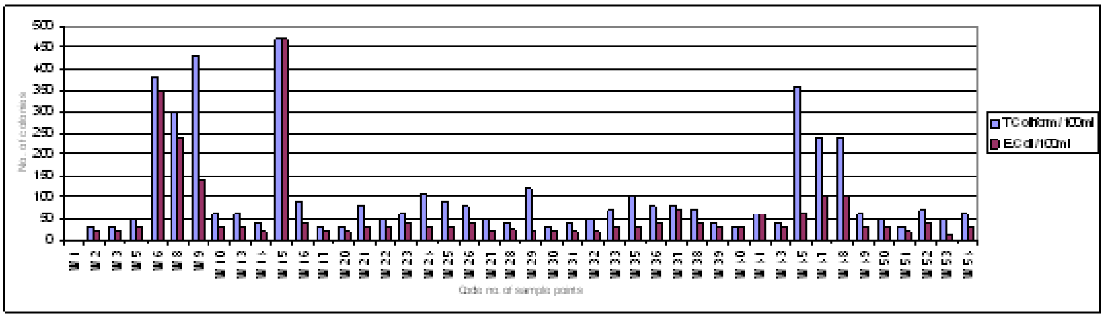

Figure 4.6: Winter microbiological contamination (WSS)

The figure 4.6 shows the heavy increase of thermotolerant faecel coliform and total coliform in one or two samples, indicates the contaminations are adding from surroundings nearby its sample point. The result shows that the quality of water in terms of water supply system in autumn season was better than that of quality of water in water supply system in winter season. Table 4.7 shows the population lies in each water quality zone of water supply system in winter season.

Table 4.7: Population in water supply system's contamination zones (Winter)

Water Quality Zone	Category	Contaminant Ranges	%age Population
No Risk Zone	A	Zero colonies per 100 ml	1
Low Risk Zone	B	1-10 colonies per 100 ml	94
Intermediate Risk Zone	C	10-100 colonies per 100 ml	5

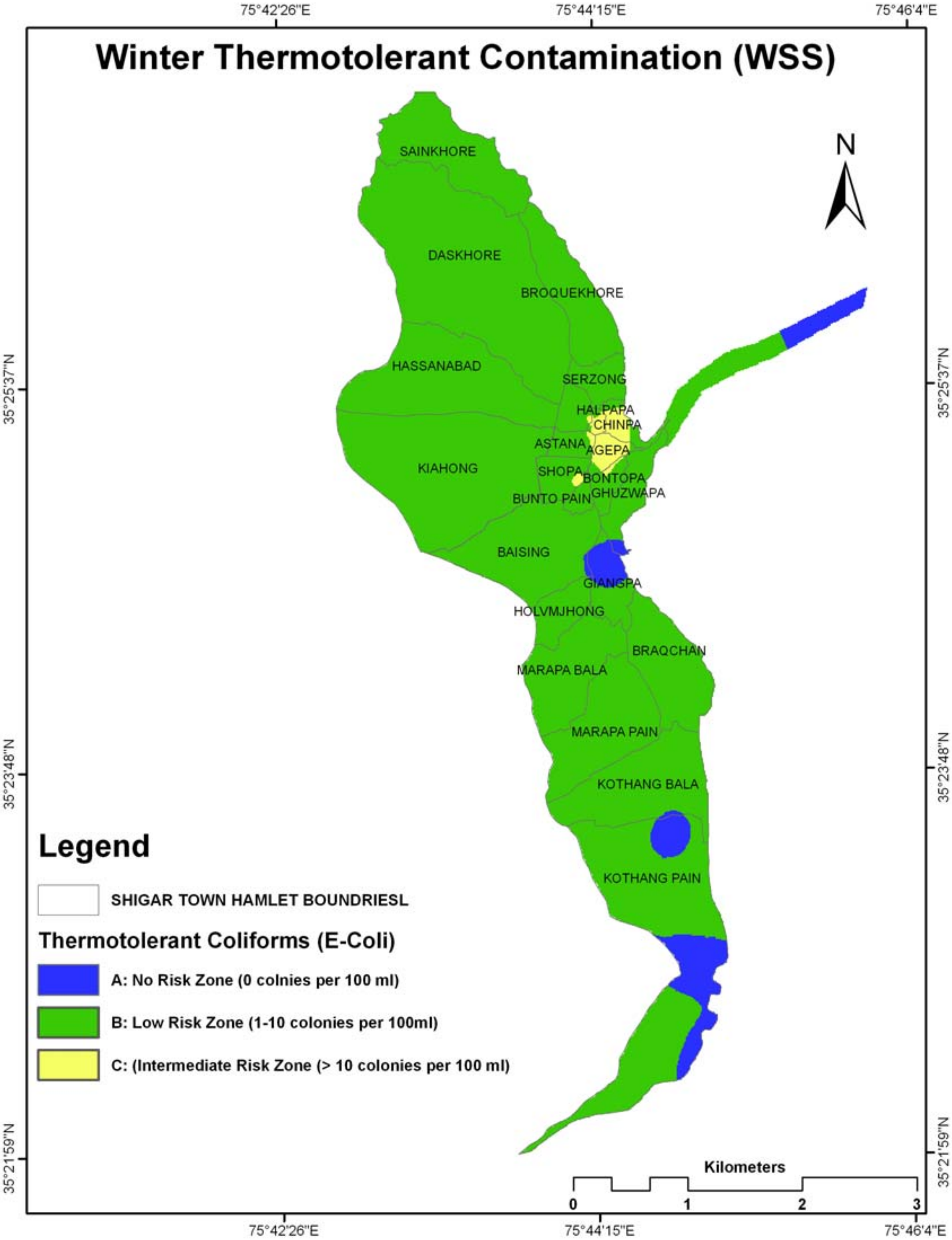

Figure 4.7: Winter water quality zones (WSS)

There were only two categories in autumn season (A & B) but in winter season some area lies in category C (Intermediate risk zone of water quality).

4.3 SPRING WATER QUALITY RESULTS

4.3.1 Water Supply System

In total 53 sample point's data of water quality was collected of water supply system network in spring season. Maximum sample locations are same as it was in autumn and winter seasons. There are only two samples that were removed form the results due to ambiguity in data. Remaining 51 samples were analyzed for further analysis in GIS for water quality zone distribution. Thermotolerant faecel coliform ranges from 0 to 28 colonies and total coliform ranges from 0 to 80 colonies per 100 ml of water.

Table 4.8: Percentage microbiological contaminations in water supply system (Spring)

Sr.#	Parameter		Total no. of samples	No. of samples beyond permissible limit	%age
1	Thermotolerant faecel coliform	cfu/100ml	55	52	95
2	Total coliform	cfu/100ml	55	52	95

The high difference in thermotolerant faecel coliform and Total coliform indicates that a lot of other coliform bacteria are added to the water in spring season. In autumn and winter season data collected from intake of water supply system is found free from microbiological contamination. In spring season, the data of water quality from intake of water supply system having some contamination.

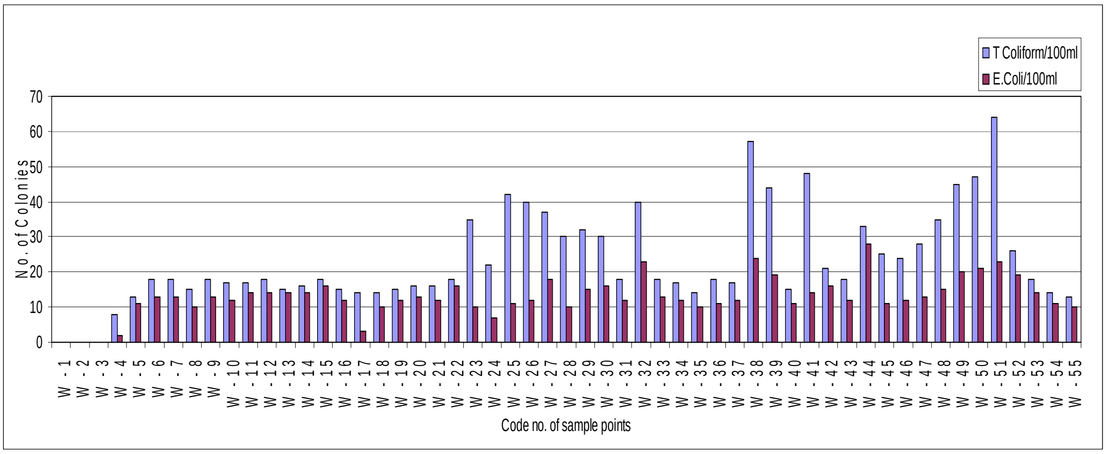

Figure 4.8: Spring microbiological contamination (WSS)

This shows some sort of contamination is adding from the catchments of Shigar steam in spring season.

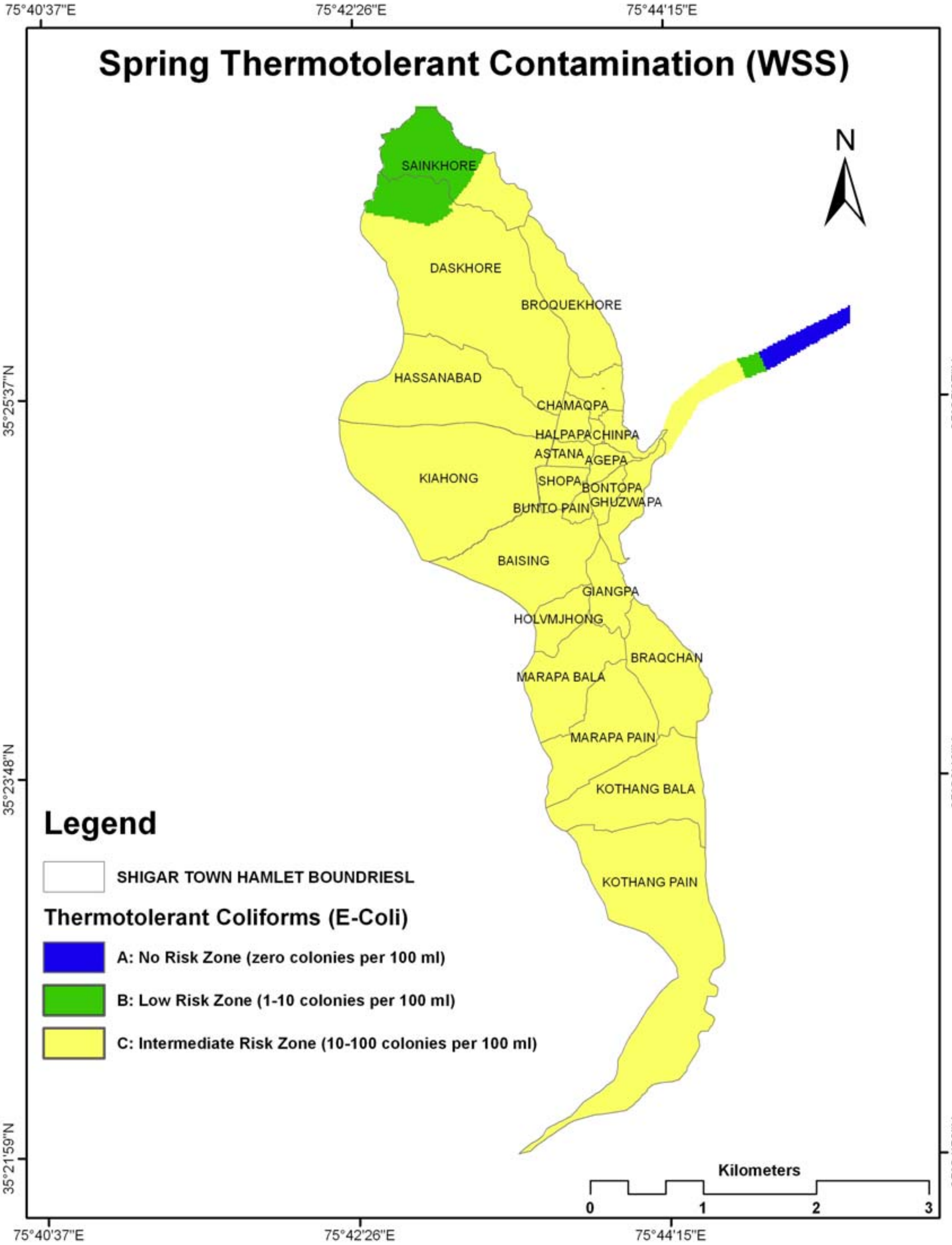

Figure 4.9: Spring water quality zones (WSS)

As a result of seasonal comparison of water contaminations in water supply system, it is found that the quality of water in water supply system in autumn season is better that that of winter and spring season. Table 4.10 indicates the population in each contamination zone of water quality in water supply network in spring season.

Table 4.9: Population in water supply system's contamination zones (spring)

Water Quality Zones	Category	Contaminant Ranges	%age Population
No Risk Zone	A	Zero colonies per 100 ml	0
Low Risk Zone	B	1-10 colonies per 100 ml	1
Intermediate Risk Zone	C	10-100 colonies per 100 ml	99

4.3.2 Water Channels

In total 41 sample's data were collected of conventional water channel network in spring season. Maximum sample locations are same as it was in autumn season. Table 4.10 shows that all the samples collected from water channels are beyond the permissible limit of water quality even the sample collected from intake of stream. The results found that the quality of water in autumn season was better as compared to the quality of water in winter season. Thermotolerant faecel coliform ranges from 16 to 16,500 colonies and total coliform ranges from 22 to 18,000 colonies per 100 ml of water. The detail of water contamination of spring season in water supply networks is shows graphically below in figure 4.10.

Table 4.10: Percentage microbiological contaminations in water channels (Spring)

Sr.#	Parameter		Total no. of samples	No. of samples beyond permissible limit	%age
1	Thermotolerant faecel coliform	cfu/1000ml	41	41	100
2	Total coliform	cfu/1000ml	41	41	100

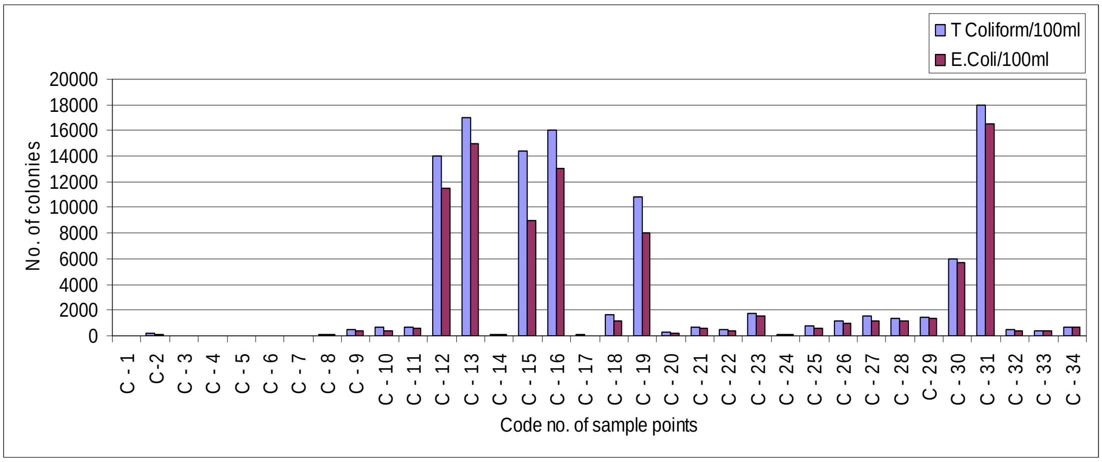

Figure 4.10: Spring microbiological contamination (W-CH)

The classification ranges of contaminants in water channels are same as it was in water channels contamination zones in autumn, to see the seasonal variations in water contaminants. Table 4.11 shows the population lies in each contamination zone from least contaminated to most contaminated zone.

Table 4.11: Population in water channel's contamination zones (spring)

Water Quality Zones	Category	Contaminant ranges	%age Population Affected
Intermediate Risk Zone	C	10-100 colonies per 100 ml	1
High Risk Zone	D	100-1000 colonies per 100 ml	46
Very High Risk Zone	E	>1000 colonies per 100 ml	53

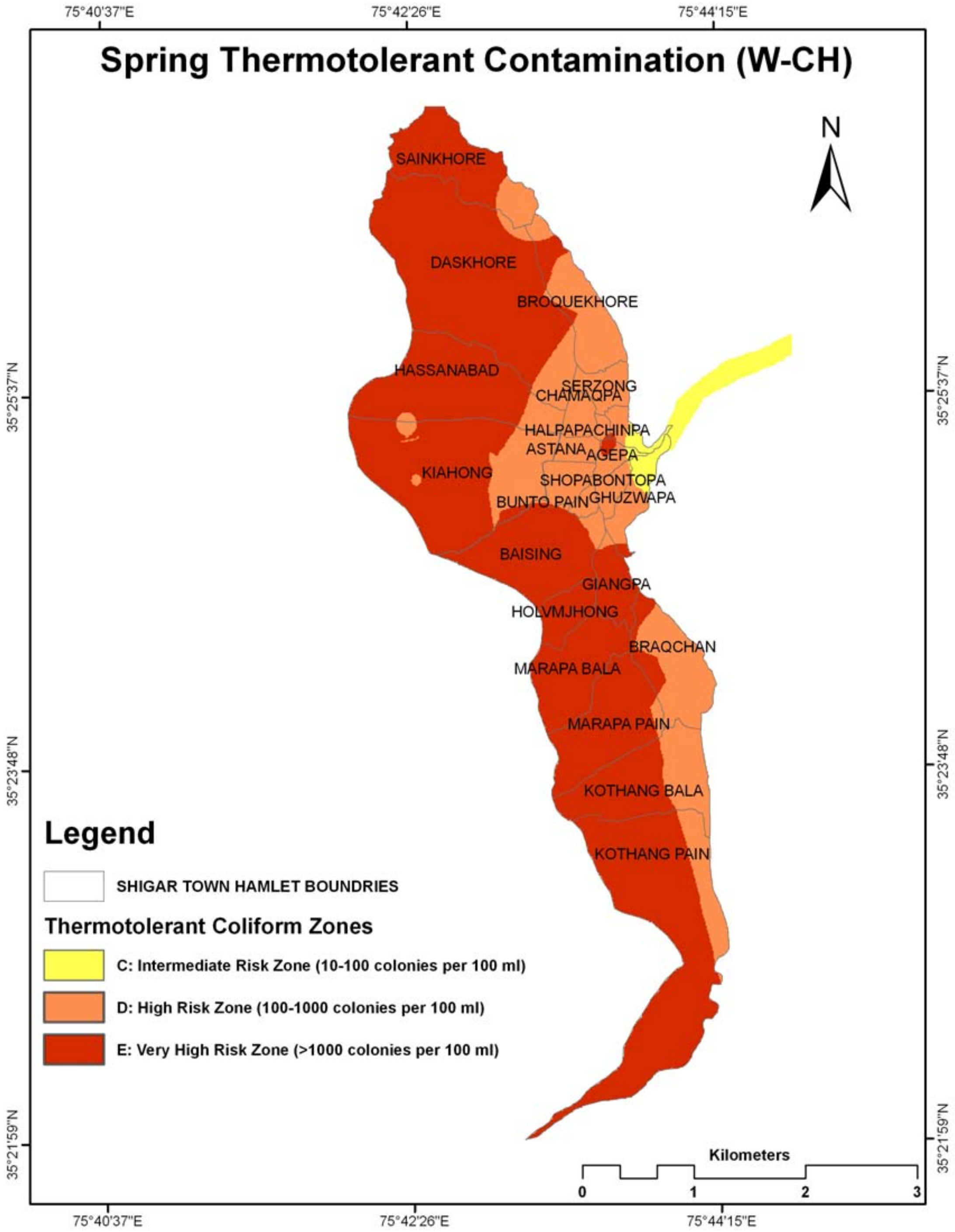

Figure 4.11 Spring water quality zones (W-CH)

4.4 PHYSICAL CONTAMINATION

According to WHO, the physical water contaminants does not matter as much as chemical and microbiological contaminants. Physical and chemical water quality data is available for winter season only. Maximum physical water quality data collected from Shigar town is found within the permissible limit given by WHO water quality guidelines standards. There are few samples that exceed the limit of drinking water quality guidelines. The Table 4.12 shows the values of physical contaminants found in drinking water of Shigar town and highlighted field shows the samples that exceed the permissible limit set by WHO. Due to small number of samples collected and less effect of physical contamination on human health, the physical parameters are not treated in GIS. The results of physical contaminations are shown in the form of tables only for better understanding of physical parameters found in drinking water of Shigar town.

Table 4.12: Water quality data results (physical parameters)

Sample Code	Color	Odor	Taste	Electrical Conductivity(µS/cm)	PH	Turbidity (NTU)
N/S-1	CL	UO	UO	394	8.14	4.20
N/S-2	CL	UO	UO	394	8.14	4.20
N/S-3	CL	UO	Obj.	7.85	7.85	**24.00**
H/S-3	**Light Muddy**	UO	UO	461	7.80	**19.00**
H/S-3(WP)	**Light Muddy**	UO	UO	409	7.39	6.00
KIA/S-3	CL	UO	UO	434	7.96	5.90
MB/S-3	CL	UO	UO	409	7.39	**6.90**
KNP/S-3	CL	UO	UO	408	7.75	**6.10**

(Source: IUCN, 2007)

UO: UnObjectable, CL: Clear, Obj: Objectionable

The highlighted bold color in table shows the sample that goes beyond the permissible limit given by PCRWR and WHO drinking water quality standards. It is found that only, turbidity, color and taste goes beyond the limits in some samples.

4.5 CHEMICAL CONTAMINATION

In terms of chemical parameters, there was not a single parameter found that exceed the Maximum Allowable Limit (MaxAL) of water for drinking purpose set by WHO. The Table 4.13 shows the statistical results for the better understanding to see the chemical contaminants found in drinking water of Shigar town.

Table 4.13 Some statistical description on chemical data of Shigar town

Variable	Qty	Min	Max	Mean	Std. Dev	Variance
Bicarbonates	8	122	142	130.13	8.84	78.13
Calcium	8	45	55	50.25	3.54	12.5
Chloride	8	6	8	7.25	1.04	1.07
Hardness	8	187	217	193.25	10.61	112.5
Magnesium	8	14	19	16.25	2.05	4.21
Potassium	8	3.4	5.1	4.33	0.65	0.43
Sodium	8	5	6	5.38	0.52	0.27
Sulfate	8	68	94	77.17	8.13	66.13
Nitrate	8	0.1	0.7	0.48	0.19	0.04
TDS	8	224	267	236.13	14.56	212.13

(Source: IUCN, 2007)

Note: all above results in Table 4.13 are the results (mg) in 1000 ml of water

4.6 QUALITY WATER AVAILABILITY IN SHIGAR TOWN

After the comparison of quality of water in water supply network, channel water and pit's water in Shigar town, it is concluded that the water supply network is the best quality water in Shigar town as compare to other sources. The results give the strength to study the accessibility and availability of quality water in Shigar town. As mentioned above AKCSP, WASEP and local Government are providing the facility of water supply network in Shigar Town. Study area is differentiated into three classes of availability of quality water in Shigar town shown in figure 4.12.

Table 4.14 Quality water accessibility to percentage of population

Classes	Criteria (distance from settlements)	Population
Easily Accessible	<20m	46%
Hardly Accessible	20m to 50m	23%
Not Accessible	>50m	31%

Table 4.14 shows that there is 46% population of Shigar town who have easy access to water supply network and 23% population have no access of water supply network (there is no access to water supply network within the range of 50m). The people that have no access of water supply network in the range of 50m lies in Not Accessible zone of quality water accessibility. Figure 4.12 shows the built-in area map and the population that has access to good quality water (Easily Accessible, Hardly Accessible and Not Accessible zones) is shown by blue, dark brown and yellow color.

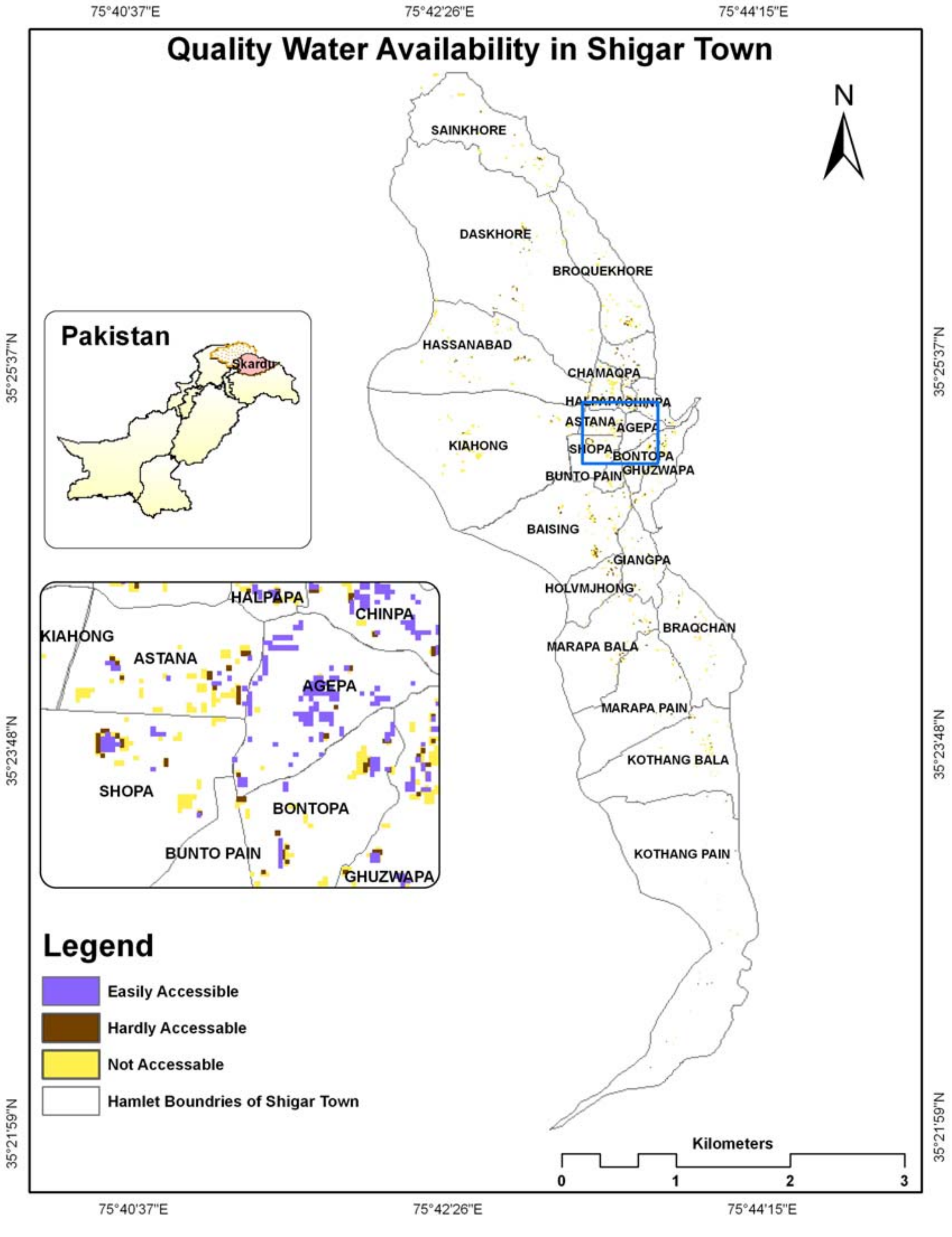

Figure 4.12 Acceptable quality drinking water availability map of Shigar town

4.7 WATER CHANNEL NETWORK IN SHIGAR TOWN

The data collected of water channels by field survey and then embedded on study area QuickBird image. The channels distributed into three classes, Main Channels, Sub-Channels and Tributaries. The distribution is based on the life, length, water flow and width of the channel etc. Major channels are named according to the information collected from local community of Shigar town. Table 4.15 shows the length of each water channel's type in Shigar town.

Table 4.15 Length of surface water channels in Shigar town

Class Name	Total Length (km)
Main Channels	38
Sub-Channels	59
Tributaries	80

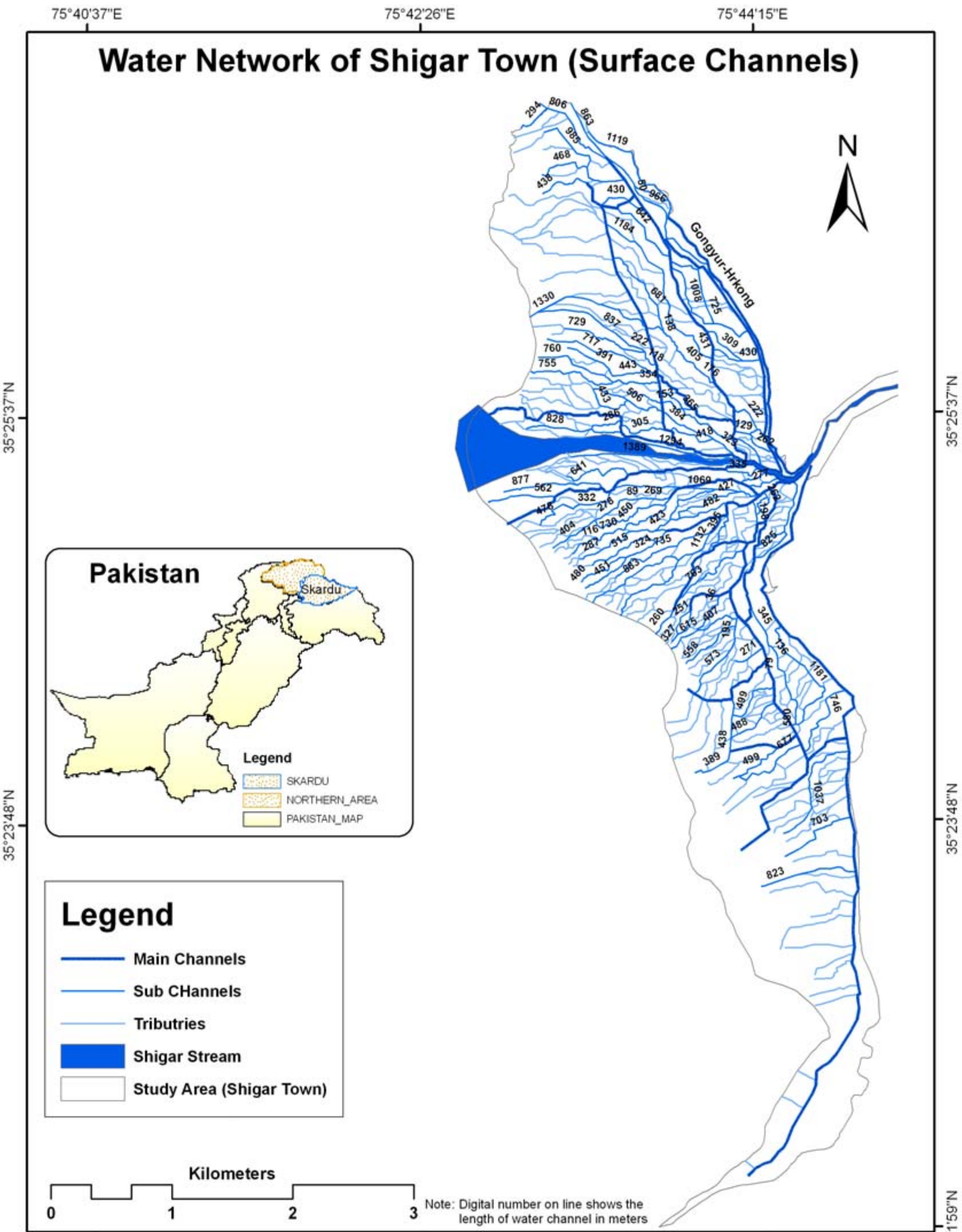

Figure 4.13 Surface water network of Shigar town

4.8 SHIGAR TOWN HEALTH INFORMATION SYSTEM (STHIS)

An application is designed to visualize the processed medical data in the form of map by using mapobject 2.2. Application is in the form of package that can be installed at any computer without any specific software requirements. All the medical data is embedded in the hamlet boundaries layer. There are some basic functions added to this application for best representation of disease data, are listed below:

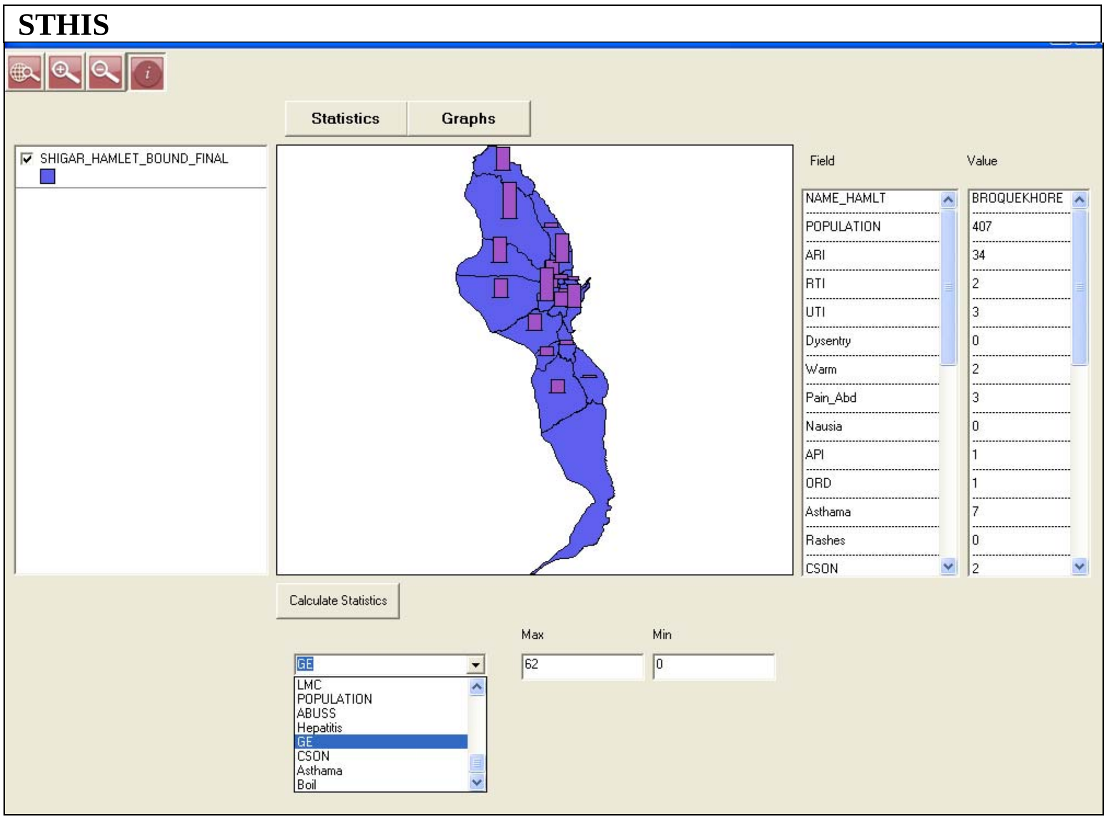

Figure 4.14: Interface of Shigar town health information system application

Map Functions	**Statistical Function**
Zoom-in	Maximum
Zoom-out	Minimum
Pan	Mean
Identify	Sum

4.8.1 Water Related Infection Ratio in Shigar Town

On the basis of medical database comparison with the results of waterborne diseases it is concluded that in Shigar town, 57% diseases are waterborne. The figure 4.15 shows graphically, the percentages of most common water borne diseases found in the data of Shigar health centre in Shigar town.

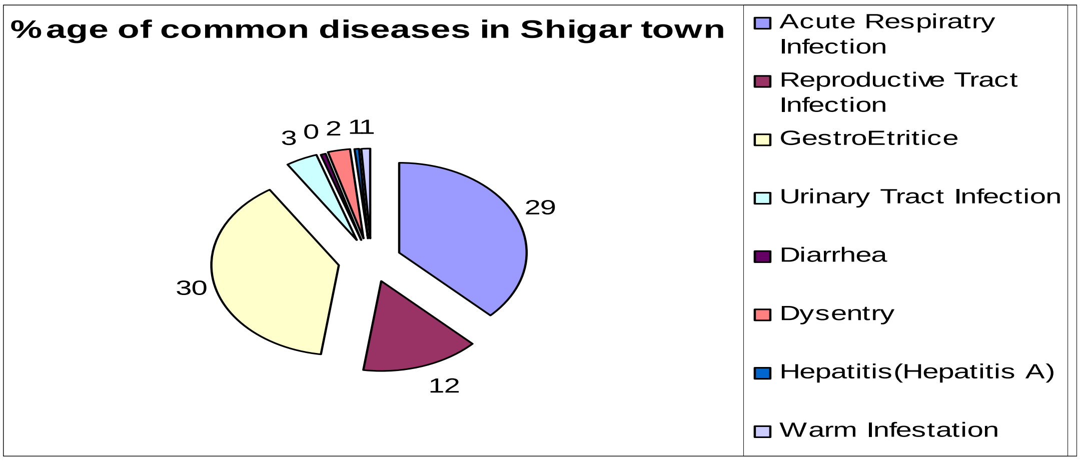

Table 4.15: Most common diseases found in disease data of Shigar town

CHAPTER 5

CONCLUSION AND RECOMENDATIONS

Based on the results obtained during this study it is concluded that water supply network is a good quality water source in Shigar town. The quality of channel water comes at second number in Shigar town. The main factors that contribute in water contamination are poor sanitation system and lack of public awareness. This shows that all the contamination induced by human beings in different ways such as animal waste, household waste and carelessness of people. Water channels within built-in areas are at highest risk of bacterial contaminations. Microbiological contamination of water supply system is very less as compared to the water pits and water channels. Water pits are at high risk of biological contaminations. The poor water supply system in the area also degrades the quality of water. The discharge/pressure of water in water supply system is higher near the intake of water supply network and decreases gradually due to the pipe burst and pipe leakage. 57% of all of the diseases in Shigar town are waterborne. In seasonal water quality comparison of all three water distribution systems it is found that quality of water in autumn is better that than of winter and spring season.

RECOMENDATIONS

Keeping in view the findings of water quality assessment and observation of sanitary condition during field survey of Shigar town, the following recommendations are made to improve the quality of water in Shigar town.

i. The involvement of community should be encouraged with respect to conservation of stream water to make its quality better and to stop probable causes of water contaminations. The people of area are not well aware about the quality of water. Through public awareness programs, it is needed to present the difference in the quality of water pits, water channels and water supply network.

ii. Assist local government, to install a complete water supply network in Shigar town, as water supply system has minimum contaminations and considered good quality drinking water in Shigar town. It is concluded that about 54% of the population of Shigar town has no/limited access to good quality water (water supply network) is Shigar town.

iii. A regular maintenance in needed to improve the existing water supply system to overcome microbiological contamination due to pipe leakage and pipe burst.

iv. It is needed to provide the facility of water supply in 24 hours through water supply system, as 4 to 6 hours per day (noted during survey) does not fulfill the public requirements.

v. A proper and complete sanitation network should be developed in Shigar town to eliminate the possibility of water contamination in the area.

vi. Assistance should be given to the community of Shigar town, to use the water of water supply system as a sole source of drinking water and for domestic use.

vii. Quality of water channels can be improved by constructing covered water channels within the built-in area or using pipelines.

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