GEOCHEMICAL CHARACTERISTICS OF POTABLE WATER IN AND AROUND KOLASIB TOWN, MIZORAM, INDIA

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DECLARATION

I, Vinod Kumar Bharati, hereby declare that the subject matter of this thesis is the record of work done by me, that the contents of this thesis did not form basis of the award of any previous degree to me or to the best of my knowledge to anybody else, and that this thesis has not been submitted by me for any research degree in any other University/Institute.

This is being submitted to the Mizoram University for the degree of Doctor of Philosophy in Geology.

Date: 18.03.2011 **(VINOD KUMAR BHARATI)**
Place: Aizawl

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CHAPTER 1: INTRODUCTION

1.1 INTRODUCTION

Water is elixir of life, without it life is not possible. The socioeconomic growth of a region is severely constrained by non availability of safe drinking water (Kumar *et al,* 2005). Civilizations have flourished with the development of reliable water supplies and they collapsed as the water supply failed. Fresh water is the most precious and one of the most vital resources of all. Requirement of water for drinking and domestic purposes depends on physical as well as socio-economic development of the area. Most of the water situations and problems are local and regional in nature. Since long distance inter-regional transportation in large quantities is impracticable, the need of place of region for fresh water has to be made from its own resources and supplies. The quality of water has been continuously declining globally in general and in developing countries in particular, due to natural and anthropogenic processes (Carpenter *et al*, 1998; Chen *et al*, 2002). Water quality also gets modified during the course of movement of water through the hydrological cycle and through certain processes like evaporation, transpiration, selective uptake by vegetation, oxidation-reduction, cation exchange, dissociation of minerals and precipitation of secondary minerals, mixing of water, leaching of fertilizers & manures and biological processes (Appelo and Postma, 1993; Gupta *et al*, 2008).

Water is an important constituent of the earth geosystem. There is plenty of water on the earth surface, the fresh water, however is limited and a large part of it is in a polluted state at present. Polluted water is the greatest source of disease. Almost half of the world's population do not have proper water supply. Only 2.7 percent of the total global content of approximately 1.4 billion cubic kilometers water is fresh and suitable for human consumption. Of this again, about 77.2 percent is permanently frozen, 22.4 percent occur as ground water and soil moisture, 0.35 percent is contained in lakes and wetlands and less than 0.01 percent in rivers and streams. Obviously, the amount of water actually available above the ground, that is, in the atmosphere, is a very small fraction and is estimated to be $1x10^{-5}$ of the total water resources of the world (Rao, 1979). The minimum requirement of clean drinking water per person is about 3 litres per day or one cubic metre per year. Thus the minimal amount of drinking water at the global level needed for survival annually is only 5 billion cubic metres or 5 cubic kilometers. However, this requirement is not fulfilled in all parts of the world (Sharma, 1987).

About 86 percent of the rural population lacks an adequate water supply and that 92 percent lack adequate facilities for excreta disposal. Only 28 percent of the urban population has sanitation and sewerage facilities and about 29 percent have no sanitation facilities of any kind. About 38 percent of urban population in India, who are below poverty line, has no access to water (Singh et al, 2003). It is estimated that about 40 countries and one billion people will not have adequate water supplies in the near future. By 2025 it will be 2.3 billion people. Today 6 billion human beings compete for this scarce resource and by 2050; 10 billion will go thirsty (Panda, 2003).

Potable water is one that is free from disease causing microorganisms (pathogens), low in concentrations of compounds that are acutely toxic or that have serious long term effects on health. Potable water should also be clear, not saline, and free from compounds that can cause colour, taste and odour (Pritchard *et al*, 2007). Quantifying the major ion composition of stream waters also has broad implications *i.e.* water quality type, hydrogeology characteristics, rock-weathering processes and rainfall chemistry (Brennan and Lowenstein, 2002; Cruz and Amaral, 2004). The chemical composition of ground water is controlled by many factors *viz.* composition of precipitation, geological structure and mineralogy of water sheds and aquifers and geological processes within the aquifers (Andre *et al.*, 2005).

Keeping in view the importance and the vulnerability of water quality towards the human health, number of studies on assessment of drinking and irrigation water quality have been carried out mainly for mining /industrial areas in different parts of India (Agrawal and Jagetia, 1997; Niranjanbabu *et al*, 1997; Mazumdar and Gupta, 2000; Dasgupta and Purohit, 2001; Khurshid *et al*, 2002; Sujatha and Reddy, 2003; Sreedevi, 2004; Pulle *et al*, 2005; Hussain *et al*, 2005;

Sunitha *et al*, 2005; Subbarao, 2006; Mishra *et al* (2003). Broadly all have concluded that water was found suitable either for drinking or irrigation purposes. Gupta *et al* (2008) have studied the geochemistry of ground water of Burdwan district of West Bengal in order to assess its suitability for drinking purposes. A study of surface and ground water in the Chalakudy river basin, southwestern India has been conducted to assess the quality by Basu *et al*, (2007). Jeelani and Shah (2007) have studied the hydrogeochmistry of water samples from the four basins of Dal Lake of Kashmir valley and reported that the lake is alkaline in nature dominated by Ca^{2+}, Mg^{2+} and HCO_3^- ions. In the industrialized sub-urbs of Pondicherry, alarming situation due to the presence of excessive concentration of such toxic elements as As, Hg, Fe, Mn, and Cd has been reported in ground water and surface water. Further, the major water quality parameters *viz.* Electrical Conductivity (EC), Total Dissolved Solids (TDS), Hardness, Alkalinity, SO_4^{2-} and Biological Oxygen Demand (BOD) have been found to be exceeding the permissible limits during all seasons in sub-urbs of Pondichery (Abbasi and Vinithan, 1999).

India is a country known to be for studded with scenic beauty, comprising of various landforms criss-crossed by rivers. There are fourteen major rivers in India that share 83 percent of the total drainage basin and contribute 85 percent of the total surface flow (Chaudhuri, 1983). India receives an average annual rainfall equivalent to about 4,000 billion cubic metres which are unevenly distributed both spatially as well as temporally (Engleman and Roy, 1993). The relationship between water quality and human activities is extremely complicated. With rapid growing population and improved living standards, the pressure on water resources is increasing. Exploitation of water from the resources for domestic, industrial and agricultural purposes puts resources *Viz. Rivers*, lakes, estuaries *etc.* into degraded state. The growth of population and industries are responsible for the increase in the total volume of sewage on one hand and the degree of toxicity due to industrial effluent on the other, in which the share of obnoxious matter has markedly increased (Gaitonde, 1995; Murugesan *et al*, 2002). These increased volume of sewage and toxicity thereby, resulting into Eutrophication of water bodies and in turn leading to the invasion of foreign vegetative species (Murugesan *et al*, 2005).

1.2 LOCATION AND ACCESSIBILITY OF STUDY AREA

Mizoram is located between $22^0$19'N and $24^0$19' N latitude and $92^0$16'E and $93^0$26'E longitude covering a geographical area of 21,081 sq.km (Plate–I). The state is bounded by Chin Hills (Myanmar) in the east, Manipur and Cachar District of Assam in the north, Tripura and Bangladesh in the west and again Myanmar in the south. The average length of the state (from N-S) is 277 Kms whereas the average width (from E-W) is 121 Kms.

Mizoram is connected by NH 54, an all weather road to Silchar, Assam. Aizawl, the state capital is about 180 Kms from Silchar (Assam) whereas the second largest town of the state, Lunglei, is about 410 Kms away from Silchar. The state is also approachable from Churachanpur (Manipur) and Tripura but the roads that connect these places are not operational throughout the year. Rail link has been established at Bairabi from where passenger as well as goods train services are available regularly. It is also connected to Kolkata, Imphal and Guwahati by air route. The Airport is at Lengpui, about 30 km. away from Aizawl and about 75 km from Kolasib.

The area under study in situated in and around the Kolasib town. Kolasib is the district headquarters of Kolasib district of Mizoram situated over the tightly folded chain of hillocks. It is situated between 23^0 70' S and 24^0 50'N latitude and 92^0 50' W and 93^0 longitude. The total area of the district is 1472.12 Sq.Km of which 70 percent of the total area of the District is under Forest cover. Total number of villages in the district is 34, four sub-towns namely-Kawnpui, Bualpui, Bairabi, Vairengte and one full-fledged town, Kolasib. It is bounded by Cachar and Hailakandi district, Assam on the north and north west respectively, on the south and east by Aizawl district and on the south west by Mamit district, Mizoram. As per 2001 census, the population of Kolasib district is 65,960.

1.3 CLIMATE AND RAINFALL OF MIZORAM

Mizoram enjoys a moderate climate. It is generally not so hot in summer but fairly cold in winter. The winter temperature ranges from 7^0C to 20^0C. The summer temperature is usually between 17^0C to 30^0C. The average temperature of

Kolasib in winter is 11.8^{0}C to 21.30^{0}C and in summer, it varies 20.80^{0}C to 29.80^{0}C. During the cold season, an individual minimum temperature may go as down as 5^{0}C.

The air is highly humid throughout the year. Relative humidity is highest during southwest monsoon, reaches above 90 percent. Wind speed is generally gentle except in March to July. During those days, the disturbances in Bay of Bengal also affect Mizoram in general and Kolasib in particular.

Mizoram comes under the influence of monsoon with the beginning of May. Therefore, the maximum rain is received in between May and September. Mizoram has annual rainfall of 2540 mm. while the average annual rainfall in Kolasib is 3500 mm. The northwest parts of the state get maximum rainfall (over 3500 mm.). The southern parts also get high rainfall over 2500 mm. The climate of Kolasib is characterized by its pleasant cool weather, relative humidity and abundant rainfall.

Table 1: Rainfall data of the study area for five years

YEAR	2004	2005	2006	2007	2008
Month	Rainfall in mm	Rainfall in mm	Rainfall in mm	Rainfall in mm	Rainfall in mm
January	0	0	0	0	0
February	30.0	10.0	70.0	80.0	38.0
March	208.0	325.0	110.5	30.0	335.0
April	122.0	35.0	289.0	309.5	278.0
May	610.0	799.0	380.5	403.0	453.5
June	435.0	177.0	678.5	670.0	703.0
July	743.0	905.0	507.0	395.5	388.5
August	655.0	494.0	650.0	718.0	725.0
September	480.0	401.0	590.0	705.5	718.0
October	65.0	32.0	107.5	281.5	62.0
November	0	90.0	60.0	105.0	57.0
December	0	0	0	0	0
Total	3348.00	3268.00	3443.00	3698.00	3758.00

(Source: Indian Council of Agricultural Research, ICAR, Kolasib, Mizoram)

1.4 VEGETATION

Mizoram is very rich in vegetation. Forest and paddy fields cover major part of the area. Forest of Mizoram is very rich where teak trees and bamboos are grown in abundance. It is covered by various kinds of medicinal plants and food trees. Since time unmemorable these ethno medicinal plants have been used in the treatment of various kinds of ailments. Lorrain (1940) was the first to document the ethno medicinal plants of Mizoram and gave details of the traditional medicinal plants used by the Lushais. Lalramnghinglova (1991) has documented 437 plants with their local names, botanical names, family, distribution, description and medicinal uses. However, due to jhoom type of cultivation, the forest cover is decreasing every year. Horticultural crops have also acquired great importance in the state due to diversified topography, agro climatic conditions and soil resources.

1.5 PEOPLE, THEIR LIVING CONDITION AND FOOD HABITS

Majority of the people living in the study area are Mizos.The Mizos are divided into several tribes - the Lushais, Pawis, Paithes, Raltes, Pang, Himars, Kukis etc. Society is based largely around tribal villages. The chief's house and the zawlbuk (community house for young, single men) are the focus of village life. Mizo and English are the official languages. The literacy rate in Mizoram is about 82 percent, one of the highest in India. More than 80 percent of the population is Christians; the great majority is Protestants who were converted by missionaries during the 19th century. There are Muslim, Buddhist, and Hindu minorities. The nomadic Chakmas practice a combination of Hinduism, Buddhism, and animism (the worship of nature deities and other spirits).

Though mostly Christians, the hill people have kept alive their rich cultural heritage, colourful customs and lively traditions. An interesting tradition amongst the Mizos is the code of Ethics which revolves around tlawmngaihna, an untranslatable term which means that every Mizo is duty bound to be hospitable, kind, unselfish and helpful to the poor and needy.

Festivals and dances of the Mizos have a unique tribal flavour. Other than Christmas and New Year's Day which are the most popular festivals, Chapchar Kut (after clearing of jungles for cultivation of the jhum crop in February-March), Pawl Kut (after harvesting in December) and Mim Kut (dedicated to departed souls after the maize harvest in September) are the other occasions celebrated with much gusto. The most popular dances of Mizoram are Cheraw (Bamboo dance), Khuallam (dance for visitors or guests), Chheih Lam (at the end of a day's work) and Solakar or Sarlamkai (prevalent among the Mara and Pawi tribes).

Food habits of the people constitute two substantial meals throughout the day. They mainly consume rice, pork, chicken, beef, egg, fish etc. Other than potato and common vegetables they depend on leafy vegetables for their vegetable needs.

1.6 PHYSIOGRAPHY OF MIZORAM

1.6.1 Drainage System of Mizoram

The Mizo Hills have ranges running from north to south. The average height of the hills is about 900 m. The hills are steep and separated by rivers which flow either to the north or to the south, creating deep gorges in between the north-south hill ranges. There are innumerable rivers, streams and brooks in the state. In the north, the Tlawng (Dhaleswari), the Tuirial (Sonai) and the Tuivawl start from the middle of Mizoram and flowing north, fall in the Barak River in Cachar district of Assam. In the south, the Karnafuli flows north from the southern tip of the state and near about the middle it flows to Bangladesh where it has been tapped for a huge hydel project. The Koladyne River enters Mizoram from Myanmar and flowing south, it enters Myanmar again. The drainage system as a whole is said to be dendritic in nature and the streams are youthful stage and nallas have much straightened and deep courses.

1.6.2 Geomorphology of Mizoram

As the terrain is very immature, topographical features show prominent relief. The major geomorphic elements are both structural and topographic 'highs' and 'depression flats' and 'slopes' sculptured on the topographic surface in a linear fashion. The physiographic expression of the state is imparted by approximately N-S trending steep, mostly anticline, longitudinal (linear fashion), parallel to sub-parallel hill ranges and synclinal narrow valleys with series of parallel hummocks or topographic highs. In general, the western limbs of the anticlines are gentler than the eastern limbs. In many cases, steep rock scarps are produced due to faulting especially along the highly dipping fault planes. The other geomorphic elements are the high dissected ridges with the formation of deep gorges, spurs, keels and cols, which developed due to intensive erosion during the isostatic adjustment. The difference of elevation between valley floor and hill tops greatly varies from east to west. The steep hill ranges are more towards east than towards west.

The major drainage pattern having different bifurcation ratios follows the N-S trending depressions and gorges in the low level topography in between them. The depressions and gorges, in most cases, are the physiographic expressions of the faults or other structural patterns.

1.7 SCOPE OF PRESENT STUDY

The majority of research work undertaken on water in developing countries (Chilton and Smith-Carrington, 1984; Lewis and Chilton, 1984) has focused on surface and borehole water quality with hardly any work being undertaken on shallow wells. Shallow wells are one of the most important types of water supplies for domestic purposes for rural districts in Malawi (Staines, 2002). The quantity of water supplied by the PHED department in the study area is not enough to meet the daily requirement of water for drinking and other household activities of the people. As on May12, 2009, the Kolasib town has only 1801 water connections for a population of 19008. According to the record of the PHED, Kolasib, the population benefited by water connections is 11,317 suggesting the fact that 7,691 people of Kolasib town are forced to fetch water for their daily needs from *tuikhurs* (spring)(Plate III-IV) or other sources including rain water (Plate VI). Water in rocks circulates through the secondary openings represented by joints, cracks, fissures and such other planes of discontinuity. The weathered residuum of the hard rocks as well as the fractures, joints, fissures, faults and other zones of discontinuity are the principal repositories of groundwater in the area (Singh *et al*, 2007). Similarly, Vairengte and Bilkhawthlir have 547 and 194 connections for 7715 and 4084 population respectively. Kawnpui is a sub-division headquarters in the district but it has only 256 water connections. People of the study area have been consuming water for their drinking and household purposes without any treatment.

In fact, there have been no detailed investigations carried out to evaluate the quality of potable water in the study area. The objective of the present work is:

- To assess the physical, chemical and bacteriological characteristics of potable water.

- To determine the level of concentration of various heavy metals and trace elements in potable water.
- To understand the sources of various contaminants in order to suggest remedies.
- To develop a data-base on water quality.

1.8 LITERATURE REVIEW

A number of studies have been carried out on water chemistry across the world. According to Garrel (1965) dissolution of rocks removes certain ions such as Ca^{2+}, Mg^{2+}, Na^{+} and K^{+} but at the equilibrium state between rock and water the ions which have been mobilized into the aqueous phase will be removed from the system producing secondary minerals such as calcite and clay. Other than rocks, HCO_3^- in water is derived from carbon dioxide extracted from air and produced in soil by biochemical activity (Hem, 1985). The rain water when passes down the organic rich soil the carbon dioxide gas present in the unsaturated pore spaces reacts with water to form carbonic acid, which in turn helps in dissolution of organically and chemically precipitated calcite and dolomite in soil (Merrits, 1997). The study of Jalali (2006) has demonstrated that the chemical composition of groundwater differs according to water types. They have concluded in their study that dissolution of halite, gypsum, dolomite, calcite and pyrite weathering determines Cl^-, SO_4^{2-}, HCO_3^-, Na^+, Ca^{2+} and Mg^{2+} content in groundwater. Langmuir (1997) has observed that the most surface water and shallow groundwater, due to precipitation process as the source is Ca^{2+} - HCO_3^- water type, with decrease in Na^+ attributes to its intake in the formation of clay, helped by the pH range which is near neutral or less. But with increase in depth, an increase in pH takes place, which can be related to carbonate dissolution induced by cation exchange with replacement of Na^+ ion (Adams *et al*, 2001; Parkhurst, 1995). This process results in the formation of Na^+-HCO_3^- type of groundwater. Recently, many research projects have examined the relationship between nitrate levels and depth of wells (Hudak, 1999, 2000; Lee *et al*, 2003; Lake *et al*, 2003). Gerba and Mc Nabb (1981) have discussed fate and transport of pathogens and microbial activity in groundwater environments as aspects of microbial groundwater pollution. Ladd *et al* (1982) have studied groundwater and stream water in Alberta, Canada and have found acridine orange direct counts (AODC) of bacteria in saturated zone groundwater are about one log higher than the AODC of stream water in their study location. The hydrological drought has been defined by Yevjevich (1967) as the climate that leads to spatial and temporal water deficits.

Hem (1985) has pointed that some mineral surfaces that are exposed to water at neutral pH, have a net positive charge, where solute anions are retained. Ibanez *et al* (2007) have defined groundwater as water that occupies voids and spaces between soil, sand and/ or gravel particles, clay, silt and rocks. They have also pointed out that groundwater is present within cracks in the bedrock and can be found under the earth's surface, either flowing slowly as underground lakes or ponds. Surface water is understood as that which is contained in streams, rivers, ponds, lakes, swamps, marshes and springs. According to Ibanez *et al.* (2007), in small streams and rivers, the biological processes do not influence the water composition significantly because the rapid flow will dilute the effect whereas in large, slow moving rivers, the biological processes have enough time to alter the water composition through biodegradation and excretion processes. Surface water is open to pollution of all kinds. Contaminants are contributed to lakes and rivers from diverse and intermittent sources such as industries and municipal wastes, runoff from urban and agricultural areas and erosion of soil (Henry and Heinke, 2004).

A number of studies have been carried out on major and small rivers like Amazon (Konhauser *et al*, 1994), Congo (Dupre *et al*, 1996), Mississippi (Shiller and Boyle, 1987) and Fraser (Cameron *et al*, 1995) for metals and trace elements. These studies have made an attempt to determine the effects of lithology, relief, water discharge, climate and anthropogenic perturbations on the water chemistry. Several studies have been employed for analysis or the closely related Principal Component Analysis (PCA). Many of these studies have been spatially oriented, such as the identification of weathering sources of dissolved species at different locations (Reeder *et al*, 1972; Puckett and Bricker, 1992) and the sources of ions in deposition across a region (Hooper and Peters, (1989). Reid *et al* (1981) identified processes controlling the chemical composition of both precipitation and runoff for a stream in Northeast Scotland, and Williams *et al* (1983) performed the similar study for a stream on Dart moor, England.

Since the discovery of chloroform in chlorinated drinking waters in 1974 the potential carcinogenicity of halogenated disinfection byproducts (DBPs) is now recognized as a secondary health risk (Rook, 1974). Richardson *et al* (2002) and Weinberg (2002) have recognized over 500 DBPs with adverse human health risk potential. Arbuckle *et al* (2002) have grouped these species into several major groups such as trihalomethanes, haloaceticacids, haloaceticnitriles, chloral hydrate, hydroxyfuranone, haloketones, haloaldehydes etc.

A lot of works have been done on the fluoride content in drinking water. Robertson (1984) has studied on the basins of Arizona and has reported concentration of fluoride between 1 and 10 mg/l in groundwater of the area. Granites and volcanic rocks are the common natural sources of fluoride in groundwater in several parts of the world (Apambire *et al*, 1997). Saether *et al* (1995) and Kim and Jeong (2005) have concluded in their study that the high concentration of fluoride in groundwater is not always derived from hard rock. Chae *et al* (2007) have focused on fluorine geochemistry in bedrock groundwater of South Korea and have come to the conclusion that the geological source of fluoride in groundwater is related to the mineral composition of metamorphic rocks and granitoids. They have suggested that the high fluoride in groundwater originates from geological sources and it can be removed by fluorite precipitation when Calcium concentration is maintained. Some researchers have studied the relationship between fluoride concentration and water- rock interaction in various aquifers with different geological settings (Nordstrom and Jenne, 1977; Edmunds *et al*, 1984; Nordstrom *et al*, 1989; Gaciri and Davies, 1993). Fluoride concentrations frequently are proportional to the degree of water- rock interaction because fluoride primarily originates from the geology (Gizaw, 1996; Banks *et al*, 1995; Dowgiallo, 2000; Frengstad *et al*, 2001; Carrillo- Rivera *et al*, 2002). It is also reported that fluoride in groundwater is negatively related to anthropogenic contaminants that may infiltrate from the land surface (Petti and Backman, 1995; Kim and Jeong, 2005)

The geochemical study of water and sediments of some of the largest rivers of the world originating from Himalaya have been investigated by many workers (Raymahashay, 1973; Abbas and Subramanian, 1984; Sarin *et al*, 1989,1990,1992;

Subramanian, 1979; Pande *et al*, 1994; Haris *et al*, 1998 and Pande *et al*, 2000). Rao *et al* (2007) have worked on principal component analysis in groundwater quality in a developing urban area of Andhra Pradesh and have reported that groundwater of Guntur urban area shows both the fresh (TDS<1000 mg/l) and brackish (TDS>1000mg/l) environments with Na^+: HCO_3^- & Na^+: Cl^- faces respectively. They have also suggested that the quality of groundwater is mainly controlled by salinity and pollution processes. According to Choubisa *et al* (1996), prolonged use of alkaline drinking waters contaminated with fluoride cause dental and skeletal fluorosis not only in villagers but also in their domestic animals. Nayak and Sawant (1996) have reported that the heavy metal content in drinking water of Mumbai city is within the maximum permissible limits yet there has to be a routine monitoring system to ascertain good quality water at the consumer end points. Pandian and Sankar (2007) have worked on hydrogeochemistry and groundwater quality of Vaippar river basin of Tamilnadu and have reported limited seasonal variations in quality. They have found that nearly 50 percent pre-monsoon samples are suitable for all uses, while 24 percent are useful only for irrigation; the remaining 26 percent is unsuitable for any use. Sahu and Vaishnav (2006) in their study of fluoride in groundwater around the BALCO, Korba area have concluded that fluoride ion concentrations in open wells and hand pumps of some villages have been found above the permissible limit. They also witnessed skeletal and dental fluorosis in youths under twenty years of age. Madhnure *et al* (2008) and Saxena and Ahmed (2003) have shown that rock-water interaction is the main process in which F^- -rich minerals are decomposed or dissociated from the source rock and F^- is dissolved in groundwater by dissolution. Ramakrishnan (1998) has observed that high concentration of fluoride in deeper aquifers compared to shallow aquifers is due to its high residence time in the aquifer system, thereby having longer contact time for dissolution of F^- -bearing minerals present.

According to Sivasankaran *et al* (2004), the inputs of nitrogenous nutrients and phosphorus in the groundwater system are primarily due to leaching from the fertilizers applied to croplands. Majumdar and Gupta (2000) have reported that nitrate formed by the biochemical activities by micro-organisms or added in chemically synthesized forms to lithosphere and biosphere enters hydrosphere with relative ease, as all these environmental components are dynamically interconnected. They have further observed that nitrate concentration in groundwater is increasing with increasing use of nitrogenous fertilizers in Indian agriculture. Umar and Absar (2007) have tried to understand the sources of dissolved ions and evaluate the influence of anthropogenic activities.

Venugopal *et al* (2009) have suggested that rivers play a major role in assimilating or carrying of industrial and municipal waste water, run-off from agricultural fields, roadways and streets, which are responsible for river pollution. Tiwari *et al* (2005) have assessed the water quality of Ganga River in Bihar region of India. The report suggests that water analyzed from four major drainages of River Ganga in Patna shows that the drain water is highly polluted mainly due to raw sewage is being discharged into the outfall drains. The analyses show that TDS, lead, chromium and cadmium are present more than permissible limits in drinking water at some stations. The TDS pick up in the domestic sewage in Indian cities is generally 400 mg/l (Arceivala, 1998).

The amount of calcium and magnesium in Kolleru lake water of Andhra Pradesh has been found to be higher in summer and decreases in monsoon and winter. The values of electrical conductivity (EC) and total dissolved solids (TDS) have also been found to be lower in winter and monsoon seasons as compared to summer season (Rao *et al*, 1999). Handa *et al* (1981) have worked on the trace elements of surface waters in Uttar Pradesh and have observed that Gomati river water is polluted at Lucknow in respect of copper and zinc while Sai River seems to be polluted with respect to molybdenum.

The Damodar Valley Corporation has propagated industries of multiple natures along the river Damodar, as a result, various types of pollutants are regularly discharged in this river (Trivedi and Kulkarni, 1988). Chakraborty and Konar (2002) have noted that the pH of river Damodar is generally alkaline in nature. Murugesan *et al* (2007) have pointed out that human activities near the aquatic systems greatly affect the physico-chemical and biological quality of the water-system. Ram and Singh (2007) have studied the Ganga water quality at Patna and have found that there is no harmful chemical contamination in it.

Despite the fact, that toxic metals have also been found below detection limits, however, the presence of higher population of microbial fauna indicates that the water is contaminated and is not suitable for organized bathing as well as for drinking purposes without conventional treatment.

Jeelani and Shah (2007) have reported that like other Himalayan lakes, Dal lake of Kashmir is alkaline in nature, dominated by Ca^{2+}, Mg^{2+} and HCO_3^- ions. The geochemical characteristics of the lake water are mostly influenced by the lithology of the basin and weathering of carbonate and silicate rocks and Karewa deposits of the catchment area. Sunitha *et al* (2005) identified that the electrical conductivity finds higher level correlation significance with many of the water quality parameters, such as total dissolved solids, total alkalinity, chlorides, sulphates, carbonates, total hardness and magnesium. Mahajan *et al* (2005) identified that all the parameters are more or less correlated with others in the correlation and regression study of the physico-chemical parameters of groundwater. Kalyanaraman (2005) identified that the water of groundwater can be predicted with sufficient accuracy just by the measurement of EC alone which provides a means for easier and faster monitoring of water quality in a location. Achuthan *et al* (2005) concluded that the correlation study and correlation coefficient values can help in selecting treatments to minimize contaminations in groundwater. Yadav *et al* (2007) studied on recharging of bore wells and analyzed harvested rooftop rainwater in houses of Udaipur city of Rajasthan. They concluded that rooftop rainwater harvesting system is very effective measure in increasing the quantity of water in bore wells. Dutta *et al* (2006) have carried out an investigation to find out the sub surface water quality at Makrana, Rajasthan. They have concluded that marble ash and slurry has its impact on the quality of groundwater, water of tube wells and hand pumps of Makrana city shows higher concentration of total dissolved solids, total hardness, total alkalinity, calcium, magnesium, chloride, nitrate and phosphate.

Singh and Lawrence (2007) have studied the groundwater quality of shallow aquifer of Chennai city using GIS. They are of the opinion that higher TDS and Cl/ HCO_3 ratio is indicative of the fact that the sea water has intruded to a considerable area adjoining the coast due to over exploitation of groundwater. The tsunami brought large scale sea water inundation and created significant variations in the marine environment and considerable variations were observed in all the parameters (Prasath *et al*, 2007). Devi *et al* (2006) have made an attempt to classify the hydrochemical characteristics of groundwater in Kodagu district in Karnataka based on Handa, Schoeller and Stuyfzand methods and have found that the groundwater of this district is suitable for domestic as well as agricultural purposes. Sunitha and Reddy (2006) studied the correlation of physico- chemical parameters of groundwater samples with nitrate concentration and observed that 92 percent of the samples during pre-monsoon season and 88 percent of the samples during post- monsoon season were exceeding the permissible limit of nitrate concentration which might be due to excessive use of nitrogenous fertilizers in the region. Ozha *et al* (1993) observed that the concentration of nitrate increased with total hardness, calcium and magnesium and decreased as the depth of water table increased. Nitrate enters the human body through the use of groundwater for drinking and causes a number of health disorders namely, methemoglobinemia, gastric cancer, goiter, birth malformations, hypertension etc. when present in higher concentration (Majumdar and Gupta, 2000).

Hussain *et al* (2006) have worked on major ion and heavy metal chemistry of Pachin River (Itanagar) and have reported that the main chemical weathering mechanisms identified in the small watershed can be generalized for the whole Pachin river basin. Heavy metal patterns clearly reflect source input from agricultural activity and urban development. The levels of iron and cobalt are amongst the highest of any rivers of the Indian sub-continent. Chakraborty *et al* (2000) have analyzed water samples of Assam and reported the highest amount of fluoride to be 20.6 ppm. The highest amount of fluoride content in water samples of Guwahati is 6.8 ppm and it can be attributed to Precambrian granite which forms the basement rock of the city (Das *et al*, 2003). Sarmah *et al* (2002) have found fluoride content higher than permissible limit in Assam. The tube well water is of Na^+- HCO_3^- type with a small shift towards Ca^{2+}- HCO_3^- field in pre-monsoon period. Dug well water shifts from Na^+- Ca^{2+}- HCO_3^- field in pre-monsoon to Ca^{2+}-HCO_3^- fields in monsoon and post-monsoon, indicating a different source of recharge water for both deep and shallow aquifers (Saji, 2007).

Plate I

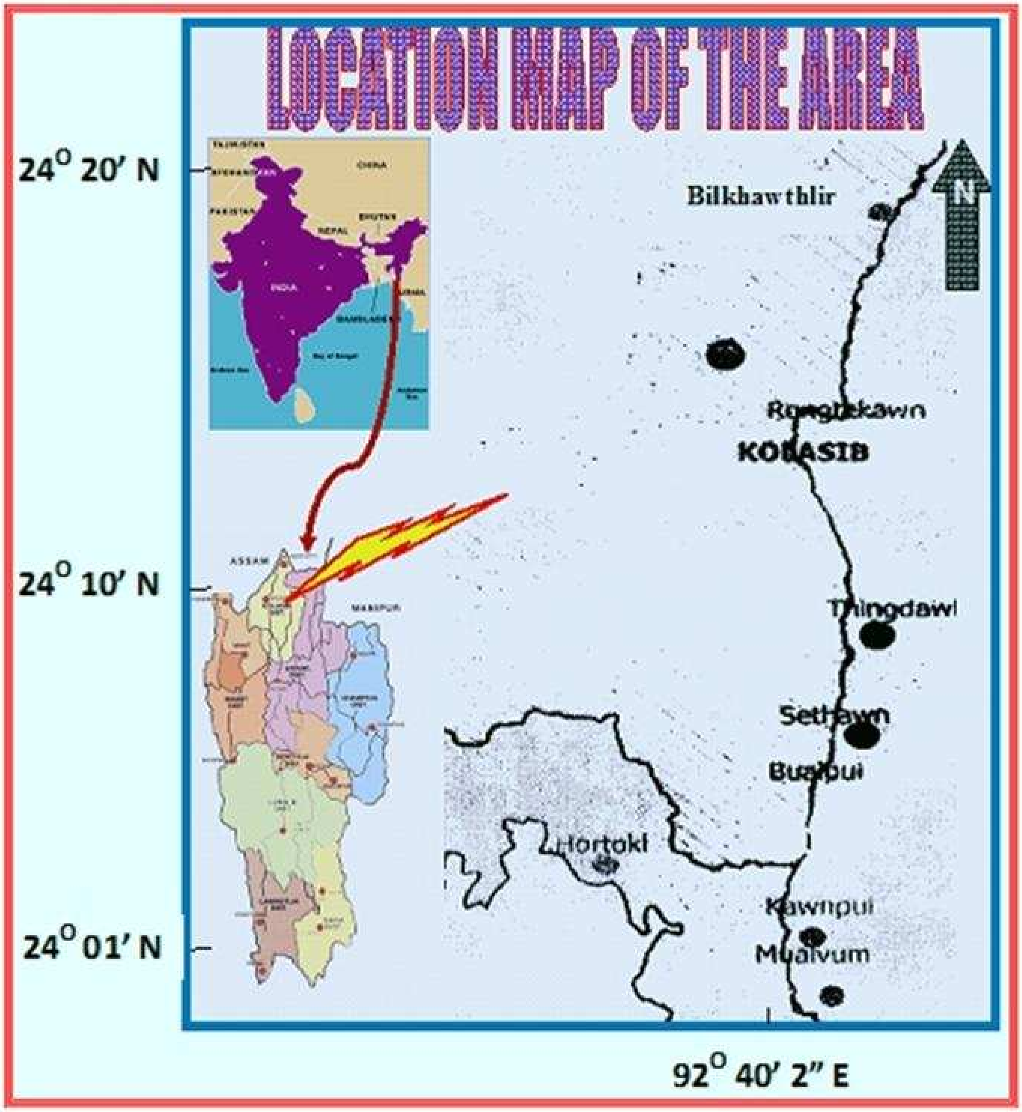
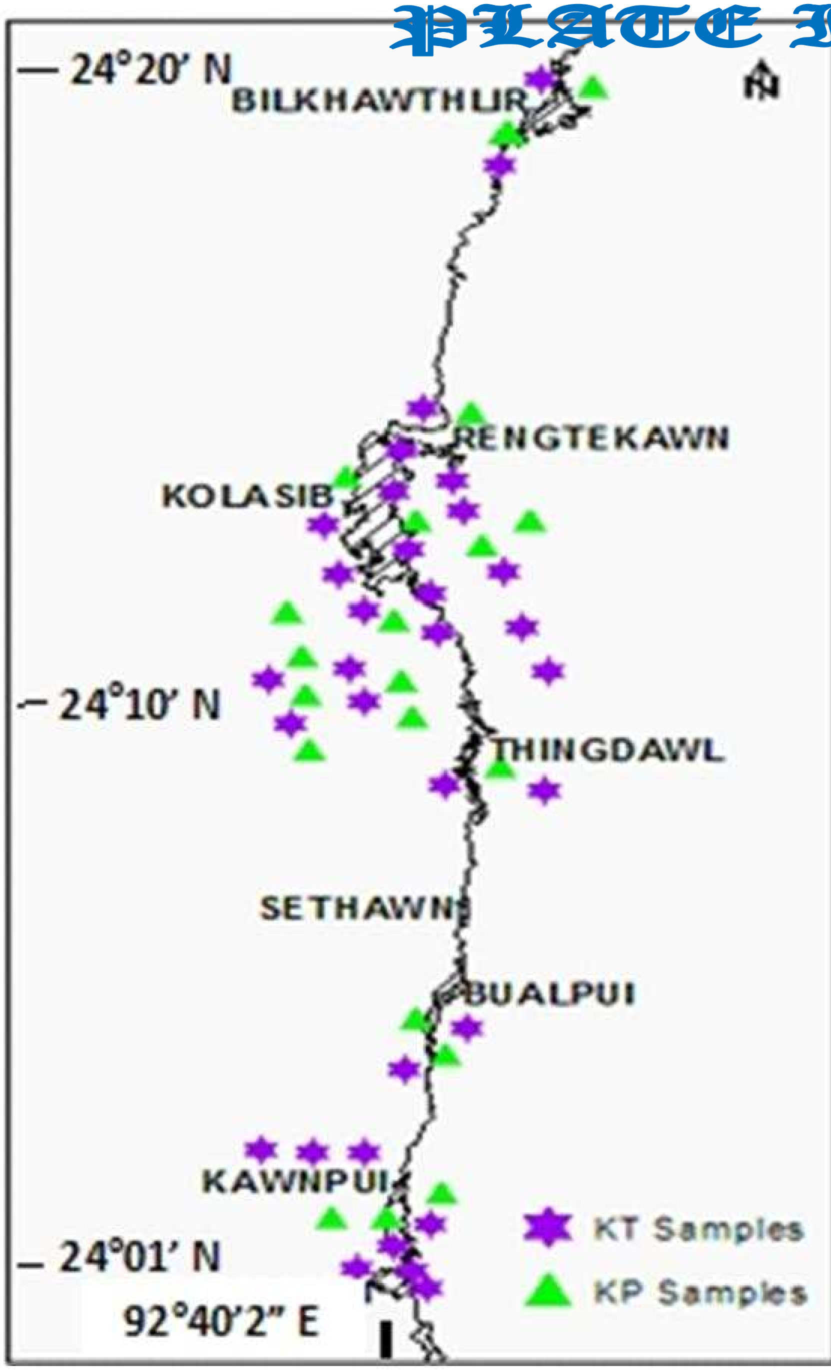

LOCATION MAP OF THE AREA
24° 20′ N
24° 10′ N
24° 01′ N
92° 40′ 2″ E
N
Bilkhawthlir
KOLASIB
Thingdawl
Sethawn
Bualpui
Hortoki
Kawnpui
Mualvum
CHINA
INDIA
ASSAM
MANIPUR

PLATE II



Sample Location Map

PLATE III

A: Tuikhur Kawnpui , Aizawl Road

B: Tuikhur Diakkawn,Kolasib

C: Tuikhur Kolasib- Silchar Road

PLATE IV

A: Tuikhur Kawnpui south

B: Tuikhur Kolasib Venglai Convent Road

C: Tuikhur Silchar Road

PLATE V

A: Tuikhur Kolasib- Diakkawn Field

B: Tuikhur Bilkhawthlir

C: Tuikhur Police Station, Kawnpui

PLATE VI

Rain Water Harvesting in Mizoram

CHAPTER 2: GEOLOGICAL SETTING

2.1 Geology of Mizoram

The area falls within the part of a Tripura - Mizoram mio-geosynclinal basin (southern extension of Surma Valley, cf. Evans, 1964) which evolved after the regional uplift of Barail Group of sediments and thus was related with the plate behavior in the subduction zone west of Arakan - Yoma, after the spreading of Indian Ocean. The geology of Mizoram includes the rocks of Surma Group. They are thickly bedded sandstones, shale, and mudstones of various stratigraphic horizons (Tiwari and Kumar, 1996). Bands of argillaceous material are present within the sandstone near the upper levels of the slopes.The siltstones are generally grey in colour, massive in appearance, hard & compact in nature and exhibiting well defined bedding planes. The shale beds are thinly bedded showing laminated splintery pattern. Mizoram is a part of Tripura - Mizoram mio-geosyncline which constitute a part of the Assam - Arakan geosynclinals basin. The Mizoram Hills (Lushai Hills) have been considered to be forming an integral part of the mobile belt constituted of very tight, elongated asymmetrical, N-S trending anticlines alternating or en-echelon with broad saucer shaped synclines showing slightly arcuate and convex westward sub-meridional trends (Shrivastava *et al*, 1979).

It is apparent that the deposition of sediments of the study area took place, after the uplift of Barail geosyncline, in a great tectonic trough of mio-geosynclinal character having a ‘Bell-shaped’ pattern.

It is revealed from studies that the sediments transport on the present area might have taken place along the canyons and canyon-extension valleys to the lower slopes or continental rise where the deposition took place from the turbidity current. The thickly bedded sandstone and shale was deposited in the channel areas as proximal deposits whereas the silt/shale interlamination was deposited in inter channel distal areas. The hill ranges mainly comprise of compact and resistant older units exposed in the synclinal troughs. The region is exposed mainly by geosynclinal mollasse sediments of Neogene age, comprising of poorly fossiliferous successions of alternating shale and sandstones in varying proportions. The generalized stratigraphic succession as worked out by G.S.I. (1974) is shown in Table-2.

2.1.1 Barail Group

This group of rock is lithologically dissimilar from those of the Bhuban Formation lying to the west. Further, they exhibit different structural alignments. The Barails comprise monotonous sequence of weathered shale, inter bedded and interlaminated with siltstone exhibiting, on weathering, pink, violet, greenish grey and white colorations. Locally, they enclose bands of weathered micaceous, feldspathic, soft, medium-grained sandstone bands. Rarely, the sandstone contains thin stringers and streaks of carbonaceous matter. Unlike Bhuban, the Barails contain few sedimentary structures. The rocks have low (30 - 150) rolling dips and have been folded onto a broad anticline with the axis trending approximately E-W.

The post - Barail unconformity could not be recognized due to two sub-parallel N-S trending marginal - regional strike faults, which have obliterated the evidence of the unconformity.

2.1.2 Surma Group

This group is constituted by Bhuban Formation and Boka Bil Formation. The Bhuban Formation has been divided into the Lower, the Middle and the Upper Bhuban based on lithology and order of superposition. The Boka Bil Formation could not be further subdivided.

2.1.3 Bhuban Formation

This formation comprises predominantly of the alternate sequence of areanaceous and argillaceous rocks. The units of this formation exhibit turbidite features. This formation also shows turbidite features with predominant interference ripples and ridge structures, convolute laminations slump structures, ripple-drift cross-laminations and load casts.

2.1.4 Boka Bil Formation

The rock of this formation exhibits typical turbidite feature, with multiple grading and ripple-drift-cross laminations etc. At places, trough cross-bedding and large beddings are also present.

The monotonous repetitive areanaceous and argillaceous sequences of this formation are typical characteristics of flysch sediments as have been evidenced by lithology, mineralogy, facies change and thickness variations, spatial relationship and finally by turbidite sedimentary structures. Sand-shale ratio within the flysch sequence is indicative of the fact that Barail Group and Lower & Upper Bhubans of Surma Group are the ‘Sandy flysch’ and the Middle Bhubans and the Boka Bils are the ‘Normal’ to ‘Shaly flysch’ respectively.

2.2 Soil Conditions

The soil type generally found within the study area varies from sandy to loam and clay to loam mixed with broken angular shape of varying size. The color of the soil varies from yellowish to brownish grey with varying depth.

The soil is acidic in nature because of the accumulation of organic matters. Generally, natural moisture content varies from 14 % to 23 %, plasticity index varies from 25 % to 26 % and permeability varies from 2.1 X 10^{-5} cm / sec. to 4.2 X 10^{-5} cm / sec. and effective angle of shearing resistance varies from 252 to 402 and the clay content varies from 15 % to 35 % whereas silt content varies from 20 % to 35 %.

2.3 Geomorphology

The Mizoram is situated on the N-S elongated hill from which many sub-hill ranges and slopes are extending towards the eastern and western directions. The hill slopes are dissected by a number of streams and local nallas forming wide and deep gullies due to destructive works of the streams, etc.

Physiographically the area is undulating and conspicuous by the presence of N-S or NNE -SSW trending linear hill ridge with steep slopes representing a very rugged and immature topography. Normally, the western slope is gentler than the eastern slopes. The slope angle generally varies from 80 to 450 forming a concave shape in the middle, but is steeper than near the banks of the streams and nallas.

Table - 2:
Generalized Geological Succession

Age	Group	Subgroup	Formation	Thickness	Generalized Stratigraphy
Recent	Alluvium				Loose silts, clays & gravels
~~UNCONFORMITY~~~					
Early Pliocene to Late Miocene	Alluvium			+900	Massive fine to medium grained, Moderately hard to friable sandtone with occasional bands
----CONFORMABLE AND TRANSITIONAL CONTACT----					
MIOCENE TO UPPER OLIGOCENE	SURMA		Bokabil	+950	Predominanatly shales with iterlaminated siltstones & soft, friable, feldspathic sandstones
			CONFORMABLE AND TRANSITIONAL CONTACT		
		BHUBAN	Upper Bhuban	+1100	Predominantly arenaceous includes compact well bedded sandstones and laminated shale and siltstones
			CONFORMABLE AND TRANSITIONAL CONTACT		
			Middle Bhuban	+3000	Predominantly argillaceous includes splintry shales, siltstones & sandstones
			CONFORMABLE AND TRANSITIONAL CONTACT		
			Lower Bhuban	+900	Predominantly arenaceious with well bedded sandstones, laminated & silty shales
~~UNCONFORMITY OBLITERATED BY FAULT~~~					
Oligocene	Barail			+3000	Predominantly shales & siltstone with bands of greywacke sandstone
----LOWER CONTACT NOT SEEN----					

CHAPTER 3: METHODOLOGY

Water, like air, is one of the most important and most precious substances of natural resources and a regular and plentiful supply of clean water is essential for the survival and health of most living organisms. Water is commonly the mediator of interactions among the major divisions of our earth. These divisions are:

i. Exosphere
ii. Lithosphere
iii. Atmosphere
iv. Biosphere
v. Hydrosphere

The hydrological cycle is responsible for our weather and it makes our rivers run and balances the level of groundwater.

Methodology of the present work involves field work and laboratory work.

3.1 Field work

Field work mainly involves survey and sampling of potable water samples. Various sources of potable water were identified during the survey of study area. Further, in consultation with the people the suitable sites were selected for alternative source of potable water i.e. tuikhurs. The PHED sites were selected in order to procure samples evenly distributed over the area.

3.1.1 Survey and Selection of sampling sites

As a rule of nature, facility makes a man lenient and it is very true in case of environmental abuse, unscrupulous choice of fertilizers, insecticides, pesticides and poor farming practices that ultimately lead to soil pollution which in turn might be polluting our natural sources of surface &/ or an underground water. Nasty chemicals enter the food chain and cause a potential health hazard to the human body. Rainfall is an important factor and is the primary source of surface as well as groundwater on the earth. Level of groundwater table is always proportional to the rainfall. In the study area highest rainfall falls generally during June and July and on the contrary the month of January receives almost nil rainfall. Kolasib area of Mizoram is selected for the present study mainly because of the following facts:

1. Least or almost negligible information is available to the consumers regarding the water they consume for their domestic uses.

2. Usage of Tuikhur water for drinking and other domestic purposes as a supplementary resource of potable water is so far not assessed.
3. The poor awareness among masses for a cleaner environment. Such awareness to avoid the fixation of piggeries and other sanitary cabins near tuikhurs is observed to be alarmingly needed.

A detailed survey of sampling sites was performed before starting sampling and analysis of potable water samples. Townships in and around Kolasib, the district headquarter incude Kolasib, Kawnpui and Bilkhwatlir. All the three townships are at least connected through water connection from PHED as a basic source of potable water. However, the urbans also use tuikhurs and rain water as supplementary resources to cope up their requirement (Bharati *et al*, 2007). The need of supplementary resources arise due to the fact, that the water through PHED could not be regularly supplied and at the same time not enough. Moreover, the connection network of PHED does not cover the whole population. However, Population residing in the vicinity of the townships has to depend wholly on the tuikhur water for their domestic needs. As on May12, 2009, the Kolasib town has only 1801 water connections for 19008 populations. According to the PHED, Kolasib itself, the population benefited by water connections is 11,317 leaving 7,691 people to procure water for their daily needs from tuikhurs. Similarly, Vairengte and Bilkhawthlir have 547 and 194 connections for 7715 and 4084 population respectively. Kawnpui is a sub-division headquarters in the district but it has only 256 water connections.

Tuikhurs are widely distributed all through the areas in and around various townships. They are in fact water seepages mostly along the foot hills in the hilly terrains. Among the tuikhurs mostly are of the seasonal nature, where water diminishes during the non-monsoon periods. Still there are some tuikhurs which are perennial in nature therefore water is available throughout the year. Shortage of the potable water is to be fulfilled by the perennial tuikhurs fully for population out of PHED network and partly for urban localities. Few tuikhurs among all under public usage are having enough constructions to minimize the in-situ contaminations. The selected sites include renovated as well as raw tuikhurs.

Quite a good number of households are equipped with water harvesting facilities during rainy season and storing it for the usages of the same in relatively dry periods. The construction of houses is typical Assam-type with tapering roofs. The channel surrounding roof-tops facilitate storage of water into tanks. This water can also be a source of potable water for the families deprived of PHED supply and situated at a distance from the tuikhurs.

Samples have been collected from all the three sources of potable water available to the citizens of the area in and around Kolasib, Mizoram. They are tuikhur water, PHED supply water and harvested rain water.

As a good chunk of population of the study area depends on tuikhurs for their water needs, 32 tuikhurs were selected from the proposed area of work. While selecting the tuikhurs, the opinion of local people was taken care of i.e. those perennial tuikhurs which are relatively more in usage than the others were selected for the present study. Twenty PHED supply households were also selected in such a way so that it covers almost all locations within the study area. Among the harvested rain water locations five were identified from different localities within Kolasib town.

3.1.2 Samples and Sample Code Plan

Detailed locations of tuikhurs, PHE points and rain water samples are given below with their codes to be used for ready reference (Plate II).

3.1.2.1 Samples of Tuikhur water (KT)

KT-1 Kolasib, Venglai- Convent road

KT-2 Kolasib, Venglai- St. John’s HS school

KT-3 Kolasib, Venglai- old UPC church

KT-4 Kolasib, Venglai - below P/S-III

KT-5 Kolasib, Banglakawn- Brahma Kumari’s off.

KT-6 Kolasib, lower electric veng

KT-7 Kolasib, Hmar veng- police station

KT-8 Kolasib, Saidan-I

KT-9 Kolasib, Saidan -II

KT-10 Kolasib, Diakkawn- petrol pump

KT-11 Kolasib, Diakkawn - football ground

KT-12 Kolasib, Diakkawn- Aizawl road I

KT-13 Kolasib, Diakkawn- Aizawl road II

KT-14 Kolasib, Vengthar- ICAR complex

KT-15 Kolasib, Project veng- Agriculture Guest House

KT-16 Kolasib, Forest veng- below old DFO's office
KT-17 Kolasib, Rengtekawn-I
KT-18 Kolasib, Rengtekawn-II
KT-19 Bilkhawthlir -near BSNL
KT-20 Bilkhawthlir- near Post Office
KT-21 Thingdawl -near Agriculture Park
KT-22 Thingdawl pumping station
KT-23 Bualpui - below FCI
KT-24 Bualpui - near BSNL
KT-25 Kawnpui –police station
KT-26 Kawnpui – Aizawl road I
KT-27 Kawnpui – Aizawl road II
KT-28 Kawnpui –PWD office
KT-29 Kawnpui – along Mualvum road
KT-30 Kawnpui – Hortoki road I
KT-31 Kawnpui – Hortoki road II
KT- 32 Kawnpui – Hortoki road III

Tuichhuahen has been divided into twelve well defined micro watersheds based on physiography. The presented results fall in the micro-watersheds identified as Number I, II, IV, VI and VII by Rai (2005).

Micro-Watershed number I: It expands over an area of 9.75 sq. km, with its stream length 5.00 km, perimeter 13.50 km. and comprises of the southern most part of the study area i.e. Kawnpui. As many as 74 streams of different orders are pouring water to the micro-watershed which includes the analysed samples KT-27 to KT-30.

Micro-Watershed number II: It expands over an area of 9.38 sq. km, with its stream length 5.50 km, perimeter 15.50 km. and comprises of the area known as Thingdawl situated in the immediate south of the Kolasib town under study area. As many as 60 streams of different orders are pouring water to the micro-watershed which includes the analysed samples KT-24 to KT-21.

Micro-Watershed number IV: It expands over an area of 8.04 sq. km, with its stream length 4.00 km, perimeter 15.90 km. and comprises of the southern part of the Kolasib town under study area. As many as 69 streams of different orders are pouring water to the micro-watershed which includes the analysed samples KT-14 to KT-4.

Micro-Watershed number VI: It expands over an area of 7.33 sq. km, with its stream length 4.00 km, perimeter 11.00 km. and comprises of the Kolasib town of the study area. As many as 59 streams of different orders are pouring water to the micro-watershed which includes the analysed samples KT-5 to KT-18.

Micro-Watershed number VII: It expands over an area of 7.46 sq. km, with its stream length 4.40 km, perimeter 12.00 km. and comprises of the northernmost part of the study area i.e. Bilkhawthlir. As many as 54 streams of different orders are pouring water to the micro-watershed which includes the analysed samples KT-19 to KT-20.

In the further chapters these tuikhur samples are arranged as they fall in the respective Micro-watersheds in the study area, established by Rai (2005).

Micro water shed	Samples	Location
water Shed I	KT-27	Kawnpui–Azl rd I
	KT-26	Kawnpui–Azl rd I
	KT-25	Kawnpui–police st
	KT-28	Kawnpui–PWD
	KT-29	Kawnpui–Mualvum rd
	KT-32	Kawnpui– Hortoki III
	KT-31	Kawnpui – Hortoki II
	KT-30	Kawnpui – Hortoki I
Water shed II	KT-24	Bualpui BSNL
	KT-23	Bualpui - below FCI
	KT-22	Thingdawl pump st
	KT-21	Thingdawl-Agri Park
Water shed IV	KT-14	Klb-ICAR complex
	KT-11	Klb-Diakkawn ground
	KT-13	Klb-Diakkawn- Azl rd II
	KT-12	Klb. Diakkawn- Azl rd I
	KT-16	Klb. Forest veng
	KT-15	Klb. Project veng
	KT-3	Klb-old UPC church
	KT-1	Klb-Convent rd
	KT-2	Klb. St. John's school
	KT-4	Klb- Venglai P/S-III
Water shed VI	KT-5	Klb-Banglakawn
	KT-6	Klb-electric veng
	KT-7	Klb. police st
	KT-9	Klb-Saidan -II
	KT-8	Klb- Saidan-I
	KT-10	Klb-petrol pump
	KT-17	Klb-Rengtekawn-I
	KT-18	Klb-Rengtekawn-II
Water shed VII	KT-19	Bilkhawthlir-BSNL
	KT-20	Bilkhawthlir-Post Off

3.1.2.2 Samples of PHE (supply) water (KP)

KP-1 Kolasib, Venglai- Paster's residence

KP-2 Kolasib, Venglai – Lalkunga's house

KP-3 Kolasib, Venglai – Hospital

KP-4 Kolasib, Banglakawn – Didi restaurant

KP-5 Kolasib, Banglakawn – Post Office

KP-6 Kolasib, Project veng – BSNL office

KP-7 Kolasib, Project veng – Electric sub station

KP-8 Kolasib, Diakkawn – Paradise restaurant

KP-9 Kolasib, Diakkawn –Pu Hlua's house

KP-10 Kolasib, Hmar veng- MST Bus stand

KP-11 Kolasib, Electric veng- near PHE office

KP-12 Kolasib, Rengtekawn- near Police check gate

KP-13 Thingdawl- near Post office

KP-14 Bualpui- Gorkha hotel

KP-15 Bualpui- FCI godown

KP-16 Kawnpui- near Govt. High school

KP-17 Kawnpui – near Hospital

KP-18 Kawnpui – near Mizoram Rural Bank Branch

KP-19 Bilkhawthlir – near Hospital

KP- 20 Bilkhawthlir – PWD office

3.1.2.3 Samples of Stored Rain water

KR-1 Venglai, Kolasib

KR-2 Project veng, Kolasib

KR-3 Banglakawn, Kolasib

KR-4 Diakkawn, Kolasib

KR-5 Hmar veng, Kolasib

3.1.3 Sample Collection Scheme

Grab samples of Tuikhur waters (KT) and PHED supply waters (KP) were collected from 2005 to 2008 in pre monsoon, monsoon and post monsoon seasons consecutively. The collection of samples was started during post monsoon season of 2005. In this session various field works were conducted and 22 KT and 11 KP samples were collected. In the next session i.e. pre monsoon of 2006, 27 KT and 20 KP samples were procured. During the monsoon season of 2006, 24 KT and 14 KP samples along with 5 KR samples were collected. Since post monsoon, 2006 till pre monsoon of 2008 consistently 32 KT and 20 KP samples were collected. However, in monsoon 2007 number of KR samples remained 5 only, because of the fact that the limited number of houses equipped with the harvested rain water collection facilities.

Samples of potable water to be analyzed are representatives of the source from which water is drawn for different purposes. Through samples we aim to mimic the entire source or get a scaled down model of the entire source. The integrity of the samples are maintained to ensure that the concentration of various water quality parameters do not change in the time that elapses between drawing the samples and analysis in the laboratory. Liquid samples are broadly classified into two major groups, i.e. the one called instantaneous/ spot/ snap/ or grab samples and the other continuous or composite samples. A grab sample is manually collected single portion of sample of water or waste water. When the grab samples of a particular water or waste water is collected at regular intervals for a specific period and mixed, then the integrated sample is known as 'composite sample'.

For the present work, as the water samples were homogeneous, it was suffice to take the grab sample only. Water samples were collected in polythene bottles of 500 ml capacity fitted with airtight caps. Before collection of samples, polythene bottles were cleaned thoroughly and rinsed with distilled water. Samples for bacteriological examination were collected in clean and sterilized narrow mouthed neutral glass bottles of 500 ml capacity. The most convenient point for sampling potable waters is the consumers' premises. Samples were possibly taken from a tap directly connected to the main in case of PHE supply water samples. Details regarding the position of the premises relative to the supply main and its possible proximity to a dead- end were noted while such samples were taken. Before collecting the samples, the inside and outside of the tap were thoroughly cleaned. The water being sampled was then allowed to waste for sometimes so that the sample was the representative of the whole supply.

3.1.4 Sample Collection Techniques

A proper record of potable water samples collected in suitable containers was maintained throughout the study period. The containers were labeled with:

- i) Sample number
- ii) Date of collection of the sample
- iii) Time of collection of the sample
- iv) Name of the source of the sample

All these information were written on gummed papers and were pasted on the respective containers. After labeling, the samples were immediately brought to the laboratory for analysis to avoid any alteration or deterioration in their quality due to chemical or microbial activity.

No single method of preservation is entirely satisfactory and the preservative should be chosen with due regard to the determinations that are to be made. It should be noted that the preservative added for one constituent should not affect the determination of other constituent. Keeping the samples in the dark at low temperature is the best possible preservation. However, to avoid any change in quality parameters during delay in the analysis, suitable preservatives were added to the water samples.

3.2 Laboratory Work

Laboratory work involves analysis of physical, chemical and bacteriological parameters. Physical parameters include pH, electrical conductivity (EC), total dissolved solids (TDS), and turbidity. Chemical parameters selected for this work include total alkalinity (TA), total hardness (TH), carbonate (CO_3^{2-}), bicarbonate (HCO_3^-), sulphate (SO_4^{2-}), total chloride (TCl^-), fluoride (F^-), nitrate (NO_3^-), and metals and heavy metals like Na, K, Ca, Mg, Cr, Mn, Fe, Co, Ni, Cu, Zn, Cd, Pb and As. The bacteriological examination includes tests for total coliforms and the result is reported as most probable number (MPN).

3.2.1 Physical Parameters

The study of physical parameters of water is highly essential because the quality of water and ability to dissolve the chemicals in it totally depends on the physical characteristics of water. The physical properties of water is very important since the disposal of domestic sewage, more utilization of fertilizers to the soil for high yield of crops, industrial effluents discharged to the surface water and ever increasing human population have threatened the requisite standard of potable waters.

3.2.1.1 In Situ Physical Parameters

Physical parameters such as temperature, colour, odour, pH, EC and TDS were tested in situ. Temperature of the water samples was measured with the help of a stem thermometer in degree Celsius. Colour of the water samples was determined by the visual method while pH, EC and TDS were tested by portable pH, EC and TDS meters.

3.2.1.2 Laboratory

3.2.1.2.1 pH: pH represents the effective concentration (activity) of hydrogen ions (H^+) in water. This concentration could be expressed in the same kind of units as other dissolved species, but H^+ concentrations are much smaller than other species in most waters. The activity of hydrogen ions can be expressed most conveniently in logarithmic units pH is defined as the negative logarithm of the activity of H^+ ions:

$$pH = -\log [H^+]$$

Where $[H^+]$ is the concentration of H^+ ions in moles per liter.

In water solution, variations in pH value from 7 are mainly due to hydrolysis of salts of strong bases and weak acids or vice versa. Dissolved gases such as carbon dioxide, hydrogen sulphide and ammonia also affect the pH of water. The overall pH range of natural water is generally between 6 and 8. Industrial wastes may be strongly acidic or basic and their effect on pH value of receiving water depends on the buffering capacity of water. pH lower than 4 will produce sour taste and higher value above 8.5 bitter tastes. Higher value of pH hastens the scale formation in water heating apparatus and reduces the germicidal potential of chlorine. pH below 6.5 starts corrosion in pipes, thereby releasing toxic metals such as Zn, Pb, Cd, Cu etc. Changes in pH can also affect aquatic life indirectly by altering other aspects of water chemistry. Low pH levels accelerate the release of metals from rocks or sediments in the stream. These metals can affect a fish's metabolism and the fish's ability to take water in through the gills, and can kill fish. pH measurements also provide a very quick and easy to obtain appraisal of the acid- base equilibrium in an ecological system. The pH measurements were done in situ on a portable pH meter (Eutech, Oakton).

3.2.1.2.2 EC: Electrical conductivity of a water sample is a measure of concentration of mineral constituents present in it. It is also a measure of the ability of the sample to carry electric current. It is an indicator of dissolved ions present in water samples. Electrical conductivity of the water samples was determined at the sampling sites itself by a portable conductivity meter (Eutech, Oakton). The EC values were recorded in µS/cm.

3.2.1.2.3 TDS: Total dissolved solids (TDS) are the amount of solid substances dissolved in the water samples. In natural waters, the dissolved solids consist mainly of carbonates, bicarbonates, sulphates, nitrates and possibly phosphates of calcium, magnesium, sodium and potassium with traces of iron, manganese and other substances. The amount of dissolved solids present in water is a consideration for the suitability for domestic use. The TDS values were also measured in situ with the help of a portable TDS meter (Eutech, Oakton).

3.2.1.2.4 Turbidity: Turbidity is a measure of the degree to which the water looses its transparency due to the presence of suspended particulates. The more total suspended solids in the water, the murkier it seems and the higher the turbidity. Turbidity is considered as a good measure of the quality of water. There are a number of parameters that influence the cloudiness of the water; however, it is generally caused by phytoplankton, sediments from erosion, waste discharge, algae growth, urban runoff etc. The suspended particles absorb heat from the sunlight, making turbid waters become warmer, and so reducing the concentration of oxygen in the water (oxygen dissolves better in colder water). Some organisms also can't survive in warmer water. The suspended particles scatter the light, thus decreasing the photosynthetic activity of plants and algae, which contributes to lowering the oxygen concentration even more. Turbidity of the samples was determined by a Nepheloturbiditymeter (Systronics Digital Nepheloturbiditymeter-132) in NTU using hydrazine sulphate and hexamethylene tetramene as standards.

3.2.1.2.4.1 Preparation of Reagents and Standards

1 g of hydrazine sulphate was dissolved in distilled water to prepare 100 ml of solution (a). 10g of hexamethylene tetraamine was dissolved in 100 ml of distilled water to prepare 100 ml of solution (b). 5 ml of each of the solutions (a and b) were mixed in a 100 ml volumetric flask and was allowed to stand for 24 hours at 25°C. This solution was diluted with distilled water to the mark. This is a suspension having 400 NTU and can be stored for about a month. 10 ml of this stock solution was diluted to 100 ml with distilled water. This standard solution has 40 NTU and can be stored for about a week.

3.2.1.2.4.2 Procedure

i. The nephelometer was set at 100 using 40 NTU standard suspensions. Every per cent on the scale is equal to 0.4NTU turbidity.
ii. The sample was shaken thoroughly to let the air bubbles subside.
iii. The sample was taken in nephelometer sample tube and the value on the scale was recorded.

Calculation: Turbidity= Nephelometer reading x 0.4 x dilution factor

3.2.2 Chemical Parameters

3.2.2.1 Total alkalinity

Alkalinity is a measure of the buffering capacity of water, or the capacity of bases to neutralize acids. Measuring alkalinity is important in determining a stream's ability to neutralize acidic pollution from rainfall or wastewater. Alkalinity does not refer to pH, but instead refers to the ability of water to resist change in pH. Alkalinity test is performed to determine bicarbonate (HCO_3^-), and carbonate (CO_3^{2-}) and occasionally hydroxide (OH^-) ions.

Total alkalinity was determined by titration with a standard solution of a strong acid indicated by means of colour. Phenolphthalein indicator enables the measurement of that alkalinity fraction that is contributed by the hydroxide and half that by carbonate. Indicators responding to the pH range 4-5 are used to measure the alkalinity contributed by hydroxide, carbonate and bicarbonate ions.

3.2.2.1.1 Reagents

Phenolphthalein indicator solution:

i. 5g of Phenolphthalein disodium salt dissolved in 1litre of distilled water;
ii. Standard sulphuric acid of 0.02N strength;
iii. Methyl orange indicator solution: 0.05g of methyl orange dissolved in 1 litre of distilled water.

3.2.2.1.2 Procedure

Phenolphthalein alkalinity (P-Alkalinity)

i. 0.1 ml of phenolphthalein indicator was added to 50 ml of the water sample.
ii. It was titrated with 0.02N standard sulphuric acid till the colouration corresponding to the proper equivalence point of pH 8.3 develops.

Total alkalinity by methyl orange indicator method

i. 0.1 ml of methyl orange indicator was added to the solution in which phenolphthalein alkalinity had been determined.
ii. This solution was titrated with 0.02N standard acid to the proper equivalence point. The indicator changes to orange at pH 4.6 and pink at pH 4.0.

Calculation

Phenolphthalein alkalinity as mg/l $CaCO_3$ = A x N x 50000

B x N x 50000

Total alkalinity as mg/l $CaCO_3$ =

Where A = ml titrant required for sample to reach phenolphthalein end point

B = total ml titrant required to reach second end point

N = Normality of the acid

Calculation of alkalinity relationship

The results obtained from the phenolphthalein and total alkalinity determinations offer a means for the stoichiometric classification of the three principal forms of alkalinity present in the water samples.

Carbonate alkalinity is present when the phenolphthalein alkalinity is not zero but less than the total alkalinity.

Hydroxide alkalinity is present if the phenolphthalein alkalinity is more than half of the total alkalinity.

Bicarbonate alkalinity is present if the phenolphthalein alkalinity is less than half of the total alkalinity.

Alkalinity relationship

Result of titration	Hydroxide alkalinity as $CaCO_3$	Carbonate alkalinity as $CaCO_3$	Bicarbonate alkalinity as $CaCO_3$
P= 0	0	0	T
P< 1/2	0	2P	T- 2P
P= 1/2	0	2P	0
P> 1/2	2P-T	2 (T-P)	0
P= T	T	0	0

P = Phenolphthalein alkalinity, T= Total alkalinity

3.2.2.2 Total hardness

Hardness is a measure of polyvalent cations (ions with a charge greater than +1) in water. It generally represents the concentration of calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions, because these are the most common polyvalent cations. Other ions, such as iron (Fe^{2+}) and manganese (Mn^{2+}), may also contribute to the hardness of water, but are generally present in much lower concentrations. Hardness affects the amount of soap that is needed to produce foam or lather. Total hardness of the samples was measured by the EDTA titrimetric method.

Principle of the titration

Ethylenediamine tetra acetic acid and its sodium salts form a chelated soluble complex when added to a solution of certain metal cations. If a small amount of Eriochrome Black T is added to an aqueous solution containing Ca^{2+} and Mg^{2+} ions at a pH of 10.0-10.2, the solution becomes wine red. If EDTA is then added as a titrant the Ca^{2+} and Mg^{2+} ions get complexed and after all the ions have been complexed the solutions turn from wine red to blue. This is the end point of the titration.

3.2.2.2.1 Reagents

i. Buffer solution: 1.179g of disodium salt of EDTA dehydrates and 0.78g of $MgSO_4.7H_2O$ was dissolved in 50 ml of distilled water. A mixture of 16.9g of NH_4Cl and 143 ml of conc.NH_4OH was added to this solution and diluted to 250 ml with distilled water.
ii. Inhibitor: 4.5g of hydroxyl amine hydrochloride was dissolved in 100 ml of ethyl alcohol. It acts as an inhibitor for interfering ions.
iii. Indicator: 0.5g of Eriochrome Black T dye was mixed with the inhibitor made above.
iv. Standard EDTA titrant of 0.01M: 3.723g of disodium ethylenediamine tetra acetate dehydrate (EDTA) was dissolved in distilled water and diluted to 1000 ml.
v. Standard calcium solution: 1.0g of anhydrous $CaCO_3$ powder was transferred into 500 ml distilled water and added to it 1+1 HCl until all $CaCO_3$ is dissolved. To this solution, 200 ml distilled water was added and boiled for few minutes. The solution so obtained is cooled and a few drops of methyl orange were added and adjusted to the intermediate orange colour by adding 1+1 HCl. The solution is transferred into a 1 litre volumetric flask and diluted to the mark with distilled water. This standard solution is equivalent to 1.0 mg $CaCO_3$ per 1.0 ml.

3.2.2.2.2 Procedure

i. 25 ml of the sample was diluted to 50 ml with distilled water and 1-2 ml of buffer solution was added.
ii. 1-2 drops of Eriochrome Black T indicator was added to the above solution.
iii. Standard EDTA titrant was added slowly with constant stirring until the last reddish tinge disappears and the colour of the solution becomes blue.

Calculation

Hardness (EDTA) as mg/l $CaCO_3$ = (ml EDTA titrant x 1000 x N)/ ml sample

Where N = mg $CaCO_3$ equivalent to 1.0 ml EDTA.

3.2.2.3 Calcium

Calcium was determined by EDTA titrimetric method. When ethylenediamine tetra acetic acid is added to water samples containing both calcium and magnesium, it combines first with calcium that is present in the sample. Calcium is determined directly using EDTA when the pH is made sufficiently high so that magnesium largely precipitated as the hydroxide and an indicator is used which combines with calcium only.

3.2.2.3.1 Reagents

i. Sodium hydroxide 1N: 40g of NaOH is dissolved and diluted to 1 litre with distilled water.

ii. Murexide indicator: It is prepared by mixing 0.20g of murexide with 100g of solid NaCl.

iii. Standard EDTA titrant 0.01M: It is prepared by dissolving 3.723g of disodium ethylenediamine tetra acetic acid dehydrate salt in 1000 ml distilled water.

3.2.2.3.2 Procedure

i. 20 ml of water sample was taken in a conical flask.

ii. 2 ml of 1N- NaOH was added to the conical flask.

iii. To the above solution 1 drop of murexide indicator was added and titrated with EDTA titrant with continuous stirring till a purple colour persists. This is the end point.

Calculation

Ca (mg/l) = ml EDTA titrant x 400.80/ ml sample

3.2.2.4 Magnesium

Magnesium ions were calculated from the total hardness obtained by the EDTA titrimetric method and the calcium ions estimated by using the formula,

Mg (mg/l) = $\underline{\text{TH- (2.497 x Ca)}}$

Where TH= Total hardness

Ca= Amount of calcium estimated by EDTA titration

3.2.2.5 Sulphate

Estimation of sulphate ions was done by turbidimetric method. Sulphate ions are precipitated in a hydrochloric acid medium with barium chloride in such a manner so as to form barium sulphate. The absorbance of sulphate suspension is measured by spectrophotometer and sulphate ion concentration is determined by comparision with a standard curve.

3.2.2.5.1 Reagents

i. Conditioning reagent: 50 ml of glycerol was mixed with a solution containing 30 ml HCl, 300 ml distilled water, 100 ml 95% ethyl alcohol and 75g sodium chloride.
ii. Barium chloride crystals
iii. Standard sulphate solution: 0.1479g of sodium sulphate was dissolved in distilled water and diluted to 1000 ml. This solution contains 100ppm of SO_4

3.2.2.5.2 Procedure

i. 100 ml of the sample was taken in a 250 ml flask. 5.0 ml of the conditioning reagent was added to this and mixed well.
ii. A pinch of $BaCl_2$ crystals was added to the above solution and stirred for one minute.
iii. Immediately after stirring some of the solution was poured into the spectrophotometer at 420nm and turbidity was measured. Readings were taken at an interval of 30 seconds for 4 minutes. The highest reading was considered as the main reading.
iv. The sulphate concentration in the sample was estimated by comparing the turbidity reading with a standard curve made by comparing with standard sulphate solution.

Calculation

Sulphate (SO_4^{2-}) mg/l= mg SO_4 x 1000/ml sample

3.2.2.6 Total Chloride

Chloride is invariably present in small quantity in almost all natural waters and its content goes up appreciably with increasing salinity. Chloride mainly reaches to the water bodies from the leaching of chloride- containing rocks and soils with which the water comes in contact. It may impart salty taste to water depending on the nature of the cation constituents. High chloride concentrations may harm metallic pipes structures. Its higher concentrations in irrigation waters may be harmful to many plant species.

Chloride was estimated by volumetric titration of neutral or slightly alkaline sample against silver nitrate solution using potassium chromate as an indicator. On adding silver nitrate to the water sample it reacts with chloride ions of the sample to form silver chloride which gets precipitated. When all the chloride ions have been converted to silver chloride, the titrant reacts with potassium chromate to form silver chromate. The red colour of silver chromate changes to pinkish yellow colour at the end point.

3.2.2.6.1 Reagents

i. Standard silver nitrate titrant, 0.0141N: 2.396g of $AgNO_3$ was dissolved in distilled water and diluted to 1000 ml. It was stored in a brown bottle.

ii. Standard sodium chloride solution, 0.0141N: 0.8241g of NaCl was dissolved in distilled water and diluted to 1000 ml.

iii. Potassium chromate indicator solution: 50g of K_2CrO_4 was dissolved in a little distilled water and added to it silver nitrate solution until a definite red precipitate is formed. The above solution was allowed to stand for 12 hours, filtered and diluted the filtrate to 1000 ml with distilled water.

3.2.2.6.2 Procedure

i. 100 ml of the sample was taken in a conical flask.

ii. 1 ml of K_2CrO_4 indicator solution was added to the sample.

iii. The above solution was titrated with standard silver nitrate solution till a pinkish red colour persists. This is the end point.

iv. Similar experiment was performed for blank also.

Calculation

Cl^-(mg/l) = (A-B) x N x 35.45 x 1000/ ml sample

Where A= ml $AgNO_3$ for sample,

B= ml $AgNO_3$ for blank,

N= normality of $AgNO_3$ solution

3.2.2.7 Fluoride

Fluoride is one of the very few chemicals that have been shown to cause significant effects in people through drinking-water. Fluoride has beneficial effects on teeth at low concentrations in drinking-water, but excessive exposure to fluoride in drinking-water, or in combination with exposure to fluoride from other sources, can give rise to a number of adverse effects. These range from mild dental fluorosis to crippling skeletal fluorosis as the level and period of exposure increases. Crippling skeletal fluorosis is significant course of morbidity in number of regions of the world. Fluoride is known to occur at elevated concentration in a number of parts of the world and in such circumstances can have, and often has, a significant adverse impact on public health and well being.

Most people associate fluoride with the practice of intentionally adding fluoride to public drinking water supplies for the prevention of tooth decay. However, fluoride can also enter public water systems from natural sources, including runoff from the weathering of fluoride-containing rocks and soils and leaching from soil into groundwater.

Fluoride contents in drinking water samples were determined using expandable Ion-Analyzer Model EA 940 with fluoride ion selective electrode (Orion Ion Selective Electrode Model 96-09) at IIT Mumbai.

3.2.2.7.1 Principle of Operation of the Fluoride ISE

In the case of the F^- ISE, the ion-selective membrane is a single crystal of Lanthanum Fluoride (LaF_3) doped with Europium Fluoride (EuF_2) which produces holes in the crystal lattice through which F^- ions can pass. When immersed in a fluoride solution and connected via a voltmeter to an AgCl/KCl external reference electrode immersed in the same solution, the negative F ions in the solution pass through the crystal membrane by normal diffusion from high concentration to low concentration until there is an equilibrium between the force of diffusion and the reverse electrostatic force due to repulsion between particles of similar charge. On the other side of the membrane there is a corresponding build-up of positive ions.

The buildup of negative F^- ions on the inside of the membrane is compensated for by Cl^- ions in the internal reference solution becoming neutralized by combining with the Ag/AgCl wire, and electrons are thus forced through the external wire to the voltage measuring device (ion meter or computer interface). The other terminal of the voltmeter is connected to the Ag/AgCl wire of the external reference electrode. Here, the influx of electrons causes Ag ions in the filling solution to accept electrons and deposit on the silver wire and, consequently, Cl^- ions to flow out into the sample solution.

Note that, in general, depending on the concentrations inside and outside the membrane and which ion is being measured, all the reactions described above could occur in the opposite direction.

3.2.2.8 Nitrate

Though nitrate is an essential element in the life processes of plants and animals, it is potentially hazardous when present in drinking water at sufficiently high concentrations. Numerous sources in the environment contribute to the total nitrate content of natural waters *viz.* atmosphere, geological sources, soils, atmospheric nitrogen fixation and anthropogenic sources that include industrial wastes containing N- compounds, human and animal wastes and agricultural activities. Nitrate (NO_3^-) is highly soluble (dissolves easily) in water and is stable over a wide range of environmental conditions. It is easily transported in streams and groundwater. Nitrate itself is relatively non- toxic but when ingested with food or water, it may be reduced to nitrite by bacteria in the mouth or gut. This reduced nitrite is a potential threat to human health when found in excess quantity in drinking water. Methemoglobinemia, commonly known as 'blue baby' disease in infants is closely related to nitrate concentration in drinking water. Infants are most prone to nitrate concentration because they have underdeveloped metallic enzyme, relatively small blood volume and greater reactivity of fetal haemoglobin.

The determination of nitrate concentration in the samples was done by ultraviolet spectrophotometric method. Measurement of UV absorption at 220 nm enables rapid determination of NO_3^-. Since dissolved organic matter also may absorb at 220 nm and NO_3^- does not absorb at 275 nm, a second measurement made at 275 nm is used to correct the NO_3^- value. Acidification with 1N HCl is designed to prevent interference from hydroxide or carbonate concentrations up to 1000 mg $CaCO_3$/l.

3.2.2.8.1 Reagents

i. Stock nitrate solution: Potassium nitrate (KNO_3) is dried in an oven at 105^{o}C for 24 hours. 0.7218g of dry KNO_3 was dissolved in distilled water and diluted to 1000 ml. This solution is stable for about a period of six months.

ii. Intermediate nitrate solution: 100 ml of stock nitrate solution was diluted to 1000 ml with distilled water. This solution is also stable for about six months.

iii. Hydrochloric acid solution, HCl, 1N.

3.2.2.8.2 Procedure

i. Treatment of sample: 1ml of HCl solution was added to 50 ml of sample and mixed thoroughly.

ii. Preparation of standard curve: NO_3^- calibration standards were prepared in the range of 0 to 7 mg NO_3^- -N/l by diluting to 50 ml the following volumes of intermediate nitrate solution: 0, 1.00, 2.00, 4.00, 7.00, …35.00ml. NO_3^- standard was treated in the same manner as sample.

iii. Spectrophotometric measurement: A wavelength of 220 nm was used to obtain NO_3^- reading and a wavelength of 275 nm was used to determine interference due to dissolved organic matter.

Calculation

Two times of the absorbance reading at 275 nm was subtracted from the reading at 220 nm for samples and standards to absorbance due to NO_3^-. A standard curve was constructed by plotting absorbance due to NO_3^- against NO_3^- - N concentration of standard.

3.2.2.9 Metals and Heavy Metals

All the metals and heavy metals were measured on ICP-AES (Horiba Jobin Vyon ULTIMA-2) at IIT Mumbai.

3.2.2.9.1 Principle

ICP emission spectrometry is a comparatively new technique with enormous potential in geochemistry. In principle the method is capable of measuring most elements in the periodic table with low detection limits and good precision over several orders of magnitude. Elements are measured simultaneously and a complete analysis can be made in the space of about two minutes, making it an extremely rapid analytical method.

ICP emission spectrometry is a ‘flame’ technique with a flame temperature in the range of 6000-10000K. It is also a solution technique and standard silicate dissolution methods are employed. The sample solution is passed as an aerosol from a nebulizer into argon plasma. The inductively coupled plasma is a stream of argon atoms, heated by the inductive heating of a radio-frequency coil and ignited by a high frequency Telsa spark. The sample dissociates in the argon plasma and a large number of atomic and ionic spectral lines are excited. The spectral lines are detected by a range of photomultipliers, they are compared with calibration lines and their intensities are converted into concentrations.

3.2.3 Bacteriological Parameters

3.2.3.1 Total Coliform

The total coliform group includes the aerobic and the facultative anaerobic, gram-negative, non-spore- forming, rod- shaped bacteria that ferment lactose with gas production within 48 hours at 35^0C (APHA, 2005). This group includes the Escherichia coli, Enterobacter, Klebsiella and Citobacter. These coliforms are discharged in high numbers (2×10^9 coliforms per day per capita) in human and animal feces, but not all of them are fecal origin. These indicators are useful for determining the potable water, shellfish- harvesting waters and recreational waters (Bitton, 1999). In water treatment plants, total coliforms are one of the best indicators of treatment efficiency of the plant. This group has also been found useful assessing the safety of reclaimed wastewater in the Windhoek reclamation plant in Namibia (Grabow, 1990)

3.2.3.1.1 Test Procedure to determine Most Probable Number (MPN)

The multiple tube fermentation technique was used to enumerate positive presumption and confirmed coliform test.

3.2.3.1.1.1 Presumptive Test

Dilution above 1:1000 was prepared; five fermentation tubes previously filled with 9 ml of Mac Conkey broth were prepared for each dilution. Now one Durham’s vial was put in an inverted condition inside each fermentation tube. The tubes were plugged with cotton and sterilized in an autoclave. Now sample was added to each test tube with the help of a sterilized pipette. The tubes were vigorously shaken and incubated at 35-37^{0}C for 48 hours. Each test tube was examined for gas production. The tubes showing gas in the Durham's vial were recorded as positive. The tubes showing positive results were now subjected to the confirmatory test.

3.2.3.1.1.2 Confirmatory Test

The fermentative tube was filled with 10 ml Brilliant Green Lactose Bile (BGLB) broth and Durham's vial was put in an inverted position in each fermentation tube. The positive tubes were shaken gently and one loopful of sample was transferred to each fermentative tube having BGLB broth. These tubes were incubated at 35-37^{0}C for 48 hours.

The tubes producing gas were recorded as positive and MPN/100 ml was calculated.

$$\text{MPN/100 ml} = \frac{\text{MPN table value x 10}}{\text{Starting value}}$$

CHAPTER 4: RESULT

The studied physico-chemical and bacteriological parameters for KT, KP and KR water samples are presented in Table 3 to Table 20 for three consecutive years starting from post monsoon season of 2005 till pre monsoon of year 2008. Further, KT water samples are arranged water-shed wise in order to understand the degree of rock-water interaction. The various watersheds exhibit variation in the host rock types.

The results are described comprehensively in order of physical, chemical and bacteriological parameters for all types of potable water in all the seasons from 2005 to 2008.

4.1 Physical Parameters

4.1.1 pH

There is a considerable amount of variations in the values of pH of samples in a particular season of a year as well as in different seasons of different years. During post monsoon season in the year of 2005 where comparatively lesser number of KT and KP samples were collected and examined, the pH values for KT samples vary from a minimum of 6.7 to a maximum of 7.9 with a mean value of 7.07 (Table 3). During the same year in the same season for the KP samples the pH values range from a minimum of 6.9 to a maximum value of 7.7 having an average value of 7.22 (Table 4). In pre-monsoon of 2006, the pH varies from a minimum of 6.7 to a maximum of 7.7 and the mean value is 7.20 for KT samples (Table 5) whereas for KP samples of the same period the pH values vary from 6.7 to 7.6 with a mean value of 7.15 (Table 6). Variation in pH has been recorded as 6.7 to 7.6 (mean 7.05) for KT samples in monsoon season of 2006 (Table 7) whereas KP samples of the same period record a minimum of 6.7 and a maximum of 7.3 (mean 6.99) (Table 8). During post monsoon season of 2006 the pH values of KT samples vary from a minimum of 6.8 to a maximum of 7.7 with a mean value of 7.18 (Table 10).The KP samples for the same period show a minimum value of 7.0 and a maximum value of 7.80 (mean 7.30) for pH (Table11).

Pre monsoon of 2007 shows variation in pH values from a minimum of 6.8 to a maximum of 7.5 having a mean value of 7.16 for all KT samples (Table 12). The value of pH for KP samples, during the period ranges from 6.8 to 7.4 (mean 7.19)

(Table 13). In monsoon season of 2007 the pH values vary from a minimum of 6.7 to a maximum value of 7.5 with an average value of 7.08 for the KT samples (Table 14) whereas during the same period the KP samples record pH values from a minimum of 6.7 to a maximum of 7.4 (mean 7.07) (Table 15). The pH values show variation from 6.7 to 7.5 (mean 7.05) for KT samples (Table 17) during post monsoon of 2007. The KP samples recorded variation in pH values from a minimum of 7.1, slightly higher, to a maximum of 7.6 with a mean value of 7.37 (Table 18). In pre monsoon 2008 the KT samples show pH values ranging from 6.8 to 7.5 (mean 7.18) (Table 19) whereas pH of KP samples for the same period varies from 6.9 to 7.5 having a mean value of 7.21 (Table 20). The pH values of KR samples vary from 6.9 to 7.2 and from 7.0 to 7.1 during monsoon of 2006 (Table 9) and 2007 (Table 16) respectively. Variation in pH for all KT samples in different watersheds has also been recorded.

Variations in pH in watershed I have been observed from a minimum of 6.7 to a maximum of 7.9. However, in watershed II it ranges from 6.7 to 7.6. Further, variation in pH in watershed IV has been recorded from a minimum of 6.7 to a maximum of 7.5. It varies from 6.8 to 7.7 in watershed VI and from 6.9 to 7.4 in watershed VI.

4.1.2 Electrical Conductivity (EC)

The values of electrical conductivity show quite a large variation in different seasons in different years. The KT samples in post monsoon season of 2005 record variation in EC values from a minimum of 67 to a maximum of 235µS/cm (mean 145.14µS/cm) (Table 3) whereas the EC values vary from 96 to 248µS/cm (Table 4) for KP samples in the same period. During pre monsoon 2006 for KT samples the EC varies from 70 to 208µS/cm (Table 5) while the same ranges from 88 to 230µS/cm (mean 150.35µS/cm) for KP samples (Table 6) in the same period. The EC values show variation from a minimum of 72 to a maximum of 190µS/cm (mean 129.29µS/cm) for KT samples (Table 7) and from 85 to 190µS/cm (mean 135µS/cm) for KP samples (Table 8) in monsoon season of 2006. The KT samples record variation in EC from 70 to 242µS/cm (mean 153.16µS/cm) during post monsoon 2006 (Table 10) whereas EC values of KP samples of the same period vary from a minimum of 106 to a maximum of 276µS/cm with a mean value of 194.90µS/cm (Table 11). The EC value during pre monsoon 2007 for KT samples ranges from 80 to 220µS/cm (mean 147.81µS/cm) (Table 12) and the variation for KP samples during this period is from 82 to 255µS/cm (mean 174.35µS/cm) (Table 13) which is higher than that of the former. During monsoon season of 2007 it ranges from 72 to 185µS/cm (mean 131.4µS/cm) for KT samples (Table 14) whereas during the same period it varies from 80 to 220µS/cm (mean 147.65µS/cm) for KP samples (Table 15). The EC varies from a minimum of 72 to a maximum of 244µS/cm (mean 154.69µS/cm) for KT samples in post monsoon 2007 (Table 17) while for KP samples it ranges from 110 to 275µS/cm (mean 197.10µS/cm) during the same period (Table 18). In the year of 2008 during pre-monsoon season the values of electrical conductivity vary from a minimum of 80 to 225µS/cm (mean 149.38µS/cm) (Table 19) and for KP samples the variation in these values has been recorded from 84 to 255µS/cm (mean 176.1µS/cm) (Table 20) during the same period. The EC values of KR samples show slight variation from 10 to 25µS/cm during monsoon seasons of 2006 and 2007 (Table 9&16).

Watershed wise variation in EC has also been observed during the study period. In water shed I, the EC content varies from a minimum value of 67µS/cm to a maximum value of 225µS/cm. Further, it ranges from 107µS/cm to 192µS/cm in watershed II. In watershed IV, the variation in EC values has been recorded from a minimum of 90µS/cm to a maximum of 244µS/cm. However, it ranges from 81µS/cm to 232µS/cm in watershed VI whereas in watershed VII it varies from a minimum of 108µS/cm to a maximum of 225µS/cm.

4.1.3 Total Dissolved Solids (TDS)

The total dissolved solids (TDS) value varies from a minimum of 50 to 162 mg/l with a mean value of 93.18 mg/l for KT samples during post monsoon season of 2005 (Table 3) where the same ranges for 72 to 162 mg/l (mean 121.73 mg/l) (Table 4) for KP samples during the same period. In pre monsoon 2006, the TDS for KT samples changes from 49 to 147 mg/l (Table 5) and that of KP samples from 57 to 153 mg/l (mean 101.60 mg/l) (Table 6). Further, in monsoon 2006 variation is from 59 to 150 mg/l (mean 96.88 mg/l) for KT samples (Table 7) and from 60 to 152 mg/l (mean 102.0 mg/l) for KP samples (Table 8). During post-monsoon season of 2006 the TDS ranges from a minimum of 77 to a maximum of 160 mg/l (mean 99.91 mg/l) of KT samples (Table 10) while it varies from 70 to 190 mg/l (mean 135.75 mg/l) in KP samples (Table 11). TDS of KT samples varies from 53 to 155 mg/l (mean 99.25 mg/l) (Table 12) whereas the same ranges from 50 to 171 mg/l (mean 118.85 mg/l) (Table 13) for KP samples during pre-monsoon 2007.

During monsoon 2007 TDS value of KT samples changes from 55 to 148 mg/l (mean 91.25 mg/l) (Table 14) and the same of KP samples varies from 59 to 150 mg/l (mean 97.25 mg/l) (Table 15). The TDS of KT samples during post-monsoon 2007 ranges from 50 to 160 mg/l (mean 100.97 mg/l) (Table 17) while the same for KP samples varies from 72 to 190 mg/l (mean 136.80 mg/l) (Table 18). During pre-monsoon 2008, it varies from a minimum of 52 to a maximum of 158 mg/l (mean 99.81 mg/l) (Table 19) for KT samples whereas it ranges from 50 to 172 mg/l (mean 118.3 mg/l) (Table 20) for KP water in the same period.

TDS of KR water does not show considerable variation. It varies from 10 to 20 mg/l during monsoon seasons of 2006 and 2007 (Table 9&16).

In watershed-I, the TDS values vary from a minimum of 49 g/l to a maximum of 154 mg/l for KT samples. Its values range from 58 to 132 mg/l in watershed-II while the same show variation from 60 to 162 mg/l in watershed-IV. In watershed-VI it varies from a minimum of 50 to a maximum of 160 mg/l whereas in watershed-VII the variation s has been recorded as 77 to 158 mg/l.

4.1.4 Turbidity

In the post monsoon season of 2005 turbidity of KT samples varies from 0.5 to 1 (Table 3) and for KP samples it ranges from 0.7 to 1 (Table 4) during the same period. Turbidity of KT samples in monsoon 2006 shows variation from 0.7 to 2.6 (Table 7) and it varies from 0.6 to 2.0 (Table 8) for KP water during the same period. During pre monsoon 2006, it varies from 0.3 to 1.0 (Table 5) and 0.4 to 1.3 (Table 6) for KT and KP samples respectively. Variation in turbidity has been recorded from 0.5 to 1.0 (Table 10) and from 0.8 to 1.7 (Table 11) for KT and KP water samples respectively during post monsoon season of 2006. During pre monsoon 2007 it varies from 0.5 to 1.0 (Table 12) and from 0.2 to 1.5 (Table 13) for KT and KP water samples respectively. The values of turbidity range from 0.8 to 2.5 slightly higher for KT samples (Table 14) and from 0.9 to 1.6 for KP samples (Table 15) during monsoon 2007.

During post monsoon season of 2007, it ranges from 0.6 to 1.2 (Table 17) for KT samples and from 0.9 to 1.6 (Table 18) for KP samples. The turbidity values vary from 0.6 to 1.1 (Table 19) and from 0.9 to 1.6 (Table 20) for KT and KP water samples respectively during pre monsoon season of 2008. The values of turbidity of KR samples vary from 0.2 to 0.6 (Table 9) and from 0.3 to 0.6 (Table 16) during monsoon seasons of 2006 and 2007 respectively.

4.2 Chemical parameters

4.2.1 Total alkalinity (TA)

All the three sources of potable water i.e. KT, KP and KR have no carbonate and hydroxide ions and as a result alkalinity present in water samples is mainly due to the presence of bicarbonate ion. Therefore the values of total alkalinity are equal to the values of bicarbonate ion present in water samples.

The total alkalinity varies from a minimum of 24.7 to a maximum value of 85.0 mg/l (mean 40.05 mg/l) (Table 3) and from 87.75 to 108.50 mg/l (mean 97.55 mg/l) (Table 4) for KT and KP samples respectively in post monsoon 2005. In the monsoon season of 2006 the value of TA ranges from 22.0 to 83.75 mg/l (mean 38.61 mg/l) (Table 7) and from 83.6 to 100.50 mg/l (mean 91.35 mg/) (Table 8) for KT and KP water respectively. It varies from 16.75 to 25.0 mg/l (mean 21.64 mg/l) (Table 9) for KR water of the same period. Total alkalinity of rain water samples is much lower than that of KT and KP water samples.

The value of TA for KT samples during pre monsoon 2006 ranges from 31.40 to 86.25 mg/l (Table 5) and the same varies from 87.25 to 108.25 mg/l (Table 6) for KP samples of the same period. The variation has been recorded from 26.35 to 85.87 mg/l (mean 39.71 mg/l) (Table 10) and from 91.25 to 108.50 mg/l (mean 100.13 mg/l) (Table 11) for KT and KP samples respectively in post monsoon 2006. The same varies from 31.40 to 48.95 mg/l (mean 40.04 mg/l) (Table 12) for KT water and from 92.25 to 106.75 mg/l (mean 97.92 mg/l) (Table 13) for KP water in pre-monsoon season of 2007. During monsoon 2007 the value of total alkalinity ranges from 25.25 to 48.95 mg/l (mean 37.63 mg/l) (Table 14) and from 83.60 to 98.85 mg/l (mean 91.55 mg/l) (Table 15) for KT and KP water samples respectively. During the same season it varies from 16.80 to 24.65 mg/l (mean 21.85 mg/l) (Table 16) for KR samples. The TA values range from 26.55 to 53.75 mg/l (mean 38.92 mg/l) (Table 17) and from 93.2 to 108.75 mg/l (mean 100.98 mg/l) (Table 18) for KT and KP water respectively during post monsoon 2007. During pre monsoon 2008, it varies from 32.25 to 48.65 mg/l (mean 40.19

mg/l) (Table 19) for KT water and from 92.50 to 106.80 mg/l (mean 98.87 mg/l) (Table 20) for KP water.

It has been observed that the total alkalinity values of KP samples are higher than those of KT samples and for KR samples these values are the least. In watershed-I the values of TA vary from a minimum of 31.96 mg/l to a maximum of 52.00 mg/l whereas the same range from 37.25 to 86.25 mg/l in watershed-II. The variation in watershed-IV has been recorded from a minimum of 22.00 to a maximum of 46.50 mg/l. Watershed-VI shows variation in TA values from 30.15 to 48.95 mg/l.

4.2.2 Total Hardness (TH)

The total hardness (TH) varies from 44.38 to 68.35 mg/l (mean 53.40 mg/l), (Table 3) from 39.75 to 65.00 mg/l (mean 51.17 mg/l) (Table 5) and from 37.25 to 57.20 mg/l (mean 47.15 mg/l) (Table 7) for KT water samples during post monsoon 2005, pre monsoon 2006 and monsoon 2006 respectively.

It ranges from 30.75 to 93.00 mg/l (mean 63.54 mg/l) (Table 4), from 35.25 to 88.00 mg/l (mean 56.46 mg/l) (Table 6) and from 36.75 to 77.35 mg/l (mean 54.08 mg/l) (Table 8) for KP water in post-monsoon 2005, pre monsoon 2006 and monsoon 2006 respectively. During post monsoon 2006 the TH values show variation from 43.95 to 65.78 mg/l (mean 53.25 mg/l) (Table 10) and from 67.90 to 106.70 mg/l (mean 82.23 mg/l) (Table 11) for KT and KP samples respectively. KT samples record variation from 43.95 to 67.90 mg/l (mean 55.36 mg/l) (Table 12) during pre monsoon 2007 whereas during the same period it varies from 63.05 to 97.00 mg/l (mean 77.37 mg/l) (Table 13) for KP samples. In monsoon season of 2007 the minimum value of TH for both KT and KP samples is 38.8 mg/l while the maximum values are 58.2 and 77.6 mg/l respectively (Table 14, 15). The values of TH of monsoon water range from 24.25 to 29.1 mg/l (mean 26.19 mg/l) (Table 16). KT samples of post monsoon 2007 record variation from 43.65 to a maximum of 63.05 mg/l (mean 52.74 mg/l) (Table 17) whereas these values change from a minimum of 63.05 to a maximum of 106.70 mg/l (mean 81.00 mg/l) (Table 18) for KP water in the same period. In the season of pre monsoon 2008, it varies from 43.65 to 67.90 mg/l (mean 55.36 mg/l) (Table 19) and from 63.05 to 97.00 mg/l (mean 78.81 mg/l) (Table 20) for KT and KP water samples respectively.

Watershed-I shows variation in TH from a minimum of 37.40 to a maximum of 58.60 mg/l while watershed-II records variation in TH values from

48.50 to 68.35 mg/l for KT samples. The TH ranges from a minimum of 38.80 to 65.23 mg/l in watershed-VI and in watershed-VI it varies from 37.25 to 63.05 mg/l.

4.2.3 Total Chloride (TCl)

The values of total chloride (TCl) vary from 8.75 to 19.20 mg/l (mean 14.42 mg/l) (Table 3) and from 5.75 to 15.00 mg/l (mean 11.82 mg/l) (Table 4) for KT and KP water respectively during post monsoon 2005. During pre monsoon 2006 it ranges from 9.65 to 18.15 mg/l (mean 13.16 mg/l) (Table 5) for KT samples while for KP samples it varies from 7.85 to 14.71 mg/l (mean 11.25 mg/l) (Table 6) during the same period. The total chloride content shows variation from 8.25 to 16.75 mg/l (mean 11.54 mg/l) (Table 7) and from 7.50 to 13.20 mg/l (mean 10.36 mg/l) (Table 8) for KT and KP samples respectively during monsoon 2006. It varies from 7.00 to 8.35 mg/l (mean 7.74 mg/l) (Table 9) for KR water in the same season of 2006.

During post monsoon season of 2006 all the KT samples show variation in TCl content from 9.11 to 18.75 mg/l (mean 13.73 mg/l) (Table 10) whereas the same ranges from 8.92 to 17.50 mg/l (mean 13.96 mg/l) (Table 11) for KP samples in the same period. The values of TCl vary from 9.58 to 18.65 mg/l (mean 13.66 mg/l) (Table 12) and from 7.98 to 16.83 mg/l (mean 13.29 mg/l) (Table 13) for KT and KP water respectively during pre monsoon season of 2007. The same range from 7.96 to 16.80 mg/l (mean 11.76 mg/l) (Table 14), from 6.42 to 14.25 mg/l (mean 10.57 mg/l) (Table 15) and from 6.35 to 8.20 mg/l (mean 7.42 mg/l) (Table 16) for KT, KP and KR water samples respectively during monsoon season of 2007. The KT samples record variation in TCl from 9.23 to 18.8 mg/l (mean 13.96 mg/l) (Table 17) during post monsoon 2007 whereas during the same season the TCl content of KP samples ranges from a minimum value of 8.95 to a maximum of 17.65 mg/l (mean 13.98 mg/l) (Table 18).

During pre monsoon season of 2008 the TCl value varies from 9.75 to 18.70 mg/l (mean 13.69 mg/l) (Table 19) and from 8.15 to 16.60 mg/l (mean 13.44 mg/l) (Table 20) for KT and KP water respectively.

In watershed-I and II the total chloride content varies from 8.65 to 16.85 and from 7.96 to 15.42 mg/l respectively. The same ranges from 9.15 to 18.61 mg/l in watershed IV for KT samples. The watershed VI experiences variation in TCl from a minimum of 10.89 to a maximum of 19.20 mg/l. The value of TCl ranges from 10.35 to 13.72 mg/l in watershed-VII.

4.2.4 Sodium (Na)

Sodium content could not be measured for water samples in the beginning of the study period i.e post monsoon 2005. In pre monsoon 2006, Na concentration varies from 4.26 to 14.80 mg/l (mean 9.43 mg/l) (Table 5) and from 6.08 to 18.51 mg/l (mean 11.40 mg/l) (Table 6) for KT and KP water respectively. The same ranges from 2.56 to 13.61 mg/l (mean 7.27 mg/l) (Table 7) and from 4.09 to 15.07 mg/l (mean 8.90 mg/l) (Table8) for KT and KP water respectively during monsoon season of 2006. It varies from 3.25 to 4.03 mg/l (mean 3.72 mg/l) (Table 9) for KR water during the same period. It shows variation from a minimum of 4.42 to a maximum of 14.72 mg/l (mean 9.21 mg/l) (Table 10) in post monsoon 2006 for KT water and from 4.46 to 14.25 mg/l (mean 11.02 mg/l) (Table 11) for KP s water. In the period of pre monsoon 2007, sodium content ranges from 4.30 to 14.56 mg/l (mean 9.04 mg/l) (Table 12) and from 4.30 to 14.20 mg/l (mean 10.69 mg/l) (Table 13) for KT and KP water respectively whereas the variation has been recorded from 2.55 to 13.66 mg/l (mean 7.12 mg/l) (Table 14) for KT water and from 4.28 to 12.95 mg/l (mean 9.40 mg/l) (Table 15) in KP water in monsoon 2007. This variation is less in KR water i.e from 2.96 to 4.15 mg/l (mean 3.69 mg/l) (Table 16). It varies from 4.40 to 14.76 mg/l (mean 9.24 mg/l) (Table 17) and from 2.25 to 14.37 mg/l (mean 10.44 mg/l) (Table 18) in KT and KP water respectively in post monsoon season of 2007. Further, it ranges from 4.30 to 14.55 mg/l (mean 9.04 mg/l) (Table 19) in KT water and from 4.32 to 14.22 mg/l (mean 10.68 mg/l) (Table 20) in KP water during pre monsoon 2008.

In watershed-I the sodium vary from a minimum of 5.12 to a maximum of 14.80 mg/l. an increasing trend has been observed in sodium content in this watershed. Sodium concentration in watershed-II varies from 5.91 to 12.62 mg/l. Sample no. KT-23 shows a decreasing trend in this watershed. In watershed-IV, it ranges from a minimum of 2.55 to a maximum of 11.63 mg/l. A decreasing trend is observed in Na content in this watershed. In watershed-VI, it varies from 2.63 to 13.37 mg/l showing a slight decreasing trend from south to north in the study area.

4.2.5 Potassium (K)

Potassium content varies from a minimum of 0.58 to a maximum of 2.45 mg/l (mean 1.49 mg/l) (Table 5) in KT and from 0.38 to 2.20 mg/l (mean 1.24 mg/l) (Table 6) in KP water in pre monsoon 2006. In monsoon 2006 it ranges from 0.28 to 2.41 mg/l (mean 1.08 mg/l) (Table 7) and from 0.26 to 2.24 mg/l (mean 1.05 mg/l) (Table 8) in KT and KP water respectively. It varies from 0.21 to 0.31 mg/l (mean 0.24 mg/l) (Table 9) in KR water. In post monsoon 2006, potassium content varies from 0.58 to 2.39 mg/l (mean 1.45 mg/l) (Table 10) and from 0.63 to 2.23 mg/l (mean 1.72 mg/l) (Table 11) in KT and KP water samples respectively.

Its values show variation from a minimum of 0.48 to a maximum of 2.50 mg/l (mean 1.49 mg/l) (Table 12) in KT water and from 0.52 to 2.20 mg/l (mean 1.60 mg/l) (Table 13) in KP water in pre monsoon 2007. In monsoon 2007, it ranges from 0.29 to 2.40 mg/l (mean 1.05 mg/l) (Table 14), from 0.48 to 2.20 mg/l (mean 1.53 mg/l) (Table 15) and from 0.19 to 0.29 mg/l (mean 0.22 mg/l) (Table 16) in KT, KP and KR water samples respectively.

The potassium concentration changes from a lower value of 0.56 to a higher value of 2.40 mg/l (mean 1.46 mg/l) (Table 17) in KT and from 0.62 to 2.24 mg/l (mean 1.72 mg/l) (Table 18) in KP water in post monsoon 2007. The same varies in pre monsoon 2008 from a minimum of 0.48 to a maximum of 2.50 mg/l (mean 1.49 mg/l) (Table 19) and from 0.51 to 2.21 mg/l (mean 1.59 mg/l) (Table 20) in KT and KP water respectively.

In watershed-I, potassium concentration varies from 0.74 to 2.48 mg/l whereas it ranges from 0.81 to 2.50 mg/l in watershed-II. There is an increasing trend in watershed-I while watershed-II shows a decreasing trend in potassium concentration.

The potassium content ranges from a minimum value of 0.29 to a maximum value of 2.14 mg/l in watershed-IV showing a decreasing trend from south to north in the watershed area.

In watershed-VI, the potassium content varies from 0.28 to 2.26 mg/l showing a mixed trend. Pre monsoon seasons of 2007 and 2008 show a decreasing trend while post monsoon seasons of 2006 and 2007 indicate an increasing trend.

4.2.6 Calcium (Ca)

Calcium has been found to be the most dominant cation in the study area. Its concentration varies from a minimum of 7.52 to a maximum of 15.68 mg/l (mean 10.82 mg/l) (Table 10) and from 9.72 to 25.28 mg/l (mean 16.92 mg/l) (Table 11) in KT and KP water in post monsoon 2006. In pre monsoon 2007, its content ranges from 5.83 to 15.56 mg/l (mean 12.36 mg/l) (Table 12) in KT and from 9.75 to 27.23 mg/l (mean 18.19 mg/l) (Table 13) in KP water. The same shows variation from 5.83 to 15.56 mg/l (mean 10.76 mg/l) (Table 14) in KT and from 5.83 to 23.34 mg/l (mean 13.42 mg/l) (Table 15) in KP water in monsoon, 2007. Calcium content in rain water (KR) is comparatively very low; it varies from 3.89 to 5.83 mg/l (mean 4.66 mg/l) (Table 16).

In post monsoon 2007, it records variation from a minimum of 7.78 to a maximum of 15.56 mg/l (mean 10.45 mg/l) (Table 17) in KT and from 9.72 to 25.28 mg/l (mean 16.43 mg/l) (Table 18) in KP water. Its concentration varies from 5.83 to 15.56 mg/l (mean 12.36 mg/l) (Table 19) and from 9.72 to 27.23 mg/l (mean 18.08 mg/l) (Table 20) in KT and KP water respectively in pre monsoon 2008.

In watershed-I calcium content ranges from a minimum of 7.52 to a maximum of 15.56 mg/l whereas it varies from 5.83 to 15.56 mg/l in watershed-II. It varies from 7.72 to 15.56 mg/l and from 5.83 to 15.68 mg/l in watersheds-IV and VI respectively. The variation has been recorded from 7.78 to 13.61 mg/l in watershed-VII.

In pre-monsoon 2007, there is a slight increasing trend while in monsoon 2007 the trend is decreasing in watershed-I. All the seasons show slight increasing trend except post-monsoon 2007 in watershed-IV.

4.2.7 Magnesium (Mg)

Magnesium content varies from a minimum of 1.16 to a maximum of 10.08 mg/l (mean 6.51 mg/l) (Table 10) and from 5.87 to 15.31 mg/l (mean 9.71 mg/l) (Table 11) in KT and KP water respectively in post monsoon 2006. During pre monsoon 2007, it ranges from 1.16 to 11.78 mg/l (mean 6.06 mg/l) (Table 12) in KT and from 5.87 to 12.95 mg/l (mean 7.82 mg/l) (Table 13) in KP water samples. It varies from 2.34 to 9.42 mg/l (men 5.07 mg/l) (Table 14) and from 2.34 to 10.06 mg/l (mean 6.21 mg/l) (Table 15) in KT and KP water respectively in monsoon season of 2007 and remains constant at 3.53 mg/l (Table 16) in KR samples. In post monsoon 2007 it ranges from 1.16 to 9.42 mg/l (mean 6.47 mg/l) (Table 17) and from 5.87 to 15.31 mg/l (mean 10.00 mg/l) (Table 18) in KT and KP water respectively. The variation has been recorded from 1.16 to 11.78 mg/l (mean 6.06 mg/l) (Table 19) in KT water whereas it varies from 5.87 to 12.95 mg/l (mean 8.17 mg/l) (Table 20) in KP water in pre monsoon 2008.

In watershed-I magnesium content varies from a minimum of 2.34 to a maximum of 9.42 mg/l whereas variation has been recorded from 4.70 to 9.56 mg/l in watershed-II. It ranges from 2.34 to 10.08 mg/l in watershed-IV and from 1.16 to 11.78 mg/l in watershed-VII. An increasing trend in Mg content has been observed in all the seasons in watersheds-I, IV and VI.

4.2.8 Fluoride

Fluoride concentration varies from less than 0.10 to 0.81 mg/l (mean 0.50 mg/l) (Table 10) in KT and from 0.28 to 0.74 mg/l (mean 0.56 mg/l) (Table 11) in KP water in post monsoon 2006. During pre monsoon 2007, it ranges from a minimum of 0.12 to a maximum of 0.82 mg/l (mean 0.40 mg/l) (Table 12) and from 0.26 to 0.69 mg/l (mean 0.53 mg/l) (Table 13) in KT and KP water respectively. In monsoon season of 2007 the variation has been recorded from 0.10 to 0.79 mg/l (mean 0.38 mg/l) (Table 14) and from 0.21 to 0.62 mg/l (mean 0.50 mg/l) (Table 15) in KT and KP water samples respectively. It is constant at 0.60 mg/l (Table 16) in all KR samples.

It varies from a minimum value of less than 0.10 to a maximum value of 0.80 mg/l (mean 0.50 mg/l) (Table 17) in KT and from 0.28 to 0.76 mg/l (mean 0.57 mg/l) (Table 18) in KP water respectively in post monsoon 2007. The variation has been recorded from 0.12 mg/l to 0.82 mg/l (mean 0.40 mg/l) (Table 19) and from 0.08 to 0.68 mg/l (mean 0.50 mg/l) (Table 20) in KT and KP water respectively in pre monsoon season of 2008.

Variation in watershed-I is from a minimum of 0.10 to a maximum of 0.81 mg/l and it varies from 0.14 to 0.82 mg/l in watershed-II. It ranges from 0.15 to 0.71 mg/l and from 0.15 to 0.61 mg/l in watershed-IV and VI respectively. It records variation from 0.60 to 0.73 mg/l in watershed-VII. A sharp decreasing trend is observed in watershed-IV.

4.2.9 Nitrate

Variation in nitrate concentration has been recorded from 0.13 to 0.71 mg/l (mean 0.32 mg/l) (Table 10) in KT and from 0.28 to 0.68 mg/l (mean 0.57 mg/l) (Table 11) in KP water in post monsoon 2006. In pre monsoon 2007 it ranges from a minimum of 0.14 to a maximum of 0.74 mg/l (mean 0.34 mg/l) (Table 12) and from 0.28 to 0.63 mg/l (mean 0.54 mg/l) (Table 13) in KT and KP water respectively.

It varies from 0.14 to 0.72 mg/l (mean 0.32 mg/l) (Table 14) and from 0.25 to 0.61 mg/l (mean 0.51 mg/l) (Table 15) in KT and KP water samples respectively in monsoon 2007. It ranges from 0.18 to 0.20 mg/l (mean 0.19 mg/l) (Table 16) in KR water. In post monsoon season of 2007, it varies from a minimum of 0.12 to a maximum of 0.70 mg/l (mean 0.32 mg/l) (Table 17) in KT and from 0.28 to 0.70 mg/l (mean 0.58 mg/l) (Table 18) in KP water. It ranges from 0.14 to 0.75 mg/l (mean 0.34 mg/l) (Table 19) and from 0.29 to 0.65 mg/l (mean 0.54 mg/l) (Table 20) in KT and KP water respectively in pre monsoon 2008.

It varies from a minimum of 0.18 to a maximum of 0.62 mg/l in watershed-I and from 0.13 to 0.62 mg/l in watershed-II. Variation in watershed-IV has been observed from 0.12 to 0.68 mg/l and the same ranges from 0.18 to 0.68 mg/l in watershed-VI. There is a sharp decreasing trend in watershed-IV.

4.2.10 Sulphate

Sulphate content varies from a minimum of 1.78 to 4.80 mg/l (mean 3.27 mg/l) (Table 10) and from 11.90 to 15.05 mg/l (mean 13.66 mg/l) (Table 11) in KT and KP water respectively in post monsoon 2006. The variation has been recorded from 1.85 to 4.75 mg/l (mean 3.41 mg/l) (Table 12) in KT and from 10.50 to 14.60 mg/l (mean 13.10 mg/l) (Table 13) in KP water during pre monsoon season of 2007. In monsoon season of 2007, it ranges from 1.85 to 4.50 mg/l (mean 3.27 mg/l) (Table 14) and from 9.75 to 13.60 mg/l (mean 11.92 mg/l) (Table 15) in KT and KP water respectively. It varies from 1.75 to 2.40 mg/l (mean 1.94 mg/l) (Table 16) in KR water. Its value stretches from a minimum of 1.75 to a maximum of 4.75 mg/l (mean 3.30 mg/l) (Table 17) and from 11.95 to 15.25 mg/l (mean 13.71 mg/l) (Table 18) in KT and KP water respectively in post monsoon 2007. The content of sulphate ranges from a minimum of 1.85 to a maximum of 4.75

mg/l (mean 3.45 mg/l) (Table 19) in KT water whereas it varies from 10.55 to 14.65 mg/l (mean 13.14 mg/l) (Table 20) in KP water in pre monsoon 2008.

In watershed-I sulphate content varies from a minimum of 2.60 to a maximum of 4.65 mg/l whereas the same ranges from 2.95 to 4.70 mg/l in watershed-II. It varies from 1.75 to 4.30 mg/l and from 1.85 to 3.65 mg/l in watershed-IV and VI respectively.

The sulphate content in KP water is much higher than that in KT water. Watershed-I is showing an increasing trend whereas a decreasing trend is observed in watersheds- IV and VI.

4.2.11 Cadmium, Zinc, Chromium, Manganese and Lead

The concentration of cadmium is almost constant at 0.03 mg/l (Table 10, 12, 14, 17&19) in KT water of all the seasons whereas it varies from 0.02 to 0.03 mg/l (Table 11, 13, 15, 18 & 20) in KP water.

Zinc content varies from 0.01 to 0.06 mg/l (Table 10, 12, 14, 17&19) in KT water and from 0.02 to 0.09 mg/l (Table 11, 13, 15, 18 & 20) in KP water. It remains constant at 0.01 mg/l (Table 16) in rain water samples in monsoon season. Its concentration is slightly higher in supply water as compared to tuikhur water in all the seasons.

Except few samples with 0.01 mg/l, chromium is found to be nil in KT, KP and KR water in all the seasons.

Manganese concentration varies from 0 to 0.03 mg/l in KT and KP water in all the seasons. It is nil in majorities of KT samples. It is constant at 0.01 mg/l (Table 16) in all the KR water samples studied.

The concentration of lead varies from 0.01 to 0.09 mg/l in both KT and KP water samples in all the seasons whereas it remains constant at 0.01 mg/l (Table 16) in KR water samples in monsoon season.

4.2.12 Nickel, Copper, Cobalt and Arsenic

Concentration of Ni, Cu, Co and As has been found to be below the limit of detection in KT, KP and KR water in all the seasons during which study was carried out.

4.2.13 Iron (Fe)

Iron concentration in KT water varies from 0.01 to 0.04 mg/l except two samples that is KT-30 and KT- 32 where it ranges from 0.32 to 0.34 mg/l in pre monsoon (Table 5, 12 & 19) and post monsoon seasons (Table 10 &17) and from 0.21 to 0.30 mg/l in monsoon season (Table 7 & 14). Its concentration gets reduced in monsoon season. It varies from 0.01 to 0.04 mg/l in KP water in all the seasons (Table 6, 8, 11, 13, 15, 18 & 20). KR water records a constant value of iron content at 0.01 mg/l (Table 9 & 16).

4.3 Bacteriological Parameter

4.3.1 Most Probable Number (MPN)

Most probable number (MPN) varies from 5 to 28/100 ml water (Table 5) and from 8 to 40/ 100 ml water (Table 6) in KT and KP water respectively in pre monsoon 2006. MPN ranges from 7 to 26 / 100 ml water (Table 7), from 15 to 42/ 100 ml water (Table 8) and from 12 to 17/ 100 ml water (Table 9) in KT, KP and KR water respectively in monsoon 2006. Variation in MPN has been recorded from 6 to 30/ 100 ml water (Table 10) and from 7 to 43/ 100 ml water (Table 11) in KT and KP water respectively in post monsoon 2006. In pre monsoon season of 2007, MPN varies from a minimum of 7 to a maximum of 28/ 100 ml water (Table 12) in KT water and from a minimum of 10 to a maximum of 57/ 100 ml water (Table 13) in KP water samples. It ranges from 12 to 41/ 100 ml water (Table 14) in KT water and from 14 to 40/ 100 ml water (Table 15) in KP water in monsoon 2007. Variation in MPN in KR water has been recorded from a minimum of 10 to a maximum of 20/ 100 ml water (Table 16). It varies from 7 to 30/ 100 ml water (Table 17) and from 11 to 46/ 100 ml water (Table 18) in KT and KP water respectively in post monsoon 2007. MPN ranges from 8 to 30/ 100 ml water (Table 19) and from 15 to 43/ 100 ml water (Table 20) in KT and KP water respectively in pre monsoon 2008.

Table 3: Physico-chemical parameters of ‘KT’ Post monsoon 2005

Micro water shed	Samples	LOCATION	pH	EC	TDS	Turbidity	TA	TH	TCl
	KT-28	Kawnpui-PWD	7.9	67	50	0.6	37.25	47.5	13.22
	KT-32	Kawnpui– Hortoki III	7.3	205	142	0.8	32.25	49.25	13.5
	KT-31	Kawnpui – Hortoki II	6.7	87	57	0.6	48.5	58.6	11.72
Water shed II	KT-24	Bualpui-BSNL	7.2	188	112	0.9	85	63	15.21
	KT-22	Thingdawl pump st	6.8	123	87	0.7	42.75	68.35	8.75
	KT-21	Thingdawl -Agri Park	6.8	147	98	0.5	37.25	52.9	10.85
Water shed IV	KT-14	Klb-ICAR complex	7.1	140	90	1	41.25	44.38	18.61
	KT-11	Klb-Diakkawn ground	7.3	150	93	0.7	31.62	55	16.23
	KT-13	Klb-Diakkawn- Azl rd II	6.8	110	72	0.5	37.25	48.12	14.92
	KT-12	Klb, Diakkawn- Azl rd I	7.2	145	92	0.8	24.7	47	16.89
	KT-16	Klb, Forest veng	7	95	60	0.6	40.25	63.5	14
	KT-15	Klb, Project veng	6.7	135	89	0.6	38.5	55	11.32
	KT-3	Klb-old UPC church	6.8	197	115	0.5	40.5	50.54	-
	KT-1	Klb-Convent rd	6.9	192	112	0.5	30.62	60	13.97
	KT-2	Klb, St. John’s school	7.1	185	110	0.6	28.25	65.23	14.89
	KT-4	Klb-Venglai P/S-III	6.9	235	162	0.5	45.3	44.68	-
Water shed VI	KT-5	Klb-Banglakawn	7.4	231	160	0.5	32.6	47.45	16.53
	KT-6	Klb-electric veng	7.3	90	55	0.6	45	59.25	19.2
	KT-7	Klb, police st	7.3	85	52	1	47.62	45.5	13.94
	KT-9	Klb-Saidan -II	6.9	110	72	0.5	35.95	44.73	14.7
	KT-8	Klb-Saidan-I	7	132	80	0.7	40	44.62	15.06
	KT-10	Klb-petrol pump	7.1	144	90	0.6	38.75	60.28	14.85
Mean			7.07	145.14	93.18	0.65	40.05	53.40	14.42
Min			6.7	67	50	0.5	24.7	44.38	8.75
Max			7.9	235	162	1	85	68.35	19.2

Table 4: Physico-chemical parameters of ‘KP’ Post monsoon 2005

Samples	LOCATION	pH	EC	TDS	Turbidity	TA	TH	TCl
KP-17	Klb–Hospital	6.9	190	122	0.8	101.75	65.8	12.28
KP-16	Kawnpui-Govt HS	6.9	183	120	0.9	102	30.75	14.23
KP-14	Bualpui-Gorkha hotel	7.2	248	162	1	87.75	65.42	10.12
KP-13	Thingdawl-Post off	7.7	135	92	0.7	91.5	72.3	8.35
KP-8	Klb-Paradise rest'rant	6.9	185	120	1	93.25	87.85	10.25
KP-9	Klb-Diakkawn Hlua’s Inn	7.1	96	72	1	98.25	34	13.91
KP-1	Klb-Venglai Paster’s Inn	7.3	178	121	1	96.25	67.85	15
KP-2	Klb–Venglai Lalkunga’s Inn	7.4	219	153	1	91.5	63.35	14.23
KP-6	Klb– BSNL	7	171	109	0.9	97	93	5.75
KP-5	Klb-Post Off	7.6	208	151	0.8	105.25	69.85	13.2
KP-4	Klb–Didi rest'rant	7.4	165	117	0.9	108.5	48.75	12.72
Mean		**7.22**	**179.82**	**121.73**	**0.91**	**97.55**	**63.54**	**11.82**
Min		**6.9**	**96**	**72**	**0.7**	**87.75**	**30.75**	**5.75**
Max		**7.7**	**248**	**162**	**1**	**108.5**	**93**	**15**

Table 5: Physico-chemical parameters of ‘KT’ Pre monsoon 2006

Micro water shed	Samples	LOCATION	pH	EC	TDS	TURB	TA	TH	TCl	MPN	Na	K	Fe
water Shed I	KT-27	Kawnpui–Azl rd I	7.3	176	125	0.3	37.25	48	14.82		8.59	1.21	0.03
	KT-26	Kawnpui–Azl rd I	6.8	136	92	0.7	38.5	45.5	11.7		8.73	0.95	0.02
	KT-25	Kawnpui–police st	6.8	147	103	0.8	37.25	48.75	9.65	17	9.85	0.79	0.02
	KT-28	Kawnpui–PWD	7.7	70	49	0.5	40.5	39.75	12.35		10.13	2.15	0.01
	KT-29	Kawnpui–Mualvum rd	7.5	189	127	0.9	45.3	42.5	13.36	14	11.31	1.72	0.03
	KT-32	Kawnpui– Hortoki III	7.2	200	145	0.9	37.25	48.5	12	28	14.17	2.13	0.34
	KT-31	Kawnpui – Hortoki II	7	80	53	0.6	32.25	56.75	10.25	26	13.92	2.11	0.01
	KT-30	Kawnpui – Hortoki I	7.1	208	147	0.6	48.25	55.75	16.85		14.8	1.36	0.33
Water shed II	KT-24	Bualpui BSNL	7.4	180	128	0.6	86.25	61.5	14.75		12.62	2.45	0.03
	KT-23	Bualpui - below FCI	7.6	128	84	0.8	42.5	60.25	11.38		10.43	1.98	0.02
	KT-22	Thingdawl pump st	6.9	130	58	0.7	40.5	65	10.23	5	11.56	2.24	0.02
	KT-21	Thingdawl-Agri Park	7.2	145	90	0.7	38.5	48.7	11.5	10	7.31	0.98	0.03
Water shed IV	KT-11	Klb-Diakkawn ground	7	146	90	0.6	33.25	50	14.75		8.18	1.78	0.02
	KT-13	Klb-Diakkawn- Azl rd II	7.1	142	91	0.5	37.5	45.75	13.15	15	6.31	1.13	0.02
	KT-16	Klb, Diakkawn- Azl rd I	6.9	100	66	0.7	42.15	62.5	11.68	9			
	KT-3	Klb, Forest veng	6.7	150	94	0.5	42.6	48.5	11.85		7.56	1.63	0.01
	KT-1	Klb-Convent rd	7	140	91	0.6	32.25	55	11.95	5	4.38	0.69	0.02
	KT-2	Klb, St. John’s school	7.3	100	68	0.7	31.4	60	13.2				
	KT-4	Klb- Venglai P/S-III	6.9	135	88	0.5	46.35	45.75	10.97	12	6.8	0.98	0.02
Water shed VI	KT-5	Klb-Banglakawn	7.4	125	82	0.6	34.25	46.25	16		11.62	1.64	0.02
	KT-6	Klb-electric veng	7.6	181	127	0.7	45.5	58	18.15	10	10.56	1.5	0.03
	KT-7	Klb, police st	7.6	82	57	1	48.6	43.25	13.67		5.72	0.83	0.01
	KT-9	Klb-Saidan -II	7.7	108	69	0.6	37.25	42.75	15.1	12	5.23	0.58	0.02
	KT-8	Klb- Saidan-I	7.1	128	83	0.7	41.25	45.5	14.5	21	10.31	1.61	0.01
	KT-10	Klb-petrol pump	7.2	151	93	1	40.25	56.5	13.7		12.15	2.23	0.03
	KT-17	Klb-Rengtekawn-I	7.2	184	130	0.8	37.25	48.5	17	24	9.23	1.94	0.04
	KT-18	Klb-Rengtekawn-II	7.3	109	71	0.8	32.25	52.3	10.89		4.26	0.6	0.03
Mean			7.20	139.63	92.63	0.68	40.98	51.17	13.16	14.86	9.43	1.49	0.05
Min			6.7	70	49	0.3	31.4	39.75	9.65	5	4.26	0.58	0.01
Max			7.7	208	147	1	86.25	65	18.15	28	14.8	2.45	0.34

Table 6: Physico-chemical parameters of 'KP' Pre monsoon 2006

Samples	Location	pH	EC	TDS	TURBI	TA	TH	TCl	MPN	Na	K	Fe
KP-18	Kawnpui -MRB Br.	7.2	88	57	0.4	100.25	55.25	14.71	-	6.83	0.73	0.01
KP-17	Kawnpui–Hospital	7	180	110	1	102.25	60	11	17	12.75	1.16	0.03
KP-16	Kawnpui- Govt. HS	7.5	140	95	1	90.25	35.25	13.71	-	11.6	1.08	0.02
KP-15	Bualpui-FCI	7.3	159	101	0.5	87.25	42.05	10.86	22	13.72	1.92	0.03
KP-14	Bualpui- Gorkha hotel	7.1	230	150	0.8	91.75	62	9.2	8	15.18	2.1	0.03
KP-13	Thingdawl-Post office	6.8	120	80	0.6	88.5	65.5	8.25		6.52	0.38	0.02
KP-8	Klb-Paradise rest'rant	7.2	181	125	0.8	95.5	88	9.25	35	13.81	1.75	0.03
KP-9	Klb- Diakkawn –Hlua Inn	6.9	96	60	1.3	96.75	36.5	13.12	-	6.08	0.52	0.02
KP-1	Klb-Venglai- Paster Inn	7.6	132	92	1.2	98.75	60	14.21	14	12.86	1.73	0.01
KP-2	Klb–Venglai Lalkunga Inn	7.4	128	90	1	92.3	61.75	12	17	18.51	2.2	0.01
KP-3	Klb–Hospital	6.7	110	75	0.8	108.25	42.3	11.75	-			
KP-7	Klb-Electric sub station	7.1	178	121	0.5	91.5	81.5	9.7		14.26	1.83	0.04
KP-6	Klb-BSNL	7.5	201	137	0.6	98.25	80.75	7.85	26	15.1	1.81	0.05
KP-5	Klb-Post Office	7	185	129	0.6	106.75	70.75	12.15				
KP-4	Klb – DIDI Rest'rant	6.9	142	98	0.7	107.25	45.75	10.89	11	9.73	0.93	0.02
KP-10	Klb-MST Stand	7	108	73	0.4	98.25	42.3	8.68	40	8.11	0.44	0.02
KP-11	Klb-PHE office	7.3	154	106	0.6	91.25	45.75	10.5		9.52	0.61	0.03
KP-12	Rengtekawn-check gate	7.3	162	110	0.7	100.25	48.5	12.32	12	8.74	0.58	0.03
KP-20	Bilkhawthlir – PWD	7.3	208	153	0.8	102.25	46.5	14.11		14.56	2.11	0.03
KP-19	Bilkhawthlir–Hospital	6.8	105	70	0.5	102.5	58.75	10.8	13	7.25	0.52	0.01
Mean		7.15	150.35	101.60	0.74	97.50	56.46	11.25	19.55	11.40	1.24	0.02
Min		6.7	88	57	0.4	87.25	35.25	7.85	8	6.08	0.38	0.01
Max		7.6	230	153	1.3	108.25	88	14.71	40	18.51	2.2	0.05

Table 7: Physico-chemical parameters of 'KT' Monsoon 2006

Micro water shed	Samples	Loaction	pH	EC	TDS	Turbidity	TA	TH	TCl	MPN	Na	K	Fe
water Shed I	KT-27	Kawnpui–Azl rd II	7.2	140	106	0.7	34.5	45	12.75	15	5.12	0.75	0.02
	KT-26	Kawnpui–Azl rd I	6.7	132	106	0.9	37.25	42.47	11		8.06	0.99	0.02
	KT-25	Kawnpui–police st	6.8	149	116	1.7	52	46.3	8.73	26	8.7	1.06	0.02
	KT-28	Kawnpui–PWD	7.6	72	61	2	40.75	37.4	11.98		9.69	1.03	0.01
	KT-29	Kawnpui–Mualvum rd	7.5	173	128	1.5	37.8	40.65	9.85	21	11.06	2.3	0.03
	KT-32	Kawnpui– Hortoki III	7	190	150	1.4	33.8	49.3	12	23	13.61	2.41	0.22
	KT-31	Kawnpui – Hortoki II	6.9	82	59	1.2	35.5	50.1	9.36		13	2.39	0.01
Water shed II	KT-24	Bualpui-BSNL	6.8	178	132	1.2	83.75	56.6	12.86	12	11.73	1.53	0.02
	KT-23	Bualpui - below FCI	6.7	130	94	2.2	40.5	53.75	9.7		6.79	0.9	0.01
	KT-22	Thingdawl pump st	6.9	107	85	1.5	46.3	55	8.25	8	10.75	1.03	0.01
	KT-21	Thingdawl-Agri Park	7.1	131	97	2.3	37.5	57.2	9.65	13	5.91	0.82	0.02
Water shed IV	KT-11	Klb-Diakkawn ground	6.7	142	108	1.3	32.25	38.98	13		6.55	1.03	0.02
	KT-13	Klb-Diakkawn- Azl rd II	7	125	86	0.8	33.5	42.85	12	15	4.78	0.73	0.01
	KT-12	Klb, Diakkawn- Azl rd I	6.9	128	90	1.5	22	48.2	14.68		5.29	0.98	0.02
	KT-16	Klb, Forest veng	7.1	90	68	1.2	38.5	46.75	12.67		2.56	0.29	0.01
	KT-15	Klb, Project veng	7.3	127	107	2.1	37.25	48.7	10.7		3.12	0.38	0.02
	KT-1	Klb-Convent rd	6.8	125	93	1.3	29.3	42.7	9.15	8	3.51	0.53	0.02
	KT-2	Klb, St. John's school	7	98	72	1.3	30.25	53.9	11.2	7	2.73	0.41	0.01
Water shed VI	KT-5	Klb-Banglakawn	7.1	122	90	0.9	32.25	42.25	11	15	6.71	1.06	0.02
	KT-6	Klb-electric veng	7.5	170	117	0.8	38.78	48.8	16.75	12	9.63	1.08	0.03
	KT-7	Klb, police st	7.3	81	63	2.6	47.2	37.25	11.9	14	2.95	0.28	0.01
	KT-10	Klb-petrol pump	6.9	130	98	1.2	37.45	49.6	12.25	17	10.82	2.21	0.01
	KT-17	Klb-Rengtekawn-I	7.1	171	121	1.7	32.5	41.3	14.92	23	7.64	1.1	0.02
Water shed VII	KT-19	Bilkhawthlir-BSNL	7.2	110	78	1	35.75	56.5	10.62	16	3.86	0.61	0.01
Mean			7.05	129.29	96.88	1.43	38.61	47.15	11.54	15.31	7.27	1.08	0.03
Min			6.7	72	59	0.7	22	37.25	8.25	7	2.56	0.28	0.01
Max			7.6	190	150	2.6	83.75	57.2	16.75	26	13.61	2.41	0.22

Table 8: Physico-chemical parameters of 'KP' Monsoon 2006

Samples	Location	pH	EC	TDS	Turbidity	TA	TH	TCl	MPN	Na	K	Fe
KP-18	Kawnpui -MRB Br.	6.8	96	62	0.9	93.6	52.9	13.2	23	5.35	0.51	0.01
KP-17	Kawnpui – Hospital	6.8	172	126	1.3	101	57	9.25	27	9.48	0.98	0.02
KP-16	Kawnpui- Govt. HS	7.3	128	102	1.6	87.5	38	12.3	21	10.12	1.05	0.01
KP-13	Thingdawl- Post office	6.9	117	83	0.9	90.7	63.5	7.5	19	4.09	0.26	0.01
KP-8	Klb-Paradise rest'rant	6.9	190	152	1.1	83.6	73	9	42	11.65	1.46	0.03
KP-9	Klb- Diakkawn –Hlua Inn	6.7	85	60	2	95	77.4	12	32	7.34	1.06	0.01
KP-1	Klb- Venglai- Paster Inn	7.2	140	105	0.9	87.5	45.3	12.4	17	10.36	1.11	0.01
KP-2	Klb–Venglai Lalkunga Inn	7.2	120	82	0.6	85	57.8	11.3	15	15.07	2.24	0.01
KP-3	Klb-Hospital	7	90	60	1.2	91.3	37.3	11	18	11.31	1.23	0.01
KP-5	Klb–Post Office	6.8	150	118	0.9	88.3	68.9	11.3	21	6.78	0.71	0.02
KP-4	Klb – DIDI Rest'rant	7.1	135	103	1.4	93.7	42	9.2	23	7.89	1.02	0.02
KP-12	Rengtekawn-check gate	7.3	160	128	1.5	97.2	50.2	10.3	26	7.19	0.93	0.02
KP-20	Bilkhawthlir–PWD	7.2	190	150	1.2	99.5	36.8	7.6	19	12.91	1.82	0.02
KP-19	Bilkhawthlir–Hospital	6.7	112	93	1	85.6	57.3	8.75	26	5.1	0.37	0.01
Mean		6.99	135	102	1.18	91.35	54.08	10.36	23.50	8.90	1.05	0.02
Min		6.7	85	60	0.6	83.6	36.75	7.5	15	4.09	0.26	0.01
Max		7.3	190	152	2	100.5	77.35	13.2	42	15.07	2.24	0.03

Table 9: Physico-chemical parameters of 'KR' Monsoon 2006

Sample	pH	EC	TDS	Turbidity	TA	TH	TCl	MPN	Na	K	Fe
KR-1	6.9	20	18	0.4	25	29.1	7.35	15	3.25	0.25	0.01
KR-2	7.1	25	20	0.3	16.75	27	7	13	4.03	0.31	0.01
KR-3	7.2	18	16	0.6	22.8	25.5	8.1	12	3.91	0.21	0.01
KR-4	7.2	10	10	0.2	23	23.75	8.35	17	3.86	0.21	0.01
KR-5	7	20	17	0.2	20.65	29.1	7.9	17	3.57	0.21	0.01
Mean	7.08	18.6	16.2	0.34	21.64	26.89	7.74	14.8	3.72	0.24	0.01
Min	6.9	10	10	0.2	16.75	23.75	7	12	3.25	0.21	0.01
Max	7.2	25	20	0.6	25	29.1	8.35	17	4.03	0.31	0.01

Table 10: Physico-chemical parameters of 'KT' Post monsoon 2006

Micro water shed	Samples	Location	**pH**	**EC**	**TDS**	**TURB**	**TA**	**TH**
Water Shed I	KT-27	Kawnpui–Azl rd I	7.40	182.00	125.00	0.60	38.12	47.80
	KT-26	Kawnpui–Azl rd I	6.90	140.00	94.00	0.80	38.25	44.23
	KT-25	Kawnpui–police st	7.00	150.00	105.00	0.90	38.73	50.12
	KT-28	Kawnpui–PWD	7.70	70.00	50.00	0.50	37.70	48.15
	KT-29	Kawnpui–Mualvum rd	7.40	200.00	146.00	1.00	45.83	44.16
	KT-32	Kawnpui– Hortoki III	7.20	225.00	148.00	0.80	32.86	50.50
	KT-31	Kawnpui – Hortoki II	7.30	85.00	53.00	0.70	31.96	56.25
	KT-30	Kawnpui – Hortoki I	7.20	210.00	147.00	0.70	47.85	56.10
Water shed II	KT-24	Bualpui BSNL	7.30	186.00	110.00	0.90	85.87	62.25
	KT-23	Bualpui - below FCI	7.40	135.00	92.00	0.70	42.15	65.27
	KT-22	Thingdawl pump st	6.90	125.00	86.00	0.70	42.50	65.78
	KT-21	Thingdawl-Agri Park	6.90	150.00	96.00	0.60	37.75	55.22
Water shed IV	KT-14	Klb-ICAR complex	7.10	139.00	90.00	0.90	40.50	45.12
	KT-11	Klb-Diakkawn ground	7.40	153.00	94.00	0.80	30.92	55.85
	KT-13	Klb-Diakkawn- Azl rd II	7.00	120.00	75.00	0.50	36.68	47.86
	KT-12	Klb, Diakkawn- Azl rd I	7.30	144.00	92.00	0.70	26.35	48.12
	KT-16	Klb, Forest veng	7.00	100.00	75.00	0.70	39.85	62.93
	KT-15	Klb, Project veng	6.80	134.00	87.00	0.60	37.90	55.80
	KT-3	Klb-old UPC church	7.50	201.00	150.00	0.50	38.65	53.20
	KT-1	Klb-Convent rd	7.10	183.00	108.00	0.70	32.25	61.30
	KT-2	Klb, St. John's school	7.30	178.00	105.00	0.60	26.78	59.60
	KT-4	Klb- Venglai P/S-III	6.80	242.00	160.00	0.50	44.85	45.33
Water shed VI	KT-5	Klb-Banglakawn	7.50	228.00	156.00	0.80	33.30	49.00
	KT-6	Klb-electric veng	7.10	83.00	50.00	0.60	44.90	60.12
	KT-7	Klb, police st	7.20	86.00	51.00	0.80	48.10	43.95
	KT-9	Klb-Saidan -II	6.80	108.00	70.00	0.70	36.38	45.20
	KT-8	Klb- Saidan-I	7.10	136.00	88.00	0.80	41.50	45.25
	KT-10	Klb-petrol pump	7.00	148.00	94.00	0.70	38.42	60.53
	KT-17	Klb-Rengtekawn-I	7.10	190.00	130.00	0.80	44.26	63.00
	KT-18	Klb-Rengtekawn-II	7.30	115.00	71.00	0.90	37.25	50.32
Water shed VII	KT-19	Bilkhawthlir-BSNL	7.40	140.00	106.00	0.70	36.50	54.40
	KT-20	Bilkhawthlir-Post Off	7.20	215.00	156.00	0.60	35.80	51.30
Mean			7.18	153.16	99.91	0.71	39.71	53.25
Min			6.80	70.00	7.00	0.50	26.35	43.95
Max			7.70	242.00	160.00	1.00	85.87	65.78

Contd…

Table 10 Contd…

- Below Limit of Detection (BLD)

Micro water	Sample	Location	**Na**	**K**	**Fe**	**Ca**	**Mg**	**Cd**	**Zn**	**Cr**	**Mn**	**Ni**	**Cu**	**Co**	**Pb**	**As**
water Shed I	KT-27	Kawnpui–Azl rd I	8.62	1.20	0.03	9.33	5.95	0.03	0.03	0.00	0.00	*	*	*	0.02	*
	KT-26	Kawnpui–Azl rd I	8.59	1.08	0.02	11.08	4.02	0.03	0.03	0.00	0.00	*	*	*	0.02	*
	KT-25	Kawnpui–police st	9.96	0.87	0.03	7.86	7.41	0.03	0.03	0.00	0.00	*	*	*	0.01	*
	KT-28	Kawnpui–PWD	10.02	2.13	0.02	10.07	4.62	0.03	0.03	0.01	0.03	*	*	*	0.01	*
	KT-29	Kawnpui–Mualvum	11.26	1.75	0.03	8.65	5.48	0.03	0.03	0.00	0.00	*	*	*	0.01	*
	KT-32	Kawnpui– Hortoki	14.06	2.15	0.34	7.52	7.70	0.03	0.03	0.01	0.03	*	*	*	0.01	*
	KT-31	Kawnpui – Hortoki II	13.90	2.24	0.02	10.26	7.44	0.02	0.02	0.01	0.03	*	*	*	0.08	*
	KT-30	Kawnpui – Hortoki I	14.72	1.45	0.34	9.73	7.72	0.03	0.03	0.00	0.02	*	*	*	0.09	*
Water shed II	KT-24	Bualpui BSNL	12.10	2.39	0.03	11.50	8.14	0.02	0.02	0.00	0.00	*	*	*	0.01	*
	KT-23	Bualpui - below FCI	11.48	2.21	0.03	10.38	9.56	0.02	0.02	0.00	0.00	*	*	*	0.09	*
	KT-22	Thingdawl pump st	10.63	1.75	0.02	14.85	6.97	0.03	0.03	0.00	0.00	*	*	*	0.09	*
	KT-21	Thingdawl-Agri Park	7.25	0.91	0.04	12.71	5.70	0.03	0.03	0.00	0.00	*	*	*	0.01	*
Water shed IV	KT-14	Klb-ICAR complex	11.56	1.51	0.04	10.12	4.82	0.03	0.01	0.00	0.00	*	*	*	0.09	*
	KT-11	Klb-Diakkawn	8.20	1.69	0.03	8.75	8.26	0.03	0.01	0.00	0.00	*	*	*	0.08	*
	KT-13	Klb-Diakkawn- Azl	4.61	0.76	0.03	9.72	5.73	0.03	0.01	0.00	0.00	*	*	*	0.01	*
	KT-12	Klb, Diakkawn- Azl	6.39	1.20	0.03	9.86	5.71	0.03	0.01	0.00	0.00	*	*	*	0.08	*
	KT-16	Klb, Forest veng	9.45	1.35	0.02	14.30	6.61	0.03	0.02	0.00	0.00	*	*	*	0.09	*
	KT-15	Klb, Project veng	10.78	1.60	0.03	9.06	8.06	0.03	0.01	0.00	0.02	*	*	*	0.08	*
	KT-3	Klb-old UPC church	7.32	1.60	0.02	7.72	8.24	0.03	0.02	0.00	0.00	*	*	*	0.01	*
	KT-1	Klb-Convent rd	4.42	0.72	0.02	15.28	5.62	0.03	0.01	0.00	0.00	*	*	*	0.08	*
	KT-2	Klb, St. John's	5.16	0.78	0.02	8.06	9.59	0.03	0.02	0.00	0.00	*	*	*	0.09	*
	KT-4	Klb- Venglai P/S-III	6.95	0.95	0.03	10.54	10.08	0.03	0.04	0.00	0.03	*	*	*	0.08	*
Water shed VI	KT-5	Klb-Banglakawn	12.03	1.71	0.02	11.05	5.20	0.03	0.05	0.00	0.00	*	*	*	0.09	*
	KT-6	Klb-electric veng	11.00	1.56	0.03	12.61	6.95	0.03	0.01	0.00	0.00	*	*	*	0.09	*
	KT-7	Klb, police st	5.68	0.87	0.20	15.68	1.16	0.03	0.02	0.00	0.00	*	*	*	0.08	*
	KT-9	Klb-Saidan -II	5.62	0.58	0.02	10.27	4.75	0.03	0.01	0.00	0.00	*	*	*	0.01	*
	KT-8	Klb- Saidan-I	10.43	1.65	0.02	11.46	4.04	0.03	0.02	0.00	0.00	*	*	*	0.01	*
	KT-10	Klb-petrol pump	12.26	2.24	0.03	14.63	5.83	0.03	0.02	0.01	0.00	*	*	*	0.09	*
	KT-17	Klb-Rengtekawn-I	9.18	2.11	0.04	15.10	6.14	0.03	0.02	0.01	0.00	*	*	*	0.09	*
	KT-18	Klb-Rengtekawn-II	9.36	1.90	0.04	10.15	6.06	0.03	0.03	0.00	0.03	*	*	*	0.08	*
Water shed VII	KT-19	Bilkhawthlir-BSNL	4.86	0.62	0.03	8.23	8.22	0.03	0.03	0.00	0.00	*	*	*	0.09	*
	KT-20	Bilkhawthlir-Post Off	6.73	0.85	0.03	9.65	6.61	0.03	0.03	0.00	0.00	*	*	*	0.01	*
Mean			9.21	1.45	0.05	10.82	6.51	0.03	0.02	0.00	0.01	*	*	*	0.06	*
Min			4.42	0.58	0.02	7.52	1.16	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Max			14.72	2.39	0.34	15.68	10.08	0.03	0.05	0.01	0.03	0.00	0.00	0.00	0.09	0.00

Contd…

Table 10 Contd…

Micro water shed	Samples	Location	**TCl**	**F**	**CO_3**	**HCO_3**	**NO_3**	**SO_4**	**MPN**
water Shed I	KT-27	Kawnpui–Azl rd I	15.36	0.10	0	38.12	0.41	2.80	18.00
	KT-26	Kawnpui–Azl rd I	10.95	0.10	0	38.25	0.27	4.25	25.00
	KT-25	Kawnpui–police st	9.78	0.10	0	38.73	0.19	3.15	20.00
	KT-28	Kawnpui–PWD	14.16	0.10	0	37.70	0.18	2.65	12.00
	KT-29	Kawnpui–Mualvum rd	12.99	0.56	0	45.83	0.26	3.90	17.00
	KT-32	Kawnpui– Hortoki III	14.17	0.75	0	32.86	0.59	4.60	30.00
	KT-31	Kawnpui – Hortoki II	12.18	0.59	0	31.96	0.24	2.65	29.00
	KT-30	Kawnpui – Hortoki I	16.19	0.45	0	47.85	0.24	4.65	26.00
Water shed II	KT-24	Bualpui BSNL	14.96	0.10	0	85.87	0.28	4.10	17.00
	KT-23	Bualpui - below FCI	10.00	0.10	0	42.15	0.62	3.65	6.00
	KT-22	Thingdawl pump st	9.11	0.10	0	42.50	0.48	4.40	8.00
	KT-21	Thingdawl-Agri Park	11.20	0.81	0	37.75	0.13	2.95	12.00
Water shed IV	KT-14	Klb-ICAR complex	17.98	0.10	0	40.50	0.17	2.25	22.00
	KT-11	Klb-Diakkawn ground	15.98	0.71	0	30.92	0.71	3.60	14.00
	KT-13	Klb-Diakkawn- Azl rd II	14.17	0.34	0	36.68	0.65	3.65	15.00
	KT-12	Klb, Diakkawn- Azl rd I	15.75	0.53	0	26.35	0.48	3.40	9.00
	KT-16	Klb, Forest veng	13.90	0.10	0	39.85	0.28	3.85	17.00
	KT-15	Klb, Project veng	12.00	0.10	0	37.90	0.25	4.25	15.00
	KT-3	Klb-old UPC church	12.52	0.52	0	38.65	0.25	3.36	17.00
	KT-1	Klb-Convent rd	13.50	0.27	0	32.25	0.16	1.78	26.00
	KT-2	Klb, St. John's school	13.85	0.6	0	26.78	0.13	2.56	15.00
	KT-4	Klb- Venglai P/S-III	11.95	0.29	0	44.85	0.23	1.90	6.00
Water shed VI	KT-5	Klb-Banglakawn	17.00	0.34	0	33.30	0.18	2.58	22.00
	KT-6	Klb-electric veng	18.75	0.31	0	44.90	0.52	3.25	14.00
	KT-7	Klb, police st	14.00	0.29	0	48.10	0.46	3.55	16.00
	KT-9	Klb-Saidan -II	13.88	0.32	0	36.38	0.23	2.20	18.00
	KT-8	Klb- Saidan-I	14.93	0.56	0	41.50	0.19	3.25	25.00
	KT-10	Klb-petrol pump	14.29	0.32	0	38.42	0.19	2.60	28.00
	KT-17	Klb-Rengtekawn-I	12.10	0.10	0	44.26	0.64	2.15	26.00
	KT-18	Klb-Rengtekawn-II	17.28	0.58	0	37.25	0.19	2.85	27.00
Water shed VII	KT-19	Bilkhawthlir-BSNL	11.68	0.63	0	36.50	0.17	4.80	25.00
	KT-20	Bilkhawthlir-Post Off	12.73	0.72	0	35.80	0.21	2.90	19.00
Mean			13.73	0.50	0.00	39.71	0.32	3.27	18.63
Min			9.11	0.27	0.00	26.35	0.13	1.78	6.00
Max			18.75	0.81	0.00	85.87	0.71	4.80	30.00

Table 11: Physico-chemical parameters of ‘KP’ Post monsoon 2006

Samples	Location	**pH**	**EC**	**TDS**	**TURB**	**TA**	**TH**
KP-18	Kawnpui -MRB Br.	7.00	205.00	150.00	1.50	99.25	77.60
KP-17	Kawnpui–Hospital	7.10	201.00	150.00	1.60	97.25	67.90
KP-16	Kawnpui- Govt. HS	7.00	195.00	148.00	1.20	101.50	77.75
KP-15	Bualpui-FCI	7.40	262.00	172.00	1.30	108.50	77.75
KP-14	Bualpui- Gorkha hotel	7.30	255.00	170.00	1.30	97.25	82.45
KP-13	Thingdawl-Post office	7.80	142.00	95.00	1.00	99.25	82.45
KP-8	Klb-Paradise rest'rant	7.00	205.00	146.00	1.30	94.00	82.45
KP-9	Klb- Diakkawn –Hlua Inn	7.40	106.00	70.00	0.90	101.50	82.45
KP-1	Klb-Venglai- Paster Inn	7.20	187.00	120.00	1.20	97.35	67.90
KP-2	Klb–Venglai Lalkunga Inn	7.40	224.00	155.00	1.20	91.25	87.30
KP-3	Klb–Hospital	7.50	210.00	147.00	1.00	96.25	77.60
KP-7	Klb-Electric sub station	7.10	191.00	122.00	1.60	97.50	87.30
KP-6	Klb-BSNL	7.20	180.00	120.00	1.20	98.75	77.75
KP-5	Klb-Post Office	7.50	206.00	142.00	1.10	107.25	82.45
KP-4	Klb – DIDI Rest'rant	7.20	170.00	103.00	0.90	107.50	87.30
KP-10	Klb-MST Stand	7.50	276.00	190.00	1.70	106.85	77.60
KP-11	Klb-PHE office	7.40	110.00	78.00	0.80	98.75	87.30
KP-12	Rengtekawn-check gate	7.30	209.00	147.00	1.00	96.25	87.30
KP-20	Bilkhawthlir – PWD	7.40	176.00	143.00	1.40	102.85	106.70
KP-19	Bilkhawthlir–Hospital	7.20	188.00	147.00	1.50	103.50	87.30
Mean		7.30	194.90	135.75	1.24	100.13	82.23
Min		7.00	106.00	70.00	0.80	91.25	67.90
Max		7.80	276.00	190.00	1.70	108.50	106.70

Contd…

Table 11Contd…

Samples	Location	**Na**	**K**	**Fe**	**Ca**	**Mg**	**Cd**	**Zn**	**Cr**	**Mn**	**Ni**	**Cu**	**Co**	**Pb**	**As**
KP-18	Kawnpui -MRB Br.	14.25	2.15	0.03	17.50	8.23	0.03	0.04	0.01	0.03	BLD	BLD	BLD	0.01	BLD
KP-17	Kawnpui–Hospital	10.30	1.93	0.03	13.61	8.24	0.03	0.04	0.01	0.02	BLD	BLD	BLD	0.02	BLD
KP-16	Kawnpui- Govt. HS	8.69	1.10	0.02	15.56	9.45	0.03	0.04	0.01	0.03	BLD	BLD	BLD	0.01	BLD
KP-15	Bualpui-FCI	9.85	1.73	0.02	17.50	8.27	0.03	0.07	0.01	0.03	BLD	BLD	BLD	0.01	BLD
KP-14	Bualpui- Gorkha hotel	10.54	1.95	0.02	21.39	7.05	0.03	0.05	0.00	0.03	BLD	BLD	BLD	0.01	BLD
KP-13	Thingdawl-Post office	11.43	2.20	0.02	23.34	5.87	0.03	0.03	0.00	0.03	BLD	BLD	BLD	0.02	BLD
KP-8	Klb-Paradise rest'rant	14.12	2.15	0.03	15.56	10.59	0.03	0.09	0.00	0.03	BLD	BLD	BLD	0.01	BLD
KP-9	Klb- Diakkawn –Hlua Inn	13.80	1.95	0.03	21.39	7.05	0.02	0.02	0.00	0.02	BLD	BLD	BLD	0.02	BLD
KP-1	Klb-Venglai- Paster Inn	4.46	0.70	0.03	17.50	5.88	0.02	0.02	0.01	0.02	BLD	BLD	BLD	0.01	BLD
KP-2	Klb–Venglai Lalkunga Inn	4.94	0.63	0.03	13.61	12.95	0.02	0.06	0.01	0.02	BLD	BLD	BLD	0.01	BLD
KP-3	Klb–Hospital	8.02	1.52	0.03	15.56	9.41	0.03	0.06	0.01	0.02	BLD	BLD	BLD	0.01	BLD
KP-7	Klb-Electric sub station	12.56	2.12	0.03	11.61	14.13	0.03	0.04	0.00	0.03	BLD	BLD	BLD	0.01	BLD
KP-6	Klb-BSNL	12.13	1.75	0.02	13.61	10.63	0.03	0.03	0.00	0.02	BLD	BLD	BLD	0.02	BLD
KP-5	Klb-Post Office	11.85	1.60	0.03	13.61	11.77	0.03	0.04	0.01	0.02	BLD	BLD	BLD	0.02	BLD
KP-4	Klb – DIDI Rest'rant	7.16	0.85	0.03	9.72	15.31	0.03	0.02	0.01	0.02	BLD	BLD	BLD	0.01	BLD
KP-10	Klb-MST Stand	11.35	1.68	0.02	19.45	7.05	0.02	0.03	0.00	0.02	BLD	BLD	BLD	0.01	BLD
KP-11	Klb-PHE office	14.08	2.08	0.03	17.50	10.59	0.03	0.04	0.01	0.02	BLD	BLD	BLD	0.01	BLD
KP-12	Rengtekawn-check gate	14.17	2.23	0.02	19.45	9.41	0.03	0.04	0.01	0.03	BLD	BLD	BLD	0.01	BLD
KP-20	Bilkhawthlir – PWD	14.11	2.16	0.02	25.28	10.58	0.03	0.04	0.01	0.02	BLD	BLD	BLD	0.01	BLD
KP-19	Bilkhawthlir–Hospital	12.60	1.95	0.03	15.56	11.77	0.03	0.08	0.01	0.02	BLD	BLD	BLD	0.01	BLD
Mean		11.02	1.72	0.03	16.92	9.71	0.03	0.05	0.01	0.02			BLD	0.01	BLD
Min		4.46	0.63	0.02	9.72	5.87	0.02	0.02	0.00	0.02	0.00	0.00	0.00	0.01	0.00
Max		14.25	2.23	0.03	25.28	15.31	0.03	0.09	0.01	0.03	0.00	0.00	0.00	0.02	0.00

Contd…

Table 11Contd…

Samples	Location	**TCl**	**F**	**CO_3**	**HCO_3**	**NO_3**	**SO_4**	**MPN**
KP-18	Kawnpui -MRB Br.	15.50	0.53	0	99.25	0.63	13.65	39.00
KP-17	Kawnpui–Hospital	13.85	0.51	0	97.25	0.49	14.60	25.00
KP-16	Kawnpui- Govt. HS	15.30	0.62	0	101.50	0.58	12.40	19.00
KP-15	Bualpui-FCI	15.36	0.71	0	108.50	0.65	12.60	27.00
KP-14	Bualpui- Gorkha hotel	10.50	0.67	0	97.25	0.60	11.90	42.00
KP-13	Thingdawl-Post office	9.25	0.53	0	99.25	0.46	15.05	37.00
KP-8	Klb-Paradise rest'rant	12.50	0.74	0	94.00	0.46	14.75	28.00
KP-9	Klb- Diakkawn –Hlua Inn	12.85	0.63	0	101.50	0.66	13.40	19.00
KP-1	Klb-Venglai- Paster Inn	14.85	0.50	0	97.35	0.63	13.60	17.00
KP-2	Klb–Venglai Lalkunga Inn	14.56	0.46	0	91.25	0.49	14.60	25.00
KP-3	Klb–Hospital	14.41	0.28	0	96.25	0.28	14.75	36.00
KP-7	Klb-Electric sub station	15.17	0.68	0	97.50	0.59	14.70	32.00
KP-6	Klb-BSNL	8.92	0.39	0	98.75	0.62	14.85	21.00
KP-5	Klb-Post Office	16.75	0.55	0	107.25	0.56	12.60	7.00
KP-4	Klb – DIDI Rest'rant	13.20	0.61	0	107.50	0.64	13.85	11.00
KP-10	Klb-MST Stand	15.75	0.56	0	106.85	0.63	11.90	22.00
KP-11	Klb-PHE office	15.90	0.48	0	98.75	0.59	12.25	38.00
KP-12	Rengtekawn-check gate	12.30	0.52	0	96.25	0.68	14.65	43.00
KP-20	Bilkhawthlir – PWD	17.50	0.64	0	102.85	0.58	14.15	21.00
KP-19	Bilkhawthlir–Hospital	14.85	0.62	0	103.50	0.65	12.95	26.00
Mean		13.96	0.56	0	100.13	0.57	13.66	26.75
Min		8.92	0.28	0.00	91.25	0.28	11.90	7.00
Max		17.50	0.74	0.00	108.50	0.68	15.05	43.00

Table 12: Physico-chemical parameters of ‘KT’ Pre monsoon 2007

Micro water shed	Samples	Location	**pH**	**EC**	**TDS**	**Turb**	**TA**	**TH**
Water Shed I	KT-27	Kawnpui–Azl rd I	7.2	185	129	0.5	40.75	48.5
	KT-26	Kawnpui–Azl rd I	7.2	140	90	0.8	40.5	43.65
	KT-25	Kawnpui–police st	7.1	145	93	0.9	38.5	53.35
	KT-28	Kawnpui–PWD	7.3	80	53	0.5	42.5	48.5
	KT-29	Kawnpui–Mualvum rd	7.5	186	130	1	48.25	43.65
	KT-32	Kawnpui– Hortoki III	7.1	195	130	0.9	38.5	53.35
	KT-31	Kawnpui – Hortoki II	7.1	85	54	0.9	37.25	58.2
	KT-30	Kawnpui – Hortoki I	7.5	220	154	0.8	48.5	58.2
Water shed II	KT-24	Bualpui BSNL	7.4	178	128	0.9	46.2	63.05
	KT-23	Bualpui - below FCI	7.2	135	89	0.8	42.75	67.9
	KT-22	Thingdawl pump st	7.2	128	84	0.7	41.25	67.9
	KT-21	Thingdawl-Agri Park	7.1	150	97	0.7	39.75	58.2
Water shed IV	KT-14	Klb-ICAR complex	7.2	156	107	0.5	42.5	47.86
	KT-11	Klb-Diakkawn ground	7	155	107	0.6	34.25	58.2
	KT-13	Klb-Diakkawn- Azl rd II	7.1	112	70	0.7	37.25	53.35
	KT-12	Klb. Diakkawn- Azl rd I	6.8	145	90	0.6	31.4	49
	KT-16	Klb. Forest veng	7.2	120	83	0.8	42.5	63.05
	KT-15	Klb. Project veng	7.1	180	125	0.8	37.85	58.2
	KT-3	Klb-old UPC church	7.2	140	90	0.6	42.15	53.35
	KT-1	Klb-Convent rd	6.9	145	90	0.7	34.25	63.05
	KT-2	Klb. St. John’s school	6.8	125	84	0.6	32.25	58.2
	KT-4	Klb- Venglai P/S-III	7.4	137	86	0.6	46.5	48.5
Water shed VI	KT-5	Klb-Banglakawn	7.1	138	86	0.7	37.25	53.35
	KT-6	Klb-electric veng	7.4	201	146	0.7	45.5	63.05
	KT-7	Klb. police st	7.5	85	53	1	48.95	48.5
	KT-9	Klb-Saidan -II	7.1	110	70	0.7	38.5	62.96
	KT-8	Klb- Saidan-I	7.2	125	85	0.8	40.8	43.65
	KT-10	Klb-petrol pump	7.3	150	105	1	41.25	63.05
	KT-17	Klb-Rengtekawn-I	7.1	205	148	0.9	38.15	62.93
	KT-18	Klb-Rengtekawn-II	6.8	108	70	0.9	32.5	50.12
Water shed VII	KT-19	Bilkhawthlir-BSNL	7	146	95	0.8	36.25	53.35
	KT-20	Bilkhawthlir-Post Off	7	220	155	0.8	36.5	53.35
Mean			7.16	147.81	99.25	0.76	40.04	55.36
Min			6.8	80	53	0.5	31.4	43.65
Max			7.5	220	155	1	48.95	67.9

Table 12 Contd…

Contd…

	Samples	Location	**Na**	**K**	**Fe**	**Ca**	**Mg**	**Cd**	**Zn**	**Cr**	**Mn**	**Ni**	**Cu**	**Co**	**Pb**	**As**
Water Shed I	KT-27	Kawnpui–Azl rd I	8.53	1.8	0.03	15.5	2.34	0.03	0.03	Nil	0	Bld	Bld	Bld	0.015	Bld
	KT-26	Kawnpui–Azl rd I	8.69	1.81	0.02	11.6	3.52	0.03	0.05	Nil	0	Bld	Bld	Bld	0.015	Bld
	KT-25	Kawnpui–police st	9.8	1.99	0.02	11.6	5.88	0.03	0.06	Nil	0	Bld	Bld	Bld	0.015	Bld
	KT-28	Kawnpui–PWD	10.0	1.72	0.02	13.6	3.52	0.03	0.03	Nil	0.03	Bld	Bld	Bld	0.012	Bld
	KT-29	Kawnpui–Mualvum rd	11.3	2.48	0.03	11.6	3.52	0.03	0.04	Nil	0	Bld	Bld	Bld	0.01	Bld
	KT-32	Kawnpui– Hortoki III	13.9	1.98	0.33	11.6	5.88	0.03	0.04	Nil	0.03	Bld	Bld	Bld	0.012	Bld
	KT-31	Kawnpui – Hortoki II	13.9	1.98	0.01	15.5	4.7	0.03	0.04	Nil	0.03	Bld	Bld	Bld	0.09	Bld
Water shed II	KT-30	Kawnpui – Hortoki I	14.5	2.01	0.32	13.6	5.88	0.03	0.05	Nil	0.03	Bld	Bld	Bld	0.09	Bld
	KT-24	Bualpui BSNL	12.5	2.38	0.03	9.72	9.42	0.03	0.03	Nil	0	Bld	Bld	Bld	0.011	Bld
	KT-23	Bualpui - below FCI	10.4	1.86	0.02	13.6	8.24	0.03	0.03	Nil	0	Bld	Bld	Bld	0.08	Bld
	KT-22	Thingdawl pump st	11.4	2.5	0.03	15.5	7.05	0.03	0.03	Nil	0	Bld	Bld	Bld	0.08	Bld
Water shed IV	KT-21	Thingdawl-Agri Park	7.28	1.41	0.03	15.5	4.7	0.03	0.03	Nil	0	Bld	Bld	Bld	0.011	Bld
	KT-14	Klb-ICAR complex	10.8	2.14	0.04	9.72	5.73	0.03	0.02	Nil	0	Bld	Bld	Bld	0.09	Bld
	KT-11	Klb-Diakkawn ground	8.02	0.91	0.02	15.5	4.7	0.03	0.02	Nil	0	Bld	Bld	Bld	0.08	Bld
	KT-13	Klb-Diakkawn- Azl rd II	6.42	0.6	0.03	11.6	5.87	0.03	0.03	Nil	0	Bld	Bld	Bld	0.015	Bld
	KT-12	Klb, Diakkawn- Azl rd I	6.2	0.52	0.03	11.0	5.2	0.03	0.02	Nil	0	Bld	Bld	Bld	0.08	Bld
	KT-16	Klb, Forest veng	10.0	1.97	0.03	15.5	5.88	0.03	0.02	Nil	0	Bld	Bld	Bld	0.01	Bld
	KT-15	Klb, Project veng	10.5	2.09	0.03	7.78	9.42	0.03	0.03	Nil	0.02	Bld	Bld	Bld	0.09	Bld
	KT-3	Klb-old UPC church	7.49	0.72	0.02	13.6	4.7	0.03	0.01	Nil	0	Bld	Bld	Bld	0.015	Bld
	KT-1	Klb-Convent rd	4.3	0.61	0.02	15.5	8.23	0.03	0.02	Nil	0	Bld	Bld	Bld	0.09	Bld
	KT-2	Klb, St. John's school	4.85	0.63	0.02	7.78	9.42	0.03	0.02	Nil	0	Bld	Bld	Bld	0.09	Bld
Water shed VI	KT-4	Klb- Venglai P/S-III	6.85	0.48	0.02	11.6	5.88	0.03	0.03	Nil	0.03	Bld	Bld	Bld	0.09	Bld
	KT-5	Klb-Banglakawn	11.4	1.75	0.03	9.72	7.06	0.03	0.04	Nil	0	Bld	Bld	Bld	0.09	Bld
	KT-6	Klb-electric veng	10.5	2.1	0.03	15.5	5.88	0.03	0.01	Nil	0	Bld	Bld	Bld	0.09	Bld
	KT-7	Klb, police st	5.72	0.68	0.01	11.6	4.7	0.03	0.02	Nil	0	Bld	Bld	Bld	0.09	Bld
	KT-9	Klb-Saidan -II	5.2	0.65	0.03	14.3	6.61	0.03	0.01	Nil	0	Bld	Bld	Bld	0.011	Bld
	KT-8	Klb- Saidan-I	10.2	1.97	0.01	15.5	1.16	0.03	0.02	Nil	0	Bld	Bld	Bld	0.012	Bld
	KT-10	Klb-petrol pump	13.3	1.84	0.02	5.83	11.7	0.03	0.02	Nil	0.02	Bld	Bld	Bld	0.01	Bld
	KT-17	Klb-Rengtekawn-I	9.17	1.65	0.04	14.3	6.61	0.03	0.02	Nil	0	Bld	Bld	Bld	0.09	Bld
	KT-18	Klb-Rengtekawn-II	4.85	0.66	0.03	7.86	7.41	0.03	0.04	Nil	0.03	Bld	Bld	Bld	0.09	Bld
Water shed VII	KT-19	Bilkhawthlir-BSNL	4.32	0.65	0.03	7.78	8.24	0.03	0.04	Nil	0	Bld	Bld	Bld	0.01	Bld
	KT-20	Bilkhawthlir-Post Off	6.13	1.14	0.02	13.6	4.7	0.03	0.05	Nil	0	Bld	Bld	Bld	0.012	Bld
Mean			9.04	1.49	0.04	12.3	6.06	0.03	0.03	Bld	0.01	Bld	Bld	Bld	0.05	Bld
Min			4.3	0.48	0.01	5.83	1.16	0.03	0.01	0	0	0	0	0	0.01	0
Max			14.5	2.5	0.33	15.5	11.7	0.03	0.06	0	0.03	0	0	0	0.09	0

Contd…

Table 12Contd…

Micro water shed	Samples	Location	**TCl**	**F**	**CO_3**	**HCO_3**	**NO_3**	**SO_4**	**MPN**
water Shed I	KT-27	Kawnpui–Azl rd I	15.21	0.18	0	40.75	0.46	3	14
	KT-26	Kawnpui–Azl rd I	11.8	0.14	0	40.5	0.28	4.6	23
	KT-25	Kawnpui–police st	9.58	0.12	0	38.5	0.22	3.35	21
	KT-28	Kawnpui–PWD	13.86	0.14	0	42.5	0.2	2.9	10
	KT-29	Kawnpui–Mualvum rd	13.05	0.58	0	48.25	0.3	4.2	15
	KT-32	Kawnpui– Hortoki III	13.17	0.8	0	38.5	0.61	4.6	27
	KT-31	Kawnpui – Hortoki II	11.21	0.62	0	37.25	0.26	2.9	22
	KT-30	Kawnpui – Hortoki I	16.72	0.5	0	48.5	0.25	4.6	23
Water shed II	KT-24	Bualpui BSNL	14.62	0.15	0	46.2	0.31	4.25	15
	KT-23	Bualpui - below FCI	10.46	0.17	0	42.75	0.62	3.5	7
	KT-22	Thingdawl pump st	9.95	0.82	0	41.25	0.5	4.65	10
	KT-21	Thingdawl-Agri Park	12.15	0.73	0	39.75	0.15	3.15	10
Water shed IV	KT-14	Klb-ICAR complex	16.54	0.2	0	42.5	0.19	2.45	24
	KT-11	Klb-Diakkawn ground	14.65	0.68	0	34.25	0.75	3.85	16
	KT-13	Klb-Diakkawn- Azl rd II	13.8	0.36	0	37.25	0.69	3.4	13
	KT-12	Klb, Diakkawn- Azl rd I	15.35	0.55	0	31.4	0.5	3.7	8
	KT-16	Klb, Forest veng	12.2	0.16	0	42.5	0.29	4.1	15
	KT-15	Klb, Project veng	12.16	0.21	0	37.85	0.28	4.3	18
	KT-3	Klb-old UPC church	11.9	0.49	0	42.15	0.24	3.4	15
	KT-1	Klb-Convent rd	12.2	0.2	0	34.25	0.16	1.85	17
	KT-2	Klb, St. John’s school	13.35	0.62	0	32.25	0.14	3.2	13
	KT-4	Klb- Venglai P/S-III	11.85	0.3	0	46.5	0.24	2	7
Water shed VI	KT-5	Klb-Banglakawn	16.5	0.35	0	37.25	0.2	2.5	20
	KT-6	Klb-electric veng	18.65	0.32	0	45.5	0.57	3.2	16
	KT-7	Klb, police st	14.15	0.3	0	48.95	0.48	3.65	14
	KT-9	Klb-Saidan -II	15.85	0.31	0	38.5	0.23	2.45	20
	KT-8	Klb- Saidan-I	15.1	0.52	0	40.8	0.21	3.5	22
	KT-10	Klb-petrol pump	13.9	0.32	0	41.25	0.21	2.8	26
	KT-17	Klb-Rengtekawn-I	17.73	0.15	0	38.15	0.68	2.1	28
	KT-18	Klb-Rengtekawn-II	13.45	0.6	0	32.5	0.21	3.15	23
Water shed VII	KT-19	Bilkhawthlir-BSNL	12.35	0.6	0	36.25	0.18	4.75	23
	KT-20	Bilkhawthlir-Post Off	13.7	0.62	0	36.5	0.19	3.2	17
Mean			13.66	0.40	0	40.04	0.34	3.41	17.25
Min			9.58	0.12	0	31.4	0.14	1.85	7
Max			18.65	0.82	0	48.95	0.75	4.75	28

Table 13: Physico-chemical parameters of 'KP' Pre monsoon 2007

Samples	Location	**pH**	**EC**	**TDS**	**TURB**	**TA**	**TH**
KP-18	Kawnpui -MRB Br.	7.3	190	130	1	98.15	77.6
KP-17	Kawnpui–Hospital	7.1	192	130	1.1	95.35	63.05
KP-16	Kawnpui- Govt. HS	7.3	178	106	1.2	99.25	67.9
KP-15	Bualpui-FCI	7.4	242	161	1.3	104.25	67.9
KP-14	Bualpui- Gorkha hotel	7.2	239	159	1.2	97.15	77.6
KP-13	Thingdawl-Post office	7.2	135	87	1.2	97.25	77.6
KP-8	Klb-Paradise rest'rant	6.8	190	145	1.5	92.5	77.6
KP-9	Klb- Diakkawn –Hlua Inn	7.2	82	50	1.4	96.25	77.75
KP-1	Klb-Venglai- Paster Inn	7.2	173	142	1	96.15	63.05
KP-2	Klb–Venglai Lalkunga Inn	6.9	180	125	0.2	92.25	82.45
KP-3	Klb–Hospital	7.2	178	125	0.9	97.5	72.75
KP-7	Klb-Electric sub station	6.9	170	117	1.3	93.95	87.3
KP-6	Klb-BSNL	7.2	165	115	0.9	96.25	72.75
KP-5	Klb-Post Office	7.3	175	142	1	101.35	77.75
KP-4	Klb – DIDI Rest'rant	7.4	145	90	0.8	106.75	82.45
KP-10	Klb-MST Stand	7.3	255	171	1.5	101.45	77.6
KP-11	Klb-PHE office	7.2	90	55	1.2	97.5	82.45
KP-12	Rengtekawn-check gate	7	183	109	0.9	94	82.45
KP-20	Bilkhawthlir – PWD	7.3	160	108	1.2	99.5	97
KP-19	Bilkhawthlir–Hospital	7.3	165	110	1	101.5	82.45
Mean		7.19	174.35	118.85	1.09	97.92	77.37
Min		6.8	82	50	0.2	92.25	63.05
Max		7.4	255	171	1.5	106.75	97

Contd…

Table 13 Contd…

Samples	Location	**Na**	**K**	**Fe**	**Ca**	**Mg**	**Cd**	**Zn**	**Cr**	**Mn**	**Ni**	**Cu**	**Co**	**Pb**	**As**
KP-18	Kawnpui -MRB Br.	14.17	2.18	0.02	17.5	8.23	0.02	0.04	0.01	0.03	BLD	BLD	BLD	0.014	BLD
KP-17	Kawnpui–Hospital	9.92	1.9	0.02	13.61	7.06	0.03	0.04	0.01	0.02	BLD	BLD	BLD	0.013	BLD
KP-16	Kawnpui- Govt. HS	8.85	1.22	0.02	17.5	5.88	0.03	0.04	0.01	0.03	BLD	BLD	BLD	0.01	BLD
KP-15	Bualpui-FCI	8.54	1.12	0.03	13.61	8.24	0.03	0.07	0	0.03	BLD	BLD	BLD	0.011	BLD
KP-14	Bualpui- Gorkha hotel	9.95	1.77	0.03	23.39	5.87	0.03	0.05	0	0.03	BLD	BLD	BLD	0.011	BLD
KP-13	Thingdawl-Post office	11.32	2.15	0.03	9.75	12.95	0.03	0.03	0	0.03	BLD	BLD	BLD	0.014	BLD
KP-8	Klb-Paradise rest'rant	14.2	2.2	0.03	17.5	8.23	0.03	0.08	0	0.03	BLD	BLD	BLD	0.09	BLD
KP-9	Klb- Diakkawn –Hlua Inn	12.75	1.8	0.03	15.56	9.45	0.02	0.02	0	0.03	BLD	BLD	BLD	0.015	BLD
KP-1	Klb-Venglai- Paster Inn	4.3	0.65	0.03	15.55	5.88	0.02	0.02	0.01	0.03	BLD	BLD	BLD	0.01	BLD
KP-2	Klb–Venglai Lalkunga Inn	4.85	0.63	0.03	21.39	7.05	0.02	0.06	0.01	0.03	BLD	BLD	BLD	0.011	BLD
KP-3	Klb–Hospital	8.13	1.46	0.03	15.56	8.23	0.03	0.05	0.01	0.02	BLD	BLD	BLD	0.012	BLD
KP-7	Klb-Electric sub station	12.26	1.7	0.02	15.56	11.77	0.03	0.04	0.01	0.02	BLD	BLD	BLD	0.011	BLD
KP-6	Klb-BSNL	11.85	1.58	0.02	15.56	8.23	0.03	0.03	0.01	0.02	BLD	BLD	BLD	0.014	BLD
KP-5	Klb-Post Office	10.42	1.42	0.02	15.56	9.45	0.03	0.04	0.01	0.02	BLD	BLD	BLD	0.014	BLD
KP-4	Klb – DIDI Rest'rant	6.87	0.52	0.03	23.34	5.87	0.03	0.02	0.01	0.02	BLD	BLD	BLD	0.012	BLD
KP-10	Klb-MST Stand	10.92	1.6	0.03	17.5	8.23	0.02	0.03	0.01	0.03	BLD	BLD	BLD	0.01	BLD
KP-11	Klb-PHE office	14.11	1.95	0.02	23.34	5.87	0.03	0.04	0.01	0.02	BLD	BLD	BLD	0.012	BLD
KP-12	Rengtekawn-check gate	14.06	2.2	0.03	23.34	5.87	0.03	0.04	0.01	0.03	BLD	BLD	BLD	0.09	BLD
KP-20	Bilkhawthlir – PWD	13.97	2.12	0.03	27.23	7.04	0.03	0.04	0.01	0.02	BLD	BLD	BLD	0.014	BLD
KP-19	Bilkhawthlir–Hospital	12.26	1.8	0.03	21.39	7.05	0.03	0.07	0.01	0.03	BLD	BLD	BLD	0.012	BLD
Mean		10.69	1.60	0.03	18.19	7.82	0.03	0.04	0.01	0.03	BLD	BLD	BLD	0.02	BLD
Min		4.3	0.52	0.02	9.75	5.87	0.02	0.02	0	0.02	0	0	0	0.01	0
Max		14.2	2.2	0.03	27.23	12.95	0.03	0.08	0.01	0.03	0	0	0	0.09	0

Contd…

Table 13 Contd…

Samples	Location	**TCl**	**F**	**CO_3**	**HCO_3**	**NO_3**	**SO_4**	**MPN**
KP-18	Kawnpui -MRB Br.	15.2	0.5	0	98.15	0.63	13.6	30
KP-17	Kawnpui–Hospital	13.6	0.52	0	95.35	0.43	13.75	25
KP-16	Kawnpui- Govt. HS	14.85	0.59	0	99.25	0.54	11.8	17
KP-15	Bualpui-FCI	14.85	0.68	0	104.25	0.62	11.8	18
KP-14	Bualpui- Gorkha hotel	9.6	0.61	0	97.15	0.56	10.5	37
KP-13	Thingdawl-Post office	8.9	0.49	0	97.25	0.39	14.6	26
KP-8	Klb-Paradise rest'rant	11.43	0.69	0	92.5	0.44	14.45	23
KP-9	Klb- Diakkawn –Hlua Inn	12.6	0.63	0	96.25	0.63	12.9	24
KP-1	Klb-Venglai- Paster Inn	13.48	0.46	0	96.15	0.6	12.9	19
KP-2	Klb–Venglai Lalkunga Inn	13.25	0.42	0	92.25	0.46	13.75	28
KP-3	Klb–Hospital	13.3	0.26	0	97.5	0.28	14.6	30
KP-7	Klb-Electric sub station	14.85	0.63	0	93.95	0.52	14.5	578
KP-6	Klb-BSNL	7.98	0.32	0	96.25	0.59	14.45	18
KP-5	Klb-Post Office	15.8	0.52	0	101.35	0.51	12.6	10
KP-4	Klb – DIDI Rest'rant	12.85	0.58	0	106.75	0.62	13.4	15
KP-10	Klb-MST Stand	15.4	0.58	0	101.45	0.6	11.05	26
KP-11	Klb-PHE office	14.95	0.46	0	97.5	0.54	11.95	35
KP-12	Rengtekawn-check gate	12.46	0.5	0	94	0.63	13.75	40
KP-20	Bilkhawthlir – PWD	16.83	0.62	0	99.5	0.58	13.6	18
KP-19	Bilkhawthlir–Hospital	13.71	0.61	0	101.5	0.6	12	28
Mean		13.29	0.53	0.00	97.92	0.54	13.10	52.25
Min		7.98	0.26	0	92.25	0.28	10.5	10
Max		16.83	0.69	0	106.75	0.63	14.6	578

Table 14: Physico-chemical parameters of 'KT' Monsoon 2007

Micro water shed	Samples	LOCATION	**pH**	**EC**	**TDS**	**Turb**	**TA**	**TH**
water Shed I	KT-27	Kawnpui–Azl rd I	7.2	145	90	0.9	38.5	43.65
	KT-26	Kawnpui–Azl rd I	7.1	130	94	1	37.75	43.65
	KT-25	Kawnpui–police st	7.1	148	104	1.7	35.85	48.5
	KT-28	Kawnpui–PWD	7.2	72	62	2.1	38.75	43.65
	KT-29	Kawnpui–Mualvum rd	7.4	175	125	1.5	45.25	38.8
	KT-32	Kawnpui– Hortoki III	7.1	185	140	1.6	36.25	48.5
	KT-31	Kawnpui – Hortoki II	7	80	58	1.4	35.8	53.35
	KT-30	Kawnpui – Hortoki I	7.3	180	128	1.2	42.75	53.35
Water shed II	KT-24	Bualpui BSNL	7.4	180	129	1.4	45.5	53.35
	KT-23	Bualpui - below FCI	7.3	128	85	2.3	40.75	58.2
	KT-22	Thingdawl pump st	7.5	110	81	1.6	48.95	58.2
	KT-21	Thingdawl-Agri Park	7.1	130	97	2.2	37.75	48.5
Water shed IV	KT-14	Klb-ICAR complex	7.1	135	86	0.9	37.5	43.65
	KT-11	Klb-Diakkawn ground	6.8	144	90	1.4	32.5	43.65
	KT-13	Klb-Diakkawn- Azl rd II	6.9	122	83	0.9	33.75	48.5
	KT-12	Klb, Diakkawn- Azl rd I	6.7	129	87	1.6	25.25	38.8
	KT-16	Klb, Forest veng	7.1	102	67	1.2	38.5	48.8
	KT-15	Klb, Project veng	7.1	155	108	2	38.15	48.8
	KT-3	Klb-old UPC church	6.9	120	82	1	33.7	43.65
	KT-1	Klb-Convent rd	6.8	128	85	1.4	32.25	43.65
	KT-2	Klb, St. John's school	6.8	100	68	1.3	32.25	53.35
	KT-4	Klb- Venglai P/S-III	7.1	125	84	0.9	38.95	48.5
Water shed VI	KT-5	Klb-Banglakawn	7.5	120	83	1	48.25	43.65
	KT-6	Klb-electric veng	7.1	178	123	0.8	38.25	48.5
	KT-7	Klb, police st	7.4	82	55	2.5	46.75	48.5
	KT-9	Klb-Saidan -II	6.9	100	65	0.8	33.5	58.2
	KT-8	Klb- Saidan-I	7.1	118	80	1	38.5	38.8
	KT-10	Klb-petrol pump	7	128	88	1.2	37.45	48.5
	KT-17	Klb-Rengtekawn-I	6.9	175	105	1.8	33.25	43.65
	KT-18	Klb-Rengtekawn-II	6.8	90	63	1.1	30.15	43.65
Water shed VII	KT-19	Bilkhawthlir-BSNL	7	108	77	1.2	35.8	53.35
	KT-20	Bilkhawthlir-Post Off	7	185	148	1	35.7	48.5
Mean			7.08	131.47	91.25	1.37	37.63	47.76
Min			6.7	72	55	0.8	25.25	38.8
Max			7.5	185	148	2.5	48.95	58.2

Contd…

Table 14 Contd…

Micro water shed	Samples	LOCATION	**TCl**	**MPN**	**Na**	**K**	**Fe**	**Ca**	**Mg**	**Cd**	**Zn**	**Cr**	**Mn**	**Ni**	**Cu**	**Co**	**Pb**	**As**
water Shed I	KT-27	Kawnpui–Azl rd I	12.93	17	5.23	0.74	0.02	11.67	3.52	0.03	0.02	0	0	*	*	*	0.012	*
	KT-26	Kawnpui–Azl rd I	11.21	28	8.15	1	0.02	11.67	3.52	0.03	0.04	0	0	*	*	*	0.012	*
	KT-25	Kawnpui–police	8.65	27	8.81	1.08	0.02	9.72	5.88	0.03	0.04	0	0	*	*	*	0.01	*
	KT-28	Kawnpui–PWD	12.25	15	9.7	1.03	0.03	9.72	4.7	0.03	0.02	0	0.02	*	*	*	0.01	*
	KT-29	Kawnpui–	10.07	26	11.1	2.33	0.02	7.78	4.7	0.03	0.04	0	0	*	*	*	0.09	*
	KT-32	Kawnpui–	12.35	32	13.66	2.4	0.21	13.61	3.52	0.03	0.04	0	0.02	*	*	*	0.09	*
	KT-31	Kawnpui –	10.68	28	12.97	2.4	0.01	15.56	3.52	0.03	0.03	0	0.01	*	*	*	0.08	*
	KT-30	Kawnpui –	9.25	35	11.43	1.57	0.3	9.72	7.06	0.03	0.04	0	0.02	*	*	*	0.08	*
Water shed II	KT-24	Bualpui BSNL	12.7	24	11.75	1.55	0.02	5.83	9.42	0.03	0.03	0	0	*	*	*	0.09	*
	KT-23	Bualpui - below	9.65	17	6.72	0.93	0.01	11.67	7.06	0.03	0.02	0	0	*	*	*	0.06	*
	KT-22	Thingdawl pump	7.96	12	11.02	1.02	0.02	13.61	5.88	0.03	0.02	0	0	*	*	*	0.06	*
	KT-21	Thingdawl-Agri	10.06	13	5.97	0.81	0.02	11.67	4.7	0.03	0.02	0	0	*	*	*	0.01	*
Water shed IV	KT-14	Klb-ICAR	14	22	8.2	1.35	0.03	7.78	5.88	0.03	0.03	0	0	*	*	*	0.08	*
	KT-11	Klb-Diakkawn	13.24	16	7.13	1.03	0.02	9.72	4.7	0.03	0.01	0	0	*	*	*	0.07	*
	KT-13	Klb-Diakkawn-	11.97	21	5.06	0.76	0.03	15.56	2.34	0.03	0.02	0	0	*	*	*	0.012	*
	KT-12	Klb, Diakkawn-	14.73	15	5.35	0.97	0.02	9.72	3.53	0.03	0.02	0	0	*	*	*	0.08	*
	KT-16	Klb, Forest veng	12.2	25	2.55	0.31	0.02	11.67	4.77	0.03	0.02	0	0	*	*	*	0.09	*
	KT-15	Klb, Project veng	11.05	26	4	0.43	0.03	9.72	5.96	0.03	0.01	0	0.02	*	*	*	0.08	*
	KT-3	Klb-old UPC	11.2	15	6.85	0.47	0.02	11.67	3.52	0.03	0.01	0	0	*	*	*	0.01	*
	KT-1	Klb-Convent rd	9.2	20	3.56	0.53	0.02	11.67	3.52	0.03	0.02	0	0	*	*	*	0.08	*
	KT-2	Klb, St. John’s	11.31	18	2.77	0.4	0.01	9.72	7.06	0.03	0.02	0	0	*	*	*	0.07	*
	KT-4	Klb- Venglai P/S-	9.43	16	4.82	0.65	0.02	11.67	4.7	0.03	0.02	0	0.03	*	*	*	0.08	*
Water shed VI	KT-5	Klb-Banglakawn	13.5	26	6.91	1.06	0.02	9.72	4.7	0.03	0.03	0	0	*	*	*	0.08	*
	KT-6	Klb-electric veng	16.8	19	9.48	1.85	0.02	11.67	4.7	0.03	0.01	0	0	*	*	*	0.09	*
	KT-7	Klb, police st	12.2	22	3.07	0.29	0.01	15.56	2.34	0.03	0.01	0	0	*	*	*	0.08	*
	KT-9	Klb-Saidan -II	14.08	28	3.72	0.59	0.02	7.78	9.42	0.03	0.02	0	0	*	*	*	0.01	*
	KT-8	Klb- Saidan-I	13.17	31	8.15	0.92	0.01	11.67	2.34	0.03	0.01	0	0	*	*	*	0.01	*
	KT-10	Klb-petrol pump	11.95	37	10.75	2.22	0.02	11.67	4.7	0.03	0.01	0	0.01	*	*	*	0.01	*
	KT-17	Klb-Rengtekawn-I	15.12	41	7.69	1.12	0.02	11.67	3.52	0.03	0.02	0	0	*	*	*	0.09	*
	KT-18	Klb-Rengtekawn-	11.87	28	2.63	0.32	0.01	5.83	7.06	0.03	0.03	0	0.02	*	*	*	0.09	*
Water shed VII	KT-19	Bilkhawthlir-	11.18	24	3.8	0.62	0.02	7.78	8.24	0.03	0.03	0	0	*	*	*	0.01	*
	KT-20	Bilkhawthlir-Post	10.35	21	4.86	0.91	0.01	9.72	5.88	0.03	0.04	0	0	*	*	*	0.01	*
Mean			11.76	23.28	7.12	1.05	0.03	10.76	5.07	0.03	0.02	0.00	0.00	*	*	*	0.05	*
Min			7.96	12	2.55	0.29	0.01	5.83	2.34	0.03	0.01	0	0	0	0	0	0.01	0
Max			16.8	41	13.66	2.4	0.3	15.56	9.42	0.03	0.04	0	0.03	0	0	0	0.09	0

- Below Limit of Detection (BLD)

Contd…

Table 14 Contd…

Micro water shed	Samples	LOCATION	**TCl**	**F**	**CO_3**	**HCO_3**	**NO_3**	**SO_4**	**MPN**
water Shed I	KT-27	Kawnpui–Azl rd I	12.93	0.15	0	38.5	0.45	3	17
	KT-26	Kawnpui–Azl rd I	11.21	0.1	0	37.75	0.25	4.5	28
	KT-25	Kawnpui–police st	8.65	0.1	0	35.85	0.22	3.1	27
	KT-28	Kawnpui–PWD	12.25	0.14	0	38.75	0.2	2.85	15
	KT-29	Kawnpui–Mualvum rd	10.07	0.53	0	45.25	0.3	4.2	26
	KT-32	Kawnpui– Hortoki III	12.35	0.78	0	36.25	0.59	4.5	32
	KT-31	Kawnpui – Hortoki II	10.68	0.6	0	35.8	0.24	2.9	28
	KT-30	Kawnpui – Hortoki I	9.25	0.48	0	42.75	0.24	4.2	35
Water shed II	KT-24	Bualpui BSNL	12.7	0.14	0	45.5	0.29	4.2	24
	KT-23	Bualpui - below FCI	9.65	0.15	0	40.75	0.6	3.15	17
	KT-22	Thingdawl pump st	7.96	0.79	0	48.95	0.49	4.5	12
	KT-21	Thingdawl-Agri Park	10.06	0.7	0	37.75	0.15	3.15	13
Water shed IV	KT-14	Klb-ICAR complex	14	0.2	0	37.5	0.19	2.25	22
	KT-11	Klb-Diakkawn ground	13.24	0.64	0	32.5	0.72	3.85	16
	KT-13	Klb-Diakkawn- Azl rd	11.97	0.3	0	33.75	0.63	3.15	21
	KT-12	Klb, Diakkawn- Azl rd	14.73	0.52	0	25.25	0.49	3.4	15
	KT-16	Klb, Forest veng	12.2	0.15	0	38.5	0.27	4.1	25
	KT-15	Klb, Project veng	11.05	0.2	0	38.15	0.27	4.25	26
	KT-3	Klb-old UPC church	11.2	0.45	0	33.7	0.23	3.2	15
	KT-1	Klb-Convent rd	9.2	0.19	0	32.25	0.15	1.85	20
	KT-2	Klb, St. John’s school	11.31	0.6	0	32.25	0.14	3.15	18
	KT-4	Klb- Venglai P/S-III	9.43	0.28	0	38.95	0.22	1.85	16
Water shed VI	KT-5	Klb-Banglakawn	13.5	0.28	0	48.25	0.18	2.5	26
	KT-6	Klb-electric veng	16.8	0.28	0	38.25	0.57	3.15	19
	KT-7	Klb, police st	12.2	0.3	0	46.75	0.46	3.15	22
	KT-9	Klb-Saidan -II	14.08	0.3	0	33.5	0.23	2.45	28
	KT-8	Klb- Saidan-I	13.17	0.51	0	38.5	0.2	3.2	31
	KT-10	Klb-petrol pump	11.95	0.3	0	37.45	0.21	2.6	37
	KT-17	Klb-Rengtekawn-I	15.12	0.15	0	33.25	0.65	1.85	41
	KT-18	Klb-Rengtekawn-II	11.87	0.57	0	30.15	0.2	3.15	28
Water shed VII	KT-19	Bilkhawthlir-BSNL	11.18	0.58	0	35.8	0.18	4.2	24
	KT-20	Bilkhawthlir-Post Off	10.35	0.6	0	35.7	0.18	3.15	21
Mean			11.76	0.38	0.00	37.63	0.32	3.27	23.28
Min			7.96	0.1	0	25.25	0.14	1.85	12
Max			16.8	0.79	0	48.95	0.72	4.5	41

Table 15: Physico-chemical parameters of 'KP' Monsoon 2007

Samples	LOCATION	**pH**	**EC**	**TDS**	**Turb**	**TA**	**TH**
KP-18	Kawnpui -MRB Br.	7.2	115	71	1	93.65	53.35
KP-17	Kawnpui–Hospital	7.4	180	107	1.3	98.85	58.2
KP-16	Kawnpui- Govt. HS	6.9	136	85	1.5	87.5	38.8
KP-15	Bualpui-FCI	7.1	220	150	1.1	93.35	58.2
KP-14	Bualpui- Gorkha hotel	7.1	205	147	1	90.5	72.75
KP-13	Thingdawl-Post office	7.1	120	83	0.9	92.15	63.05
KP-8	Klb-Paradise rest'rant	6.7	185	110	1.2	83.6	72.75
KP-9	Klb- Diakkawn –Hlua Inn	7.3	80	59	1.6	97.2	77.6
KP-1	Klb-Venglai- Paster Inn	6.9	145	91	1.1	88.25	43.65
KP-2	Klb–Venglai Lalkunga Inn	6.9	140	90	0.9	87.5	58.2
KP-3	Klb–Hospital	7.1	110	70	1.2	92.15	38.8
KP-7	Klb-Electric sub station	6.7	150	102	1.2	85	72.75
KP-6	Klb-BSNL	7.2	130	85	1.1	93.85	63.05
KP-5	Klb-Post Office	6.9	152	105	1	88.5	67.9
KP-4	Klb – DIDI Rest'rant	7	135	86	1.3	90.65	43.65
KP-10	Klb-MST Stand	7.4	210	150	1.1	98.3	67.9
KP-11	Klb-PHE office	6.9	82	59	1	88.75	72.75
KP-12	Rengtekawn-check gate	7.2	165	110	1.5	93.95	75.75
KP-20	Bilkhawthlir – PWD	7.4	170	101	1.1	98.75	38.8
KP-19	Bilkhawthlir–Hospital	6.9	123	84	1.1	88.5	58.2
Mean		7.07	147.65	97.25	1.16	91.55	59.81
Min		6.7	80	59	0.9	83.6	38.8
Max		7.4	220	150	1.6	98.85	77.6

Contd…

Table 15 Contd…

Samples	LOCATION	Na	K	Fe	Ca	Mg	Cd	Zn	Cr	Mn	Ni	Cu	Co	Pb	As
KP-18	Kawnpui -MRB Br.	12.95	2.05	0.01	5.83	9.42	0.02	0.03	0	0.03	BLD	BLD	BLD	0.013	BLD
KP-17	Kawnpui–Hospital	8.85	1.75	0.02	11.67	7.06	0.02	0.04	0.01	0.02	BLD	BLD	BLD	0.012	BLD
KP-16	Kawnpui- Govt. HS	7.65	1.18	0.01	9.72	3.53	0.02	0.04	0.01	0.02	BLD	BLD	BLD	0.01	BLD
KP-15	Bualpui-FCI	7.78	1.02	0.02	13.61	5.88	0.03	0.07	0	0.02	BLD	BLD	BLD	0.01	BLD
KP-14	Bualpui- Gorkha hotel	8.63	1.71	0.02	15.56	8.23	0.03	0.04	0	0.02	BLD	BLD	BLD	0.09	BLD
KP-13	Thingdawl-Post office	10.53	2	0.01	7.78	10.06	0.02	0.03	0	0.03	BLD	BLD	BLD	0.012	BLD
KP-8	Klb-Paradise rest'rant	12.26	2.2	0.03	15.56	8.23	0.02	0.06	0	0.03	BLD	BLD	BLD	0.08	BLD
KP-9	Klb- Diakkawn –Hlua Inn	8.4	1.72	0.02	17.5	5.9	0.02	0.02	0	0.03	BLD	BLD	BLD	0.014	BLD
KP-1	Klb-Venglai- Paster Inn	4.28	0.62	0.01	11.67	3.52	0.02	0.02	0.01	0.02	BLD	BLD	BLD	0.01	BLD
KP-2	Klb–Venglai Lalkunga Inn	4.65	0.6	0.01	15.56	4.7	0.02	0.05	0.01	0.02	BLD	BLD	BLD	0.01	BLD
KP-3	Klb–Hospital	7.89	1.42	0.01	11.67	2.34	0.02	0.04	0.01	0.02	BLD	BLD	BLD	0.01	BLD
KP-7	Klb-Electric sub station	11.85	1.65	0.02	15.56	8.23	0.02	0.04	0	0.02	BLD	BLD	BLD	0.01	BLD
KP-6	Klb-BSNL	10.25	1.56	0.02	9.72	9.42	0.02	0.03	0	0.02	BLD	BLD	BLD	0.013	BLD
KP-5	Klb-Post Office	9.63	1.39	0.02	15.56	7.05	0.02	0.03	0	0.02	BLD	BLD	BLD	0.012	BLD
KP-4	Klb – DIDI Rest'rant	5.23	0.48	0.01	11.67	3.52	0.02	0.02	0	0.02	BLD	BLD	BLD	0.01	BLD
KP-10	Klb-MST Stand	7.59	1.63	0.02	15.56	7.05	0.02	0.03	0.01	0.02	BLD	BLD	BLD	0.01	BLD
KP-11	Klb-PHE office	12.75	1.88	0.02	23.34	3.51	0.03	0.04	0.01	0.02	BLD	BLD	BLD	0.011	BLD
KP-12	Rengtekawn-check gate	12.6	2.15	0.02	17.5	7.06	0.02	0.03	0	0.02	BLD	BLD	BLD	0.07	BLD
KP-20	Bilkhawthlir – PWD	12.86	1.96	0.02	7.78	4.7	0.02	0.04	0.01	0.02	BLD	BLD	BLD	0.012	BLD
KP-19	Bilkhawthlir–Hospital	11.32	1.65	0.02	15.56	4.7	0.02	0.06	0	0.03	BLD	BLD	BLD	0.011	BLD
Mean		9.40	1.53	0.02	13.42	6.21	0.02	0.04	0.00	0.02	BLD	BLD	BLD	0.02	BLD
Min		4.28	0.48	0.01	5.83	2.34	0.02	0.02	0	0.02	0	0	0	0.01	0
Max		12.95	2.2	0.03	23.34	10.06	0.03	0.07	0.01	0.03	0	0	0	0.09	0

Contd…

Table 15 Contd…

Samples	LOCATION	TCl	F	CO_3	HCO_3	NO_3	SO_4	MPN
KP-18	Kawnpui -MRB Br.	14.25	0.5	0	93.65	0.59	12.25	25
KP-17	Kawnpui–Hospital	10.1	0.51	0	98.85	0.4	12.25	25
KP-16	Kawnpui- Govt. HS	12.27	0.58	0	87.5	0.52	10.5	22
KP-15	Bualpui-FCI	12.6	0.58	0	93.35	0.61	10.5	22
KP-14	Bualpui- Gorkha hotel	8.45	0.59	0	90.5	0.52	9.75	35
KP-13	Thingdawl-Post office	8.15	0.45	0	92.15	0.35	12.25	21
KP-8	Klb-Paradise rest'rant	9.25	0.62	0	83.6	0.41	13.25	40
KP-9	Klb- Diakkawn –Hlua Inn	12.43	0.6	0	97.2	0.6	11.05	34
KP-1	Klb-Venglai- Paster Inn	12.45	0.42	0	88.25	0.54	12.5	16
KP-2	Klb–Venglai Lalkunga Inn	11.4	0.38	0	87.5	0.41	12.9	16
KP-3	Klb–Hospital	11.32	0.21	0	92.15	0.25	13.6	22
KP-7	Klb-Electric sub station	10.25	0.58	0	85	0.5	13.25	25
KP-6	Klb-BSNL	6.42	0.31	0	93.85	0.52	13.2	15
KP-5	Klb-Post Office	10.85	0.5	0	88.5	0.48	11.85	14
KP-4	Klb – DIDI Rest'rant	9.4	0.51	0	90.65	0.6	12.5	23
KP-10	Klb-MST Stand	12.6	0.55	0	98.3	0.55	9.85	30
KP-11	Klb-PHE office	11.85	0.43	0	88.75	0.52	9.85	28
KP-12	Rengtekawn-check gate	10.65	0.45	0	93.95	0.59	11.95	27
KP-20	Bilkhawthlir – PWD	7.85	0.6	0	98.75	0.57	12.85	20
KP-19	Bilkhawthlir–Hospital	8.87	0.58	0	88.5	0.57	12.25	28
Mean		10.57	0.50	0.00	91.55	0.51	11.92	24.40
Min		6.42	0.21	0	83.6	0.25	9.75	14
Max		14.25	0.62	0	98.85	0.61	13.6	40

Table 16: Physico-chemical parameters of 'KR' Monsoon 2007

Samples	LOCATION	pH	EC	TDS	Turb	TA	TH
KR-1	Klb-Venglai	7	26	20	0.3	24.65	24.25
KR-2	Klb-Project veng	7	24	18	0.4	16.8	24.25
KR-3	Klb-Banglakawn	7.1	18	16	0.6	23.25	24.25
KR-4	Klb-Diakkawn	7.1	10	10	0.3	23.2	29.1
KR-5	Klb-Hmar veng	7	25	18	0.3	21.35	29.1
Mean		7.04	20.6	16.4	0.38	21.85	26.19
Min		7	10	10	0.3	16.8	24.25
Max		7.1	26	20	0.6	24.65	29.1

Table 16 contd….

Samples	LOCATION	Na	K	Fe	Ca	Mg	Cd	Zn	Cr	Mn	Ni	Cu	Co	Pb	As
KR-1	Klb-Venglai	2.96	0.24	0.01	3.89	3.53	0.01	0.01	0	0.01	BLD	BLD	BLD	0.01	BLD
KR-2	Klb-Project veng	4.15	0.29	0.01	3.89	3.53	0.01	0.01	0	0.01	BLD	BLD	BLD	0.01	BLD
KR-3	Klb-Banglakawn	3.87	0.2	0.01	3.89	3.53	0.01	0.01	0	0.01	BLD	BLD	BLD	0.01	BLD
KR-4	Klb-Diakkawn	3.9	0.19	0.01	5.83	3.53	0.01	0.01	0	0.01	BLD	BLD		0.01	BLD
KR-5	Klb-Hmar veng	3.6	0.2	0.01	5.83	3.53	0.01	0.01	0	0.01	BLD	BLD		0.01	BLD
Mean		3.696	0.224	0.01	4.666	3.53	0.01	0.01	0	0.01	BLD	BLD	BLD	0.01	BLD
Min		2.96	0.19	0.01	3.89	3.53	0.01	0.01	0	0.01	0	0	0	0.01	0
Max		4.15	0.29	0.01	5.83	3.53	0.01	0.01	0	0.01	0	0	0	0.01	0

Table 16 contd….

Samples	LOCATION	TCl	F	CO_3	HCO_3	NO_3	SO_4	MPN
KR-1	Klb-Venglai	7.25	0.06	0	24.65	0.18	1.75	10
KR-2	Klb-Project veng	6.35	0.06	0	16.8	0.18	1.75	12
KR-3	Klb-Banglakawn	7.63	0.06	0	23.25	0.18	2.4	10
KR-4	Klb-Diakkawn	8.2	0.06	0	23.2	0.2	1.85	16
KR-5	Klb-Hmar veng	7.65	0.06	0	21.35	0.2	1.95	20
Mean		7.416	0.06	0	21.85	0.188	1.94	13.6
Min		6.35	0.06	0	16.8	0.18	1.75	10
Max		8.2	0.06	0	24.65	0.2	2.4	20

Table 17: Physico-chemical parameters of 'KT' Post monsoon 2007

Micro water shed	Samples	Location	pH	EC	TDS	Turb.	TA	TH
water Shed I	KT-27	Kawnpui–Azl rd I	7.1	185	110	0.6	38.5	48.5
	KT-26	Kawnpui–Azl rd I	7	140	93	1	37.62	43.65
	KT-25	Kawnpui–police st	7.1	160	106	1.1	38.75	48.5
	KT-28	Kawnpui–PWD	7	72	50	0.6	37.62	48.5
	KT-29	Kawnpui–Mualvum rd	7.3	205	147	1.1	46.25	43.65
	KT-32	Kawnpui– Hortoki III	6.8	225	146	1	32.25	58.2
	KT-31	Kawnpui – Hortoki II	6.8	84	53	0.8	32.25	53.35
	KT-30	Kawnpui – Hortoki I	7.3	208	147	0.9	48.3	53.35
Water shed II	KT-24	Bualpui BSNL	7.5	192	112	1	53.75	63.05
	KT-23	Bualpui - below FCI	7.2	134	90	0.8	43	63.05
	KT-22	Thingdawl pump st	7.2	126	86	0.9	43	63.05
	KT-21	Thingdawl-Agri Park	7	152	95	0.6	37.62	53.35
Water shed IV	KT-14	Klb-ICAR complex	7.2	146	94	1.1	42.15	43.65
	KT-11	Klb-Diakkawn ground	6.8	152	95	0.9	31.5	53.35
	KT-13	Klb-Diakkawn- Azl rd II	7	118	75	0.7	37.15	48.5
	KT-12	Klb, Diakkawn- Azl rd I	6.7	145	93	0.8	26.55	48.5
	KT-16	Klb, Forest veng	7.1	102	72	0.8	40.15	63.05
	KT-15	Klb, Project veng	7	134	87	0.9	37.62	53.35
	KT-3	Klb-old UPC church	7.1	205	147	0.6	38.62	53.35
	KT-1	Klb-Convent rd	6.8	185	109	0.8	32.3	63.05
	KT-2	Klb, St. John's school	6.7	177	103	0.6	27.1	58.2
	KT-4	Klb- Venglai P/S-III	7.2	244	160	0.7	45	43.65
Water shed VI	KT-5	Klb-Banglakawn	6.9	232	157	1	33.45	48.5
	KT-6	Klb-electric veng	7.2	83	50	0.9	45.22	63.05
	KT-7	Klb, police st	7.3	87	51	1	48.6	43.65
	KT-9	Klb-Saidan -II	7	108	69	0.7	36.4	48.5
	KT-8	Klb- Saidan-I	7.2	136	88	0.9	41.5	43.65
	KT-10	Klb-petrol pump	7.1	150	95	0.8	38.65	58.2
	KT-17	Klb-Rengtekawn-I	7.2	193	130	1	43	63.05
	KT-18	Klb-Rengtekawn-II	7	113	71	1.2	37.5	48.5
Water shed VII	KT-19	Bilkhawthlir-BSNL	6.9	142	95	0.9	36.5	53.35
	KT-20	Bilkhawthlir-Post Off	7	215	155	0.8	37.62	48.5
Mean			7.05	154.69	100.97	0.86	38.92	52.74
Min			6.7	72	50	0.6	26.55	43.65
Max			7.5	244	160	1.2	53.75	63.05

Contd…

Table 17 Contd…

Micro water shed	Samples	Location	Na	K	Fe	Ca	Mg	Cd	Zn	Cr	Mn	Ni	Cu	Co	Pb	As
water Shed I	KT-27	Kawnpui–Azl rd I	8.65	1.2	0.03	7.78	7.06	0.03	0.02	0	0	*	*	*	0.015	*
	KT-26	Kawnpui–Azl rd I	8.6	1.08	0.03	9.72	4.7	0.03	0.05	0	0	*	*	*	0.016	*
	KT-25	Kawnpui–police st	10.05	0.9	0.03	7.78	7.06	0.03	0.05	0	0	*	*	*	0.014	*
	KT-28	Kawnpui–PWD	10.1	2.15	0.02	9.72	5.88	0.03	0.02	0.01	0.03	*	*	*	0.014	*
	KT-29	Kawnpui–Mualvum rd	11.28	1.8	0.03	7.78	5.88	0.03	0.02	0.01	0.02	*	*	*	0.011	*
	KT-32	Kawnpui– Hortoki III	14.1	2.15	0.34	7.78	9.42	0.03	0.04	0.01	0.03	*	*	*	0.012	*
	KT-31	Kawnpui – Hortoki II	13.95	2.28	0.03	9.72	7.06	0.03	0.04	0.01	0.03	*	*	*	0.09	*
	KT-30	Kawnpui – Hortoki I	14.76	1.45	0.33	9.72	7.06	0.03	0.04	0	0.02	*	*	*	0.01	*
Water shed II	KT-24	Bualpui BSNL	12.21	2.4	0.03	11.67	8.24	0.03	0.02	0	0	*	*	*	0.09	*
	KT-23	Bualpui - below FCI	11.52	2.25	0.03	9.72	9.42	0.02	0.03	0	0	*	*	*	0.09	*
	KT-22	Thingdawl pump st	10.6	1.77	0.02	13.61	7.06	0.03	0.02	0	0	*	*	*	0.01	*
	KT-21	Thingdawl-Agri Park	7.3	0.9	0.04	11.67	5.88	0.03	0.02	0	0	*	*	*	0.011	*
Water shed IV	KT-14	Klb-ICAR complex	11.63	1.55	0.04	9.72	4.7	0.03	0.02	0	0.01	*	*	*	0.09	*
	KT-11	Klb-Diakkawn ground	8.32	1.7	0.03	7.78	8.24	0.03	0.01	0	0	*	*	*	0.09	*
	KT-13	Klb-Diakkawn- Azl rd II	4.6	0.75	0.02	9.72	5.88	0.03	0.01	0	0	*	*	*	0.015	*
	KT-12	Klb, Diakkawn- Azl rd I	6.45	1.2	0.03	9.72	5.88	0.03	0.01	0	0	*	*	*	0.09	*
	KT-16	Klb, Forest veng	9.45	1.35	0.03	13.61	7.06	0.03	0.02	0.01	0	*	*	*	0.01	*
	KT-15	Klb, Project veng	10.85	1.63	0.04	7.78	8.24	0.03	0.01	0	0.02	*	*	*	0.08	*
	KT-3	Klb-old UPC church	7.34	1.62	0.03	7.78	8.24	0.03	0.02	0	0	*	*	*	0.015	*
	KT-1	Klb-Convent rd	4.4	0.75	0.03	15.55	5.88	0.02	0.02	0	0	*	*	*	0.09	*
	KT-2	Klb, St. John's school	5.21	0.77	0.03	7.78	9.42	0.03	0.02	0	0	*	*	*	0.09	*
	KT-4	Klb- Venglai P/S-III	6.94	0.98	0.03	9.72	4.7	0.03	0.04	0	0.03	*	*	*	0.08	*
Water shed VI	KT-5	Klb-Banglakawn	12.08	1.7	0.03	11.67	4.7	0.03	0.05	0	0	*	*	*	0.09	*
	KT-6	Klb-electric veng	11.07	1.56	0.03	13.61	7.06	0.03	0.01	0	0	*	*	*	0.01	*
	KT-7	Klb, police st	5.72	0.88	0.03	15.56	1.16	0.03	0.03	0	0	*	*	*	0.09	*
	KT-9	Klb-Saidan -II	5.62	0.56	0.02	11.67	4.7	0.03	0.02	0.01	0	*	*	*	0.011	*
	KT-8	Klb- Saidan-I	10.4	1.64	0.03	11.67	3.52	0.03	0.02	0	0	*	*	*	0.011	*
	KT-10	Klb-petrol pump	12.3	2.26	0.03	13.61	5.88	0.03	0.02	0.01	0.03	*	*	*	0.09	*
	KT-17	Klb-Rengtekawn-I	9.2	2.14	0.04	15.56	5.88	0.03	0.02	0.01	0	*	*	*	0.09	*
	KT-18	Klb-Rengtekawn-II	9.35	1.9	0.04	9.72	5.88	0.03	0.02	0	0.03	*	*	*	0.08	*
Water shed VII	KT-19	Bilkhawthlir-BSNL	4.92	0.62	0.04	7.78	8.24	0.03	0.01	0	0	*	*	*	0.01	*
	KT-20	Bilkhawthlir-Post Off	6.75	0.86	0.04	7.78	7.06	0.03	0.02	0	0	*	*	*	0.011	*
Mean			9.24	1.46	0.05	10.45	6.47	0.03	0.02	0.00	0.01	*	*	*	0.05	*
Min			4.4	0.56	0.02	7.78	1.16	0.02	0.01	0	0	0	0	0	0.01	0
Max			14.76	2.4	0.34	15.56	9.42	0.03	0.05	0.01	0.03	0	0	0	0.09	0

- Below Limit of Detection (BLD)

Contd…

Table 17 Contd…

Micro water shed	Samples	Location	**TCl**	**F**	**CO_3**	**HCO_3**	**NO_3**	**SO_4**	**MPN**
water Shed I	KT-27	Kawnpui–Azl rd I	15.75	0.10	0	38.5	0.43	2.95	18
	KT-26	Kawnpui–Azl rd I	11.36	0.10	0	37.62	0.28	4.2	22
	KT-25	Kawnpui–police st	10.12	0.10	0	38.75	0.2	3.2	18
	KT-28	Kawnpui–PWD	14.8	0.10	0	37.62	0.18	2.6	14
	KT-29	Kawnpui–Mualvum rd	13.28	0.55	0	46.25	0.28	4	15
	KT-32	Kawnpui– Hortoki III	14.6	0.73	0	32.25	0.6	4.65	30
	KT-31	Kawnpui – Hortoki II	12.35	0.61	0	32.25	0.25	2.7	25
	KT-30	Kawnpui – Hortoki I	16.5	0.47	0	48.3	0.25	4.6	24
Water shed II	KT-24	Bualpui BSNL	15.42	0.10	0	53.75	0.27	4.15	15
	KT-23	Bualpui - below FCI	10.15	0.10	0	43	0.6	3.7	7
	KT-22	Thingdawl pump st	9.23	0.10	0	43	0.49	4.5	8
	KT-21	Thingdawl-Agri Park	11.35	0.8	0	37.62	0.14	2.95	10
Water shed IV	KT-14	Klb-ICAR complex	18.15	0.10	0	42.15	0.17	2.35	18
	KT-11	Klb-Diakkawn ground	16.28	0.7	0	31.5	0.7	3.75	12
	KT-13	Klb-Diakkawn- Azl rd II	14.29	0.31	0	37.15	0.63	3.7	11
	KT-12	Klb, Diakkawn- Azl rd I	16.33	0.54	0	26.55	0.5	3.4	10
	KT-16	Klb, Forest veng	14.11	0.10	0	40.15	0.27	3.8	17
	KT-15	Klb, Project veng	12	0.10	0	37.62	0.25	4.25	12
	KT-3	Klb-old UPC church	13	0.54	0	38.62	0.24	3.45	17
	KT-1	Klb-Convent rd	14.1	0.27	0	32.3	0.17	1.75	25
	KT-2	Klb, St. John’s school	14.28	0.61	0	27.1	0.12	2.6	17
	KT-4	Klb- Venglai P/S-III	12.2	0.3	0	45	0.24	1.9	8
Water shed VI	KT-5	Klb-Banglakawn	17.35	0.34	0	33.45	0.2	2.6	20
	KT-6	Klb-electric veng	18.8	0.32	0	45.22	0.51	3.25	10
	KT-7	Klb, police st	14	0.29	0	48.6	0.48	3.6	15
	KT-9	Klb-Saidan -II	14.06	0.33	0	36.4	0.24	2.25	18
	KT-8	Klb- Saidan-I	15.13	0.56	0	41.5	0.2	3.35	22
	KT-10	Klb-petrol pump	14.62	0.32	0	38.65	0.21	2.6	30
	KT-17	Klb-Rengtekawn-I	12.2	0.10	0	43	0.65	2.25	23
	KT-18	Klb-Rengtekawn-II	16.65	0.56	0	37.5	0.19	2.85	23
Water shed VII	KT-19	Bilkhawthlir-BSNL	11.78	0.64	0	36.5	0.18	4.75	22
	KT-20	Bilkhawthlir-Post Off	12.56	0.73	0	37.62	0.2	3	19
Mean			13.96	0.50	0.00	38.92	0.32	3.30	17.34
Min			9.23	0.27	0	26.55	0.12	1.75	7
Max			18.8	0.8	0	53.75	0.7	4.75	30

Table 18: Physico-chemical parameters of 'KP' Post monsoon 2007

Samples	Location	**pH**	**EC**	**TDS**	**Turb**	**TA**	**TH**
KP-18	Kawnpui -MRB Br.	7.4	205	150	1.4	101.25	77.6
KP-17	Kawnpui–Hospital	7.3	205	150	1.5	98.65	63.05
KP-16	Kawnpui- Govt. HS	7.4	190	146	1.2	103.5	77.6
KP-15	Bualpui-FCI	7.6	266	175	1.3	108.75	77.6
KP-14	Bualpui- Gorkha hotel	7.3	258	170	1.2	97.6	82.45
KP-13	Thingdawl-Post office	7.4	140	93	1.2	101.3	82.45
KP-8	Klb-Paradise rest'rant	7.1	208	148	1.4	93.65	82.45
KP-9	Klb- Diakkawn –Hlua Inn	7.4	112	72	0.9	102.2	77.6
KP-1	Klb-Venglai- Paster Inn	7.3	189	120	1.2	98.15	67.9
KP-2	Klb–Venglai Lalkunga Inn	7.1	224	156	1.3	93.2	82.45
KP-3	Klb–Hospital	7.2	216	152	1.1	96.5	77.6
KP-7	Klb-Electric sub station	7.3	195	125	1.5	98.75	87.3
KP-6	Klb-BSNL	7.3	180	120	1.2	99.35	77.75
KP-5	Klb-Post Office	7.6	210	150	1.1	108	82.45
KP-4	Klb – DIDI Rest'rant	7.6	175	105	1	108.45	87.3
KP-10	Klb-MST Stand	7.5	275	190	1.6	105.85	72.75
KP-11	Klb-PHE office	7.4	110	77	0.9	99.2	82.45
KP-12	Rengtekawn-check gate	7.2	212	150	1.1	96.5	87.3
KP-20	Bilkhawthlir – PWD	7.4	182	142	1.4	103.5	106.7
KP-19	Bilkhawthlir–Hospital	7.5	190	145	1.5	105.3	87.3
Mean		7.37	197.10	136.80	1.25	100.98	81.00
Min		7.1	110	72	0.9	93.2	63.05
Max		7.6	275	190	1.6	108.75	106.7

Contd…

Table 18 Contd…

Samples	Location	**Na**	**K**	**Fe**	**Ca**	**Mg**	**Cd**	**Zn**	**Cr**	**Mn**	**Ni**	**Cu**	**Co**	**Pb**	**As**
KP-18	Kawnpui -MRB Br.	14.37	2.15	0.03	17.5	8.23	0.03	0.04	0.01	0.03	BLD	BLD	BLD	0.015	BLD
KP-17	Kawnpui–Hospital	10.32	1.92	0.04	11.67	8.24	0.03	0.04	0.01	0.02	BLD	BLD	BLD	0.015	BLD
KP-16	Kawnpui- Govt. HS	8.72	1.1	0.02	15.56	9.41	0.03	0.04	0.01	0.03	BLD	BLD	BLD	0.012	BLD
KP-15	Bualpui-FCI	9.8	1.75	0.03	17.5	8.23	0.03	0.08	0.01	0.03	BLD	BLD	BLD	0.011	BLD
KP-14	Bualpui- Gorkha hotel	10.5	1.95	0.03	19.45	8.23	0.03	0.05	0	0.03	BLD	BLD	BLD	0.013	BLD
KP-13	Thingdawl-Post office	11.46	2.2	0.03	23.34	5.87	0.02	0.03	0	0.02	BLD	BLD	BLD	0.017	BLD
KP-8	Klb-Paradise rest'rant	14.17	2.15	0.03	15.56	10.59	0.03	0.09	0	0.03	BLD	BLD	BLD	0.011	BLD
KP-9	Klb- Diakkawn –Hlua Inn	13.8	1.94	0.03	19.45	7.05	0.03	0.02	0	0.03	BLD	BLD	BLD	0.017	BLD
KP-1	Klb-Venglai- Paster Inn	4.48	0.7	0.03	17.5	5.88	0.02	0.02	0.01	0.03	BLD	BLD	BLD	0.013	BLD
KP-2	Klb–Venglai Lalkunga Inn	4.92	0.62	0.03	13.61	11.77	0.02	0.06	0.01	0.03	BLD	BLD	BLD	0.012	BLD
KP-3	Klb–Hospital	8	1.52	0.03	15.56	15.31	0.02	0.06	0.01	0.02	BLD	BLD	BLD	0.012	BLD
KP-7	Klb-Electric sub station	12.6	2.15	0.03	11.67	14.13	0.03	0.04	0	0.03	BLD	BLD	BLD	0.013	BLD
KP-6	Klb-BSNL	12.15	1.75	0.03	13.61	10.63	0.03	0.03	0	0.02	BLD	BLD	BLD	0.016	BLD
KP-5	Klb-Post Office	11.88	1.6	0.03	13.61	11.77	0.03	0.04	0.01	0.02	BLD	BLD	BLD	0.016	BLD
KP-4	Klb – DIDI Rest'rant	7.15	0.84	0.03	9.72	15.31	0.03	0.02	0.01	0.02	BLD	BLD	BLD	0.012	BLD
KP-10	Klb-MST Stand	11.4	1.69	0.03	17.5	7.06	0.02	0.03	0.01	0.02	BLD	BLD	BLD	0.013	BLD
KP-11	Klb-PHE office	14	2.08	0.03	15.56	10.59	0.03	0.04	0.01	0.02	BLD	BLD	BLD	0.013	BLD
KP-12	Rengtekawn-check gate	2.25	2.24	0.02	19.45	9.41	0.03	0.04	0.01	0.03	BLD	BLD	BLD	0.011	BLD
KP-20	Bilkhawthlir – PWD	14.12	2.17	0.03	25.28	10.58	0.03	0.04	0.01	0.03	BLD	BLD	BLD	0.015	BLD
KP-19	Bilkhawthlir–Hospital	12.69	1.96	0.04	15.56	11.77	0.03	0.08	0.01	0.03	BLD	BLD	BLD	0.014	BLD
Mean		10.44	1.72	0.03	16.43	10.00	0.03	0.04	0.01	0.03	BLD	BLD	BLD	0.01	BLD
Min		2.25	0.62	0.02	9.72	5.87	0.02	0.02	0	0.02	0	0	0	0.011	0
Max		14.37	2.24	0.04	25.28	15.31	0.03	0.09	0.01	0.03	0	0	0	0.017	0

Contd…

Table 18 Contd…

Samples	Location	**TCl**	**F**	**CO_3**	**HCO_3**	**NO_3**	**SO_4**	**MPN**
KP-18	Kawnpui -MRB Br.	15.45	0.54	0	101.25	0.64	13.7	40
KP-17	Kawnpui–Hospital	14	0.51	0	98.65	0.51	14.75	28
KP-16	Kawnpui- Govt. HS	15.45	0.63	0	103.5	0.6	12.5	24
KP-15	Bualpui-FCI	15.4	0.71	0	108.75	0.66	12.5	25
KP-14	Bualpui- Gorkha hotel	10.5	0.67	0	97.6	0.6	11.95	46
KP-13	Thingdawl-Post office	9.35	0.52	0	101.3	0.45	15.25	40
KP-8	Klb-Paradise rest'rant	12.5	0.76	0	93.65	0.46	14.5	32
KP-9	Klb- Diakkawn –Hlua Inn	13.1	0.64	0	102.2	0.66	13.4	23
KP-1	Klb-Venglai- Paster Inn	15.1	0.48	0	98.15	0.63	13.75	25
KP-2	Klb–Venglai Lalkunga Inn	14.7	0.47	0	93.2	0.5	14.6	27
KP-3	Klb–Hospital	13.55	0.28	0	96.5	0.28	15	35
KP-7	Klb-Electric sub station	14.95	0.68	0	98.75	0.6	14.7	35
KP-6	Klb-BSNL	8.95	0.4	0	99.35	0.62	15	23
KP-5	Klb-Post Office	17.21	0.54	0	108	0.58	12.55	11
KP-4	Klb – DIDI Rest'rant	13.27	0.62	0	108.45	0.65	13.8	16
KP-10	Klb-MST Stand	15.6	0.56	0	105.85	0.65	11.95	22
KP-11	Klb-PHE office	15.85	0.5	0	99.2	0.61	12.5	36
KP-12	Rengtekawn-check gate	12.25	0.52	0	96.5	0.7	14.6	40
KP-20	Bilkhawthlir – PWD	17.65	0.64	0	103.5	0.59	14.25	23
KP-19	Bilkhawthlir–Hospital	14.7	0.64	0	105.3	0.64	13	31
Mean		13.98	0.57	0.00	100.98	0.58	13.71	29.10
Min		8.95	0.28	0	93.2	0.28	11.95	11
Max		17.65	0.76	0	108.75	0.7	15.25	46

Table 19: Physico-chemical parameters of 'KT' Pre monsoon 2008

Micro water shed	Samples	Location	**pH**	**EC**	**TDS**	**Turb**	**TA**	**TH**
water Shed I	KT-27	Kawnpui–Azl rd I	7.2	183	129	0.6	40.75	48.5
	KT-26	Kawnpui–Azl rd I	7.2	142	90	0.9	40.6	43.65
	KT-25	Kawnpui–police st	7.1	145	93	1	38.5	53.35
	KT-28	Kawnpui–PWD	7.3	80	52	0.7	42.5	48.5
	KT-29	Kawnpui–Mualvum rd	7.5	190	131	1	48.5	43.65
	KT-32	Kawnpui– Hortoki III	7.1	194	130	0.9	38.65	53.35
	KT-31	Kawnpui – Hortoki II	7.1	85	53	1	37.25	58.2
	KT-30	Kawnpui – Hortoki I	7.5	220	154	0.9	48.65	58.2
Water shed II	KT-24	Bualpui BSNL	7.4	182	129	0.9	46.5	63.05
	KT-23	Bualpui - below FCI	7.3	138	90	0.9	43.15	67.9
	KT-22	Thingdawl pump st	7.2	130	84	0.8	41.5	67.9
	KT-21	Thingdawl-Agri Park	7.1	150	96	0.7	39.7	58.2
Water shed IV	KT-14	Klb-ICAR complex	7.3	160	107	0.7	43	47.86
	KT-11	Klb-Diakkawn ground	7	155	105	0.6	34.3	58.2
	KT-13	Klb-Diakkawn- Azl rd II	7.1	115	72	0.8	37.62	53.35
	KT-12	Klb, Diakkawn- Azl rd I	6.8	150	103	0.7	32.25	49
	KT-16	Klb, Forest veng	7.3	120	82	0.9	43	63.05
	KT-15	Klb, Project veng	7.1	180	125	1	37.62	58.2
	KT-3	Klb-old UPC church	7.3	140	90	0.7	43	53.35
	KT-1	Klb-Convent rd	7	150	92	0.7	34.75	63.05
	KT-2	Klb, St. John's school	6.8	128	85	0.7	32.25	58.2
	KT-4	Klb- Venglai P/S-III	7.4	138	85	0.7	46.5	48.5
Water shed VI	KT-5	Klb-Banglakawn	7.1	142	90	0.8	37.25	53.35
	KT-6	Klb-electric veng	7.4	200	145	0.9	46	63.05
	KT-7	Klb, police st	7.5	88	54	1	48.37	48.5
	KT-9	Klb-Saidan -II	7.1	112	71	0.9	37.62	62.96
	KT-8	Klb- Saidan-I	7.3	125	85	0.9	41	43.65
	KT-10	Klb-petrol pump	7.2	150	102	1.1	41.6	63.05
	KT-17	Klb-Rengtekawn-I	7.1	208	147	1.1	38.5	62.93
	KT-18	Klb-Rengtekawn-II	6.8	110	70	1	32.25	50.12
Water shed VII	KT-19	Bilkhawthlir-BSNL	7	145	95	0.9	36.5	53.35
	KT-20	Bilkhawthlir-Post Off	7	225	158	0.8	36.5	53.35
Mean			7.18	149.38	99.81	0.85	40.19	55.36
Min			6.8	80	52	0.6	32.25	43.65
Max			7.5	225	158	1.1	48.65	67.9

Table 19Contd…

Contd…

Micro water shed	Samples	Location	**Na**	**K**	**Fe**	**Ca**	**Mg**	**Cd**	**Zn**	**Cr**	**Mn**	**Ni**	**Cu**	**Co**	**Pb**	**As**
Water Shed I	KT-27	Kawnpui–Azl rd I	8.53	1.8	0.03	15.56	2.34	0.03	0.04	0	0	*	*	*	0.014	*
	KT-26	Kawnpui–Azl rd I	8.67	1.8	0.02	11.67	3.52	0.03	0.05	0	0	*	*	*	0.015	*
	KT-25	Kawnpui–police st	9.8	1.98	0.02	11.67	5.88	0.03	0.06	0	0	*	*	*	0.015	*
	KT-28	Kawnpui–PWD	10.08	1.72	0.02	13.61	3.52	0.03	0.03	0	0.03	*	*	*	0.012	*
	KT-29	Kawnpui–Mualvum rd	11.36	2.48	0.03	11.67	3.52	0.03	0.04	0	0	*	*	*	0.011	*
	KT-32	Kawnpui– Hortoki III	13.98	1.98	0.33	11.67	5.88	0.03	0.04	0	0.03	*	*	*	0.012	*
	KT-31	Kawnpui – Hortoki II	13.9	1.98	0.01	15.56	4.7	0.03	0.04	0	0.03	*	*	*	0.09	*
	KT-30	Kawnpui – Hortoki I	14.55	2.01	0.32	13.61	5.88	0.03	0.06	0	0.03	*	*	*	0.09	*
Water shed II	KT-24	Bualpui BSNL	12.62	2.39	0.03	9.72	9.42	0.03	0.04	0	0	*	*	*	0.011	*
	KT-23	Bualpui - below FCI	10.41	1.86	0.02	13.61	8.24	0.03	0.03	0	0	*	*	*	0.08	*
	KT-22	Thingdawl pump st	11.48	2.5	0.03	15.56	7.05	0.03	0.03	0	0	*	*	*	0.08	*
	KT-21	Thingdawl-Agri Park	7.3	1.41	0.03	15.56	4.7	0.03	0.03	0	0	*	*	*	0.011	*
Water shed IV	KT-14	Klb-ICAR complex	10.86	2.14	0.04	9.72	5.73	0.03	0.02	0	0	*	*	*	0.01	*
	KT-11	Klb-Diakkawn ground	8.05	0.91	0.02	15.56	4.7	0.03	0.02	0	0	*	*	*	0.08	*
	KT-13	Klb-Diakkawn- Azl rd II	6.42	0.6	0.03	11.67	5.87	0.03	0.03	0	0	*	*	*	0.015	*
	KT-12	Klb, Diakkawn- Azl rd I	6.25	0.52	0.03	11.05	5.2	0.03	0.02	0	0	*	*	*	0.09	*
	KT-16	Klb, Forest veng	10.08	1.97	0.03	15.55	5.88	0.03	0.02	0	0	*	*	*	0.011	*
	KT-15	Klb, Project veng	10.5	2.08	0.03	7.78	9.42	0.03	0.03	0	0.02	*	*	*	0.01	*
	KT-3	Klb-old UPC church	7.5	0.72	0.02	13.61	4.7	0.03	0.02	0	0	*	*	*	0.015	*
	KT-1	Klb-Convent rd	4.3	0.61	0.02	15.56	8.23	0.03	0.02	0	0	*	*	*	0.08	*
	KT-2	Klb, St. John's school	4.86	0.63	0.02	7.78	9.42	0.03	0.02	0	0	*	*	*	0.09	*
	KT-4	Klb- Venglai P/S-III	6.85	0.48	0.02	11.67	5.88	0.03	0.03	0	0.03	*	*	*	0.09	*
Water shed VI	KT-5	Klb-Banglakawn	11.42	1.75	0.03	9.72	7.06	0.03	0.04	0	0	*	*	*	0.09	*
	KT-6	Klb-electric veng	10.52	2.11	0.03	15.56	5.88	0.03	0.01	0	0	*	*	*	0.01	*
	KT-7	Klb, police st	5.73	0.68	0.01	11.67	4.7	0.03	0.03	0	0	*	*	*	0.09	*
	KT-9	Klb-Saidan -II	5.22	0.66	0.03	14.3	6.61	0.03	0.02	0	0	*	*	*	0.011	*
	KT-8	Klb- Saidan-I	10.28	1.96	0.01	15.56	1.16	0.03	0.02	0	0	*	*	*	0.012	*
	KT-10	Klb-petrol pump	13.37	1.85	0.02	5.83	11.78	0.03	0.02	0	0.02	*	*	*	0.011	*
	KT-17	Klb-Rengtekawn-I	9.16	1.65	0.04	14.3	6.61	0.03	0.03	0	0	*	*	*	0.09	*
	KT-18	Klb-Rengtekawn-II	4.85	0.67	0.03	7.86	7.41	0.03	0.04	0	0.03	*	*	*	0.01	*
Water shed VII	KT-19	Bilkhawthlir-BSNL	4.33	0.65	0.03	7.78	8.24	0.03	0.04	0	0	*	*	*	0.01	*
	KT-20	Bilkhawthlir-Post Off	6.18	1.15	0.02	13.61	4.7	0.03	0.04	0	0	*	*	*	0.012	*
Mean			9.04	1.49	0.04	12.36	6.06	0.03	0.03	0.00	0.01	*	*	*	0.04	*
Min			4.3	0.48	0.01	5.83	1.16	0.03	0.01	0	0	0	0	0.03	0.01	0
Max			14.55	2.5	0.33	15.56	11.78	0.03	0.06	0	0.03	0	0	0.57	0.09	0

***-** *Below Limit of Detection (BLD*

Contd…

Table 19Contd…

Micro water shed	Samples	Location	**TCl**	**F**	**CO_3**	**HCO_3**	**NO_3**	**SO_4**	**MPN**
water Shed I	KT-27	Kawnpui–Azl rd I	15.25	0.19	0	40.75	0.45	3.15	15
	KT-26	Kawnpui–Azl rd I	11.9	0.14	0	40.6	0.28	4.65	23
	KT-25	Kawnpui–police st	9.75	0.12	0	38.5	0.23	3.35	20
	KT-28	Kawnpui–PWD	13.86	0.15	0	42.5	0.22	2.9	10
	KT-29	Kawnpui–Mualvum rd	13.15	0.58	0	48.5	0.3	4.2	16
	KT-32	Kawnpui– Hortoki III	13.3	0.81	0	32.25	0.62	4.65	30
	KT-31	Kawnpui – Hortoki II	11.26	0.62	0	34.75	0.27	2.9	24
	KT-30	Kawnpui – Hortoki I	16.8	0.51	0	48.65	0.26	4.65	26
Water shed II	KT-24	Bualpui BSNL	14.68	0.16	0	46.5	0.31	4.3	18
	KT-23	Bualpui - below FCI	10.47	0.17	0	43.15	0.62	3.5	8
	KT-22	Thingdawl pump st	10	0.82	0	41.5	0.52	4.7	12
	KT-21	Thingdawl-Agri Park	12.2	0.72	0	39.7	0.15	3.15	10
Water shed IV	KT-14	Klb-ICAR complex	16.61	0.21	0	43	0.2	2.5	24
	KT-11	Klb-Diakkawn ground	14.75	0.68	0	34.3	0.75	3.85	18
	KT-13	Klb-Diakkawn- Azl rd II	13.76	0.35	0	37.62	0.68	3.45	13
	KT-12	Klb, Diakkawn- Azl rd I	15.4	0.55	0	32.25	0.5	3.72	11
	KT-16	Klb, Forest veng	12.2	0.16	0	43	0.29	4.1	15
	KT-15	Klb, Project veng	12.2	0.21	0	37.62	0.28	4.3	20
	KT-3	Klb-old UPC church	11.85	0.5	0	43	0.23	3.5	16
	KT-1	Klb-Convent rd	12.18	0.21	0	34.75	0.15	1.85	19
	KT-2	Klb, St. John's school	13.3	0.62	0	32.25	0.14	3.25	13
	KT-4	Klb- Venglai P/S-III	11.8	0.31	0	46.5	0.24	2.15	10
Water shed VI	KT-5	Klb-Banglakawn	16.5	0.35	0	37.25	0.2	2.5	23
	KT-6	Klb-electric veng	18.7	0.33	0	46	0.58	3.2	20
	KT-7	Klb, police st	14.15	0.31	0	48.37	0.47	3.65	17
	KT-9	Klb-Saidan -II	15.8	0.32	0	37.62	0.23	2.45	24
	KT-8	Klb- Saidan-I	15	0.52	0	41	0.22	3.6	23
	KT-10	Klb-petrol pump	14.05	0.32	0	41.6	0.21	2.85	30
	KT-17	Klb-Rengtekawn-I	17.7	0.15	0	38.5	0.68	2.15	29
	KT-18	Klb-Rengtekawn-II	13.5	0.61	0	32.25	0.21	3.2	25
Water shed VII	KT-19	Bilkhawthlir-BSNL	12.35	0.6	0	36.5	0.18	4.75	26
	KT-20	Bilkhawthlir-Post Off	13.72	0.62	0	36.5	0.2	3.25	18
Mean			13.69	0.40	0.00	39.91	0.34	3.45	18.94
Min			9.75	0.12	0	32.25	0.14	1.85	8
Max			18.7	0.82	0	48.65	0.75	4.75	30

Table 20: Physico-chemical parameters of 'KP' Pre monsoon 2008

Samples	Location	**pH**	**EC**	**TDS**	**Turb**	**TA**	**TH**
KP-18	Kawnpui -MRB Br.	7.2	190	130	1.1	99.7	77.6
KP-17	Kawnpui–Hospital	7.1	190	130	1.1	96.42	63.05
KP-16	Kawnpui- Govt. HS	7.3	182	107	1.3	101.2	72.75
KP-15	Bualpui-FCI	7.4	242	160	1.4	104.8	67.9
KP-14	Bualpui- Gorkha hotel	7.2	240	159	1.2	97.7	82.45
KP-13	Thingdawl-Post office	7.2	138	88	1.3	97.95	77.6
KP-8	Klb-Paradise rest'rant	7	195	146	1.5	93.62	77.6
KP-9	Klb- Diakkawn –Hlua Inn	7.2	84	50	1.5	97.25	82.45
KP-1	Klb-Venglai- Paster Inn	7.2	178	144	1.1	97.5	67.9
KP-2	Klb–Venglai Lalkunga Inn	6.9	182	125	1.2	92.5	82.45
KP-3	Klb–Hospital	7.2	181	124	1	98.15	72.75
KP-7	Klb-Electric sub station	7	170	117	1.3	94.45	87.3
KP-6	Klb-BSNL	7.2	168	115	1	97	72.75
KP-5	Klb-Post Office	7.4	180	125	1.2	102.3	82.45
KP-4	Klb – DIDI Rest'rant	7.5	145	92	0.9	106.8	82.45
KP-10	Klb-MST Stand	7.3	255	172	1.6	103.2	77.6
KP-11	Klb-PHE office	7.2	92	55	1.3	98.35	82.45
KP-12	Rengtekawn-check gate	7	182	108	1	94.25	87.3
KP-20	Bilkhawthlir – PWD	7.3	160	108	1.3	101.2	97
KP-19	Bilkhawthlir–Hospital	7.4	168	111	1	103	82.45
Mean		7.21	176.1	118.3	1.21	98.86	78.81
Min		6.9	84	50	0.9	92.5	63.05
Max		7.5	255	172	1.6	106.8	97

Contd…

Table 20Contd…

Samples	Location	**Na**	**K**	**Fe**	**Ca**	**Mg**	**Cd**	**Zn**	**Cr**	**Mn**	**Ni**	**Cu**	**Co**	**Pb**	**As**
KP-18	Kawnpui -MRB Br.	14.16	2.17	0.03	17.5	8.23	0.02	0.04	0.01	0.03	BLD	BLD	BLD	0.013	BLD
KP-17	Kawnpui–Hospital	9.92	1.9	0.02	13.61	7.06	0.03	0.04	0.01	0.02	BLD	BLD	BLD	0.013	BLD
KP-16	Kawnpui- Govt. HS	8.85	1.23	0.02	19.45	5.87	0.03	0.04	0.01	0.03	BLD	BLD	BLD	0.011	BLD
KP-15	Bualpui-FCI	8.55	1.12	0.03	13.61	8.24	0.03	0.07	0	0.03	BLD	BLD	BLD	0.011	BLD
KP-14	Bualpui- Gorkha hotel	9.94	1.78	0.03	19.45	8.23	0.03	0.06	0	0.03	BLD	BLD	BLD	0.012	BLD
KP-13	Thingdawl-Post office	11.32	2.15	0.03	9.72	12.95	0.03	0.03	0	0.03	BLD	BLD	BLD	0.014	BLD
KP-8	Klb-Paradise rest'rant	14.22	2.21	0.03	17.5	8.23	0.03	0.08	0	0.03	BLD	BLD	BLD	0.01	BLD
KP-9	Klb- Diakkawn –Hlua Inn	12.76	1.8	0.03	17.5	9.41	0.03	0.02	0	0.03	BLD	BLD	BLD	0.015	BLD
KP-1	Klb-Venglai- Paster Inn	4.32	0.65	0.03	17.5	5.88	0.02	0.02	0.01	0.03	BLD	BLD	BLD	0.01	BLD
KP-2	Klb–Venglai Lalkunga Inn	4.85	0.63	0.03	19.45	8.23	0.02	0.06	0.01	0.03	BLD	BLD	BLD	0.011	BLD
KP-3	Klb–Hospital	8.15	1.46	0.03	15.56	8.23	0.03	0.06	0.01	0.02	BLD	BLD	BLD	0.013	BLD
KP-7	Klb-Electric sub station	12.25	1.71	0.02	15.56	11.77	0.03	0.04	0.01	0.02	BLD	BLD	BLD	0.012	BLD
KP-6	Klb-BSNL	11.87	1.58	0.02	15.56	8.23	0.03	0.03	0.01	0.02	BLD	BLD	BLD	0.013	BLD
KP-5	Klb-Post Office	10.4	1.41	0.03	17.5	9.41	0.03	0.04	0.01	0.02	BLD	BLD	BLD	0.014	BLD
KP-4	Klb – DIDI Rest'rant	6.88	0.51	0.03	23.34	5.87	0.03	0.02	0.01	0.02	BLD	BLD	BLD	0.012	BLD
KP-10	Klb-MST Stand	10.92	1.6	0.03	17.5	8.23	0.03	0.03	0.01	0.03	BLD	BLD	BLD	0.011	BLD
KP-11	Klb-PHE office	14.1	1.95	0.03	23.34	5.87	0.03	0.04	0.01	0.02	BLD	BLD	BLD	0.012	BLD
KP-12	Rengtekawn-check gate	14.07	2.2	0.03	19.45	9.41	0.03	0.04	0.01	0.03	BLD	BLD	BLD	0.09	BLD
KP-20	Bilkhawthlir – PWD	13.97	2.12	0.03	27.23	7.04	0.03	0.04	0.01	0.02	BLD	BLD	BLD	0.014	BLD
KP-19	Bilkhawthlir–Hospital	12.28	1.81	0.03	21.39	7.05	0.03	0.08	0.01	0.03	BLD	BLD	BLD	0.012	BLD
Mean		10.689	1.5995	0.028	18.086	8.172	0.0285	0.044	0.0075	0.026	BLD	BLD	BLD	0.016	BLD
Min		4.32	0.51	0.02	9.72	5.87	0.02	0.02	0	0.02	0	0	0	0.01	0
Max		14.22	2.21	0.03	27.23	12.95	0.03	0.08	0.01	0.03	0	0	0	0.09	0

Contd…

Table 20 Contd…

Samples	Location	**TCl**	**F**	**CO_3**	**HCO_3**	**NO_3**	**SO_4**	**MPN**
KP-18	Kawnpui -MRB Br.	14.9	0.52	0	99.7	0.63	13.65	32
KP-17	Kawnpui–Hospital	13.6	0.54	0	96.42	0.45	13.85	27
KP-16	Kawnpui- Govt. HS	15.26	0.6	0	101.2	0.55	11.8	17
KP-15	Bualpui-FCI	15.2	0.68	0	104.8	0.62	11.85	22
KP-14	Bualpui- Gorkha hotel	9.75	0.6	0	97.7	0.58	10.55	43
KP-13	Thingdawl-Post office	9.25	0.49	0	97.95	0.4	14.6	27
KP-8	Klb-Paradise rest'rant	11.9	0.68	0	93.62	0.45	14.55	27
KP-9	Klb- Diakkawn –Hlua Inn	12.78	0.64	0	97.25	0.65	13	31
KP-1	Klb-Venglai- Paster Inn	13.55	0.45	0	97.5	0.61	12.9	18
KP-2	Klb–Venglai Lalkunga Inn	13.4	0.42	0	92.5	0.46	13.8	30
KP-3	Klb–Hospital	13.3	0.27	0	98.15	0.29	14.65	30
KP-7	Klb-Electric sub station	15.1	0.64	0	94.45	0.52	14.5	30
KP-6	Klb-BSNL	8.15	0.3	0	97	0.6	14.5	24
KP-5	Klb-Post Office	15.75	0.51	0	102.3	0.53	12.65	15
KP-4	Klb – DIDI Rest'rant	13	0.55	0	106.8	0.61	13.35	17
KP-10	Klb-MST Stand	15.65	0.59	0	103.2	0.6	11.15	33
KP-11	Klb-PHE office	15.2	0.46	0	98.35	0.55	12	34
KP-12	Rengtekawn-check gate	12.7	0.51	0	94.25	0.63	13.7	38
KP-20	Bilkhawthlir – PWD	16.6	0.53	0	101.2	0.58	13.6	22
KP-19	Bilkhawthlir–Hospital	13.76	0.08	0	103	0.61	12.15	31
Mean		13.44	0.503	0	98.867	0.546	13.14	27.4
Min		8.15	0.08	0	92.5	0.29	10.55	15
Max		16.6	0.68	0	106.8	0.65	14.65	43

CHAPTER 5: DISCUSSION

The area around Kolasib town, where the present work has been carried out is covered by rock exposures belonging to upper Bhuban formation of Surma Group. They are dominated by shale/soil and also alternation of sandstones. In order to discuss rock-water interaction, particularly in case of tuikhur water sources, the physic-chemical and bacteriological results have been observed vis-à-vis micro water sheds established in Tuichhuahen water shed (Rai, 2005).

Tuichhuahen watershed area is composed of sedimentary rock succession belonging to Surma and Tipam Groups of Tertiary period. Middle and upper unit of Bhuban Formations are exposed in the watershed. The main rock types of Bhuban Formation in the watershed are sandstone, siltstone, shales and mudstone along with the admixture of the above. The shales are dark grey to pale greenish, thinly laminated and crumpled at places. The siltstone and mudstone are grayish in colour, thinly bedded, hard and ripple cross laminated. The sandstones are thinly bedded and silty.

This Formation shows highest topographic expression due to its hard compact nature and its resistance to weathering. Dense jungles and appreciable jhum cultivation can be seen in the area covered by this formation (Ganguli, 1975; Ganju, 1975 and Tiwari and Kumar, 1996),

Middle Bhuban Formation is conformably overlain by Upper Bhuban Formation, which is predominantly arenaceous with a maximum thickness of 1100 m. It is mainly composed of sandstone, shale, siltstone and mudstones are also found in subordinate quantities. The sandstones are massive, grey and brown coloured fine grained, ill sorted, silty and micaceons. The siltstones are massive while the shales are dark to bluish grey, thinly laminated and splintery (Ganguli, 1975; Ganju, 1975 and Tiwari & Kumar, 1997). This area covered by this formation has subdued topographic expression. Considerable jhum cultivation can be noticed in this formation.

The entire water shed is covered by thin to thick vegetation and as such the surface area of exposed rock is very less. The rocks are mainly exposed along the streams, road sections, on jhum patches and on valley slopes. Since, the rocks are structurally disturbed and geologically young; these are weak and are prone to deep weathering giving rise to silty and clayey soils.

Complete dissolution of the minerals of a rock or the partial alteration of the composition of a mineral due to leaching of its components is termed chemical weathering. These reactions occur because the initially dilute rain water or snowmelt that contacts the rock is not in chemical equilibrium with the minerals and amorphous solids comprising the rock. The water/ rock system reacts and moves toward equilibrium by dissolving or leaching constituents out of the rock into the solution. The primary minerals in the rock may have formed under pressure, temperature and water vapour conditions far different from that present near the earth's surface. These minerals will become unstable with seasonal chemical variation with ground water aquifers at the pressure and temperature regimes of normal aquifers. These minerals will dissolve irreversibly, releasing their constituents into the water. Depending on site-specific conditions, complete dissolution of a mineral may take hundreds to millions of years. Primary minerals in some rock types (e.g. calcite in limestone and gypsum in a salt deposit) can and do form under aquifer conditions; therefore their dissolution reactions are reversible and they may equilibrate with the ground water.

The alteration products of weathering are dissolved constituents and secondary minerals that can form in the ground water environment. These are the minerals that are most important to the study of ground water geochemistry because they are reactive in the aquifer environment. They can limit solution concentration for their constituents and also tend to provide the most common substrates for adsorption reactions. The term reactive mineral is used to denote a mineral that will dissolve or precipitate from ground water in a reasonable period of residence time for the water in the aquifer. They clay minerals and metal oxides are particularly important because they not only form in the aquifer environment, but they provide very reactive surfaces on which dissolved constituents can be adsorbed from water. The minerals, amorphous oxides and organic matter present in an aquifer that participate in adsorption/ desorption processes each have separate affinities for the dissolved constituents and based on the amount of the substrate, they each have different capacities for adsorption.

It is in the soil zone that water first enters the subsurface and comes into close contact with inorganic and organic solids. The natural organic matter in the soil is composed of a continuum from readily degradable plant debris and roots of dead vegetation to humic substances that have been partially decomposed by soil processes. Solid organic matter plays an important role in the movement of dissolved organic matter because of the attraction of the solid phase for the dissolved phase and consequent removal of dissolved organic carbon from solution from adsorption. The solid organic matter also adsorbs metals from the water and where inorganic adsorbents are present in low concentration compared with organic adsorbents, the solid organic carbon may be an important control on the mobility of trace metals. Organic carbon in the soil also affects the inorganic chemistry of ground water because the oxidation of organic matter produces carbon dioxide gas. Carbon dioxide gas reacts with the water to produce carbonic acid and the other inorganic carbon species bicarbonate and carbonate. The production of carbonic acid makes the water a more aggressive weathering solution and the increase in the level of anionic carbon species enhances ion complexation.

The composition of ground water is a function of the sources and sinks of chemical elements along the ground water flow path. The relative concentrations of dissolved constituents are determined by the available supply from the solid phases and the solubility of secondary minerals formed from weathering processes. If a chemical element is present only at small concentrations in the aquifer solids, then ground water will have little opportunity to accumulate the element in solution unless the flow path and ground water residence times are long. If a chemical element is present in high concentrations in aquifer solids, then it has the potential for occurring as a major component of the ground water. In an aquifer the primary rock-forming minerals will be leached and dissolved by the ground water to produce more stable secondary minerals and release some components to solution. For example, depending on local conditions, the weathering of biotite might form the secondary minerals kaolinite [$Al_2Si_2O_5(OH)_4$] and ferrihydrite [$Fe(OH)_3$]. Potassium, magnesium and silica may also be released into solution according to the following reaction:

$K_2[Si_6Al_2]Mg_4Fe_2O_{20}(OH)_4(\text{biotite}) + 10H^+ + 6H_2O + 1/2O_2 \rightarrow$

$Al_2Si_2O_5(OH)_4 + Fe(OH)_3 + 4H_4SiO_4^0 + 4Mg^{2+} + 2K^+$

Ferrihydrite and kaolinite are secondary minerals that will equilibrate with the ground water containing their dissolved components iron, aluminium and silicon as per the following reactions:

$$Fe(OH)_3 + 3H^+ \leftrightarrow Fe^{3+} + 3H_2O$$

$$Al_2Si_2O_5(OH)_4 + 5H_2O \leftrightarrow 2Al(OH)_3^0 + 2H_4SiO_4^0$$

The solubility of biotite does not control the concentrations of its products because biotite is not a stable mineral under aquifer conditions. Biotite dissolves irreversibly and the amount of its products (both solid phases and elements released to solution) in the system is mainly a function of the rate at which biotite weathers and the amount of time weathering has occurred. The secondary minerals that form from the alteration of the primary minerals can limit the solution concentration of their constituents. In this case ferrihydrite will control the dissolved iron concentration and kaolinite may limit the solution concentration for one of its components. Each mineral can only limit the solution concentration for one of its components.

Among physical parameters, though pH has no direct effect on human health, it is of the utmost importance in determining the corrosivity of water. Further it plays an important role in almost all the biochemical reactions. The corrosivity is inversely related with pH (Gupta *et al*, 2009; Nordberg *et al*, 1985; Mc Clanathan and Mancy, 1974); Langelier 1946; Webber *et al*, 1989; Murrel, 1987 and Stone *et al,* 1987). It was found that pH varies within subtle range in almost all the seasons except in rainy season where its values are consistently 7.

Solutions with pH values greater than 7 are suggestive of the fact that it must contain cations other than H^+. This can be evident from considerations of charge balance. It is a fundamental principle of solution chemistry that solutions are electrically neutral, that is, that the total number of positive charges carried by cations must equal the total number of negative charges carried by anions:

$$\Sigma\ m_i z_i = 0$$

where m is the concentration and z the charge, of the ith ion.

For the system H_2O-CO_2, the charge balance equation is as follows:

$$m_{H^+} = m_{HCO3^-} + 2\ m_{CO3^{2-}} + m_{OH^-}$$

At pH 7, $m_{H^+} = m_{OH^-}$. Thus if m_{HCO3^-} or m_{CO3^-} has any finite value, m_{H^+} must be correspondingly greater than m_{OH^-} and the solution will have a pH lower than 7. If we introduce sodium into the system, the charge of balanced equation becomes as follows:

$$m_{H^+} + m_{Na^+} = m_{HCO3^-} + 2m_{CO3^{2-}} + m_{OH^-}$$

Moreover, there are no immediate constraints on the value of m_{H}^{+} and hence pH. For solutions that are approximately neutral, m_{H}^{+}, m_{OH}^{-} and m_{CO3}^{2-} are generally negligible compared to m_{Na}^{+} and m_{HCO3}^{-}. In this case the charge balance equation simplifies to

$m_{Na}^{+} = m_{HCO3}^{-}$

At constant P_{CO2} hydrogen ion activity is related to HCO_3^- concentration. In the absence of other anions such as Cl^- and SO_4^{2-}, the total concentration of cations will approximately equal the HCO_3^- concentration, and hence pH and salinity in HCO_3^-‾rich waters are inversely related. In the present study also HCO_3^- ion is the dominant anion but pH values still remain closer to 7. It is because of the fact that introduction of sodium ion balances the charges (Drever, 1982). In case pH value is higher than 8.5, it will adversely affect alkalinity of soil, microbial life, aquatic organisms and corrosion rate (Shyamala *et al*, 2008; Shaikh and Mandre, 2009). Solutions having pH 10-12.5 have been reported to cause hair fibres to swell (WHO, 2008). All the values of pH lie in the permissible limit of 6.5 to 8.5 (ISI, 1991). Low value of pH may be attributed to the lack of carbonate minerals in the study area. This is in agreement with the rock types present in the area.

In pH versus total alkalinity plots, pH remains almost constant whereas later shows variation. For the same pH value, the total alkalinity of KT-24 in post monsoon, 2006 rises up to 86.25 mg/l (Fig.1) whereas it fluctuates below 50 mg/l in other KT samples (Fig. 2 & 3). The high alkalinity value in KT-24 water sample in a particular season may be due to addition of sodium which can increase the alkalinity value. There is no remarkable variation in pH and total alkalinity in supply water (Fig. 4&5).

The electrical conductivity reflects the total amount of soluble salts in water. It is a measure of the ability of water to transmit an electrical current in it and is proportional to presence of dissolved inorganic contents. Hence, it can be a measure of the degree of suitability of potable water. The EC values of KT samples range from 70 to 225µS/cm in pre monsoon, from 72 to 190µS/cm in monsoon and from 70 to 244µS/cm in post monsoon while that of KP samples it varies from 82 to 255µS/cm in pre monsoon, 80 to 220 µS/cm in monsoon and from 96 to 276µS/cm in post monsoon in KP water. It is evident that EC values are lower in monsoon season as compared to pre monsoon and post monsoon seasons. Futher, EC of KR samples, the range is within the values lower than that of KP and KT. This can be attributed to the dilution during rainy season. The lower values of EC in general including KP and KT can be explained by low solubility of silicate minerals constituting the host rock i.e. sandstone (Li and Zhang, 2008).

However, among watersheds the water shed I and VI exhibits lower values than other water sheds. The low values of EC in Water shed I and VI may be attributed to fewer amounts of dissolved salts indicative of less solubility of minerals and ions from the host rock and has insignificant rock-water interaction. Further, it characterizes dominance of more silica content in the host rock.

Total dissolved solids indicate the amount of chemical substances dissolved in water. TDS in potable water upto 500 mg/l is considered to be good (ISI, 1991). Primary sources of TDS in receiving water include agricultural residential runoff, leaching of soil contamination and point source water pollution discharge from industrial or sewage treatment plants. The most common chemical constituents are calcium, phosphates, nitrates, sodium, potassium and chloride, which are found in nutrient runoff and general storm water runoff. The chemicals may be cations, anions, molecules or agglomerations on the order of one thousand or fewer molecules, so long as soluble micro- granule is formed. Low levels of TDS indicate the recharging of groundwater through either rain water or water from nearby canals (Gupta *et al*, 2009).

TDS value ranges from a minimum of 49 to a maximum of 162 mg/l in KT water. The lowest value of 49 mg/l has been recorded in KT- 28 which lies in watershed I in pre monsoon, 2006 whereas the highest value lies with KT- 4 in post monsoon, 2005. KT- 7, KT- 28 and KT- 31 have low TDS values in all the seasons whereas KT- 20 and KT- 30 record high values of TDS in all the seasons. The higher value of TDS may be attributed to the presence of colloidal or finely divided suspended matter which does not readily settle. The presence of colloidal or finely divided suspended matter may be due to the direct discharge of solid waste or construction activities around the area (Rajurkar *et al*, 2003).

The toxicity of TDS may vary depending upon the specific constituent composition of the TDS in the effluent. Relative ion toxicity is in the order of $K^+ > HCO_3^- \approx Mg^{2+} > Cl^- > SO_4^{2-}$ (Mount *et al*, 1997). Peterson (1999) has pointed that TDS level below 700 mg/l are considered safe. TDS levels in all the water samples studied are below 700 mg/l and thus may be considered safe. As per the TDS classification (Fetter, 1990) all the samples studied belongs to fresh water type. Electrical conductivity and total dissolved solids are proportional to each other i.e. with an increase in the value of electrical conductivity; the value of total dissolved solids also increases. These values are higher in post monsoon seasons in KT samples (Fig. 6&7) due to increase in concentration of minerals in the dry period of the year. EC and TDS are proportional to each other in KP samples also but their values remain almost unchanged in pre monsoon and post monsoon seasons (Fig. 8&9). The low value of EC and TDS in monsoon seasons (Fig.10) may be attributed to low mineralization (Li and Zhang, 2008).

There is no correlation between TDS and most probable number (MPN) on total coliform which is suggestive of the fact that TDS is not contributing to coliforms (Fig. 11&12) and MPN is so less that it can not affect the TDS content.

Turbidity is a measure of cloudiness of water, it has no health effects. However, it can interfere with disinfection and provide a medium for microbial growth (Akoto and Adiyiah, 2007). Turbidity may indicate the presence of disease causing organisms. These organisms include bacteria, viruses and parasites that can cause symptoms such as nausea, cramps, diarrhea and associated headaches (EPA, 2003). All the samples have turbidity values much less than the WHO permissible value of 5 NTU. Heavy rain falls, strong winds and convection currents can greatly increase the turbid state of both lakes and rivers. Although microbial contamination is commonly accompanied by increase in turbidity, other facters including silt and organic matter also affect turbidity levels of water (Mann *et al*, 2007). Limits of turbidity levels vary between countries, but are generally below 1 to 2 NTU (Rouse, 2001 and Le Chevallier, 2004). Turbidity is well known to hinder disinfection by shielding microbes, some of them perhaps pathogens (Hauser, 2001). Low turbidity values in the water samples in this study are suggestive of the fact that disinfection is not required. However, minor increase in turbidity in future will easily be disinfected.

The value of alkalinity in water provides an idea of natural salts present in water. The major causes of alkalinity are the minerals which dissolve in water from soil and rocks. The various ionic species which contribute to alkalinity include bicarbonate, hydroxide, phosphate, borate and organic acids (Patel *et al*, 1994 and Shyamala *et al*, 2008). These factors are characteristics of the source of water and natural processes taking place at any given time (Sharma, 2004). The total alkalinity measures with minimum at 31.96 mg/l and maximum at 48.65 mg/l in watershed I of the study area. The highest alkalinity has been observed in the pre monsoon season. The lowest value of 22 mg/l is associated with KT-

12 which falls in watershed IV. Since carbonate and hydroxide ions are absent and bicarbonate ion is dominant anion in all the samples of the area under study, the major cause of alkalinity seems to be the presence of bicarbonate ion. The soil zone is the subsurface environment that contains elevated CO_2 pressure (produced as a result of decay of organic matter and root respiration) which in turn combines with rain water to form bicarbonate by the following reactions (Singh *et al*, 2007):

$CO_2 + H_2O \rightarrow H_2CO_3$

$H_2CO_3 \rightarrow H^+ + HCO_3^-$

Bicarbonate may also be derived from the dissolution of carbonates and silicate minerals by the carbonic acid from the reactions:

$CaCO_3 + H_2CO_3 \rightarrow Ca^{2+} + 2\ HCO3^-$

Limestone

$CaMg(CO_3)_2 + H_2CO_3 \rightarrow Ca^{2+} + Mg^{2+} + 4\ HCO_3^-$

Dolomite

$2\ NaAlSi_3O_8 + H_2CO_3 + 9H_2O \rightarrow Al_2Si_2O_5(OH)_4 + 2Na+ + 4H_4SiO_4^+ + 2\ HCO_3^-$

Albite Kaolinite

Water is a good solvent and picks up impurities easily. When water is combined with CO_2 to form very weak carbonic acid it exhibits even better solvent results. As water moves through soil and rocks, it dissolves very small amount of minerals and holds them in solution. Calcium and magnesium dissolved in water are the two most common minerals that make water hard. The degree of hardness becomes greater as the calcium and magnesium content increases and is related to the concentration of multivalent cations dissolved in water. Hard water is not a health hazard. In fact, hard drinking water generally contributes a small amount towards total calcium and magnesium human dietary needs. The high concentration of total hardness may be due to dissolution of polyvalent metallic ions from sedimentary rocks, seepage and runoff from soil (Nawlakhe, 1995).

The total hardness in supply water (KP) ranges from 30.75 to 106.70 mg/l whereas its variation in tuikhur water is from 37.25 to 68.35 mg/l only. It has been widely observed that the total hardness in supply water is higher than that of tuikhur water. But all the values are very much within the permissible limit of 200 mg/l (ISI, 1991& WHO, 2008). The higher value of total hardness in supply water may be attributed to the principal natural sources of polyvalent metallic ions from sedimentary rocks and runoff from soils (Fig. 13&14). Since supply water is lifted from rivers, hence it exhibits higher concentration of Ca^{2+} and Mg^{2+} than their counterparts of tuikhur water. In the later case water is confined to an aquifer only in contrast to the supply water from the rivers which are flowing through rocks and soils (Fig. 15&16). Magnesium, the bivalent metal is contributing less towards total hardness as compared to calcium (Fig. 17) as the magnesium content in all the water samples is comparatively less. Higher values of total hardness is observed during pre monsoon and post monsoon seasons and lower during monsoon season in all the samples which may be due to addition of rain water in the monsoon season.

Chlorine gas is highly toxic but chloride ion is essential for life (Duffus, 1996). Chloride in small concentrations is not harmful to humans in drinking water and with some adaptation the human body can tolerate water with as much as 200 mg/l chloride. However, above a concentration of 250 mg/l chloride, the water may taste salty (Hauser, 2001 & Nduka *et al*, 2008). The chloride concentration in all the KP, KT and KR samples are much lower than that prescribed by WHO (250 mg/l). Concentration of chloride in KT water samples (8.25 to 19.20 mg/l) is higher than that of KP water (5.75 to 17.83). The slightly higher concentration of chloride in tuikhur water may be attributed to the contamination from sewage waste leaching (Kumar *et al*, 2010). It has been observed that chloride content is higher in pre monsoon and post monsoon seasons and it may be attributed to leaching from upper soil layers due to industrial and domestic activities and dry climates (Srinivasamoorthy *et al*, 2008 & Bouwer, 1978). According to Desai *et al* (1979) if the chloride versus bicarbonate ratio is above 2, it indicates the water is highly saline, which may be due to intrusion of sea water into the water bodies. In the case of present study, bicarbonate is much higher than the chloride concentration and as a result Cl^- versus HCO_3^- ratio is much less than 2 and hence the water samples from all the sources are not saline. It is also evident from the fact that the sodium concentration is significantly low in all the samples.

Watershed IV and VI observe comparatively higher chloride content (9.15 to 18.61 mg/l and 10.89 to 19.20 mg/l respectively) as compared to watershed I and II. Chloride concentration is increasing from south to north in the study area and it may be attributed to anthropogenic activity because of higher population density in the Kolasib town. Chloride has good correlation with Na and Ca as compared to magnesium and potassium in all the samples of tuikhur and supply water. Chloride is generally higher than metals but the reverse is observed in KT-22, KT-23 and KT-31 in post monsoon 2006 in tuikhur water (Fig. 18) where chloride content is higher than that of sodium. The same trend has been found in pre monsoon 2007 and monsoon 2007 (Fig.19&20). Sodium concentration is higher than that of chloride in KP-6, KP-8, KP-9 and KP-13 in post monsoon 2007 (Fig. 21) and pre monsoon 2008 (Fig. 22) Correlation of chloride with potassium is not very significant (Fig. 23&24). Chloride maintains a good correlation with calcium in tuikhur water samples (Fig. 25&26). Calcium concentration is slightly higher in pre monsoon 2008 than that in monsoon 2007. Calcium concentration is higher in KP samples than KT samples (Fig. 27) which may be attributed to anthropogenic activity in the study area (David Allan, 2006). Magnesium is nowhere exceeding the chloride concentration in tuikhur water (Fig. 28) whereas it is higher than chloride in KP-3 and KP-4 in supply water (Fig. 29) which may be due to weathering of dolomite mineral (Singh *et al*, 2007).

Fluoride concentration in the samples varies from 0.10 to 0.82 mg/l and from 0.08 to 0.76 mg/l in KT and KP water respectively. The recommended value of fluoride concentration in potable water is 0.50-1.50 mg/l (ISI, 1991 & WHO, 2008). Most of the samples have less fluoride than the recommended level. Fluoride in drinking water can originate from the fluoride bearing minerals such as fluorspar, fluorite, cryolite, fluorapatite and hydroxylapatite (Meenakshi *et al*, 2004).The low level of fluoride in water samples may be attributed to the lack of fluoride bearing minerals in the strata through which water is filtering. The similar observation has been reported by Singh (2002), Handa (1981) and Chae *et al* (2007). It has been widely observed that the fluoride content of tuikhur water is high compared to that of water supplied by PHED obviously because of tuikhur water is getting more residence time for rock-water interaction compared to supply water.

In a temperate climate, the recommended level to help reduce tooth decay is 1.0 mg/l of water, while the minimum recommended level is 0.50 mg/l (WHO, 2004). However,sample No.KT-31 and KT-32 in watershed I, KT-21 and KT-22 in watershed II, KT-2 and KT-11 in watershed IV and KT-18 in watershed VI show comparatively higher value of fluoride concentration but they are also well within the permissible limit of ISI (1991) and WHO (2008).

Fluoride concentration is very less as compared to sodium, calcium and magnesium and at the same time its content in water samples is much higher than heavy metals and trace elements. It combines with potassium in all water samples. Though potassium content in water samples is higher than that of fluoride, the reverse is observed in two tuikhur samples i.e. KT-2 and KT- 18 in monsoon 2007 (Fig.30). Variation in fluoride and potassium is corresponding to each other in tuikhur water (Fig. 31). In the potassium versus fluoride plot in supply water, with less variation in fluoride concentration, potassium is varying significantly in all the seasons (Fig. 32&33).

Sulphate concentration is significant in all the KT and KP samples. Higher values of sulphate in KP samples (9.75 to 15.25 mg/l) than those of KT samples (1.75 to 4.80 mg/l) have been observed in the study area. Rock weathering and pollution are the most significant sources of sulphate (Saini *et al*, 2006). Dissolved sulphate has its origin from dissolution of gypsum, oxidation of pyrites and contaminated sulphate from industrial discharge. The very low ratio of SO_4^{2-}/Ca^{2+} indicates that gypsum dissolution is not a primary source of SO_4^{2-} in these waters. SO_4^{2-} is a major constituent in the aerosols where burning of forests or forest fires are frequent (Saini *et al*, 2006 & Balasubramanian *et al*, 1999). The higher concentration of sulphate ion in supply water may be attributed to burning of forests as the area under study experiences frequent burning of forests in the summer season for jhum cultivation which is still prevalent in Mizoram.

The concentration of sodium is generally higher than sulphate content in all the KT water samples irrespective of the seasons (Fig. 34) but in KT-16 and KT-18 in monsoon 2007 (Fig. 35) it is less than sulphate concentration. Unlike KT water samples, in KP samples sulphate content exceeds the sodium content with few exceptions. In pre monsoon 2007 (Fig. 36) sodium concentration is higher than sulphate concentration in KP-11 and KP-12 whereas both the ions have same values in KP-8, KP-18 and KP-20 (Fig. 36). KP-12 in post monsoon 2007 has much lower value of sodium content than its corresponding sulphate content (Fig. 37) suggesting its high affinity with other anions in this sample. Again the sodium content is greater than sulphate content in KT-11 in pre monsoon 2008 (Fig. 38). There is significant relation between potassium and sulphate in KP water samples (Fig. 39) as the concentrations of both the ions are close to each other. Like sodium, calcium concentration is higher than the sulphate concentration in KT samples (Fig. 40&41). Calcium and sulphate contents are almost same in monsoon 2007 (Fig. 40). Concentrations of both these ions are near to each other in KP water samples (Fig. 42, 43&44). Calcium content in KP-11 in monsoon 2007 is much greater than its corresponding sulphate content (Fig. 42) which may be due to interference by other cations with sulphate. For similar reason KP-20 in post monsoon 2007 and pre monsoon 2008 shows greater content of calcium as compared to corresponding sulphate content (Fig. 43&44). Contents of magnesium and sulphate are close to each other with few exceptions (Fig. 45, 46&47) in KT water samples. Magnesium is less than its corresponding sulphate concentration in KT-8 in pre monsoon 2007 (Fig. 45) which is also observed in pre monsoon 2008 (Fig. 47). Concentration of magnesium is less than the sulphate concentration in KP samples (Fig. 48&49) but in KP-4 in post monsoon 2007 magnesium is slightly greater than the sulphate content (Fig. 49).

Nitrate is the most common form of nitrogen that occurs in surface and groundwater. Because of its anionic form, NO_3^- is very soluble and mobile in aqueous solution. High content of NO_3^- can cause birth malformation, goiter, hypertension and high- iron haemoglobin (Jalali, 2006). Concentrations of nitrate in drinking water are the result of different pollution processes, municipal wastewaters, fertilizers and pesticides application in agriculture (Jalali, 2006).

In the present study, KT samples have nitrate concentration less than 0.60 mg/l except KT-11, KT-13, KT-17, KT-23 and KT-32 where it exceeds 0.60 mg/l. Majority of the KP samples have nitrate concentration higher than or close to 0.60 mg/l. Watershed IV records slightly higher concentration of nitrate where it reaches to 0.75 mg/l. There is no variation in nitrate concentration with respect to seasons. All the samples of KT, KP and KR record NO_3^- concentration much less than the permissible limit of 45 mg/l (WHO, 2008). Low content of NO_3^- in water samples in the study area may be attributed to denitrification and plant assimilation of NO_3^- before entering the streams (Akoto and Adiyiah, 2008). Less use of fertilizers and algal assimilation may be another reason for low content of NO_3^- in water samples (Chimwanza *et al*, 2006). Another reason of low concentration of nitrate may be low rate of application of nitrogen fertilizer in the study area. The intensive irrigation in the study area has not yet started and as a result accumulation of nitrate in ground water is not significant (Sivasankaran *et al*, 2004).

Sodium is an essential element required in our body for its proper physiological functions. Sodium concentration in KT water samples ranges from 2.55 to 14.80 mg/l whereas the same varies from 2.25 to 14.37 mg/l in KP water samples. Its concentration in rain water samples is comparatively very low i.e. from 2.96 to 4.15 mg/l only. Low content of sodium in the water samples under study may be due to absence of evaporites and halites in the study area.

The concentration of potassium cation is very low as compared to sodium in water samples. It varies from 0.28 to 2.50 mg/l in KT water samples and from 0.48 to 2.24 mg/l in KP water samples. Potassium content is the least in rain water samples i.e. from 0.19 to 0.29 mg/l. The source of potassium in potable water is weathering of silicate minerals especially potassium feldspar and mica (David Allan, 2006). As potassium is less mobile, it has been found to be less than sodium content in the study area. In the present case, the aquifer is mostly sandstone where K-feldspar is present in sufficient amount and mica also is found in small quantity. The similar result has been observed by Sivasankaran *et al* (2005).

Calcium is the most abundant cation in the drinking water samples of the study area. Its concentration ranges from 5.83 to 15.68 mg/l in KT water and from 5.83 to 27.23 mg/l in KP water samples. All these values are well within the desirable limit of 75 mg/l (ISI, 1991). The source of calcium in drinking water is weathering of sedimentary carbonate rocks. Calcium and magnesium in water samples is due to the presence of lime stone and calcareous soils in cretaceous aquifer system (Sivasankaran *et al*, 2005). Anthropogenic activities may be another reason for high level of calcium content in potable water. Slightly higher concentration of calcium in supply water of the study area may be mainly attributed to anthropogenic activities in the area.

Magnesium is mainly derived in potable sources by weathering of rocks particularly dolomite and magnesium silicate minerals. Magnesium content in tuikhur water ranges from 1.16 to 11.78 mg/l whereas its concentration varies from 2.34 to 15.31 mg/l in supply water. It remains constant at 3.53 mg/l in rain water. All these values are within the most desirable limit of 30 mg/l (ISI, 1991).

The alteration products of weathering are dissolved constituents and secondary minerals that can form in the ground water environment. These are the minerals that are most important to the study of ground water geochemistry because they are reactive in the aquifer environment. They can limit solution concentration for their constituents and also tend to provide the most common substrates for adsorption reactions. The term reactive mineral is used to denote a mineral that will dissolve or precipitate from ground water in a reasonable period of residence time for the water in the aquifer. They clay minerals and metal oxides are particularly important because they not only form in the aquifer environment, but they provide very reactive surfaces on which dissolved constituents can be adsorbed from water. The minerals, amorphous oxides and organic matter present in an aquifer that participate in adsorption/ desorption processes each have separate affinities for the dissolved constituents and based on the amount of the substrate, they each have different capacities for adsorption.

The trace metals in water behave in a typical manner. No single mechanism is sufficient to explain the process that are undergoing in the water. Trace metals like Fe, Mn, Cu, Zn, Co, Ni etc are very important for the proper functioning of the biological system and their deficiency or excess in the human system can lead a number of disorders. Other trace metals like Pb, As, Hg etc are not only biologically non essential but definitely toxic. The potential toxic metal elements such as Cr, Pb, Cu, Zn etc are identified to cause health hazards in animals. Trace elements are generally present in small concentration in natural water system. Their occurrence in groundwater and surface water can be due to natural sources such as dissolution of naturally occurring minerals containing trace elements in the soil zone or the aquifer material or to human activities such as mining, fuels, smelting of ores and improper disposal of industrial wastes (Jinwal *et al*, 2009).

Except two KT samples- KT-30 and KT-32 where iron content is above 0.30 mg/l, all other samples of KT and KP water have iron concentration between 0.01 to 0.05 mg/l. The concentration of iron in rain water samples remains constant at 0.01 mg/l in monsoon season. The higher concentration of iron in KT-30 and KT-32 may be due to anoxic condition in which the solubility of iron bearing minerals increases leading to enrinchment of dissolved iron in water (Applin and Zhao, 1989). According to Apello and Postma (1993) it is reasonable to expect the anomalous values of iron in small zones of highly depleted oxygen beneath the peaty soils. The iron (Fe^{2+}) present in limonitic minerals would be picked up much faster by ground water travelling through the peaty sediments and remain in solution where highly anoxic condition prevails.

The concentration of lead in KT water is higher than that of KP water. The mean value of Pb content in KT water is 0.05 mg/l which is higher than the prescribed limit of 0.01 mg/l (WHO, 2008) whereas the same in KP water is 0.01 mg/l (Fig. 50, 51, 52& 53). It remains constant at 0.01 mg/l in KR water. The higher concentration of Pb in KT water samples (Fig. 54, 55, 56 &57) may be attributed to gasoline coming out of vehicles as most of the tuikhurs are situated on or near the highway.

Zinc is one of the important trace elements that play a vital role in the physiological and metabolic process of many organisms. Nevertheless, at higher concentration, zinc can be toxic to the organisms. It plays an important role in protein synthesis. It is a metal that shows fairly low concentration in surface water due to its restricted mobility from the place of rock weathering or from the natural sources (Rajappa et al, 2010). Zinc imparts an astringent taste to water; only 5% population can distinguish between free water and water containing zinc at a level of 4 mg/l (WHO, 2008). Zinc content in the present study is higher in KP-8, KP-15 and KP-19 samples of supply water in pre monsoon 2007 (Fig. 50), monsoon 2007 (Fig. 51), post monsoon 2007 (Fig. 52) and pre monsoon 2008 (Fig. 53) as compared to other KP samples. The higher concentration of zinc in these samples of supply water may be attributed to zinc plated domestic water tanks and leaching of zinc from galvanized pipes, through which water is supplied (Jinwal et al, 2009; Nriagu, 1980) however, all the values of zinc are under permissible limit of WHO (2008) and ISI (1991). No unsteady value has been observed in tuikhur water samples (Fig. 54, 55, 56 &57).

The concentration of Cd, Cr and Mn is within the prescribed limit of WHO (2008) & ISI (1991) in all the samples of KP (Fig. 50, 51, 52& 53) and KT waters (Fig. 54, 55, 56 &57) in all the three seasons. The concentration of Ni, Cu, Co and As is below the limit of detection in all the samples.

Such a low contents of heavy metals in the both types of potable waters i.e. surface water (Supply water through PHED) and the subsurface water (tuikhur water) is not in agreement with the potable waters of the neighbouring states of Manipur (Chakraborty *et al*, 2008), South Assam, Tripura (Banerjee *et al*, 2011) and neighbouring country Bangladesh (Smith *et al*, 2000). The low amounts of heavy metals may be attributed by pronounced adsorption phenomenon in area under study. The area is dominated by shale which consists of clay minerals having phyllosilicate structure providing enormous space as structural voids, where metals ions of large ionic size can be accommodated by replacing OH^-, K^+ … ions.

Coliform populations are indicators for pathogenic organisms. They should not be found in drinking water but are usually present in surface water, soil and feces of humans and animals. Human waste contaminant in water causes water-borne diseases such as diarrhea, typhoid and hepatitis (Root et al, 1982; Esry and Habicht, 1986). High coliform populations in all the water samples are an indication of poor sanitary conditions in the community.

The most probable number (MPN) in KT and KP water samples exceeds the permissible limit of 10 MPN/100 ml water sample (ISI, 1991). The MPN is slightly higher in monsoon season compared to pre monsoon and post monsoon seasons (Fig. 58). The higher number of MPN may be attributed to source contamination, absence of sewerage system and improper treatment of water (Ghimire *et al*, 2007). Inadequate and unhygienic handling of solid-wastes in the rural area could have also generated high concentration of microbial organisms (Adekunle et al, 2007; Shar *et al*, 2010). It may also be attributed to the use of pit latrines, piggeries and poultries (Rajurkar *et al*, 2003) which is predominant in the study area. The higher value of MPN in monsoon season may be attributed to transfer of human excreta and waste from piggeries and poultry farms by rain water to the water sources (Kumar *et al*, 2010). Pritchard *et al* (2007) are also of the opinion that the pollutants are easily transported to water points by rain water.

A ternary diagram is used to identify trend and relationship between groups of samples. Calcium and the sum of sodium and potassium have almost equally contributed towards cation composition in sub surface water of pre monsoon 2008. The clustering has taken place between 40- 60% (Fig. 59) whereas in KT post monsoon 2007, clustering for calcium has been found to fall between 30-50% and sodium and potassium together contribute 30-40% to the total cations (Fig. 60). Magnesium is contributing only about 30% to the total cation load in post monsoon 2007 (Fig. 60). Calcium has been found to be above 70% in one sample in monsoon 2007 in sub surface water (Fig.61). Contribution of calcium and Na+K in pre monsoon 2007 is 40-55% and 30-50% respectively (Fig. 62) whereas magnesium is contributing about 20% only in the same season. Cation composition of surface water is also dominated by calcium. Clusters of calcium are observed between 40-50% whereas Na+K records cluster at 30% only in pre monsoon 2008 (Fig. 63). Contribution of magnesium is higher in post monsoon 2007 (Fig. 64) compared to pre monsoon 2008. In monsoon 2007 also clustering is formed between 40-50% and four samples record lower content of calcium as compared to pre and post monsoon seasons (Fig. 65).

The ternary anion diagram relating HCO_3^-, $SO4^{2-}$ and Cl^- shows that all the samples of sub surface water and surface water contain a high amount of HCO_3^- and plotted points cluster towards the alkalinity apex with secondary trends towards Cl^- (Bhardwaj *et al*, 2010). Bicarbonate ion, undoubtedly, is the dominant anion in both sub surface and surface water irrespective of seasonal variation. It contributes over 90% to the total anions in sub surface water (Fig. 66-69) whereas its contribution remains at about 90% in surface water (Fig. 70-73). Bicarbonate ion is the dominant anion in rain water also; it contributes above 90% to the total anions (Fig. 74).

Piper (1944) developed a form of trilinear diagram which is an effective tool in segregating analysis data with respect to sources of the dissolved constituents in potable water, modifications in the character of water as it passes through an area, and related geochemical problems. For the Piper trilinear diagram, water is treated substantially as though it contained three cation constituents (Mg, Na+K and Ca) and three anion constituents (Cl, SO_4 and HCO_3). The diagram presents graphically a group of analysis on the sample plot. The diagram combines three distinct fields of plotting, two triangular fields at the lower left and lower right respectively and an intervening diamond-shaped field. All three fields have scales reading in 100 parts. In the triangular field at the lower left, the percentage reacting values of the three cation groups (Ca, Mg, and Na) are plotted as a single point according to conventional trilinear coordinates. Three anion groups (Cl, SO_4 and HCO_3) are plotted likewise in the triangular field at the lower right. Thus, two points on the diagram, one in each of the two triangular fields, indicate the relative concentrations of the several dissolved constituents of potable water. The central diamond-shaped field is used to show the overall chemical character of the water by a third single-point plotting, which is at the intersecting of rays projected from the plotting of cations and anions. The position of this plotting indicates the relative composition of water in terms of the cation-anion pair that corresponds to the four vertices of the field. The three trilinear plots will show the essential chemical character of potable water according to the relative concentrations of its constituents (Jain et al, 1996).

In the present study the surface and sub surface water chemistry is dominated by Calcium followed by Na>Mg>K except in some samples where Mg replaces Na in cationic abundance. The order of abundance in anionic chemistry is HCO_3>Cl>SO_4>F>NO_3. The plots of chemical data on trilinear diagram reveal that majority of surface (Fig. 75&78) and sub surface (Fig. 76&77) waters fall in the fields of 1, 3, and 5 suggesting that alkaline earths exceed alkalis and weak acids exceed strong acids respectively that is the total hydrochemistry of the area under study is dominated by alkaline earths and weak acids. Sigh et al (2007) have found the similar result in their study. Chloride and sulphate do not exceed bicarbonate in any of the samples. Most of the surface and sub surface waters in the study area occur as Ca-Na-HCO_3 facies while in some samples of surface water Na is replaced by Mg giving rise to Ca-Mg-HCO_3 type of water.

Moreover, White *et al* (1963) have provided an extensive compilation of ground water analyses from a wide variety of aquifer host rocks (Fig. 79 & 80). The aquifer material includes igneous rocks (granite and basalts), sedimentary rocks (sandstone, shale, limestone and dolomite), a metamorphic quartzite and unconsolidated sand and gravel. Several water analyses have been averaged for five to ten separate samples from each aquifer type and are plotted in fig. 80. It is somewhat surprising that all but one of the aquifer rock types has bicarbonate as the dominant anion. The only exception is the water from oil and gas field regions in which chloride is the dominant anion. In aquifers without primary carbonate minerals, such as granite, basalt and quartzite aquifers, the source of bicarbonate is carbon dioxide gas in atmospheric air and soil vapour and low concentrations of carbonate minerals present as weathering products. As shown in fig. 80, calcium is the dominant cation in several of the aquifers (limestone, dolomite, quartzite and sand/gravel) and is present in high concentration in those dominated by another cation such as sodium (silicic igneous rock, sandstone, and shale-claystone) and magnesium (gabbro-basalt). The source of the cation in ground water is the weathering of the predominantly silicate and carbonate minerals in the aquifer host rock.

When compared to our samples, they have been found to fall in fields of sandstone and shale/claystone in the diamond-shaped quadrant, whereas in the anion triangle samples are not falling in any identified field rather they are having relatively higher chloride content. Moreover, in the cation triangle the surface water samples are falling in fields of quartzite which is a rock consisting of quartz mineral. This is in accordance with the result shown in the diamond-shaped sector since quartz is an essential constituent of sandstone and shale is also silicic in nature.

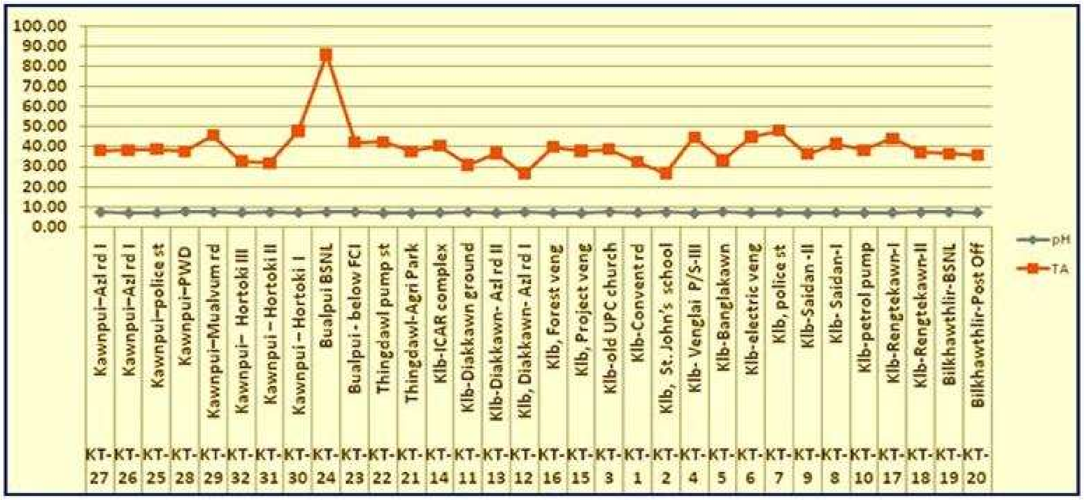


Fig. 1: pH vs TA for Post monsoon, 2006

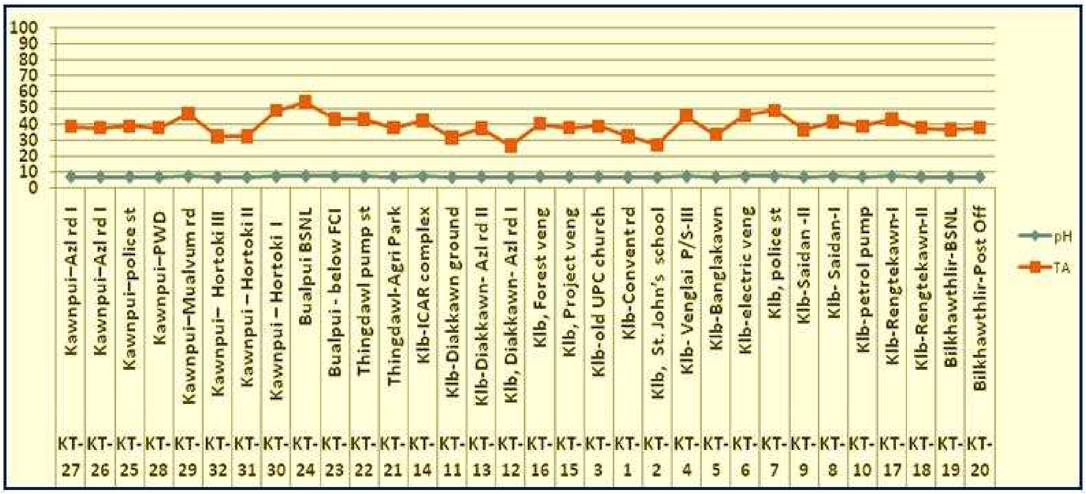


Fig. 2: pH vs TA for Post monsoon, 2007

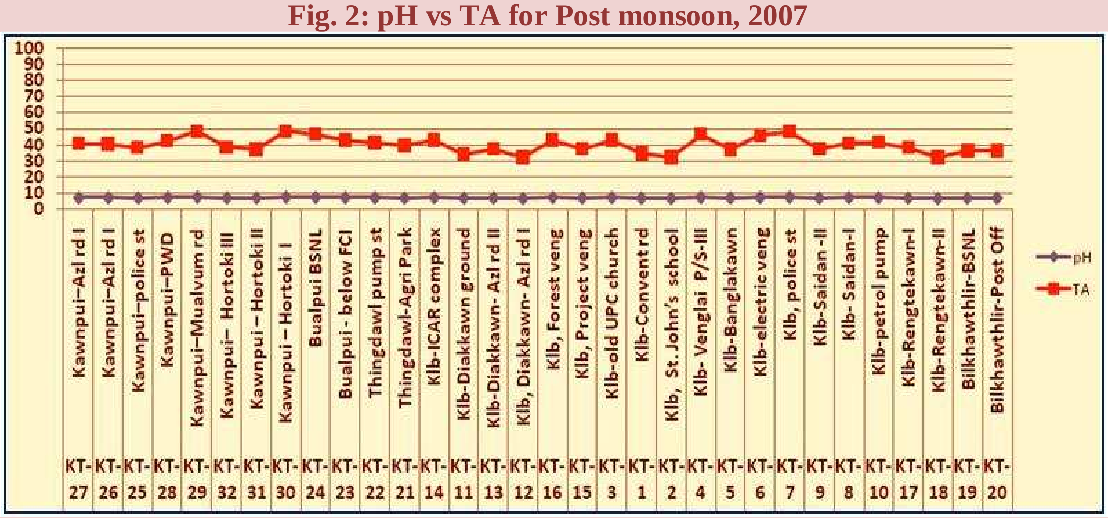


Fig. 3: pH vs TA for Pre monsoon, 2008

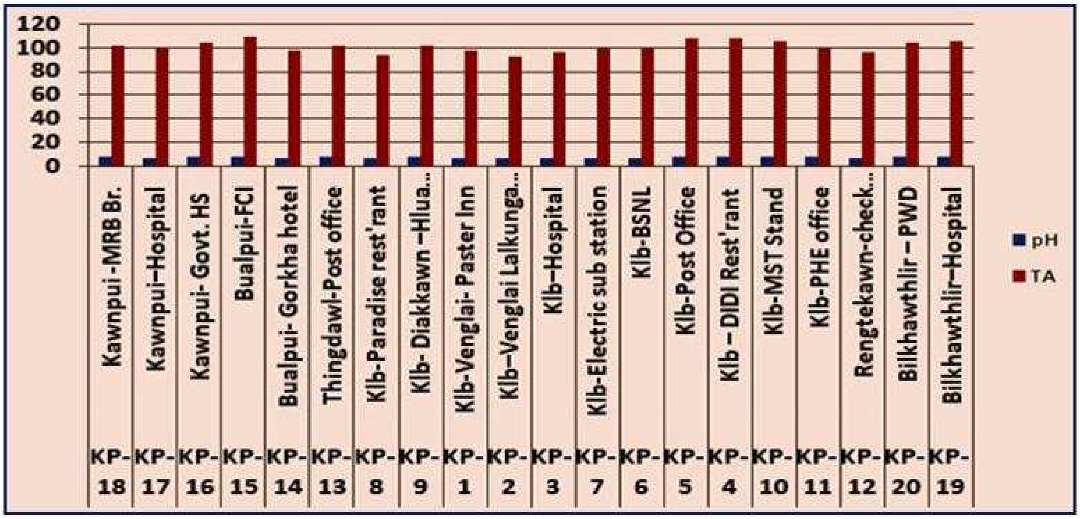


Fig. 4: pH vs TA for Post monsoon, 2007

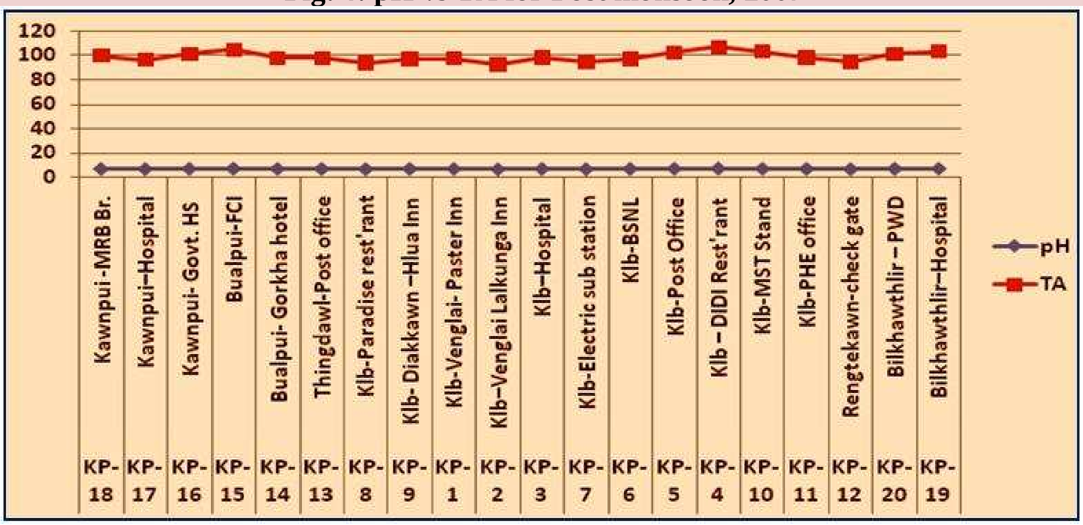


Fig. 5: pH vs TA for Pre monsoon, 2008

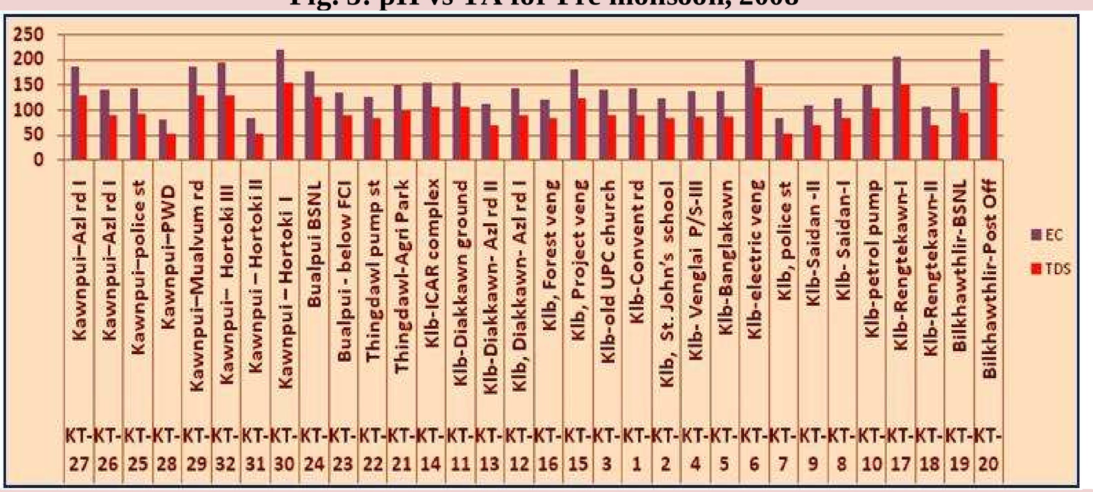


Fig. 6: EC vs TDS for Pre monsoon, 2007

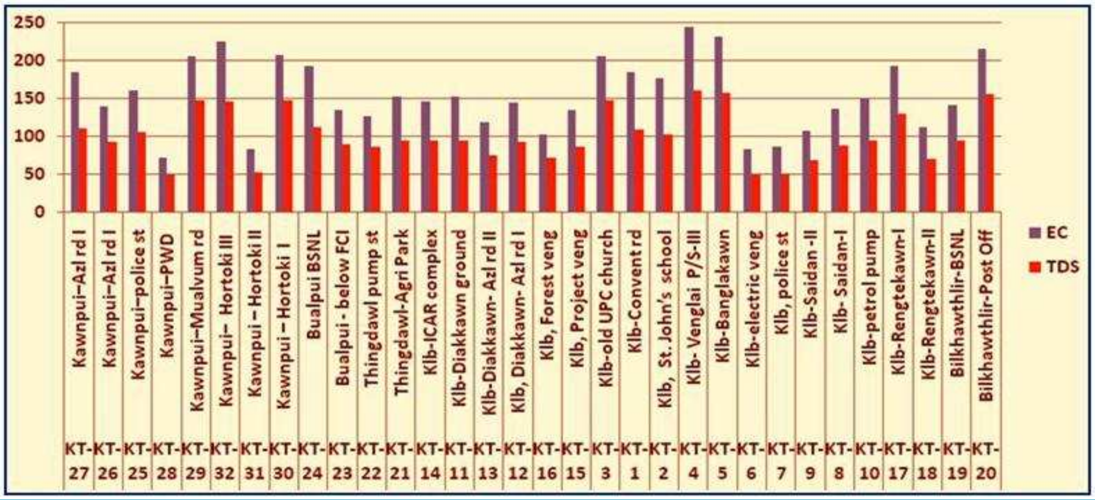


Fig. 7: EC vs TDS for Post monsoon, 2007

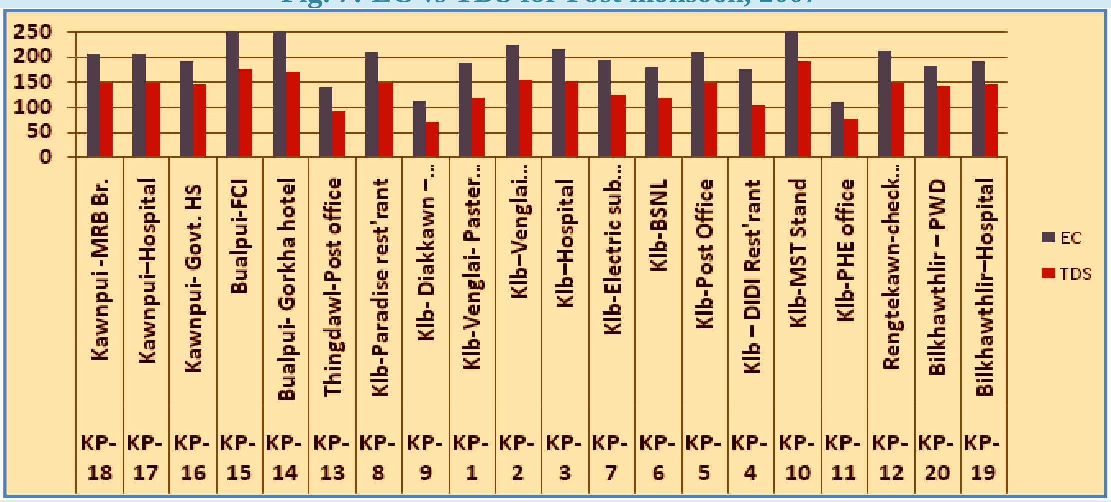


Fig.8: EC vs TDS for Post monsoon, 2007

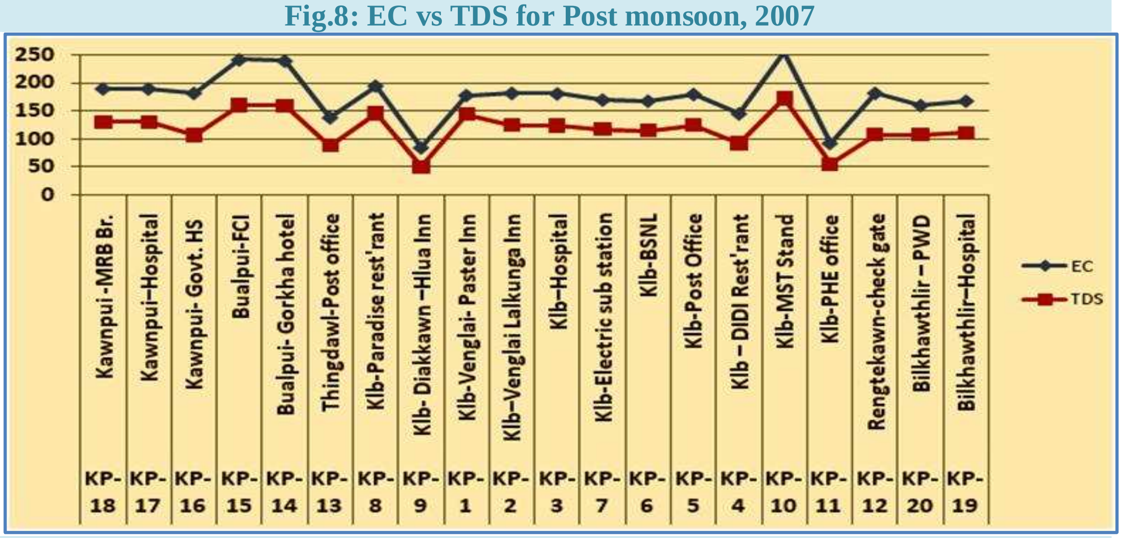


Fig.9: EC vs TDS for Pre monsoon, 2008

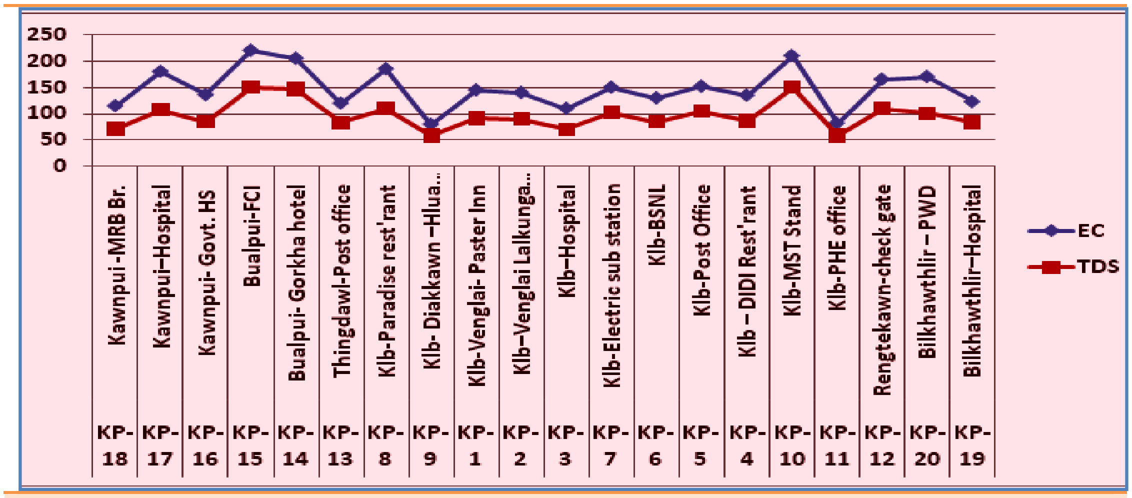


Fig.10: EC vs TDS for Monsoon, 2007

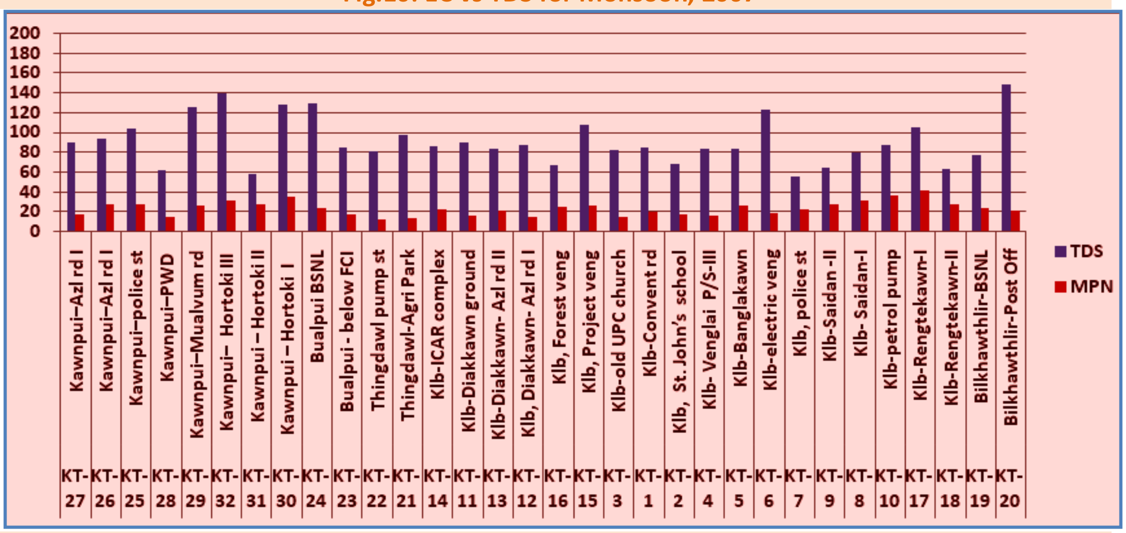


Fig.11: TDS vs MPN for Monsoon, 2007

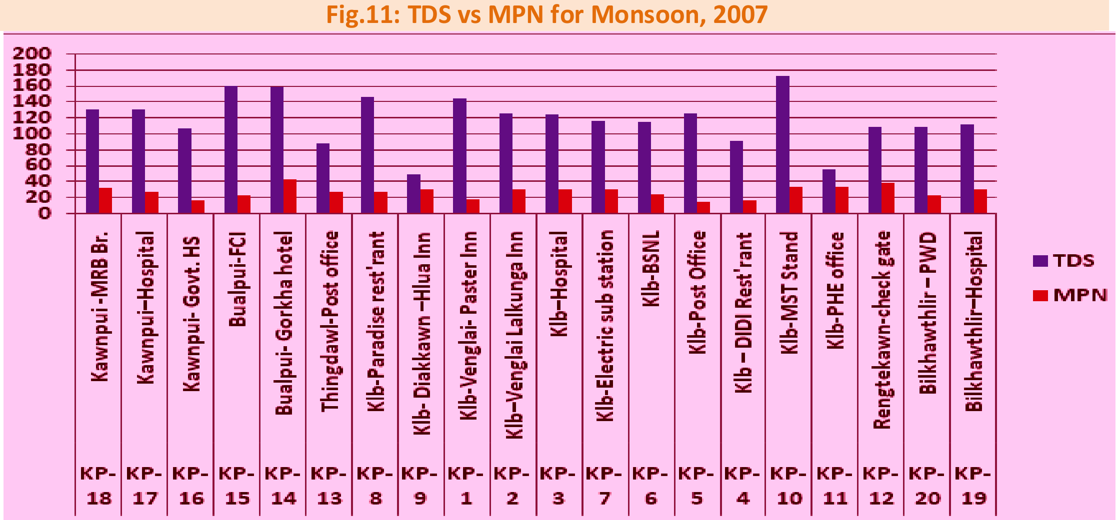


Fig.12: TDS vs MPN for Pre monsoon, 2008

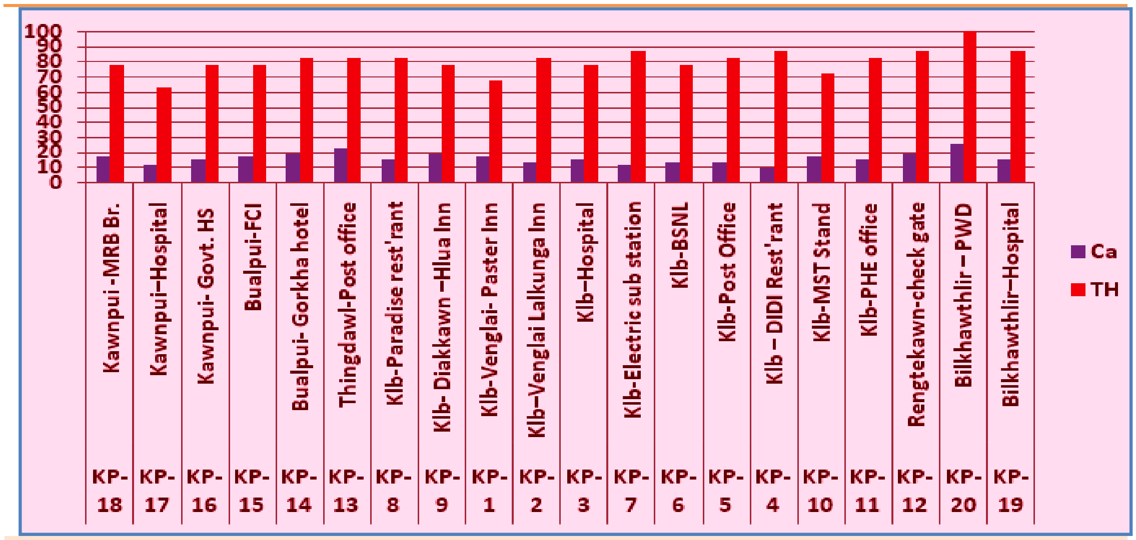


Fig.13: Ca vs TH for Post monsoon, 2007

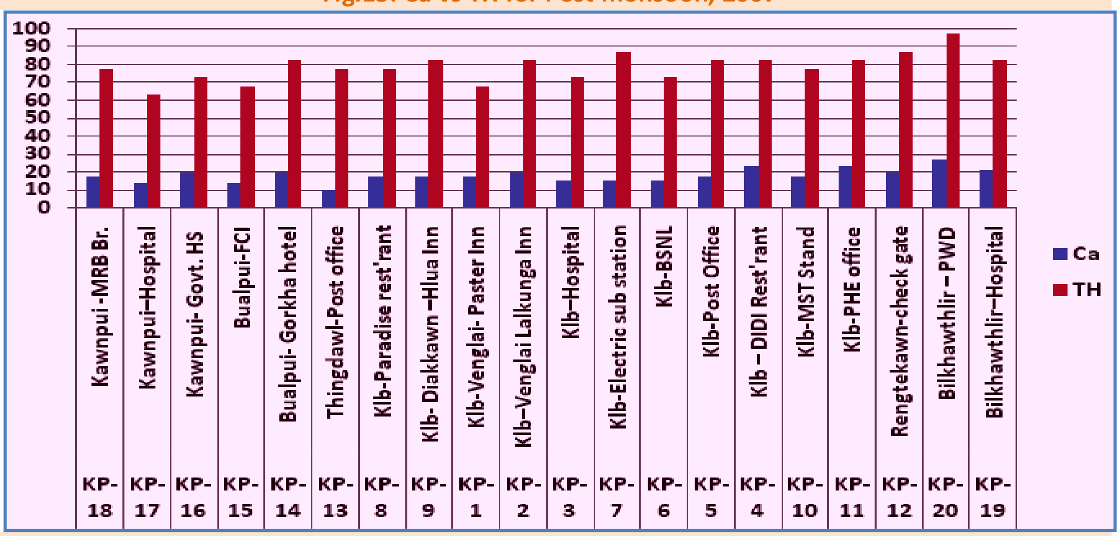


Fig.14: Ca vs TH for Pre monsoon, 2008

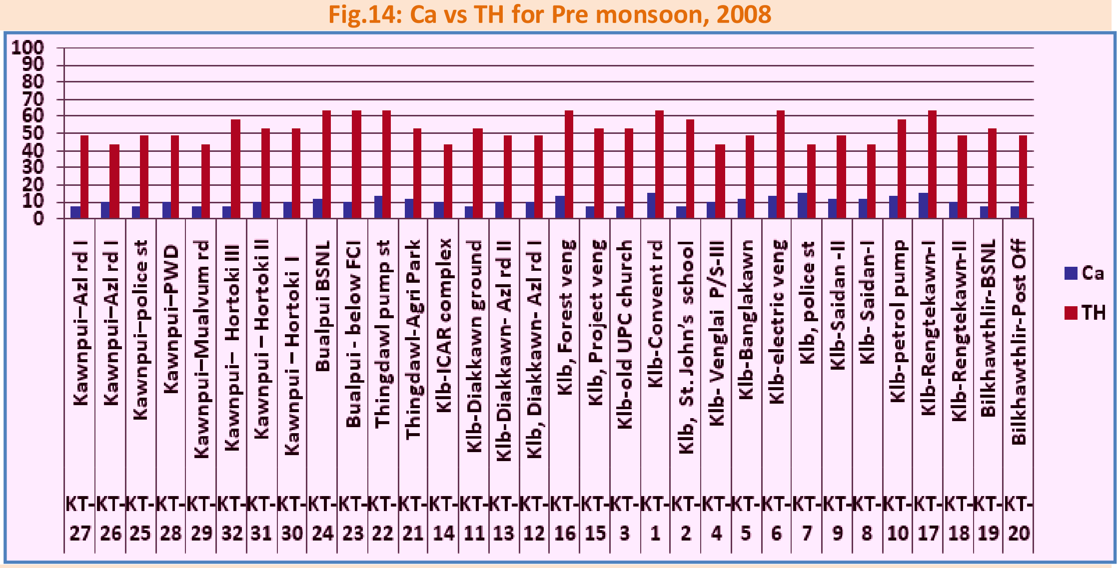


Fig.15: Ca vs TH for Post monsoon, 2007

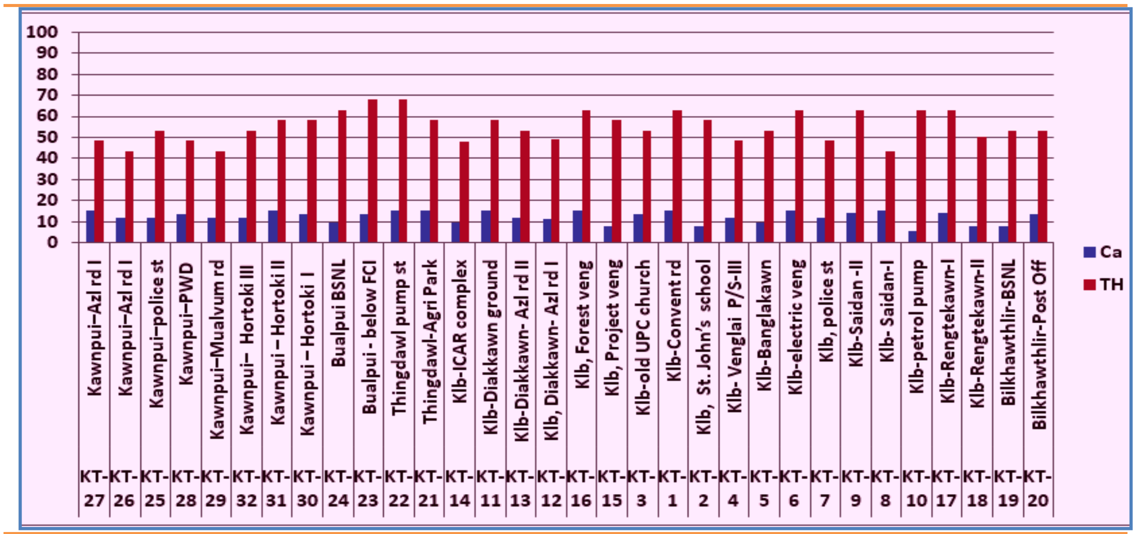


Fig.16: Ca vs TH for Pre monsoon, 2008

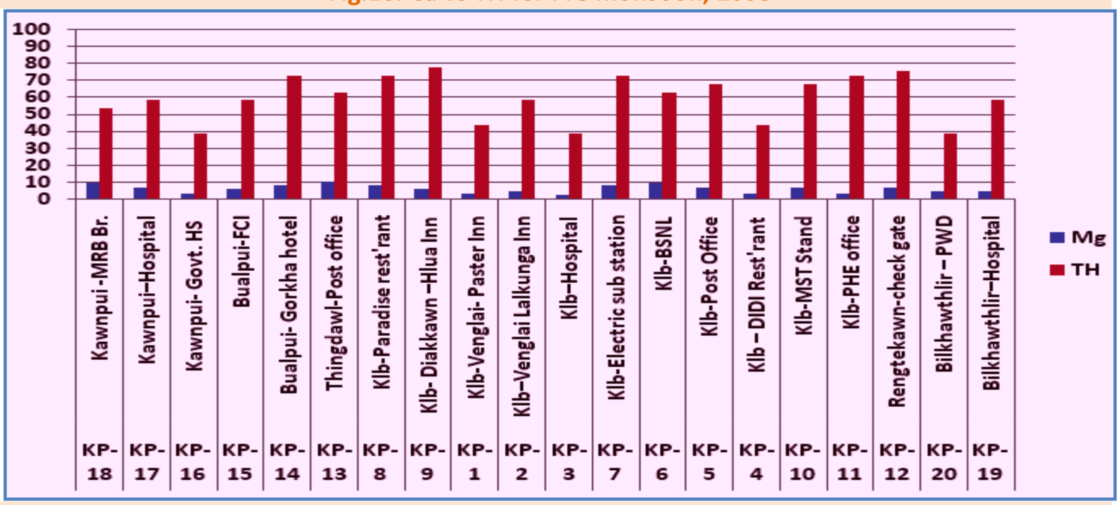


Fig.17: Mg vs TH for Monsoon, 2007

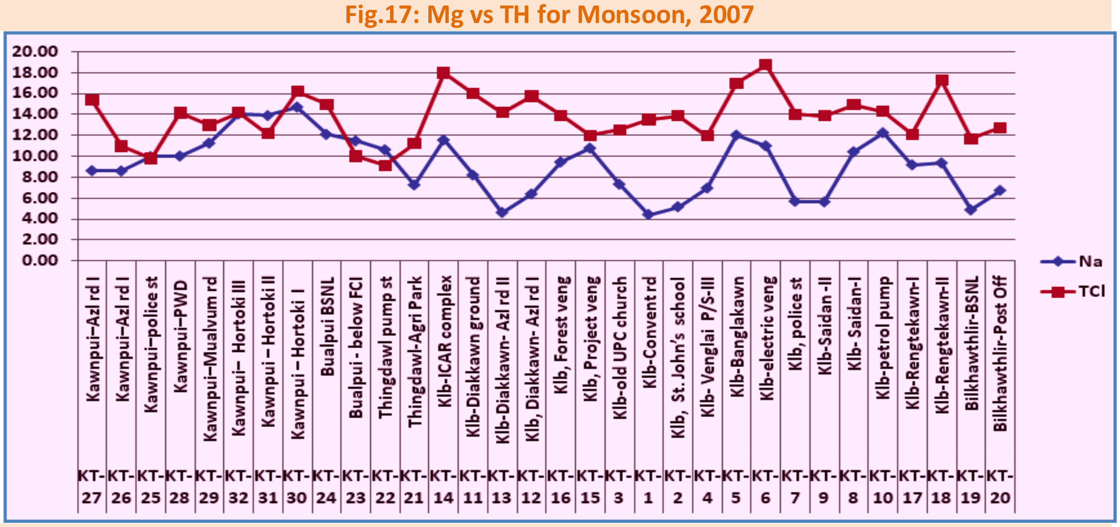


Fig.18: Na vs Cl for Post monsoon, 2006

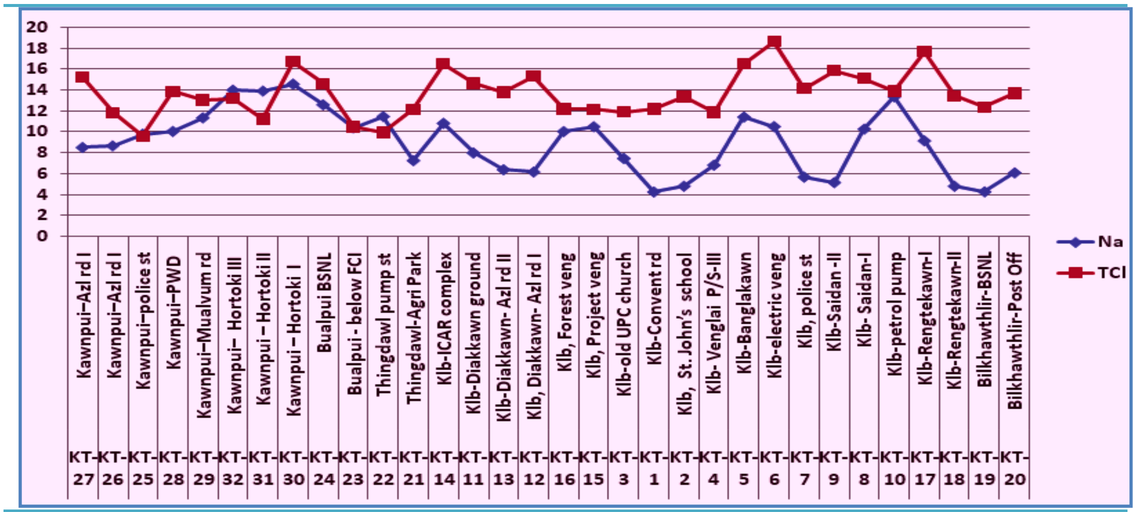


Fig.19: Na vs Cl for Pre monsoon, 2007

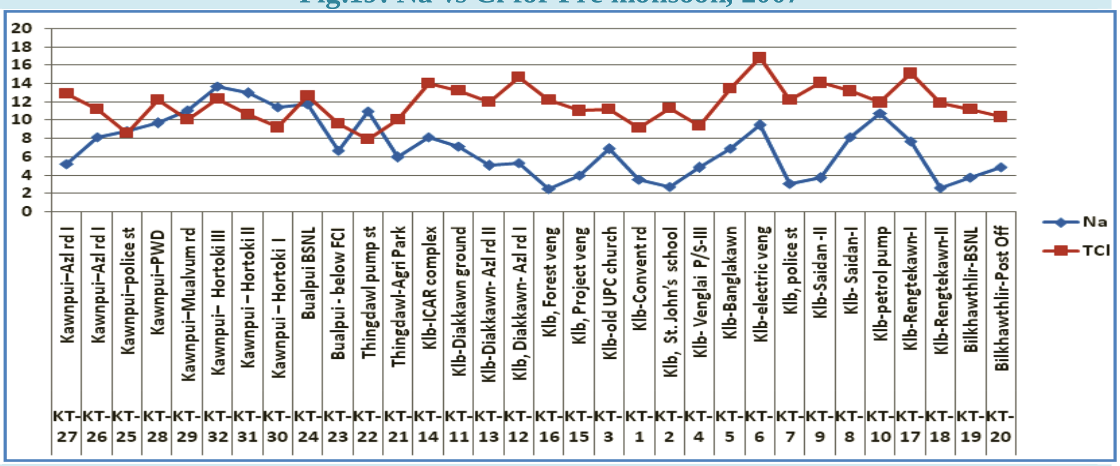


Fig.20: Na vs Cl for Monsoon, 2007

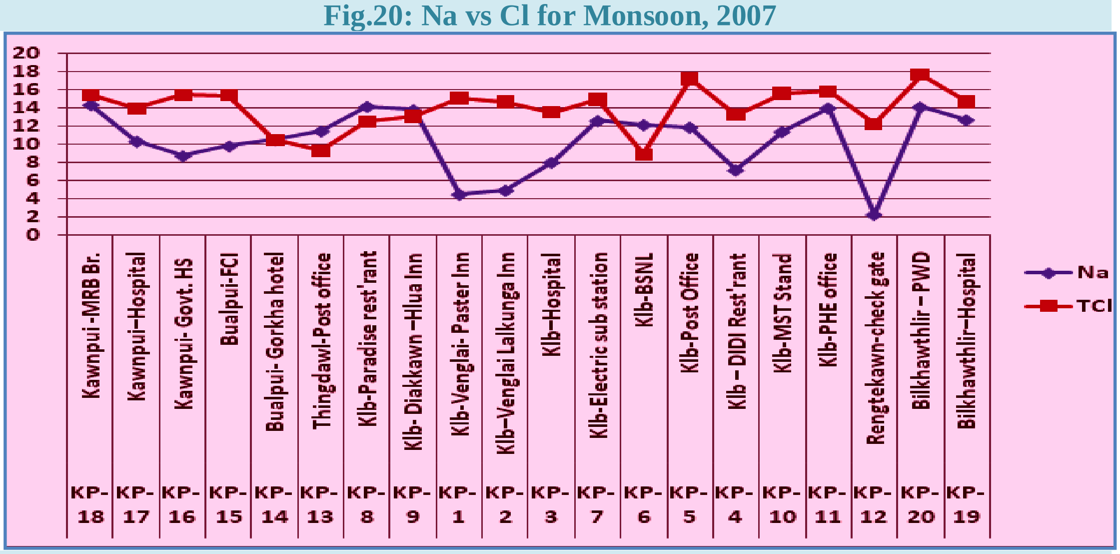


Fig.21: Na vs Cl for Post monsoon, 2007

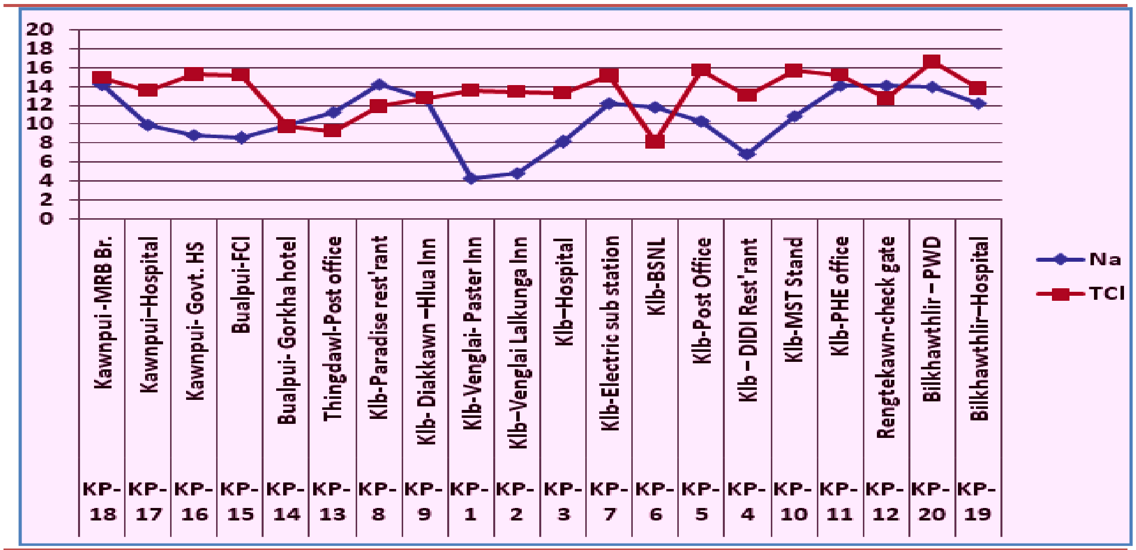


Fig.22: Na vs Cl for Pre monsoon, 2008

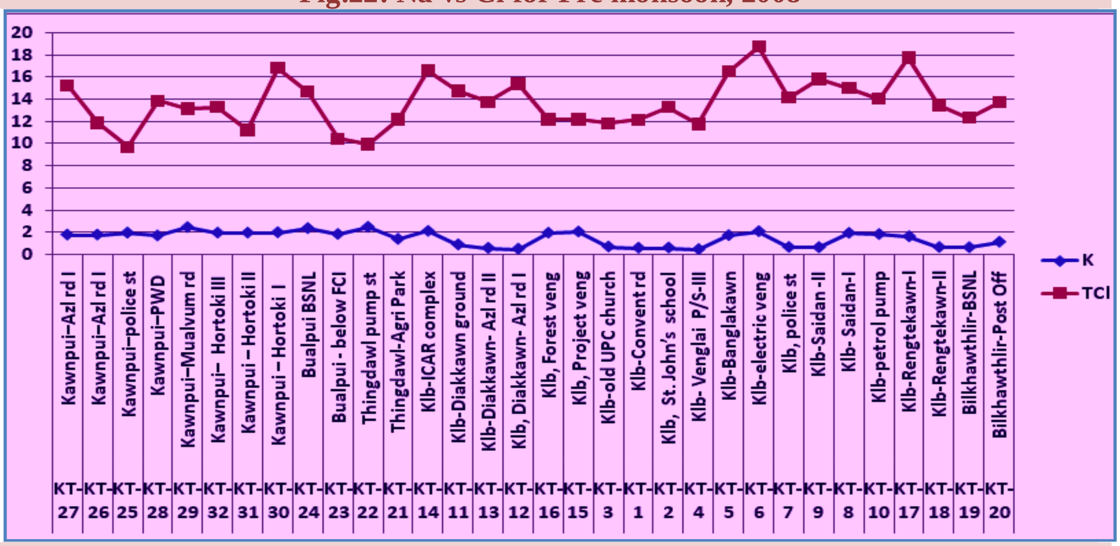


Fig.23: K vs Cl for Pre monsoon, 2008

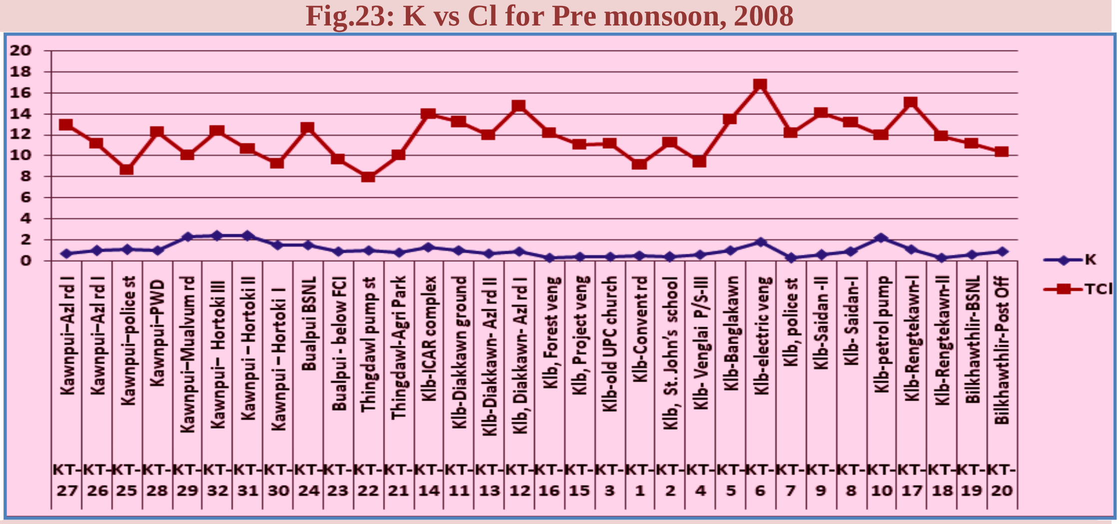


Fig.24: K vs Cl for Monsoon, 2007

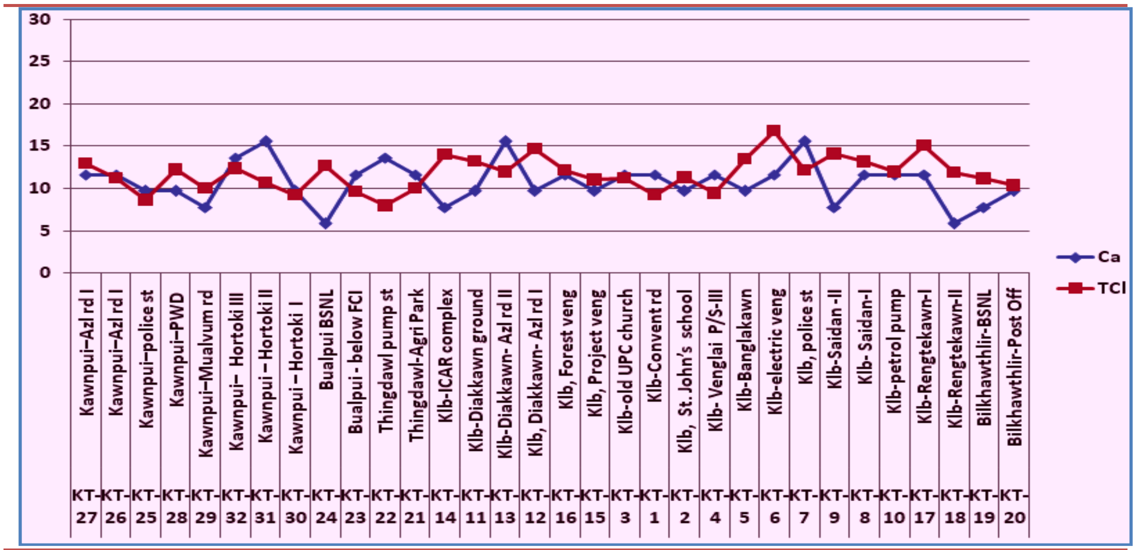


Fig.25: Ca vs Cl for Monsoon, 2007

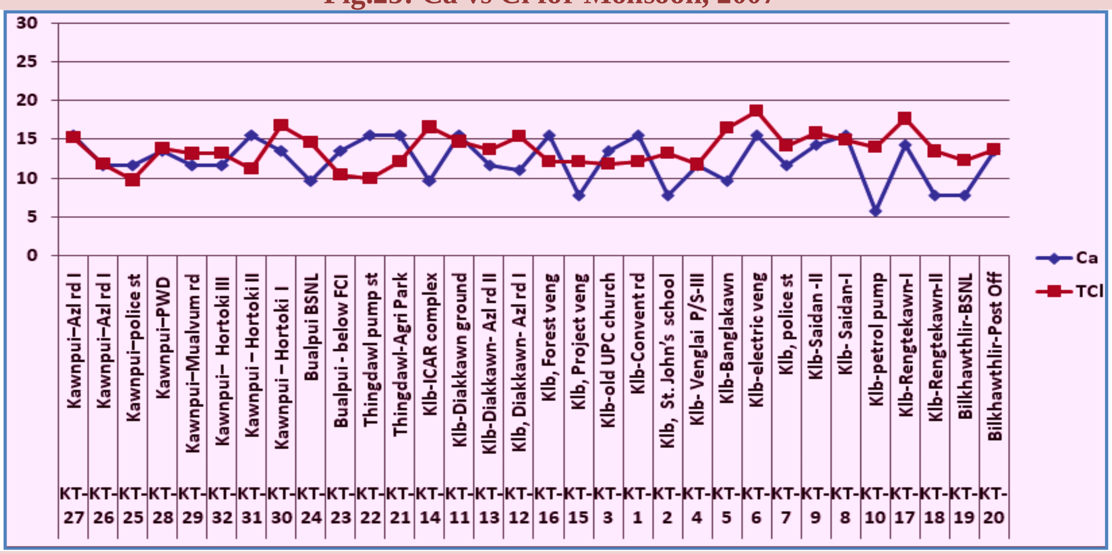


Fig.26: Ca vs Cl for Pre monsoon, 2008

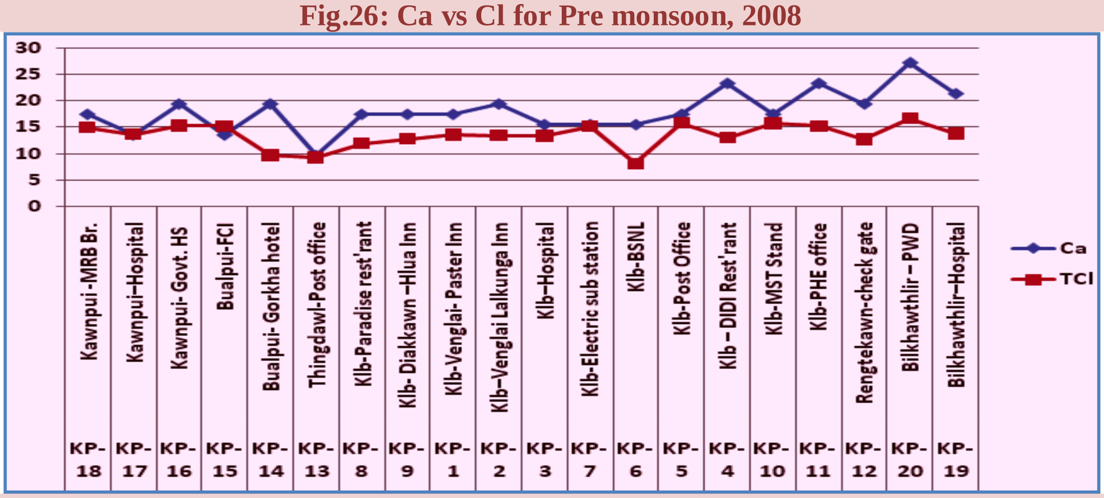


Fig.27: Ca vs Cl for Pre monsoon, 2008

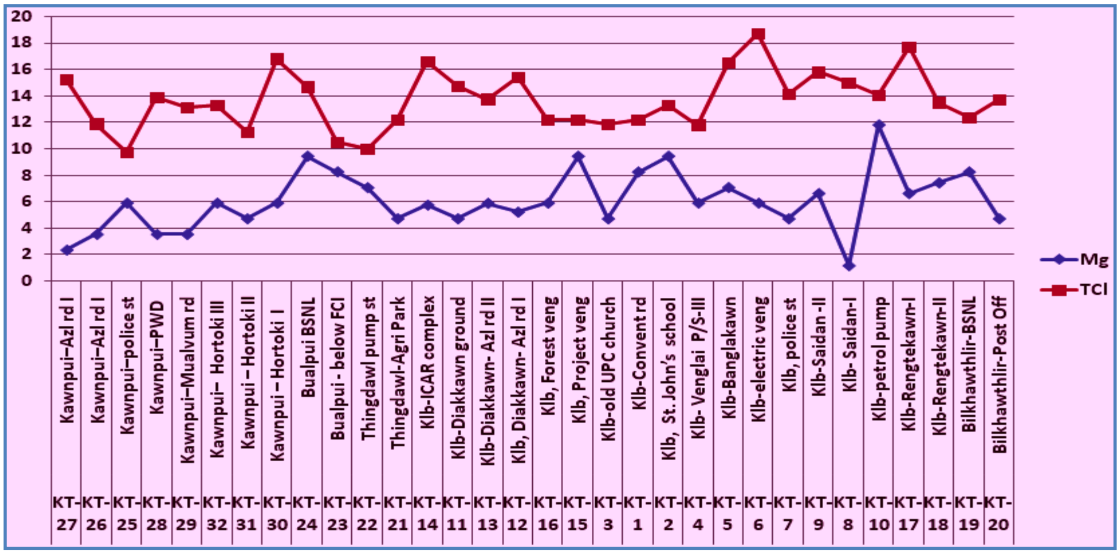


Fig.28: Mg vs Cl for Pre monsoon, 2008

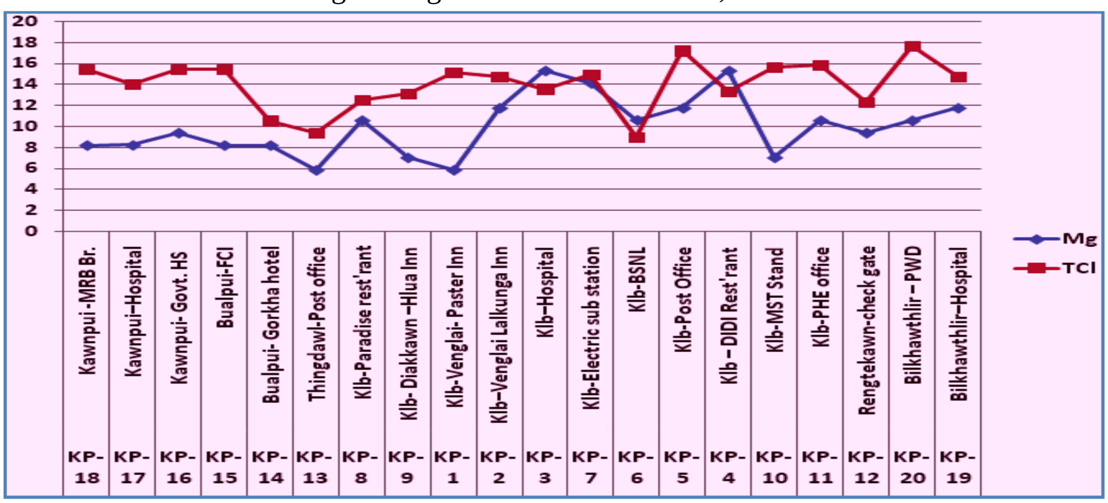


Fig.29: Mg vs Cl for Post monsoon, 2007

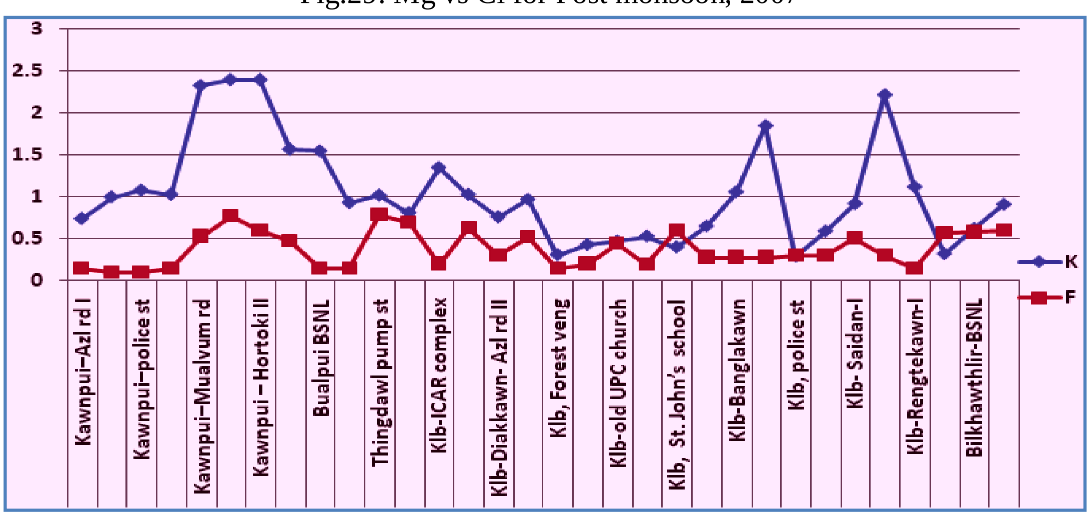


Fig.30: K vs F for Monsoon, 2007

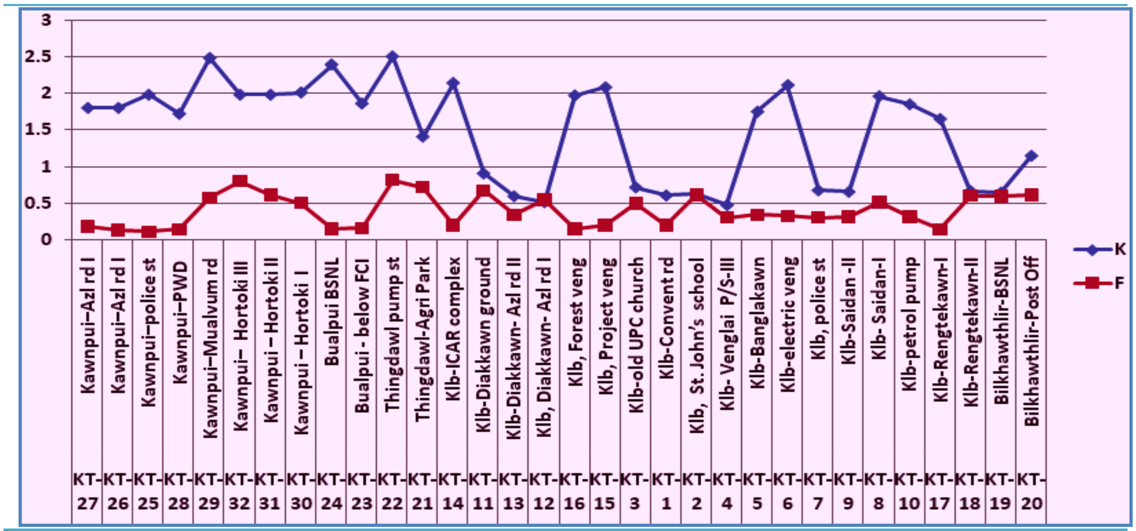


Fig.31: K vs F for Pre monsoon, 2008

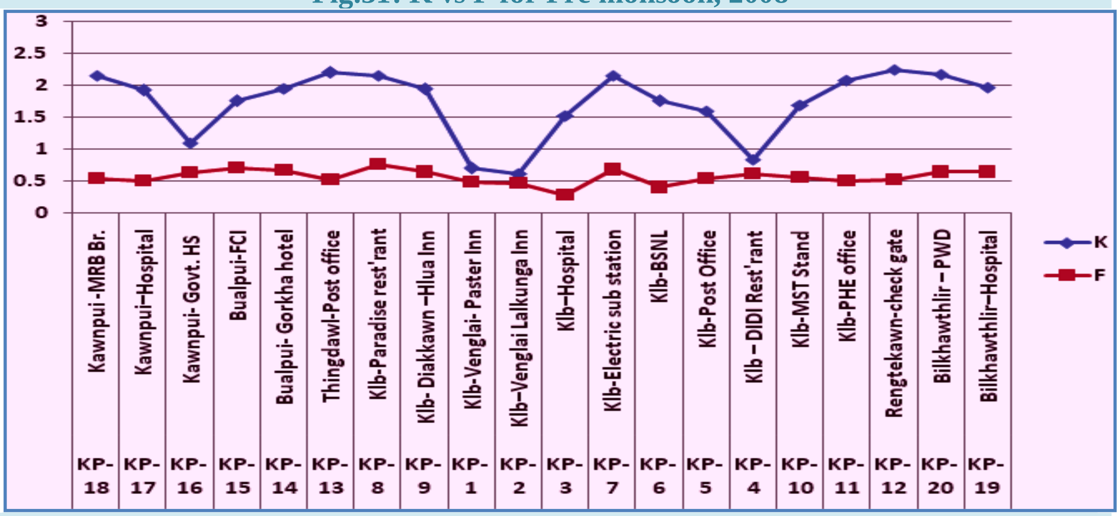


Fig.32: K vs F for Post monsoon, 2007

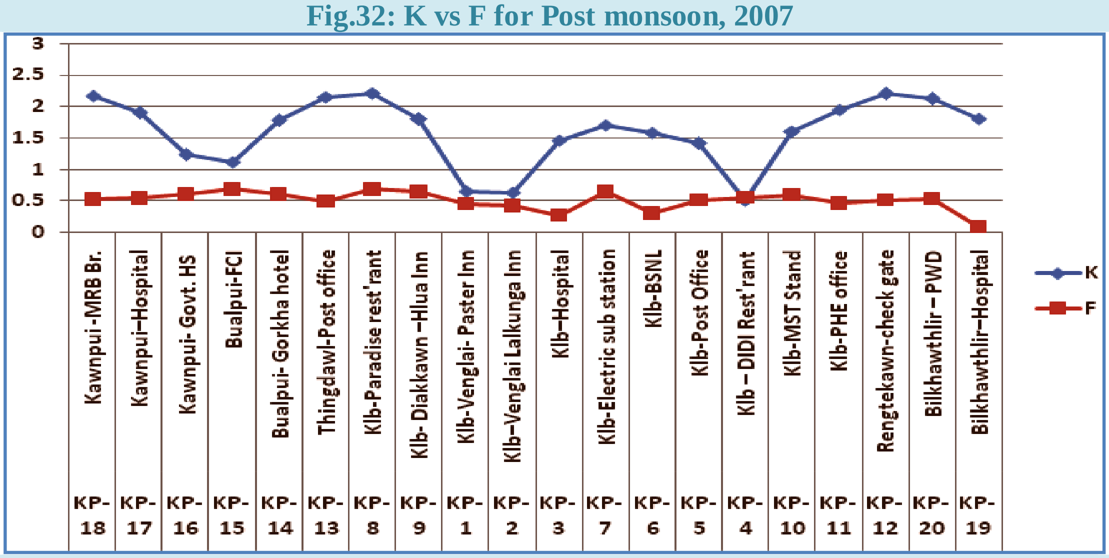


Fig.33: K vs F for Pre monsoon, 2008

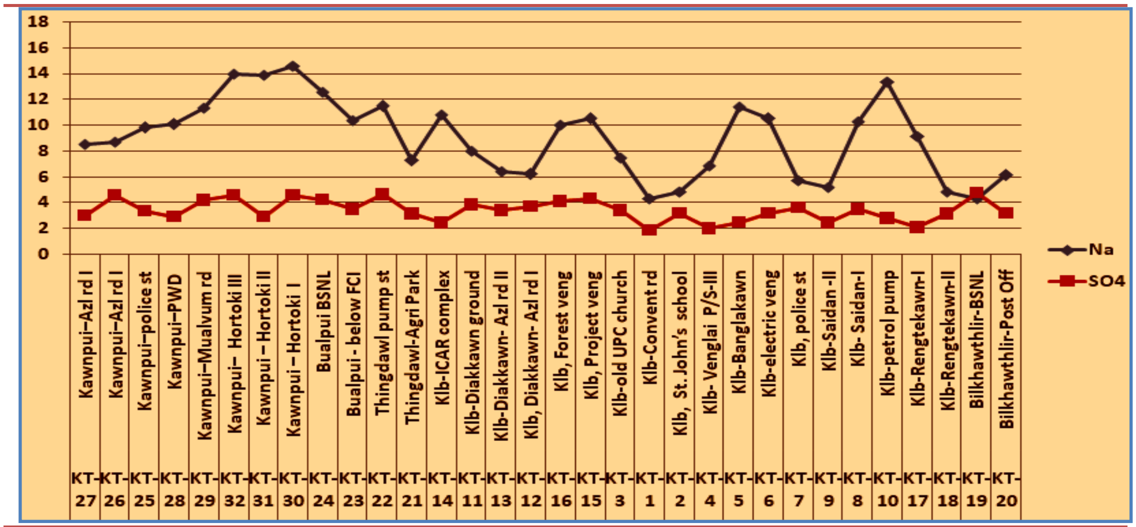


Fig. 34: Na vs SO4 for Pre monsoon, 2007

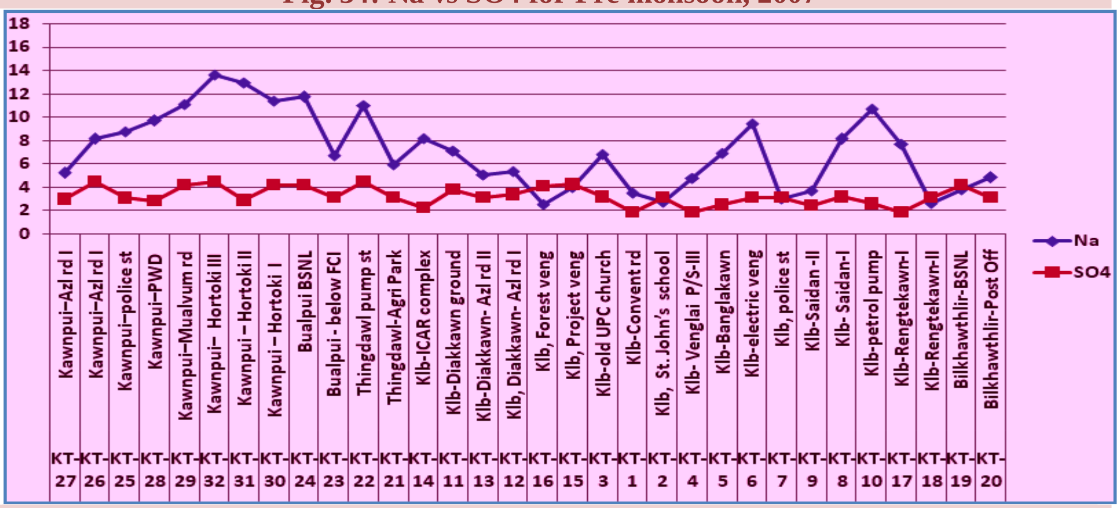


Fig. 35: Na vs SO4 for Monsoon, 2007

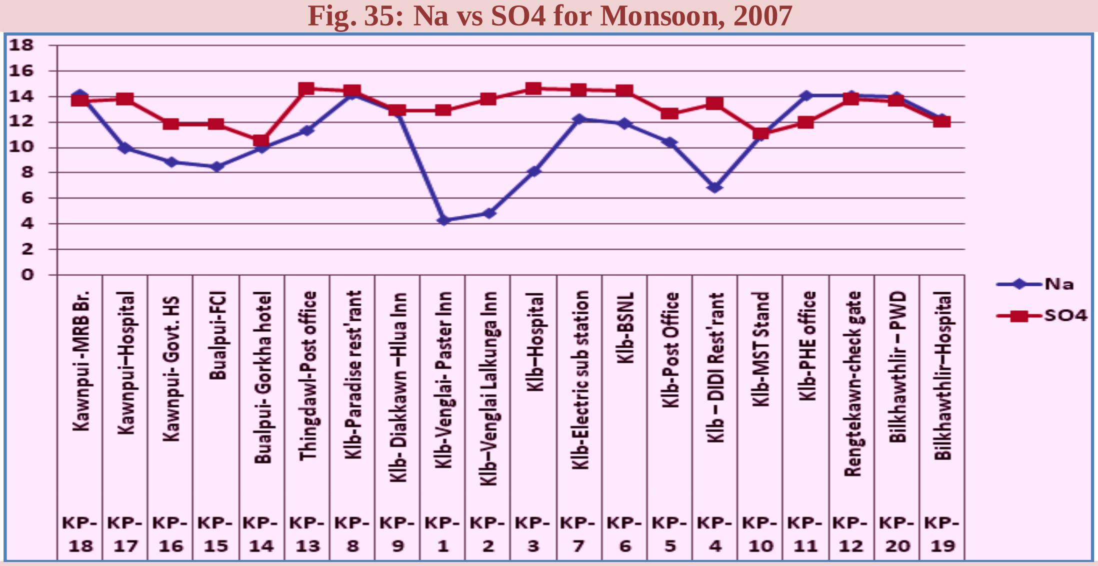


Fig. 36: Na vs SO4 for Pre monsoon, 2007

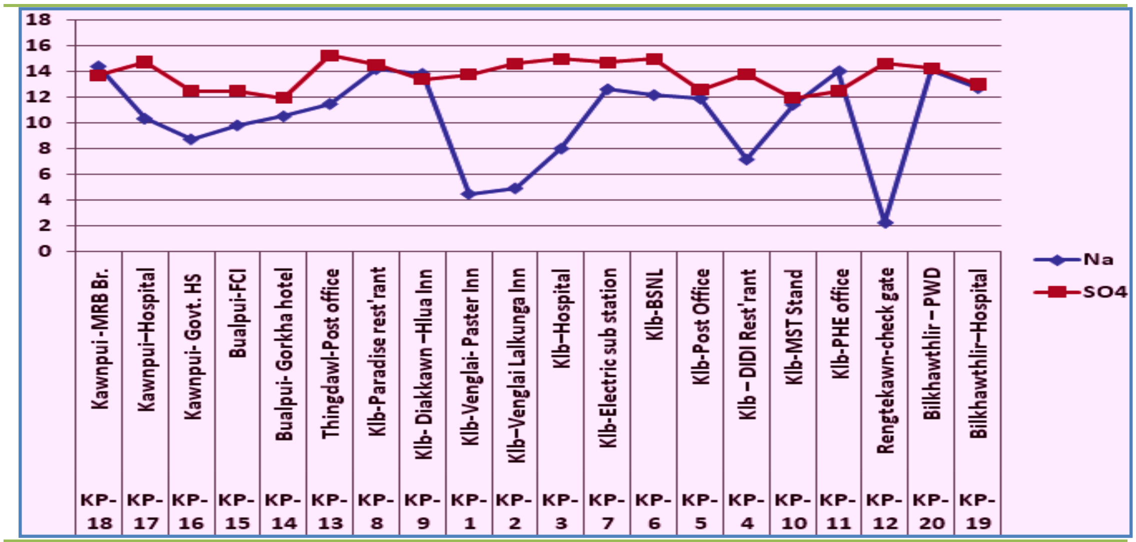


Fig. 37: Na vs SO4 for Post monsoon, 2007

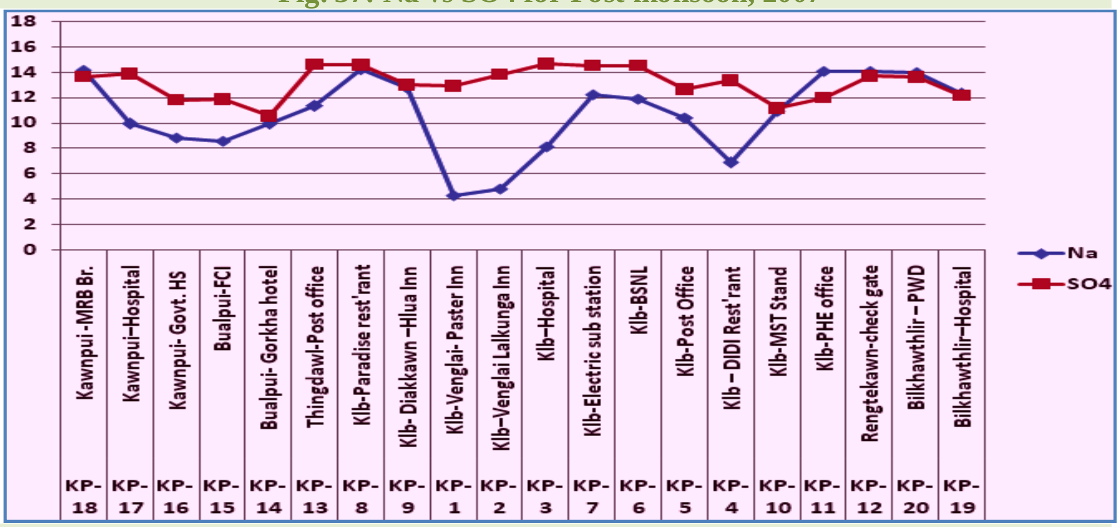


Fig. 38: Na vs SO4 for Pre monsoon, 2008

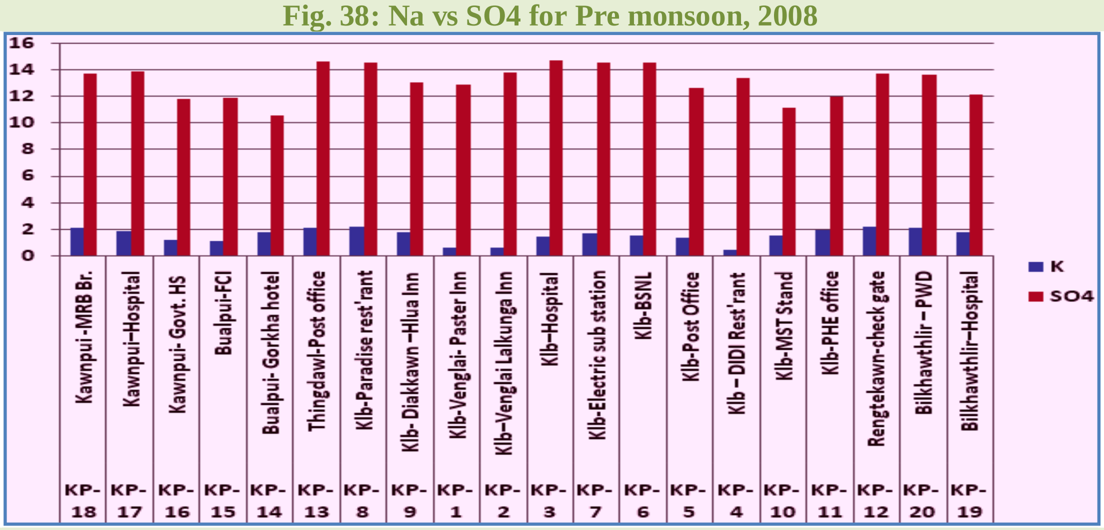


Fig. 39: K vs SO4 for Pre monsoon, 2008

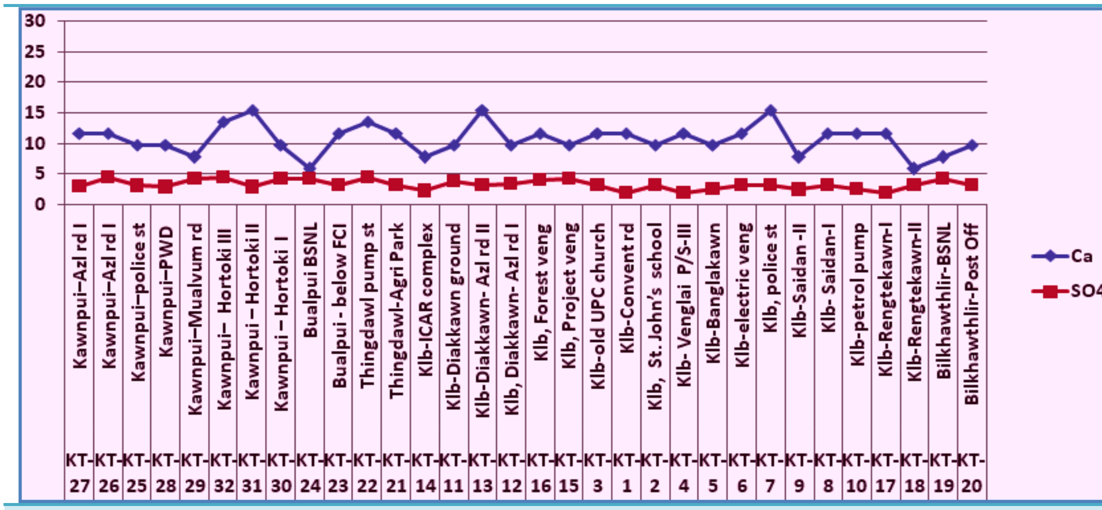


Fig. 40: Ca vs SO4 for Monsoon, 2007

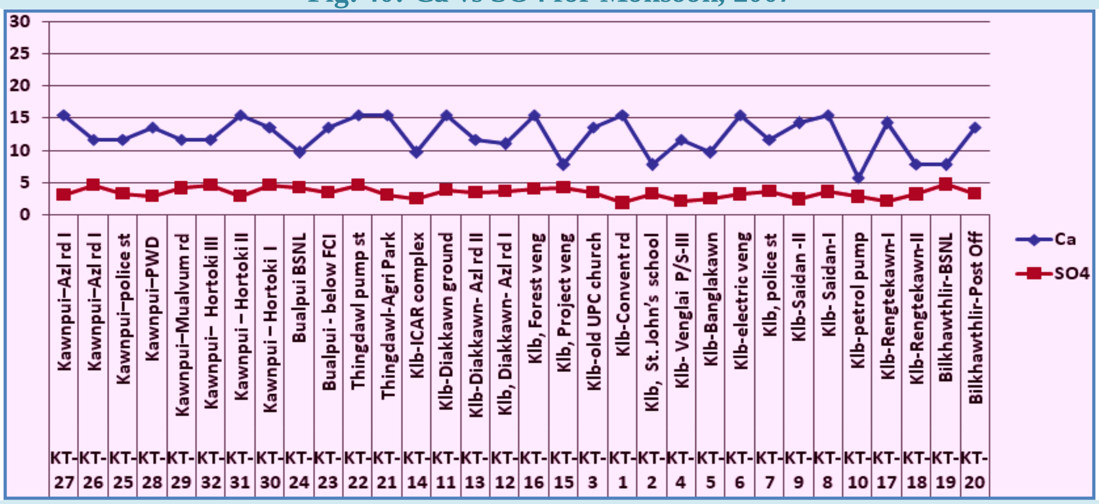


Fig. 41: Ca vs SO4 for Pre monsoon, 2008

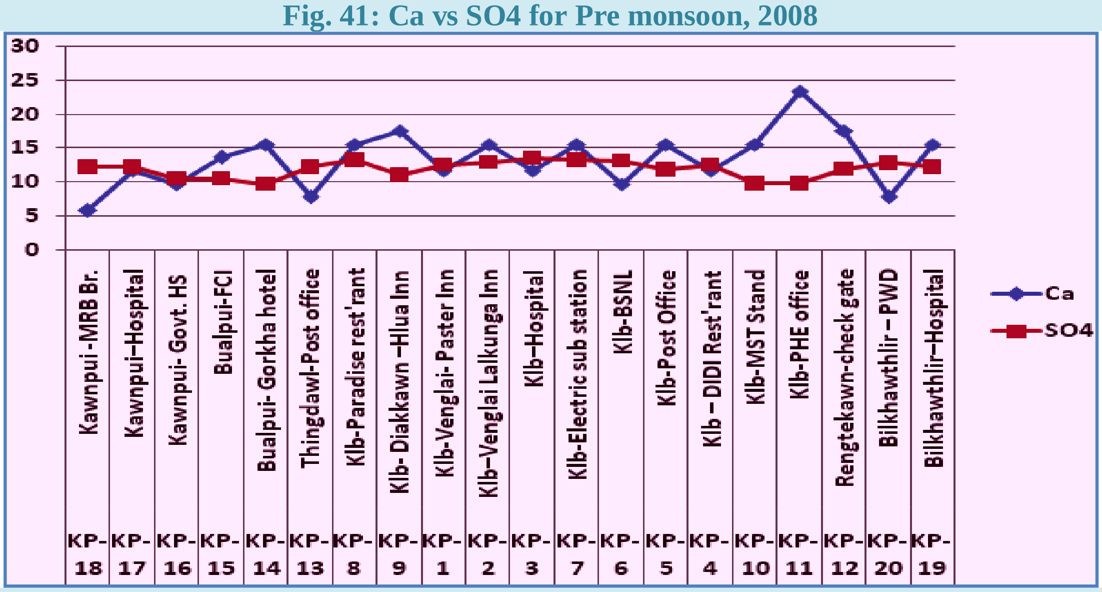


Fig. 42: Ca vs SO4 for Monsoon, 2007

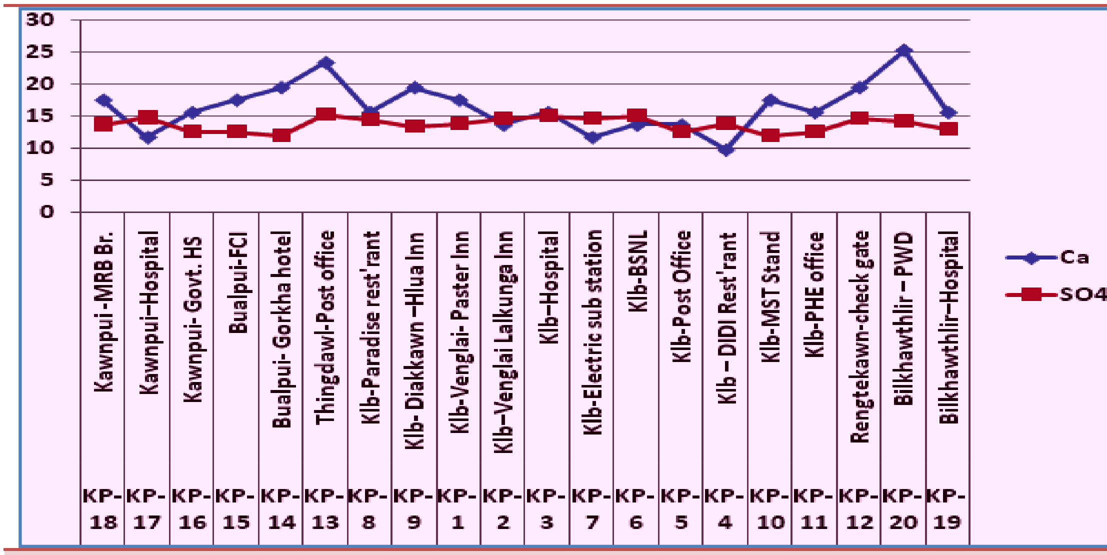


Fig. 43: Ca vs SO4 for Post monsoon, 2007

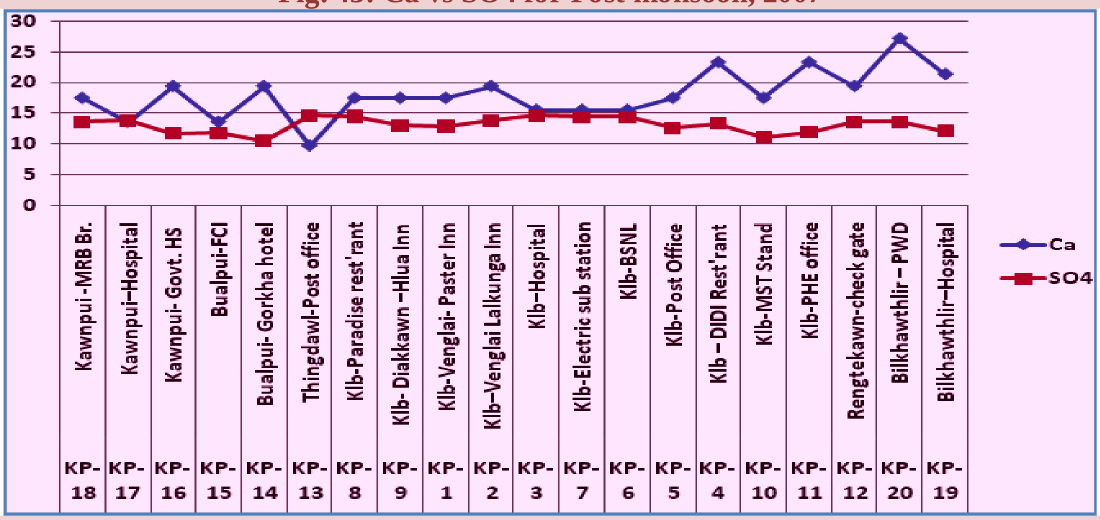


Fig. 44: Ca vs SO4 for Pre monsoon, 2008

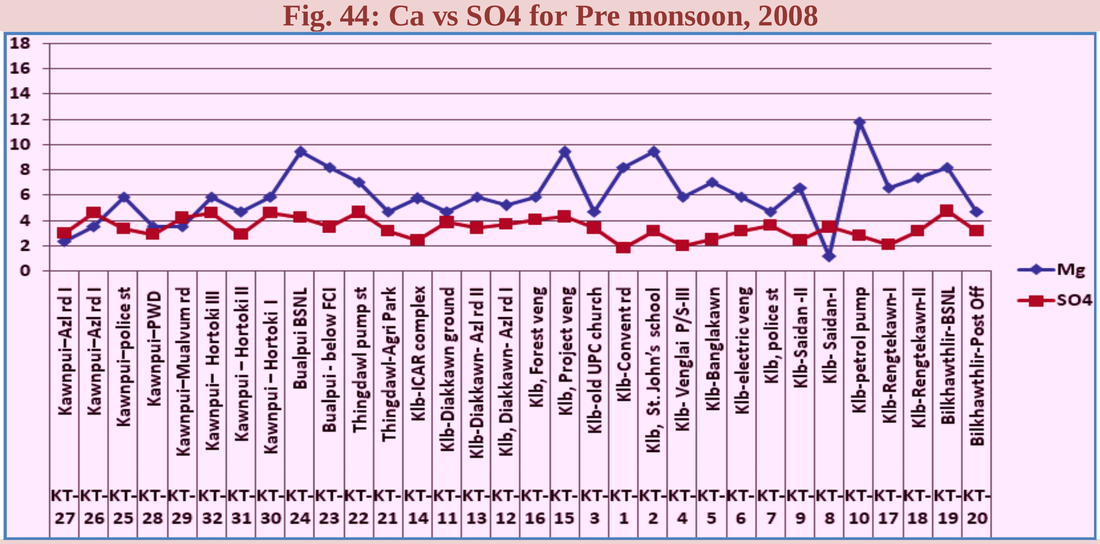


Fig. 45: Mg vs SO4 for Pre monsoon, 2007

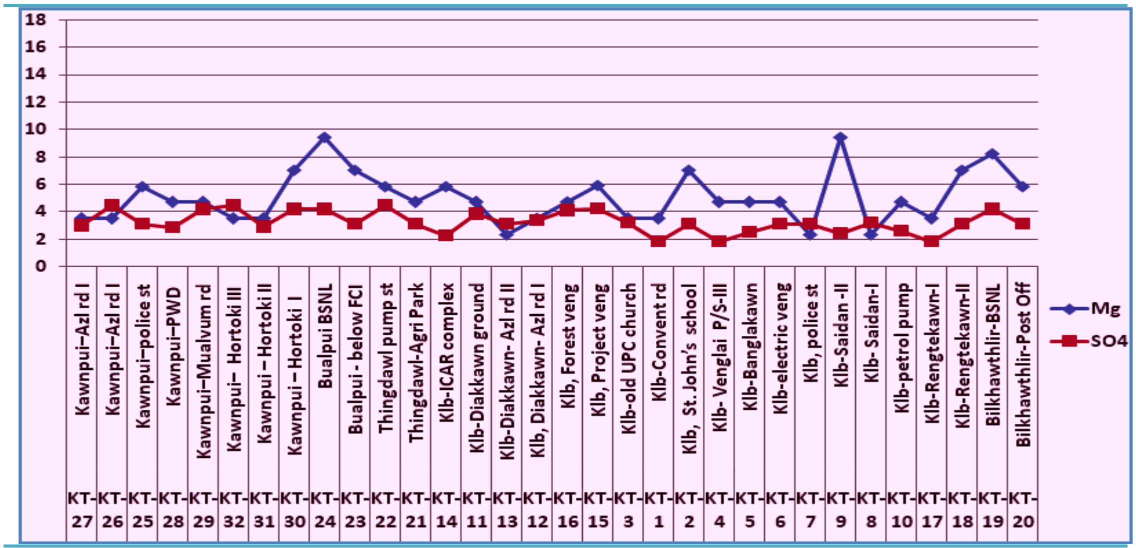


Fig. 46: Mg vs SO4 for Monsoon, 2007

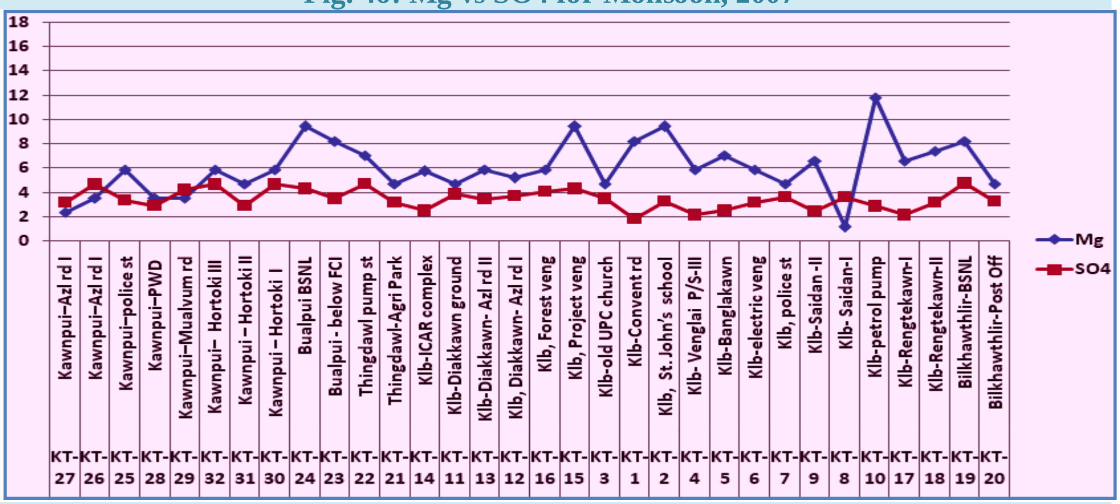


Fig. 47: Mg vs SO4 for Pre monsoon, 2008

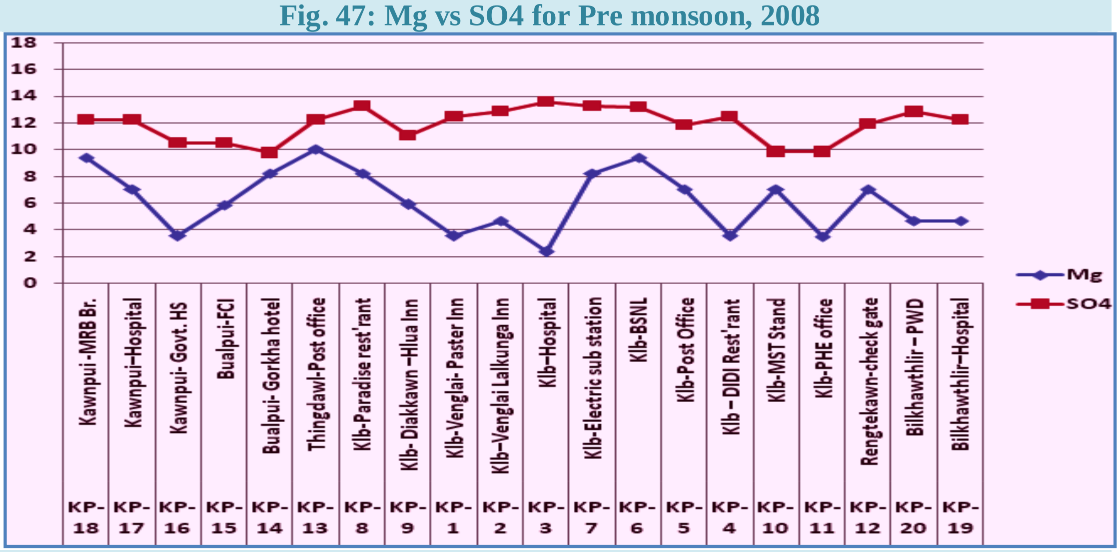


Fig. 48: Mg vs SO4 for Monsoon, 2007

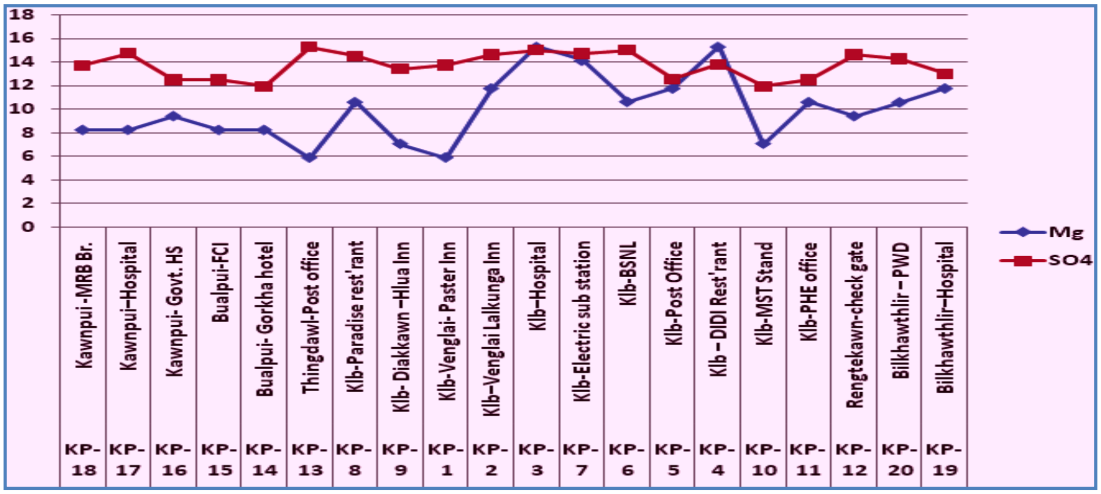


Fig. 49: Mg vs SO4 for Post monsoon, 2007

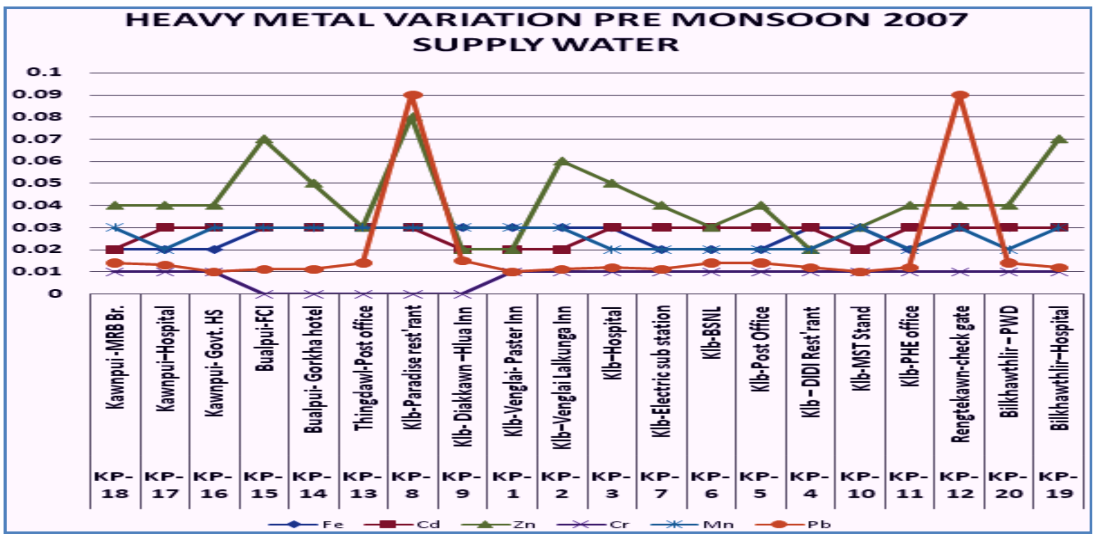


Fig. 50: Heavy metals in supply water

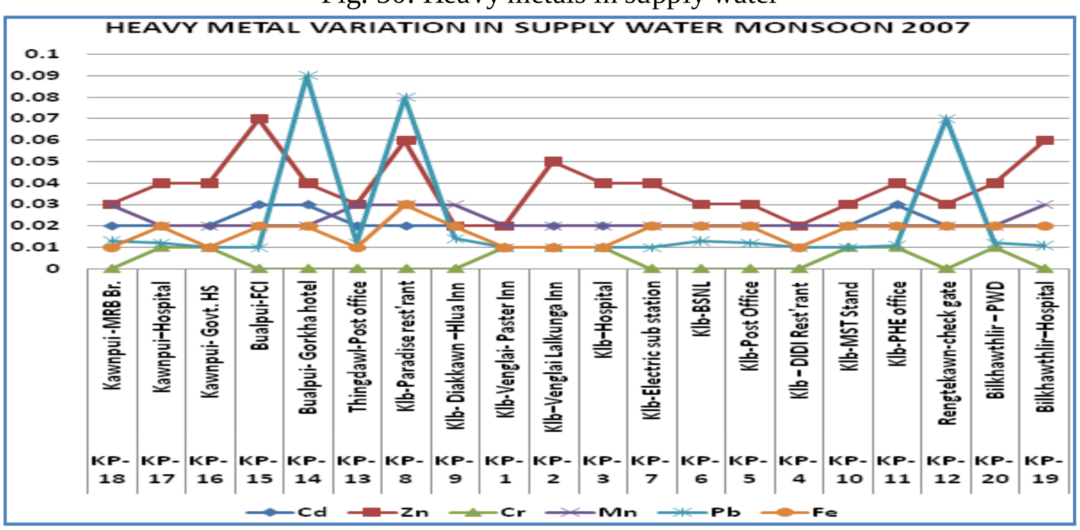


Fig. 51: Heavy metals in supply water

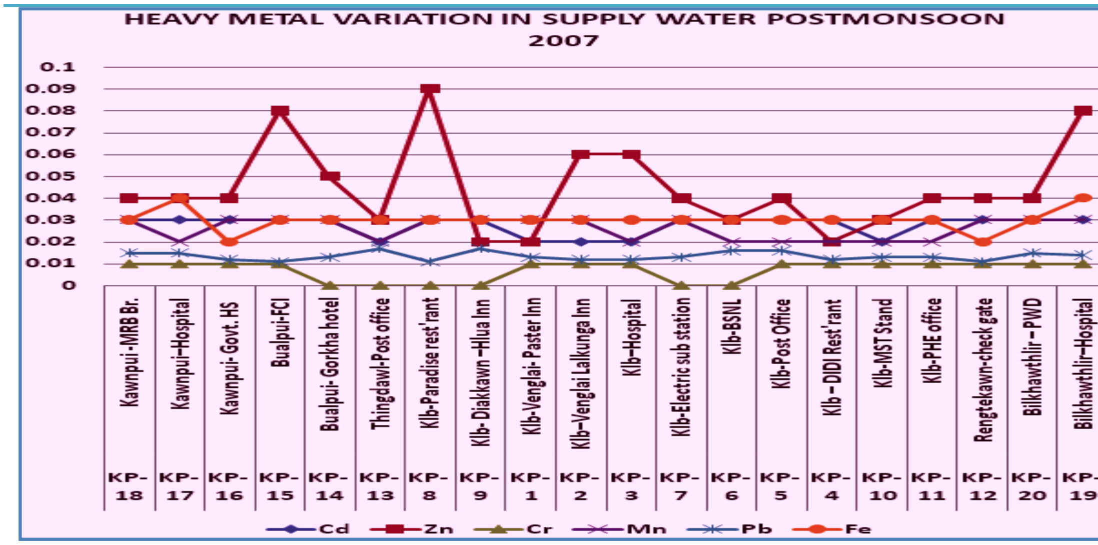


Fig. 52: Heavy metals in supply water

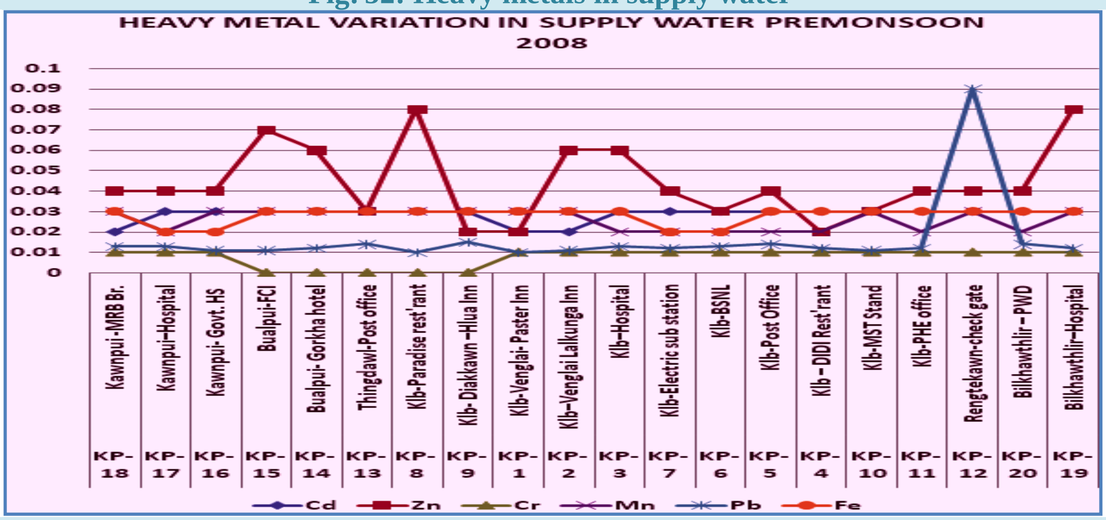


Fig. 53: Heavy metals in supply water

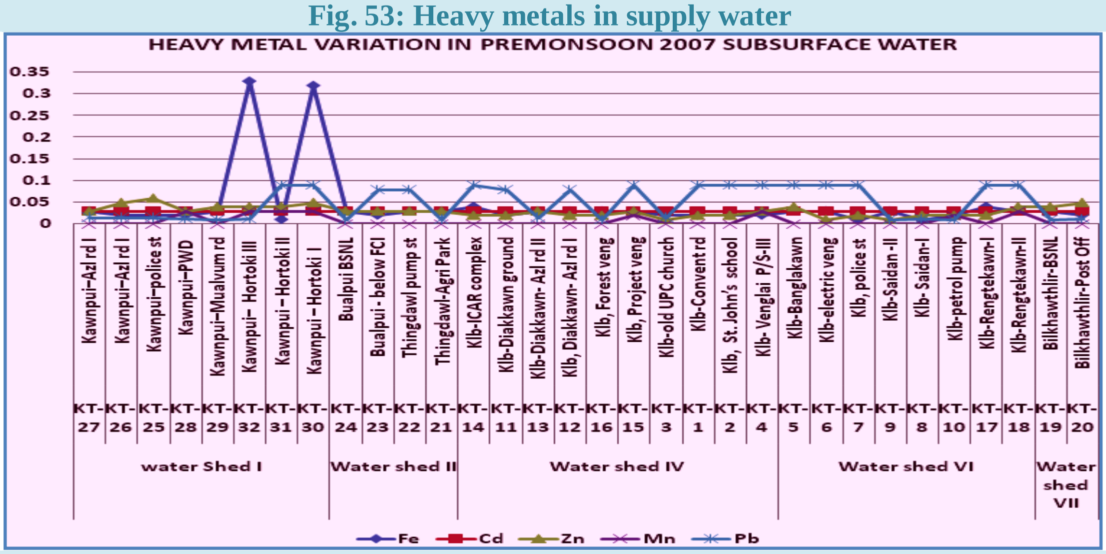


Fig. 54: Heavy metals in sub surface water

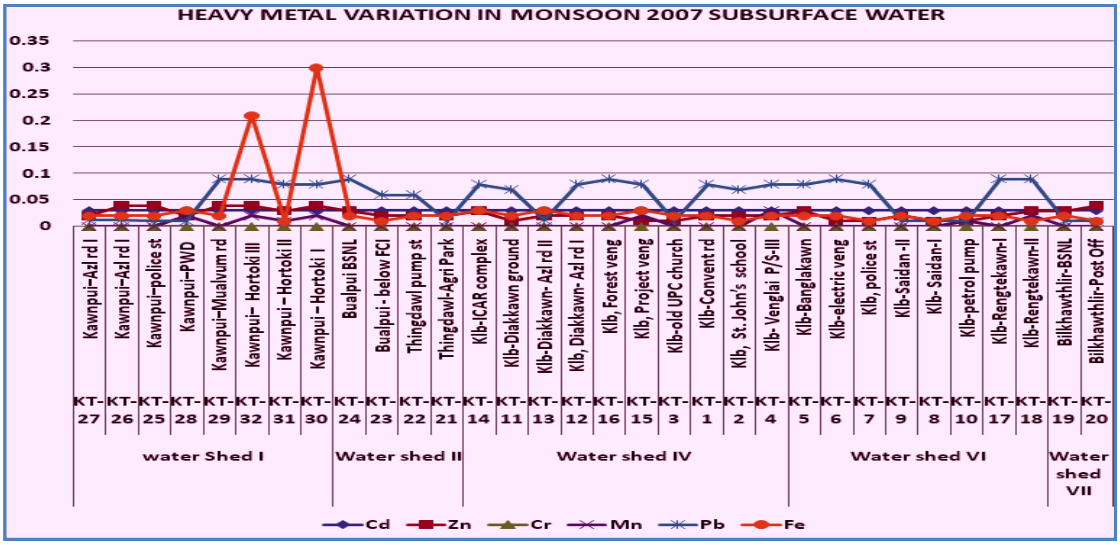


Fig. 55: Heavy metals in sub surface water

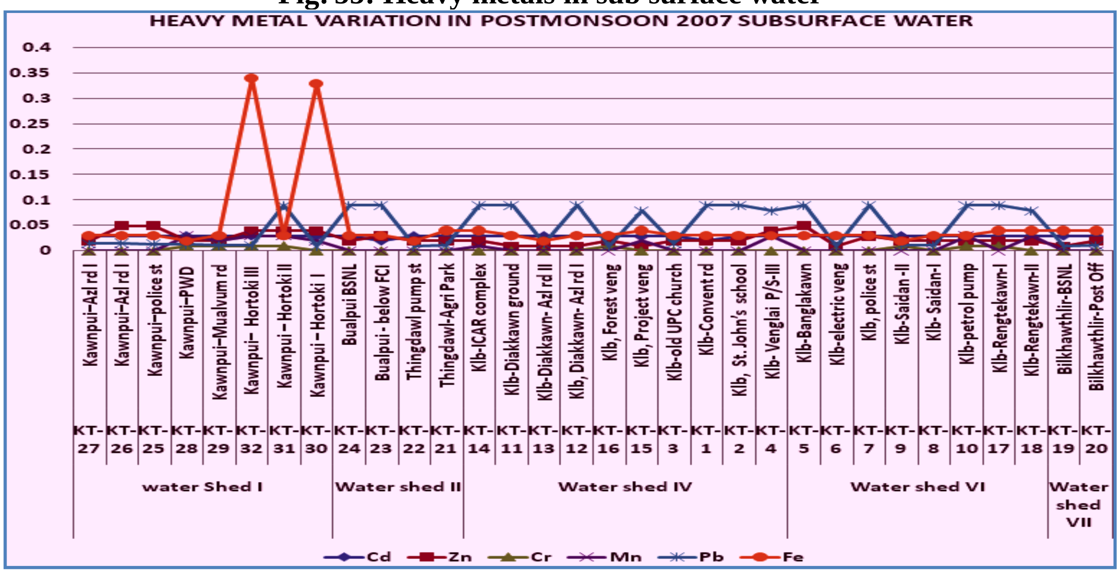


Fig. 56: Heavy metals in sub surface water

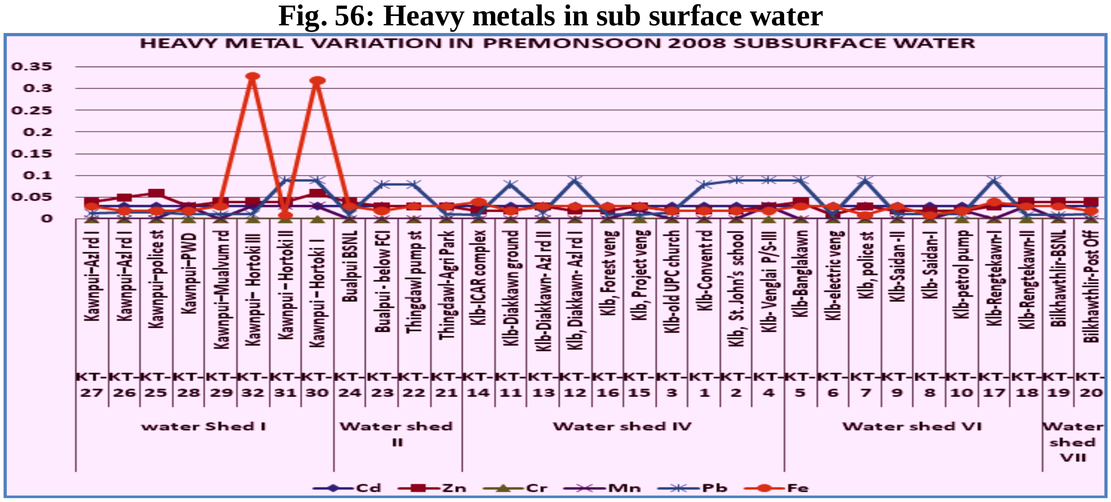


Fig. 57: Heavy metals in sub surface water

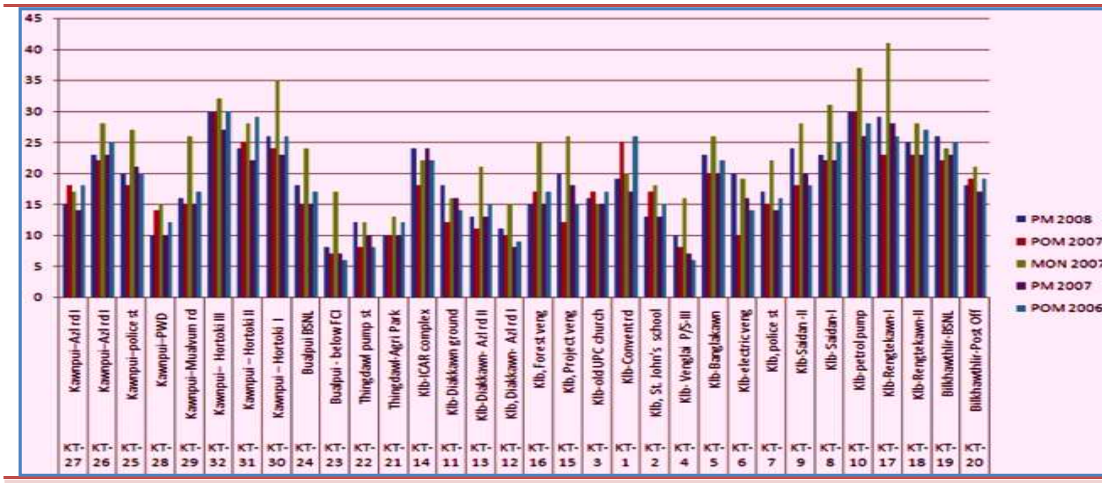


Fig. 58: MPN variation in sub surface water

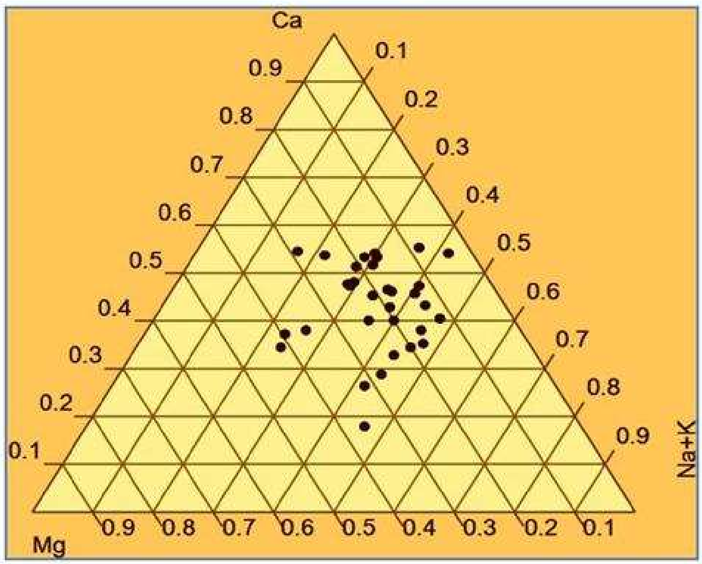


Fig. 59: TERNARY PLOT for KT- Pre monsoon, 2008 (Cation composition)

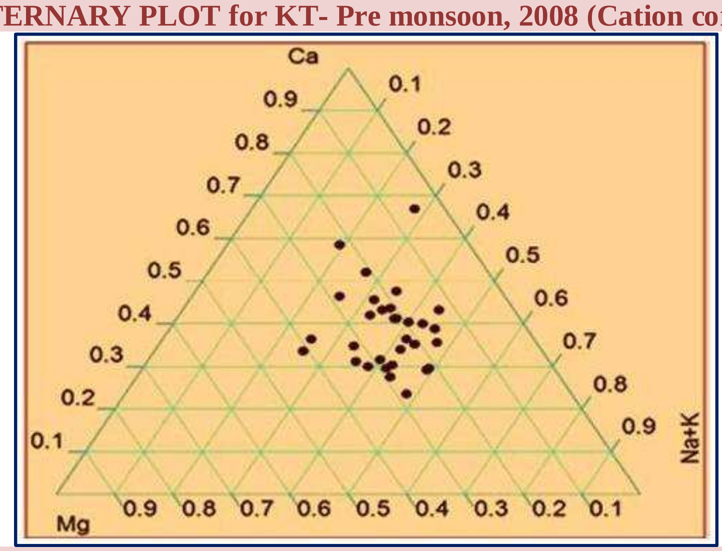


Fig. 60: TERNARY PLOT for KT- Post monsoon, 2007 (Cation composition)

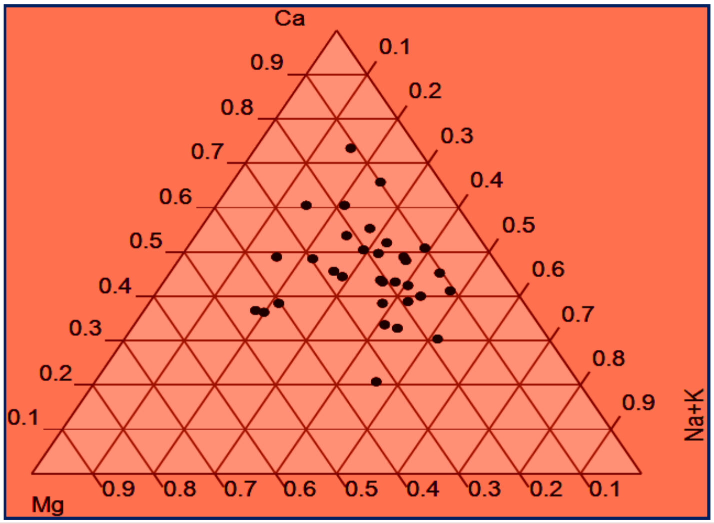


Fig. 61: TERNARY PLOT for KT- monsoon, 2007 (Cation composition)

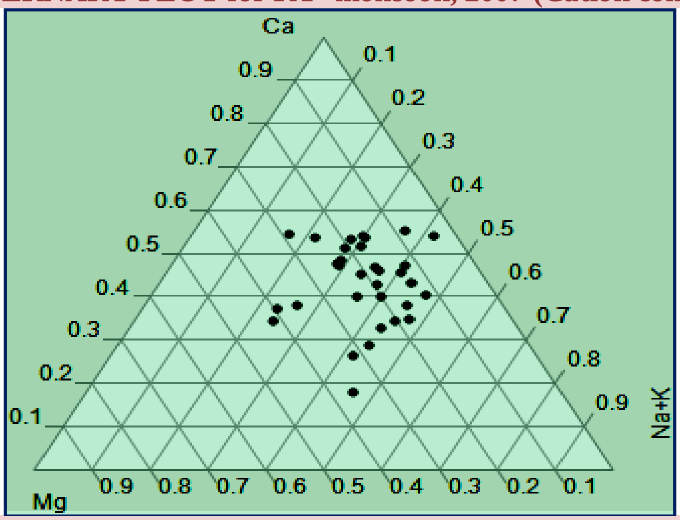


Fig. 62: TERNARY PLOT for KT- Pre monsoon, 2007 (Cation composition)

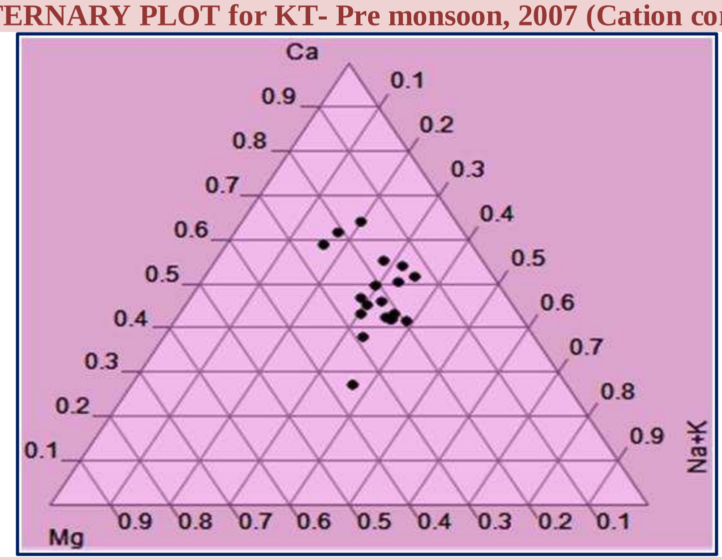


Fig. 63: TERNARY PLOT for KP- Pre monsoon, 2008 (Cation composition)

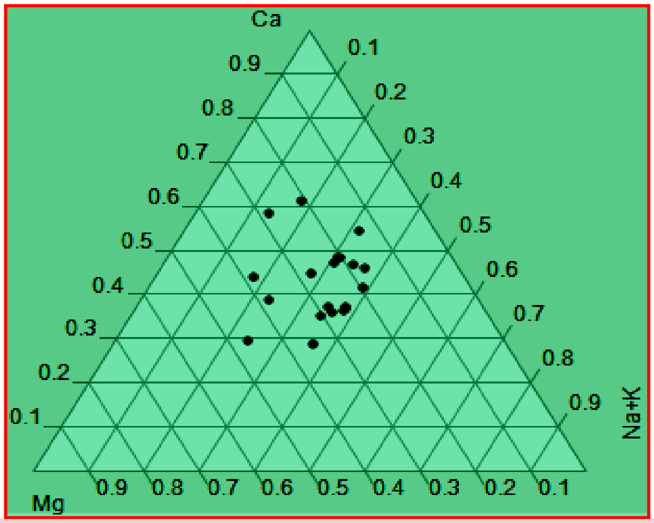


Fig. 64: TERNARY PLOT for KP- Post monsoon, 2007 (Cation composition)

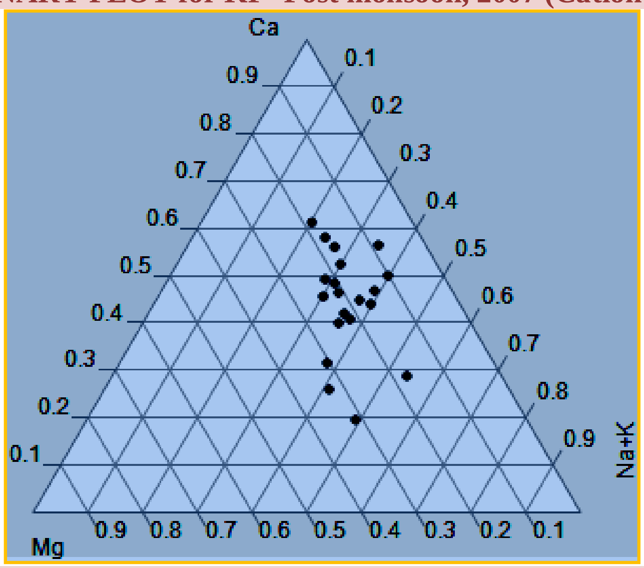


Fig. 65: TERNARY PLOT for KP- Monsoon, 2007 (Cation composition)

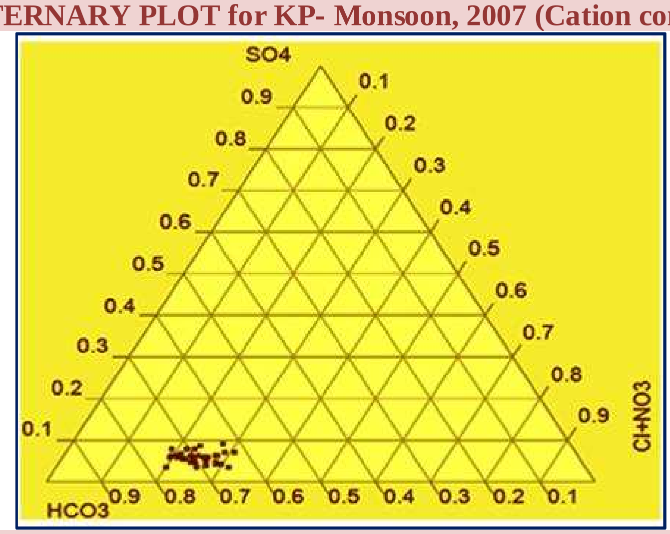


Fig. 66: TERNARY PLOT for KT- Pre monsoon, 2008 (Anion composition)

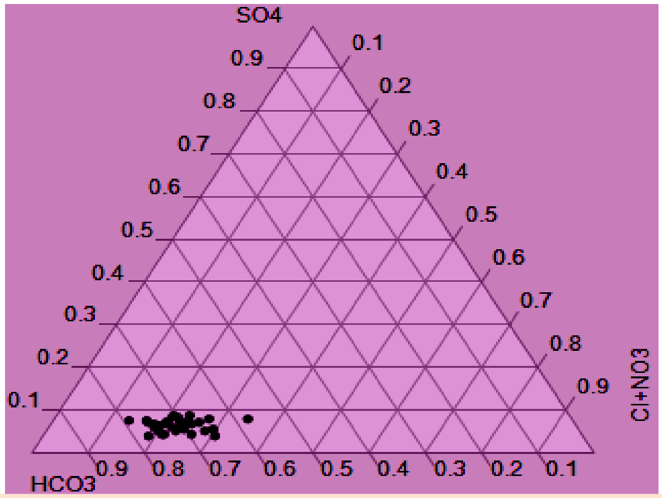


Fig. 67: TERNARY PLOT for KT- Monsoon, 2007 (Anion composition)

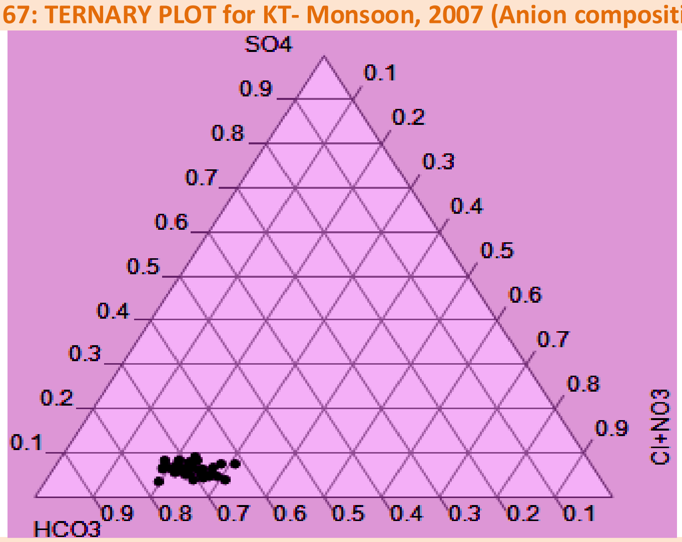


Fig. 68: TERNARY PLOT for KT- Pre monsoon, 2007 (Anion composition)

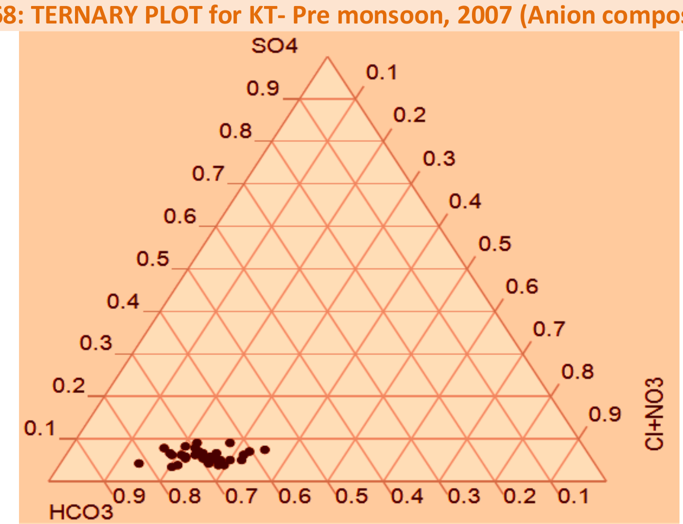


Fig. 69: TERNARY PLOT for KT- Post monsoon, 2006 (Anion composition)

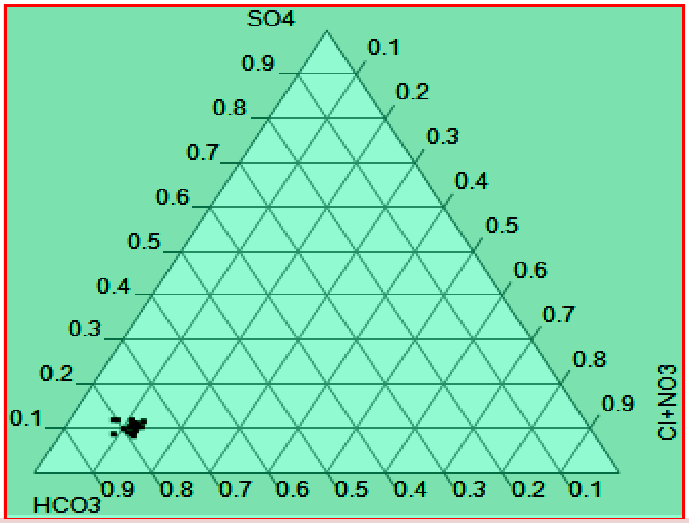


Fig. 70: TERNARY PLOT for KP- Pre monsoon, 2008 (Anion composition)

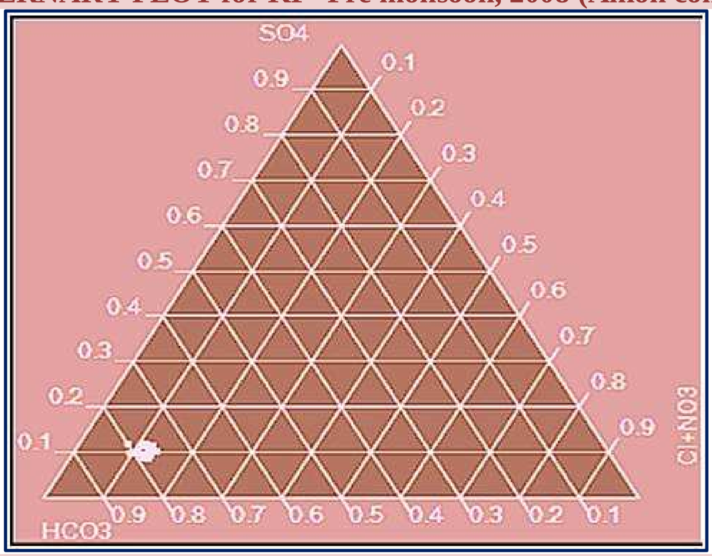


Fig. 71: TERNARY PLOT for KP- Post monsoon, 2007(Anion composition)

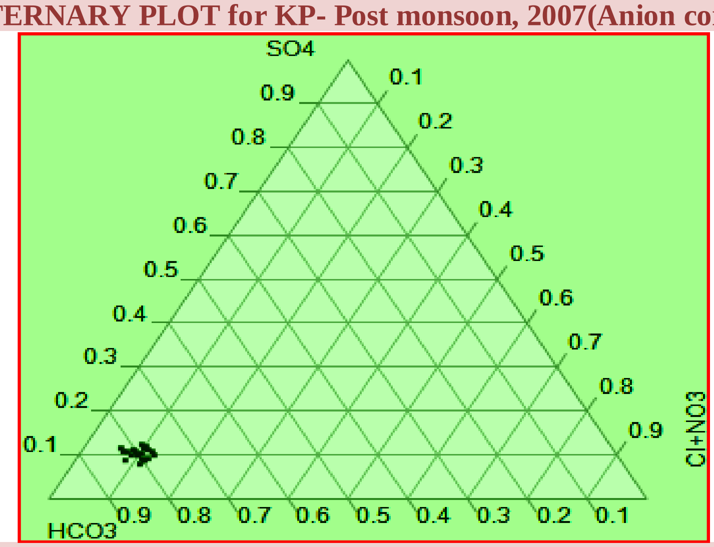


Fig. 72: TERNARY PLOT for KP- Monsoon, 2007(Anion composition)

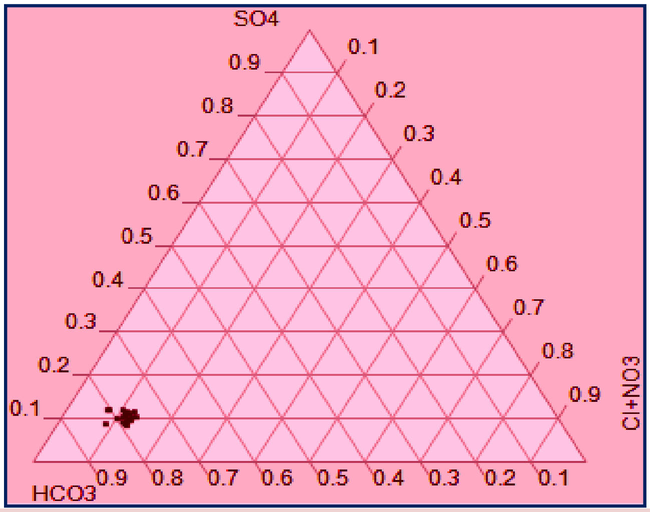


Fig. 73: TERNARY PLOT for KP- Pre monsoon, 2007(Anion composition)

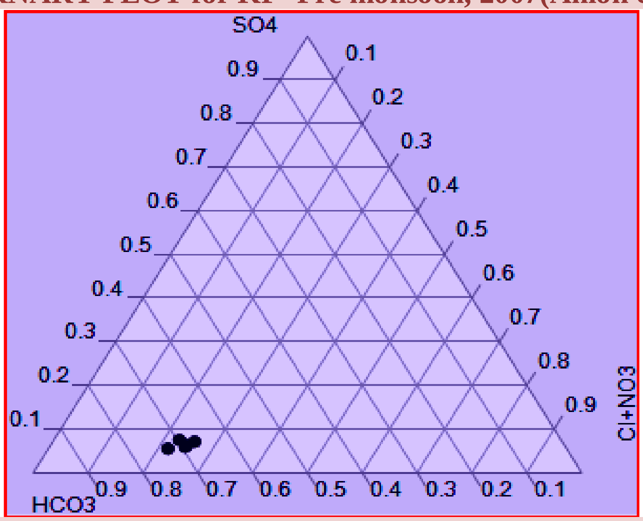


Fig. 74: TERNARY PLOT for KR- Monsoon, 2007(Anion composition

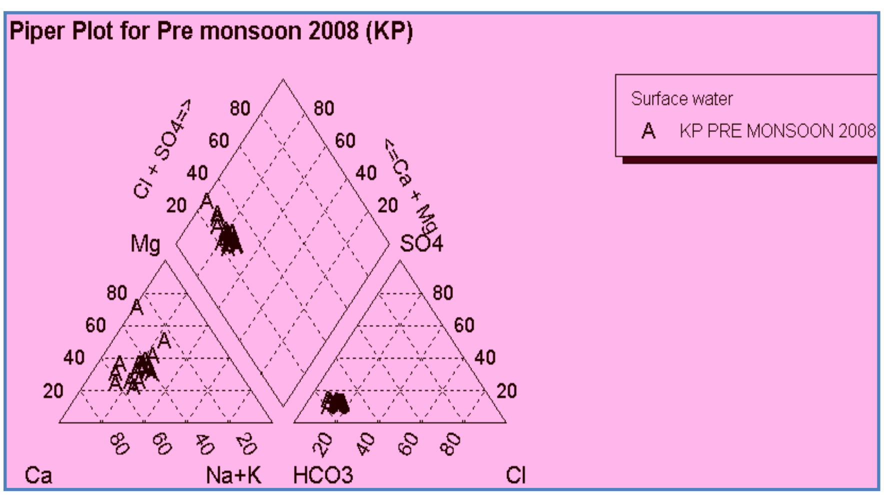


Fig. 75: Piper (1944) diagram for surface water of pre monsoon 2008

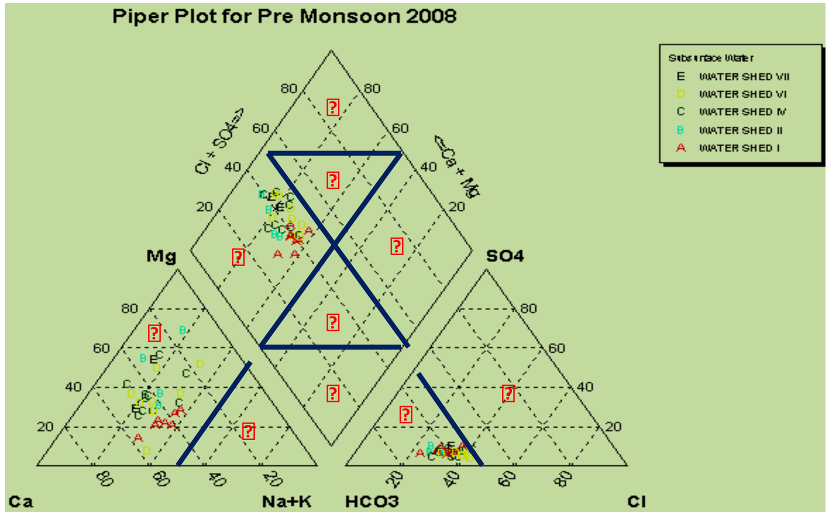


Fig. 76: Piper (1944) diagram for sub surface water of pre monsoon 2008

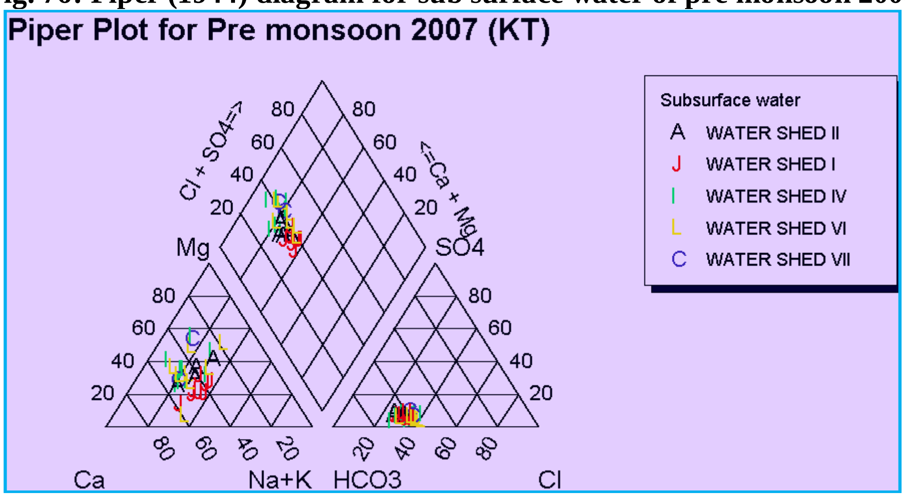


Fig. 77: Piper (1944) diagram for sub surface water of pre monsoon 2007

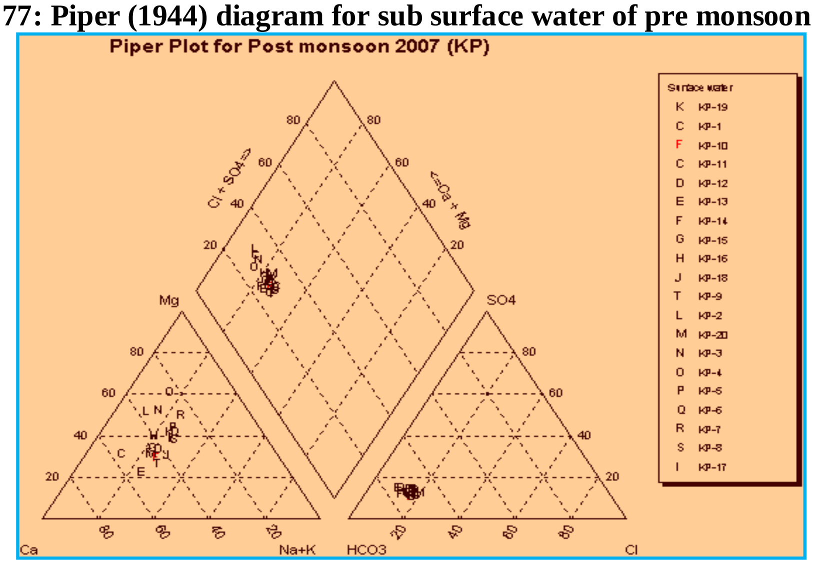


Fig. 78: Piper (1944) diagram for surface water of post monsoon 2007

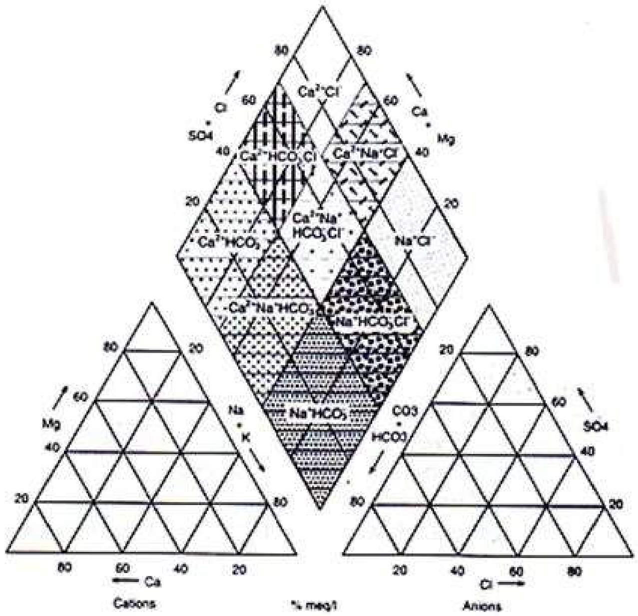
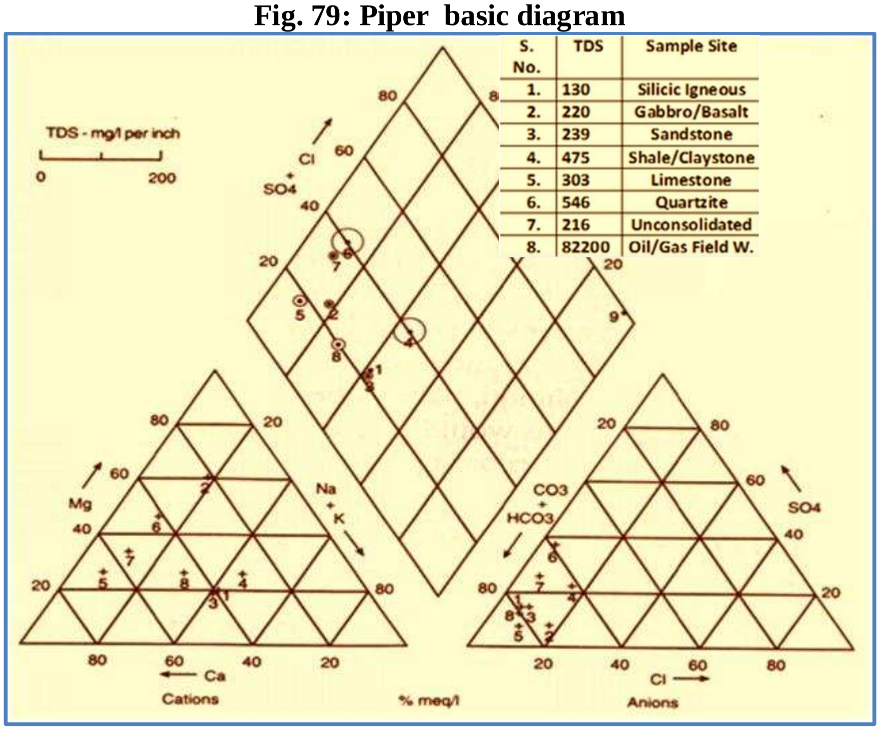


Fig. 79: Piper basic diagram



S. No.	TDS	Sample Site
1.	130	Silicic Igneous
2.	220	Gabbro/Basalt
3.	239	Sandstone
4.	475	Shale/Claystone
5.	303	Limestone
6.	546	Quartzite
7.	216	Unconsolidated
8.	82200	Oil/Gas Field W.

Fig. 80: Extensive compilation of groundwater analyses from a wide variety of aquifer host rocks (After White et al, 1963)

CHAPTER 6: CONCLUSIONS

Kolasib town of Mizoram and its surrounding localities are selected for the geochemical and bacteriological characteristics of the water used for domestic use. Further, estimation of heavy metals and other cations in trace amounts is also aimed for the work undertaken in the area. These trace elements and other parameters together were discussed with geological composition of the host rock and with other anthropogenic activities due to increasing urbanization. The samples from all sources of potable water were collected and studied for their physic-chemical and bacteriological parameters. The Main source is the water supplied by the PHED and other alternative sources available in the study area are tuikhur and harvested rain water. According to research plan the samples were tested three times in a calendar year, as pre monsoon, monsoon and post monsoon. The same has been continued for three consecutive years starting from post monsoon 2005 to pre monsoon 2008. The physical parameters include pH, electrical conductivity, total dissolved solids and turbidity whereas the chemical parameters include total alkalinity, total hardness, calcium, magnesium, sulphate, bicarbonate, total chloride, fluoride and nitrate. The bacteriological parameter is the determination of total coliform.

All the physical parameters are well within the permissible limits of ISI (1991) and WHO (2008). The aquifer rocks are mostly sandstone and Shale intercalation with absence of carbonate rocks i.e. limestone. The consistent values of pH which are found to be closer to 7 are mainly indicating the absence of limestone and confirming silicic nature of aquifers in various micro-water sheds for tuikhur water samples. The same is also true for the surface water as the same type of rocks is at the base of the rivers from where PHED lifts the supply water. Lower values of EC are suggesting the low solubility of salts from host rocks, which is in accordance with the fact silicic host rock. As per Fetter's classification based on TDS the water quality of the studied area is grouped as 'Fresh water type'.

In chemical parameters, the total alkalinity has been found mainly due to the presence of bicarbonate ion as hydroxide and carbonate ions are absent in all the samples because of the fact that carbonate minerals are absent in the study area. The soil zone is the subsurface environment that contains elevated CO_2 pressure (produced as a result of decay of organic matter and root respiration) which in turn combines with rain water to form bicarbonate. Deficiency of calcite and dolomite in the host rock is also supported by the low values of total hardness in the water samples. The slightly higher concentration of chloride in tuikhur water may be attributed to the contamination from sewage waste leaching from upper soil layers due to industrial and domestic activities. Fluoride in drinking water can originate from the fluoride bearing minerals such as fluorspar, fluorite, cryolite, fluorapatite and hydroxylapatite. The low level of fluoride in water samples may be attributed to the lack of fluoride bearing minerals in the strata through which water is filtering. The concentration of sulphate in water samples is mainly due to burning of forests as the area under study experiences frequent burning of forests in the summer season for jhum cultivation which is still prevalent in Mizoram. Denitrification and plant assimilation of NO_3^- before entering the streams is main factor for low nitrate content in the potable water sources and subtle usage of fertilizers particularly nitrogen fertilizers throughout the Mizoram in general and algal assimilation might be other reasons for low content of nitrate in water samples.

Despite the fact, that the there is scarcity of carbonate minerals in the rock composition, Calcium is the most dominant cation in the region under study of course the values are too less. The calcium content is supposed to be mainly contributed by anthropogenic sources. Low content of sodium in the water samples under study may be due to absence of evaporites and halites in the host rocks as they constitute only sandstone and shale intercalations. . Since potassium is considered to be less mobile, its contents are also less than that of sodium in the potable water of the Kolasib town and adjoining small town/villages.

Among heavy metals as trace elements in the potable water the concentrations of Cd, Cr and Mn are within the prescribed limit of WHO (2008) & ISI (1991) in all the samples of KP and KT waters in all the three seasons. The concentration of Ni, Cu, Co and As is below the limit of detection in all the samples. The low amounts of heavy metals in the studied area in contrast to the neighbouring states and Bangladesh where they are present in significant amounts particularly arsenic in potable water is an interesting fact and can be explained by the dominance of shale in the present area. Clay minerals constituting shale are having phyllosilicate structure providing enormous space as structural voids, where metals ions of large ionic size can be accommodated by replacing OH^-, K^+ … ions. Pronounced adsorption capacity of clay minerals illite, montmorillonite etc. play a dominant role in depletion of heavy/toxic elements and cations.

Slightly higher values of coliforms in water samples may be attributed to the use of pit latrines, piggeries and poultries which is predominant in the study area. Transfer of human excreta and waste from piggeries and poultry farms by rain water to the water sources seems to be the major cause behind the sudden increase in coliform during monsoon season.

Bicarbonate and calcium are found to be in dominance among anion and cation respectively suggested by the ternary diagrams of cations and anions. However, the next dominant cation is sodium and chloride is the next dominant anion.

White diagram (Piper) supports the geological composition of aquifers as sandstone and Shale/Claystone. The total hydrochemistry of the area under study is dominated by alkaline earths and weak acids. Most of the surface and sub surface waters in the study area can be classified as Ca-Na-HCO_3 facies while in some samples of surface water Na is replaced by Mg giving rise to Ca-Mg-HCO_3 type of water.

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