CHAPTER ONE

1. INTRODUCTION

1.1 Background

Water is the most essential requirement of all the living organisms on the earth. Water is the basis of life and has two characteristics that distinguish it from other resources: No plant or animal can survive without it and there are no substitutes for most of its uses (Miller 2002). Moreover, it is a precious and most commonly used resource. The major sources of water are rainfall, glaciers, rivers and ground water (UNEP, 2001). Water has been described as the "universal solvent" because it can dissolve a wide variety of substances. The consequences are that even drinking water is obtained from a relatively unpolluted source, it always contain a wide variety of chemicals, both organic and inorganic, usually in low concentration.

Water is a finite source that, without appropriate consideration given to its quantity and quality, will not support development in both developed and developing countries. Water quality is used to refer as the suitability of water to sustain living organisms and other uses such as drinking, bathing, washing, irrigation, industry and so on. Water quality has direct influence in public health (World Health Forum, 1997). In developing countries large sections of the population may be dependent on raw water for drinking purposes without any treatment. The purpose of drinking water criteria is to protect the portability of treated water from a human health point of view. These criteria include microbiological, inorganic & organic and radiological characteristics of significance to human health. Drinking water criteria define a quality of water that can be safely consumed by human throughout their lifetimes and have been developed by international organizations such as WHO for the use by countries that have not developed their own criteria. Water scarcity is not only a product of demand, but also a product of the degradation of water quality, i.e., the quality of the aquatic environment. The continued increase in global population associated socio-economic pressures on fresh water supply,

general lack of sanitation and waste- treatment facilities in high population areas of developing countries are placing increasing demands on available water.

Nepal is considered as rich in water resources. It is the second richest country in water resources. The country has four times the world's average water availability but more than a third of the people in the country have problems obtaining drinking water. Most peoples of urban and sub-urban areas are facing the problem of adequate safe drinking water.

Provision of clean and safe drinking water is pre-requisite for public health and wellbeing. Consumption of water contaminated with hazardous chemicals or pathogenic microorganisms possess serious health threat or various water borne diseases. It is estimated that about 80% of all sickness & disease in the world is caused by inadequate sanitation, polluted water or unavailability of water (WHO, 1990). In absence of adequate safe drinking water supplies or the distribution of contaminated water will cause disease such as diarrhea, dysentery, typhoid, fever, cholera, amoebiasis, helminthiasis, skin and eye infections, infestation, etc.

The unhygienic waste disposal practice and poor sewerage system cause the microbial pollution of ground water. There are frequent reports of faecal or bacterial contamination of drinking water including piped water supply in Kathmandu valley. Due to the inadequate and intermittent piped water supply, people in Kathmandu valley largely rely on ground water sources like traditional dug wells, stone spouts, shallow tube wells etc. to meet daily water need. Most people determine the quality of water merely in the basis of clarity and odour.

1.2 Ground Water:

Some precipitation infiltrates the ground and percolates downward through voids (pores, fractures, crevices, and other spaces) in soil and rock. The water in these voids is called ground water (Miller 2002). Ground water is a result of various physical, chemical &

biological phenomena that occur on surface and surface layers. The quality depends on the type of soil, rock, minerals and gases with which the water interacts. Human activities can change water quality greatly. High conductivity is due to domestic pollution (ENPHO, 1999).

Ground water is a precious and the most widely distributed resource of the earth, it gets its annual replenishment from the meteoric precipitation. The world's total water resources are estimated at $1.37x10^8$ M ha-m. Of these global water resources about 97.2% is salt water mainly in oceans, and only 2.8% is available as fresh water any time on the earth. Out of this 2.8%, about 2.2% is available as surface water and 0.6% as ground water. Out of 0.6% stored ground water, only 0.3% ($41.1x10^4$ M ha-m) can be economically extracted with the present drilling technology, the remaining being unavailable as it is situated below a depth of 800m.The amount of ground water within 800m from the ground surface is over 30 times the amount in all fresh water lakes and reservoirs, and about 300 times the amount in stream channels, at any one time. Thus ground water is the largest source of fresh water on the earth excluding the polar icecaps and glaciers. At present nearly one fifth of all the water used in the world is obtained from ground water resources (HM Raghunath). Ground water is a source for 75% of municipal water supplying systems in the USA. (Water: a Looming crisis?). 50% of the population of Nepal relies on groundwater for its drinking water supply (Warner, Nathaniel).

Kathmandu Valley can be divided into the following three aquifer zones:

1. Unconfined/ semi-confined aquifer zone believed to be the recharge area for the valley lies to the north of Maharajgunj and Bouddha and west of Gokarna extending to the western and northern foothills of the valley.
2. Unconfined surface aquifer, 15-20 deep, expands on the surface of the valley. Numerous dug wells, rower pumps and stone spouts are fed by water from this zone.
3. Confined aquifer zone lies to the south of Maharajgunj and Bouddha and west of Bode, extending towards the western and southern boundaries. (ENPHO 1999).

Wells can be broadly divided into 3 categories:

1. Shallow tube wells (<50m depth):Boring or tube well
2. Deep tube wells (>50m depth)
3. Dug wells or Percolation wells: These are also known as Draw wells or open wells. These are shallow wells which are usually confined to soft ground, sand and gravel. The diameter of these wells may be between 1m to 4m and depth may be up to 20m depending upon the requirement and geological structure of the earth. These wells are suitable for small discharge of about 20cu m/hr. These wells are usually cased with bricks or concrete ring masonry with a diameter of 1-2 meters dug below the water table. Water will accumulate in the well at the level of water table. Water is collected either with a bucket and rope or hand pump fitted with pipe.

1.3 Population & Water Resources: A Delicate Balance

The lack of adequate safe drinking water and sanitation is one of the major health and economic consequences of surging world urbanization. Increasing population concentration in urban areas has contributed to the depletion and contamination of fresh water. (Population Bulletin (PRB) Nov. 1992)

Due to rapid population growth and urbanization drinking water become scarce in urban and suburban areas of Nepal. Surface Water is getting polluted day by day. The clean water is taken from the environment, used for human activities and then discharged and polluted into the rivers. Sewage and industrial wastes are the most visible factors of contamination. Access to clean water has become a growing challenge within the Kathmandu valley. The current pipe water supply demand in Kathmandu valley is about 294 MLD but the supply is only 145 MLD. (NWSC 2004). As the surface water yield is crucial during the dry season, a policy of conjunctive use of ground and surface sources has been implemented. On an average the contribution of the ground water remains close to 50% of the total supply. Ground water is an important source of water for the inhabitants of the Kathmandu valley as majority of the residents depends on this source.

Ground water is usually less contaminated than surface water. Leachate from agriculture field, underground sewage storage tanks, landfills, abandoned Hazardous wastes, industrial wastes storage lagoons etc. located above or near aquifers usually the cause of ground water contamination. Once ground water becomes contaminated, cleansing itself from degradable wastes as surface water is almost impossible. Ground water flow is slow and non turbulent thus contaminants are not effectively diluted and dispersed.

To curb the issues arised from water pollution would require implementation of feasible measures for prevention and treatment which should include sanitation and disinfection of drinking water. For the water treatment, various chemicals that are being popularly employed elsewhere in the world for water treatment include chlorine and its derivatives, ozone, potassium permanganate and hydrogen peroxide. (Cheremssinoff et, al., 1981). The use of chlorine and some of its derivatives will continue as an integral part of the disinfection process in water and waste water treatment. It also applies to developing countries, where this mode of disinfection is fairly well established.

1.4. Water Resources

Water in the Kathmandu Valley is derived from two sources: Surface water (rivers and ponds) and ground water. They are basically fed with rainfall. Rivers are important running surface water in terms of water volume and potential development.

1.4.1 Drinking Water Resources

Over time, requirements for water for drinking and personal hygiene, agriculture, religious activities, industrial production, and recreational activities such as swimming and fishing, have increased in the valley. Nevertheless, the rivers are the main repository for the valley’s untreated sewage, solid waste, and industrial effluents.

Use of water resources can be considered as a measure of development, since it is directly related to agricultural activities, environmental conservation and human health. With increasing population and development activities, pressure on water resources is increasing. However the use of water resources is diversified. Since water is a basic element in different types of activities, it is used by tapping most of the available sources and its use is being intensified in order to meet the growing demand for water. Thus water resources have implications on quality and human health, environment and watershed conservation, access to water resources and conflicts, and so on (Pradhan and Pradhan 2006).

Table 1: Access to drinking water by household at district level (%)

District	Tap	Well	Tube Well	Spout	River	Other
Bhaktapur	74.55	11.74	7.22	4.93	0.07	1.49
Kathmandu	84.05	6.25	5.71	2.63	0.08	1.27
Lalitpur	83.05	9.79	1.2	4.5	0.16	1.31

Source: CBS 2001

1.4.2 Socioeconomic Driving Forces

The socioeconomic driving forces for describing drinking water resources are made in the following points:

Population Growth – Population is one of the fundamental driving forces shaping the water environmental base in the Kathmandu valley. The valley's population increased from 410, 995 in 1952/54 to 1,645,091 in 2001. The population density increased from 457 persons/km^2 in 1952-54 to 1830 persons/km^2 in 2001. This has increased the demand for water enormously.

Urban Growth and Expansion-The valley with its five municipal towns has an urban population of nearly 1 million, constituting slightly over 60% of its total population, accounting for nearly 31% of the country's total urban population. The urban population

in the valley increased from181, 082 in 1950 to 995,996in 2001. The main contribution to the rapid growth of urban population in the valley is migration. The density of population of the urban areas ranges from 139 person/km^2 (Kathmandu) to 72 persons/km^2 (Kirtipur). The urban areas have expanded in a rapid and haphazard manner. Some of the visible consequences of the haphazard urbanization include the increase in the volume solid wastes and their haphazard disposal, level of pollution of air and water, and squatting on river banks, in open space and on public land.

Agricultural Development – The economically active population above 10 years of age constitutes 40.3% of the total population of the valley districts, which is less than the country average. Agriculture in the valley is the second most important sector and is characterized by very intensive farming – use of fertilizers, irrigation, human labour, and terracing of farmland.

Tourism- One of the economic and social developments in the valley is tourism. The valley is the first destination for tourists because of its cultural, social, and natural uniqueness. The number of tourist's arrivals in the valley has increased each year. Tourism has many facets in terms of employment generation. As a result of increase in tourists, the number of hotels and associated activities like restaurants, travel and communication services, groceries, curio, and others have increased as well.

Infrastructural development-Roads are the most important infrastructure among the driving forces. The total road length in 2001 was 1,319km; blacktop accounted for 53.2%, followed by earthen (24.8%), and graveled (22%).

Regarding health services in the valley, one health service unit (hospital +health post) excluding private clinics, serves an area of 17.4 sq. km and 32,257 persons. It seems that the available public health services in the valley bear the greatest pressure in terms of coverage of population.

1.4.3 Pressure on Water Resources

The amount of water required for drinking, domestic, industrial, and recreational uses has increased over time long with the increase in population, quality of life, economic activities and development activities in the valley. In particular, the rivers are not only the main source of water, but also the main repository for untreated sewage, solid waste, and industrial effluents.

Demand for water is always on the increase in the valley. The pressure on water sources is intense due to the limited amount of water available with respect to demand. Over the last few decades, the population has grown rapidly at over 2% per annum, with migration as the main cause of the rapid growth in the valley's urban areas (Pradhan 2004). This additional growth of population leads to demands for more housing. Increase in obviously puts pressure on the existing water supply. Along with the increase in population, other activities such as industries, irrigation, motor workshops, and so on also require water. Natural factors, such as landslides and floods, also put pressure on water sources by damaging reservoirs, river channels, and irrigation canals. All these activities affect water quality. (Kathmandu Valley an Environmental Outlook).

Table 2: Drinking Water Supply and demand, Kathmandu Valley Cities

Description	Bhaktapur	Kathmandu	Kirtipur	Lalitpur	Madhyapur
Water supply coverage % by DWSC	70	71	71	70	70
Total city water demand (m^3/day)	7464	80662	4900	19559	3836
Total city water Supply by DWSC (m^3/day)	3732	40311	2450	9780	1918
Total volume of surface water supply (m^3/day)	2612	28218	1715	6846	1343
Total volume of groundwater supply (m^3/day)	1120	12093	735	2934	575

Source: DWSC 2004

Table 3: Status of water supply in Kathmandu Valley

Description	1999	2001	2002	2003	2004
Production capacity million liters per day (MLD)	125	132	141	144	165
Water demand (MLD)	160	177	281	290	294
Average daily Production (MLD)	105	112	120	124	145
Water leakage (waste) in %	38	37	37	37	36

Source: DWSC 2004

CHAPTER TWO

2. LITERATURE REVIEW

2.1 Review of literatures

NPC/IUCN, 1991 reviewed the previous studies on environmental pollution in Nepal including water pollution, air pollution, land pollution & noise pollution. Higher bacteriological and chemical contamination was found in water from wells, tube wells and stone spouts, almost all the chemical parameters tested from these sources exceeded international standards. Industrial discharge, sewage seepage and poor hygienic practices around the wells were the major factors found to be contributing to the poor state of Kathmandu groundwater.

UDLE, 1993 studied about rehabilitation of traditional water supply system of Patan. At the time of study, 34 hittis (stone spouts) and 218 dug wells were there. The water samples collected and tested from hittis over a period of time showed mixed results. Some were found to be of excellent quality whereas others were contaminated. Only few dug wells were tested for the water quality, the results being however satisfactory.

ENPHO, 1993 studied on Heavy Metals pollution in water and waste water in the Kathmandu Valley. Iron concentration in dug wells of Thimi is higher than WHO value though other heavy metals are in traces. Iron can be present in water naturally and due to pollution too. Iron in deep wells could be due to the natural property of the underlying sediments.

Ghimire, 1996 assessed 11 groundwater samples from Patan areas in two seasons. In rainy season, pH and temperature ranged from 5.6-6.3 and 19.7-22.5 ^{0}C respectively. Conductivity, hardness and N-ammonia for all samples were found to be within WHO permissible level. Chloride and ammonia ranged from 60-288 mg/l, and > 1.5 mg/l respectively. Similarly, in summer season, pH and temperature ranged from 5.9-6.7 and

21 ^{0}C – 22 ^{0}C. They also studied the water quality of 6 dug wells at the Patan area during two seasons. All the spouts and well were found to be heavily contaminated during rainy season. Thapa, 1997 also found the same result in the water samples collected from different sites in Baluwa VCD near Kathmandu city.

Ground Water Resources Development Board, 1997 showed that the shallow aquifer in the Kathmandu Valley is extensively polluted by sewage. Overall faecal contamination was present in almost 60% of ground water samples from dug wells and shallow tube wells in the shallow aquifer. The most significant pollution of the shallow aquifer was beneath the old cities of Bhaktapur, Kathmandu and Patan. The sources of contamination are presumed to be infiltrations from leaking sewer pipes and septic tanks. The study indicates the possibility of contaminants infiltrating from the polluted rivers to the shallow aquifer and recommends for further investigation.

Jha etal, 1997 reported the nitrate- N concentration in the shallow tube wells and dug wells are higher than the WHO standard. The shallow aquifers are extensively polluted by sewage and at places by industrial effluents. Faecal contamination is common and is generally associated with higher concentration of ammonia, nitrate and phosphate.

A survey carried by Madhyapur Thimi Municipality, 1998 reported there are 107 public wells (Dug wells) within the municipality.

Maharjan, 1998 conducted the study about the physiological and microbiological water quality of 70 water samples from shallow pumps, shallow wells, stone spouts, dug wells in urban areas of Patan. He found that ground water have been extensively used by the people in Patan. The result of this study also found that most of the groundwater sources (68.6%) in urban areas of patan exceed the WHO (1984) permissible level for coliforms. Different enteric bacteria including highly pathogenic ones were also isolated from 70% water samples. Only 14.3% of the sources showed iron value within WHO limit.

Environmental Workbook of Madhyapur Thimi Municipality, Bhaktapur, May 1999 reported monitoring results of the well water point to the fact that water of all the wells of Madhyapur Thimi are not suitable for drinking purpose without adequate treatment. In the central part of the Thimi, water contain high amount of Nitrate making the water unsuitable for consumption particularly to the children.

ENPHO, 1999 monitored ground water quality in the Kathmandu valley. It reported that stone spouts and dug wells are more contaminated than the shallow wells and deep wells. Several stone spouts and dug wells have exceeded the WHO limit of nitrogen nitrate content. Further regular analysis of waters of stone taps Nyapuchatole, Bhaktapur and dhobighat and of dugwells of Marutole, Thimi (nitrate >30mg/L), Golachen (Bhaktapur), Thapahity (Lalitpur), and Lachhitole (Pulchowk) should be carried out. If it is confirmed that the nitrate concentration exceeds 30mg/L, then the use of water for drinking should be minimized. 30mg/L has been considered arbitrarily very high. Dug wells & stone taps had higher concentration of nitrate than deep tube wells & shallow wells. In the stone tap samples 84% and in the dug wells 91% samples were found contaminated. It is quite apparent that the deep wells have the cleanest water.

CEMAT, 1999 & ENPHO, 2000 reported that the ammonia-N, Phosphate and dissolved iron concentration in deep tube wells are higher than the WHO standard.

Metcalf and Eddy, 2000 studied a report from Teku Hospital, Kathmandu which showed that 16.5% of all deaths had been due to water -borne diseases.

Nathaniel et al, 2001 conducted a groundwater survey of over 100 water sources including public stone spouts, municipal taps, dug wells, and tube wells in Kathmandu valley. All water sources had total coliform contamination but the dug wells were the most contaminated. Interestingly, when people have a choice of different water sources, on average they choose the more contaminated source with respect to fecal coliform. This may be due to the fact that a taste-based preference is given to shallower water with lower iron content, but higher levels of fecal coliform. Statistical analyses show

increasing Fe content with depth and an inverse relationship between Fe content and fecal coliform levels. In private dug wells, nitrate and phosphate levels were both found to significantly decrease with distance from the nearest pit toilet or municipal sewage pipe. No such relationships, however, were found for bacteria.

Dhaubadel, 2002 carried out study in 7 sectors of drinking water quality of Bhaktapur city. During the study bacterial analysis of tap water showed that bacteriological quality of tap water is far away from the safety value. The numbers of coliform group bacteria were high in most of the sample that indicate the probability of pollution of water by sewage on the whole ,in general the chemical and bacteriological contamination of water was found to be increasing more in the surface water than drinking water.

Joshi, *et al* (2004) analyzed 160 samples, randomly collected from 86 tube wells and 77 open wells in urban areas and reported that more than 87% of analyzed ground water samples of tube wells and open wells were contaminated. Temperature ranged from 14.7 ^{0}C to 27.4 ^{0}C and pH ranged from 6.5 to 7.5. Turbidity measurement of 21% samples exceeded WHO guideline value of 5 NTU. Hardness as ($CaCO_3$ concentration) values of 9% samples exceeded maximum permissible limit set by Nepal. However electrical conductivity of 79% of tested samples crossed USPH standard. Total iron concentration of 48.5% of samples exceeded WHO guideline (0.3 mg/l). Arsenic contamination was not detected in any of the tested ground water samples. More than 87% of analysed ground water samples of tube wells and open wells were found to be contaminated with coliform bacteria.

ENPHO & JICA, 2005 showed that the values of Iron, Manganese and ammonia for the most of the water samples from all types of ground water sources of Kathmandu valley were found above WHO guideline value for drinking water. Shallow dug wells are comparatively unsafe in terms of bacteriological contamination than that of shallow tube wells. It is noteworthy that the proportion of contaminated shallow dug wells (38.5%) is three fold to that of shallow tube wells (12.5%).

Pradhan et al. 2005 studied Bacteriological water quality of different water sources of Kathmandu Valley which showed the values of selected chemical parameters lie within WHO guide line values, whereas the values of selected bacteriological parameters are not within WHO guidelines.

Jayana, 2006 assessed 105 drinking water samples from wells, stone spouts and tap of Madhyapur Thimi Municipality. The study explored that most of the wells and stone spouts were found microbially contaminated as 64.76% of samples crossed the WHO guideline value. Arsenic content 0.025 mg/l (25 ppb) was detected from two well water samples, Makanani well and Ajimanani well. Maximum nitrate content up to 50 mg/l like in Lokanthali well. 12 water samples (11.42%) exceeded the allowable limit for ammonia content in drinking water.

2.2 Rationale of the study

People in Madhyapur, Thimi depend upon the well, stone spout and tap water to fulfill their needs. Bode Water Treatment Plant supplies drinking water to the Madhyapur Thimi Municipality, few areas of Bhaktapur and Baneshwor. This Treatment Plant supplies 14-15 MLD in rainy season and 5-8 MLD in dry season. Only 40% of the total population of the Kathmandu valley is benefited by this supply. This water supply benefits about 50% population of the Municipality and its surrounding VDCs. Although, piped water supply is preferred by most people, piped system has not been sufficient to meet their demand. Thus, many people increase dependency on wells and stone spout water. So, this study is intended to reveal the existing status of water quality of dug wells. There were 107 dug wells (in 1998). Among them water quality status of few wells were studied by ENPHO, 1999 and Jayana, 2006. These wells also play historical and cultural value. “Sithi Nakha” is feast which is especially celebrated by Newars. In this day, people used to clean drinking water sources like stone spouts, wells, springs etc. as they get contaminated during monsoon. Recently this day is also celebrated as “water day” with an aim to conserve existing water resources. The main aim of this study is to know existing condition of dug wells and their water quality status.

CHAPTER THREE

3. OBJECTIVES

3.1 Objectives of the study

General Objective

To assess the drinking water quality of public wells (dug wells) of Madhyapur Thimi Municipality based on physico- chemical parameters and microbial parameters.

Specific Objectives

i) To analyze important physico- chemical parameters such as temperature, pH, electrical conductivity, total dissolved solids, dissolved oxygen, free carbondioxide, total alkalinity, hardness, calcium, magnesium, chloride, nitrate nitrogen, ortho-phosphate and Iron of well water.

ii) To detect the faecal coliforms count by using membrane filter method.

iii) To analyze the bacteriological examination of well water by Most Probable Number (MPN) method.

iv) To study the monthly and spatial variation of physico-chemical parameters.

3.2 Limitations of the study

The limitations of the present study are mentioned as follows:

a. Time was the most limiting factor in the present study.
b. Due to lack of instrument depth of the wells could not be measured.
c. Due to lack of ammonia free distilled water in the CDES lab, ammoniacal nitrogen could not be measured.

CHAPTER FOUR

4. STUDY AREA

4.1 Geography

Kathmandu Valley

Kathmandu valley lies at 1,300 amsl and is located between latitudes 27^0 $32^{'}$ $13^{"}$ and 27^0 $49^{'}$ $10^{"}$north and longitudes 85^0 $11^{'}$ $31^{"}$ and 85^0 $31^{'}$ $38^{"}$ east. Its three districts, Kathmandu, Lalitpur, and Bhaktapur, cover an area of 899 square kilometers. The valley encloses the entire area of Bhaktapur district, 85% of Kathmandu district and 50% of Lalitpur district.

The valley is bowl shaped and surrounded by the Mahabharat mountain range on all sides. There are four hills acting as forts of the valley, phulchoki in the South East, Chandragiri/ Champa Devi in the south West, Shivapuri in the North West, Nagarkot in the North East. The highest altitudes are 2,166m (in Bhaktapur), 2,732m (in Kathmandu) and 2,831m (in Lalitpur).

Madhyapur Thimi Municipality

Geographically, Thimi lies within 27^o 40'00" to 27^o 42'00" N Latitudes and 81^o 22' 30" to 81^o 25'00"E Longitudes, at an average altitude of 1300 meters amsl. It is spread over an area of 11.47 sqkm. Thimi was built on a terrace plateau, which is safe from flooding. Madhyapur Thimi Municipality is located in the central east part of the Kathmandu Valley. River Manohara delimits its boundary with Kathmandu district on the west. Bordering VDCs of Kathmandu districts are Mulpani and Gothatar in the Northwest and Kathmandu municipality in the west. River Hanumante Khola demarcates Western boundary with Lalitpur District's bordering VDCs, Imadol, Tikathali, and Balkot. Surya

Binayak VDCs of Bhaktapur district demarcate its southern border along Hanumante Khola. Bhaktapur Municipality and Saraswoti Duwakot VDCs lie on the east and northeast respectively. River Garkhu Khola, a tributary of Hanumante Khola, demarcates the boundary in the east and northeast. It is believed that being situated exactly in between three major cities of Kathmandu Valley -Kathmandu, Lalitpur and Bhaktapur, the city was named Madhyapur which means mid town.

4.2 Climate

The climate is good, soil is fertile, and it is endowed with rich forests and scenic beauty. The three major river systems in the valley are the Bagmati, Bishnu mati, and Manohara. There are lakes and ponds in all three districts –Taudaha and Indra daha in Kathmandu; Gunaldaha, Katuwaldaha, Godavari, Nagdaha, Bojho Pokhari, and Saraswatidaha in Lalitpur; and Siddhapokhari, Bhajupokhari, and Kamalpokhari in Bhaktapur. Kathmandu Valley has Waterfalls at Sundarijal, Chobhar and Matatirtha. The climate is sub-tropical, temperate, and cool-temperate, with four distinct seasons: spring from March to May; summer from June to August; autumn from September to November; and winter from December to February.

In general, the annual maximum and minimum temperatures are between 29 ^{0}C in June and 1 ^{0}C in January. The average wind speed recorded by the Hydrology and Meteorology department's station at Tribhuvan International Airport in 1998 was highest in March (2.1km/hr) and lowest in December (0.8 km/hr).

Climatically, Madhyapur Thimi Municipality lies in the Humid Temperate Zone. The seasons are dominated by two distinct wind systems; namely, the southwest monsoon in the summer characterized by heavy rain and warm temperatures, and the northwest monsoon in the winter. The mean annual temperature is 19 ^{0}C. Generally the summer months are warm and pleasant and winter months are cold and chilly. Temperature inversion is noted in the winter months.

4.3 Geology

The geological condition of Thimi shows that the banks of Manohara and Hanumante River have alluvial soils. These soils have low bearing capacity, loose density and soft consistency, prone to subsidence, erosion and flooding. High potential of ground water with periodic change of shallow ground water table. High infiltration, high risks to pollution of ground water and surface water. Highly susceptible to liquefaction. Here construction of building not advisable. Sand mining on very limited scale but no mining closer than 500m from bridges. No waste disposal and storage of chemicals and other hazardous material.

The area along Kausaltar, Lokanthali, Sanothimi, Bode, Nagadesh and Nilbarahi are light to brownish gray fine laminated and poorly graded silty sand. These soils are locally prone to erosion and flooding. Medium ground water potential. Moderate to high groundwater infiltration. Medium to low susceptible to liquefaction. These areas are potential areas for ground water recharge. Favorable lands for dry and wet cultivation. Potential area for sand resources. For heavy construction pile foundation should be used to avoid differential settlement. (Environmental Workbook of Madhyapur Thimi Municipality, Bhaktapur, 1999)

4.4 Demography

Madhyapur Thimi Municipality covers an area of 11.11 sq. km. The total population of the Municipality is 47751. The population density is 4297.31 persons/sq.km. (CBS 2001). The distribution of Population according to the wards, their area and the no. of households can be tabulated as follows:

Table 4: Population Distribution among the wards

Ward No.	Total Population	Area (ha.)	No. of Households
1.	2545	58.75	441
2.	2147	83.78	358
3.	2820	165.10	416
4.	1816	41.26	339
5.	1792	50.25	345
6.	1412	12.75	288
7.	2732	41.3	509
8.	2374	25.43	431
9.	1543	31.62	278
10.	1936	19.72	380
11.	2299	36.98	470
12.	2218	28.75	388
13.	3168	23.19	620
14.	2215	33.80	431
15.	7531	158.05	1780
16.	4788	95.94	1075
17.	4415	244.59	1002
Total	47751	1147.26	9551

Source: Madhyapur Thimi Municipality, CBS 2001

CHAPTER FIVE

5. MATERIALS AND METHODS

5.1 Sampling stations

The sampling stations of public wells were selected on the basis of reconnaissance survey throughout the core area (old settlement) of the Municipality where traditional dug wells exist. The sampling stations were selected on the basis of questionnaire survey among local peoples about how often they use the well water for drinking purpose. Altogether 20 sampling stations were selected within in the municipality. These stations are tabulated below:

Table 5: Name of the sites, their location and ward no.

Sites	Name of the location	Ward No.
1.	Kumhalachi, Nagadesh	4
2.	Bahanani-12, Nagadesh	6
3.	Dhwakasi, Nagadesh	5
4.	Gungachiwa, Bahakha Bazar	7
5.	Kasmatuthi-18, Chapacho	8
6.	Chanko, Bode	1
7.	Khapala Nayabasti, Bode	3
8.	Nachutole, Bode	2
9.	Taraa Tole, Tigani	3
10.	Lokanthali Sanothimi Marga, Lokanthali	16
11.	Tahanani	11
12.	Bhulankhel	11
13.	Bramhanani, Chapacho	10
14.	Tulanani, Chapacho	9

15.	Tachu Tole Marga-26, Balkumari	14
16.	Baamune Tole, Balkumari	14
17.	Parsiko Marga-28, Laachi Tole	13
18.	Gachen Marga-32, Dathu Tole	13
19.	Shiva Tole-2, Layeku	12
20.	Chode Marga-81, Chode Tole	11

5.2 Sampling Frequency

The study of physico-chemical parameters were carried in each month from February to September 2006 for 8 months. The microbiological study was carried for the month of September.

5.3 Methods of sample collection and analysis

5.3.1 Water sample collection and preservation

In each sampling station, water sample was collected with the help of bucket tied with rope and poured in clean sample bottles (plastic). Sample was collected from the surface of the well. But in some dug wells fitted with hand pumps water sample was directly collected in sample bottles. Samples were collected at the morning time within 7 AM to 9 AM. Most of the physicochemical parameters such as temperature, pH, dissolved oxygen, free carbondioxide, total alkalinity, hardness, calcium, magnesium, chloride were measured in the sampling site (field measurement). Water samples were brought to CDES laboratory as soon as possible and conductivity and total dissolved solids were measured. All the samples were refrigerated ($< 4^0$ C but above freezing) for the analysis of NO_3 –N, PO_4 –P and Iron.

For the microbial analysis water samples were collected in 50 ml sterilized bottles. Sterilized bucket was used to withdraw water from the well. Water samples were collected as aseptically as possible and brought to CDES laboratory.

5.3.2 Methods of analysis of Physico-chemical Parameters

1. Temperature:

The temperature of water and air was measured by using a mercury- filled Celsius thermometer graduated to an accuracy of 0.1 ^{0}C (APHA, 1995). The well water was collected in a beaker. Soon after the collection of the water sample, the thermometer was dipped into the water sample and noted the reading. To minimize the error, the thermometer was always calibrated with another thermometer of known accuracy (Trivedi and Goel, 1986).

2. pH

pH (potentia hydrogenia) is a scale of intensity of acidity or alkalinity and measures the concentration of hydrogen ions in water. The pH was measured by using a portable pH meter. For the measurement of pH of water, water sample was taken in a clean beaker and electrode (rinsed with distilled water & blot dried) of pH meter of model HI 8314 portable pH meter (Hanna instruments, Manufacturers with accuracy of ± 0.01 at 20 ^{0}C/ 68 ^{0}F) was dipped into the water sample. Equilibrium between electrodes and water sample was established by stirring water sample to ensure homogeneity. It was stirred gently to minimize CO_2 entrainment. Then, the reading of pH meter was noted. On each sampling day, electrodes from storage solution was removed, rinsed with distilled water, blot dried with tissue paper and placed in buffer solutions (pH 4 & 9.2) and set the pH meter with the pH of buffer (APHA, 1995).

3. Conductivity:

Electrical conductivity is the ability of a substance to conduct the electric current. In water, it is the property caused by the presence of various ionic species. The conductivity

was measured by using digital conductivity meter (Hanna instruments, Manufacturers of model 4150 with accuracy of ± 0.5% ± 2 digits). The conductivity meter was first calibrated with standard potassium chloride solution of 0.01 N and brought into the conductivity mode. Then the electrode was washed and rinsed with distilled water and then dipped in the beaker containing the sample water. The conductivity reading was noted down after the reading become stable.

4. Total Dissolved Solids (TDS):

Total Dissolved Solids refer to the amount of solid substances dissolved in water. TDS in water sample can be estimated by multiplying conductivity (in µS/cm) by an empirical factor. This factor may vary from 0.55 to 0.9, depending on the soluble components of the water and on the temperature of measurement. Relatively, high factors may be required for saline or boiler water, where as lower factors may apply where considerable hydroxide or free acid is present (APHA, 1995). As a general rule; the TDS is 0.65 times the conductivity of water because the dissolved solids in the highly mineralized water are usually more than 65 % of the conductivity. This is true within the conductivity value of 50, 000 µS/cm (Trivedi and Goel, 1986).

5. Dissolved Oxygen

Dissolved Oxygen (DO) was determined by the Winkler's or Iodometric Method. The sample was filled in a glass stoppered bottle (BOD bottle) avoiding any kind of bubbling and trapping of the air bubbles in the bottle after placing the stopper. 2ml of each $MnSO_4$ and alkaline KI solution was poured well below the surface from the walls. A precipitate appeared. The contents were shaken well in an '8'shape repeatedly. The bottle was kept for some time to settle down the precipitate. If the titration is to be prolonged for few days, the sample at this stage with precipitate should be kept. Then 2 ml of concentrated H_2SO_4 was added and shaken well to dissolve the precipitate. 50 ml of the contents was taken preventing any bubbling to avoid further mixing of oxygen. 2-3 drops of starch as indicator was added to it and titrated against sodium thiosulphate where colour changed from blue to colourless at the end. DO is calculated by the following equation (APHA, 1995; Trivedi and Goel, 1986).

$$\text{Dissolved oxygen (mg/L)} = \frac{\text{(ml x N) of titrant x 8 x 1000}}{V_2 (V_1 - v) / V_1}$$

Where, V_1= volume of sample bottle after placing the stopper

V_2= volume of the part of the contents titrated

V=Volume of $MnSO_4$ and KI added.

6. Free Carbon dioxide (CO_2):

Free carbondioxide can be determined by titrating the sample using a strong alkali (such as carbonate free NaOH) to pH 8.3.At this pH all the free CO_2 is converted into bicarbonates.100 ml of sample was taken and a few drops of phenolphthalein indicator was added. If color turns pink, free CO_2 is absent. If the sample remains colorless, it was titrated against 0.05 N NaOH. At the end point a pink color appeared. It is calculated by the following equation (APHA, 1995).

$$\text{Free } CO_2 \text{ (mg/L)} = \frac{\text{(ml x N) of NaOH x 1000 x 44}}{\text{ml of sample}}$$

Where, N= Normality

7. Alkalinity:

For the determination of alkalinity, 100 ml of sample was taken and added 2 drops of phenolphthalein indicator. When the solution remained colourless, Phenolphthalein Alkalinity (PA) is zero. When the colour changed to pink after addition of phenolphthalein, titrated it with 0.1N HCl until the colour disappeared at end point. This is PA. Then 2-3 drops of methyl orange was added to the same sample and continued the titration further until the yellow colour changed to pink at end point. This is total alkalinity (TA) (APHA, 1995; Trivedi and Goel, 1986). They are calculated by the following equations:

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PA as $CaCO_3$, mg/L = $\frac{\text{(A x Normality) of HCl x 1000 x 50}}{\text{ml of sample}}$

TA as $CaCO_3$, mg/L = $\frac{\text{(B x Normality) of HCl x 1000 x 50}}{\text{ml of sample}}$

Where, A = ml of HCl used with only phenolphthalein

B= ml of total HCl used with phenolphthalein and methyl orange

PA = Phenolphthalein alkalinity

8. Hardness:

For the determination of hardness, 50 ml of sample was taken. If sample is having higher calcium, a smaller volume should be taken and diluted to 50 ml. Then 1 ml of buffer solution was added. If the sample is having higher amounts of heavy metals, 1 ml of Na_2S should be added. But in this study heavy metals were not studied. 100-200 mg of Erichrome Black T indicator was added, the solution turns wine red. The contents was titrated against the EDTA solution, at the end color changes from wine red to blue. The hardness is calculated by the following equation. (APHA, 1995; Trivedi and Goel, 1986).

Hardness (EDTA) as mg $CaCO_3$ /L = $\frac{\text{ml EDTA used x B x 1000}}{\text{ml of sample}}$

$= \frac{\text{ml EDTA used x 1000}}{\text{ml of sample}}$

Where, B = mg $CaCO_3$ equivalent to 1.00 ml of 0.01 M EDTA = 1

9. Calcium:

For the determination of calcium, 50 ml of sample was taken. If the sample is having higher calcium, smaller volumes diluted upto50 ml should be used. 2 ml of NaOH solution was added in the solution and 100-200 mg of murexide indicator was added; a

pink color developed and titrated against EDTA solution (0.01 M) until the pink color changes to purple. For better judgment of end point, the purple color should be compared with the distilled water blank titration end point. It is calculated by the following equation (APHA, 1995).

$$\text{Calcium (mg/L)} = \frac{\text{ml of EDTA used x B x 400.8}}{\text{ml of sample}}$$

$$\text{Calcium hardness as mg } CaCO_3\text{/L} = \frac{\text{ml of EDTA used x B x 1000}}{\text{ml of sample}}$$

Where, B = mg $CaCO_3$ equivalent to 1.00 ml of 0.01 M EDTA at calcium indicator end point = 1

10. Magnesium:

Magnesium can be estimated as the difference between hardness and calcium as $CaCO_3$, if interfering metals are present in non interfering concentrations in the calcium titration. It is calculated by the following equation (APHA, 1995).

$$\text{Mg (mg/L)} = [\text{Hardness (as mg } CaCO_3\text{/L)} - \text{Calcium hardness (as mg } CaCO_3\text{/L)}] \times 0.243$$

11. Chloride:

To determine chloride, 50 ml of sample was taken and 2 ml of potassium chromate (K_2CrO_4) solution was added .Then the contents was titrated against 0.02 N silver nitrate ($AgNO_3$) until a persistent red tinge appears. It is calculated by the following equation (Trivedi and Goel, 1986).

$$\text{Chloride (mg/L)} = \frac{\text{(ml x N) of } AgNO_3 \text{ x 1000 x 35.5}}{\text{ml of sample}}$$

12. Nitrate - Nitrogen:

Nitrate was determined by phenol disulphonic acid method. The standard calibration curve containing concentration and absorbance was prepared as follows. For this 0.722 gm of potassium nitrate (KNO_3) was dissolved in distilled water to make up the volume to 1 liter. This solution contained 100mg N/L. It was diluted to 100 times to prepare a solution having 1 mg N/L. From this standard nitrate solution, a different dilution from 0.1 mg N/L to 1.0 mg N/L at the interval of 0.1 was prepared. Absorbance of these diluted standard solutions was determined following the same procedure as for the sample. Using concentrations and their respective absorbance, a standard calibration curve was prepared (APHA, 1995; Trivedi and Goel, 1986).

Sample measurement

50 ml of sample containing not more than 1 mg/L of NO_3-N was taken in a conical flask. Then an equivalent amount of silver sulphate solution was added to remove chlorides. It was then heated slightly and the precipitate of silver chloride (AgCl) was filtered. Then the filtrate in the porcelain basin was evaporated to dryness. It was then cooled & the residue was dissolved in 2 ml phenol disulphonic acid and diluted to 50 ml. Then 6 ml of liquid ammonia was added which developed yellow colour. Similar process was done for blank distilled water. Then the absorbance was noted in spectrophotometer of model 7225 at 410nm (Trivedi and Goel, 1986).

13. Orthophosphates*:*

Orthophosphate can be calorimetrically determined by stannous chloride method which is more suited for the range of 0.01 to 6 mg P/L. (APHA, 1995). The standard calibration Curve containing concentration and absorbance was prepared as follows. For this, 4.388 grams of dried anhydrous potassium hydrogen phosphate (KH_2PO_4) was dissolved in distilled water to make up a volume of 1 liter. The solution was diluted to 100 times to make the standard solution containing 10 mg P/L i.e. 1 ml = 0.01 mg P. From the standard phosphate solution, various dilutions at the interval of 0.1 mg P/L were made. Absorbance of these diluted standard solutions was determined following the same

procedure as for the sample. Using concentrations and their respective absorbance, a standard calibration curve was prepared (APHA, 1995; Trivedi and Goel, 1986).

Sample measurement

50 ml of filtered water sample was taken in a volumetric flask. If the water sample contains colloidal impurities& colour, they can be removed by the addition of activated charcoal and then filtering the water sample. Then, 2 ml of ammonium molybdate was added to the water sample which was followed by 5 drops of stannous chloride. A blue colour appeared. Reading was taken at 690 nm in spectrophotometer of model 7225 using a distilled water blank with the same amount of chemicals. The absorbance was noted after blue colour fully developed after 10 minutes but before 12 minutes of the addition of the latest reagent. Then the concentration of sample was directly found out by plotting the absorbance of the sample against the standard curve prepared earlier. (APHA, 1995; Trivedi and Goel, 1986).

14. Iron:

Iron contained in the water sample was determined by Phenonthroline method (APHA, 1995). The standard calibration Curve containing concentration and absorbance was prepared as follows. For this, Stock Iron solution was prepared by dissolving the calculated amount of Ferrous Ammonium Sulphate in distilled water. Standard Iron solutions ranging from 1 to 4 mg/L of iron were prepared. Absorbance of these diluted standard solutions was determined following the same procedure as for the sample. Using concentrations and their respective absorbance, a standard calibration curve was prepared (APHA, 1995; Trivedi and Goel, 1986).

Sample measurement

50 ml of the water sample was taken in a conical flask and added 2 ml conc. HCl and 1 ml of hydroxylamine hydrochloric solution. The contents were boiled to half of the volume for dissolution of all the iron. It was cooled and added 10 ml ammonium acetate buffer and 2 ml phenonthroline solution. If the sample contains interference of heavy metals, 10 ml of phenonthroline instead 2 ml should be added. An orange-red colour

appeared and made the volume to 100 ml by adding distilled water in a volumetric flask. The absorbance was recorded in spectrophotometer of model 7225 using a distilled water blank with the same amount of chemicals at 510 nm. Then the concentration of sample was directly found out by plotting the absorbance of the sample against the standard curve prepared earlier. (APHA, 1995; Trivedi and Goel, 1986).

5.3.3 Methods of analysis of Microbial Parameters

5.3.3.1. Membrane Filter Method:

In Membrane Filter Method, a water sample is passed through a thin sterile membrane filter (pore size 0.45µm) which is kept in a special filter apparatus contained in a suction flask. The filter disc that contained the trapped microorganisms is aseptically transferred to a sterile Petri dish having an absorbent pad saturated with a selective, differential liquid medium and the colonies which develop following incubation are counted. This method enables a large volume of water to be tested more economically, results obtained are more accurate and are obtained more quickly than by the multiple tube technique.

Procedure:

1. First of all filter holder with stopper was assembled, sterile on the filter flask.
2. Using sterile blunt- edged forceps, a sterile membrane filter of pore size 0.45 µm (grid side up) was placed over the porous disc in such a way that it overlapped the entire circumference of sintered filterable area.
3. The sterile funnel was secured placed on the filter base.
4. The sample of water was well mixed by inverting the bottle several times and then the 100 ml of the water sample was poured into the funnel.
5. The sample was slowly filtered under partial vacuum by using electric vacuum pump.
6. The funnel was removed and the membrane was directly transferred, keeping its upper side upwards, on to a plate of M- Endo agar with the help of sterile forceps. Care was taken not to entrap air bubbles between the membrane and the medium.
7. Then it was incubated at 45.5 ^{0}C for 24 hours in inverted position.

8. After proper incubation total colony forming unit (CFU) were counted. For this, all sheen producing colonies were counted.

5.3.3.2. Most Probable Number Method (MPN):

The test was performed sequentially in 3 stages: Presumptive, Confirmed and Completed tests.

a) Presumptive Test:

Procedure:

1. 5 double strength lactose broth tubes, 5 single strength lactose broth tubes and other 5 Single strength lactose broth tubes were labeled as 10 ml, 1.0 ml and 0.1 ml respectively.
2. 10 ml tubes were aseptically inoculated with 10 ml of water sample using sterile pipette.
3. 1.0 ml tubes were aseptically inoculated with 1 ml of water sample using sterile pipette.
4. 0.1 ml tubes were aseptically inoculated with 0.1 ml of water sample using sterile pipette.
5. All these 15 inoculated tubes were incubated at 35 ^{0}C for 48 hours.
6. After 48 hours of incubation all the tubes were examined for the production of acid (yellow colour) and gas formation.

b) Confirmed Test:

Procedure:

1. Brilliant green lactose broth tubes were inoculated from all positive presumptive tubes.
2. Inoculated tubes were incubated at 35 ^{0}C for 48 hours.
3. After 48 hours of incubation all the tubes were examined for the gas production.

C) Completed Test:

Procedure:

1. EMB agar plates were streaked from all positive confirmed tubes with the inoculating loop.
2. The inoculated tubes were incubated at 35 ^{0}Cfor 24 hours in inverted position.
3. The plates were observed after 24 hours for coliform colonies.
4. Brilliant green lactose broth tubes and nutrient agar slant were inoculated with the coliform culture from the EMB agar plates.
5. Broth tubes and agar slants were incubated at 35 ^{0}C for 24 hours.
6. Broth tubes were observed for the production of the gas.
7. Organisms found on the slant were gram stained and observed the slide for the positive or negative gram reaction and cell morphology.

5.4 Statistical analysis

5.4.1 Hypotheses

The hypotheses, null hypothesis (H_0) and alternative hypothesis (H_A) of the present study are as follows:

a. H_0: There is no significant difference in the physico- chemical features of the well water at different months of the investigation period.

   H_A: There is significant difference in the physico- chemical features of the well water at different months of the investigation period.

b. H_0: There is no significant difference in the physico- chemical features of the well water in different sites of the investigation period.

   H_A: There is significant difference in the physico- chemical features of the well water in different sites of the investigation period.

CHAPTER SIX

6. RESULTS

6.1 Physico-chemical features

6.1.1 Water temperature

The seasonal variation of water temperature of the wells over the period of eight months (2006) are shown in the Figure 1.

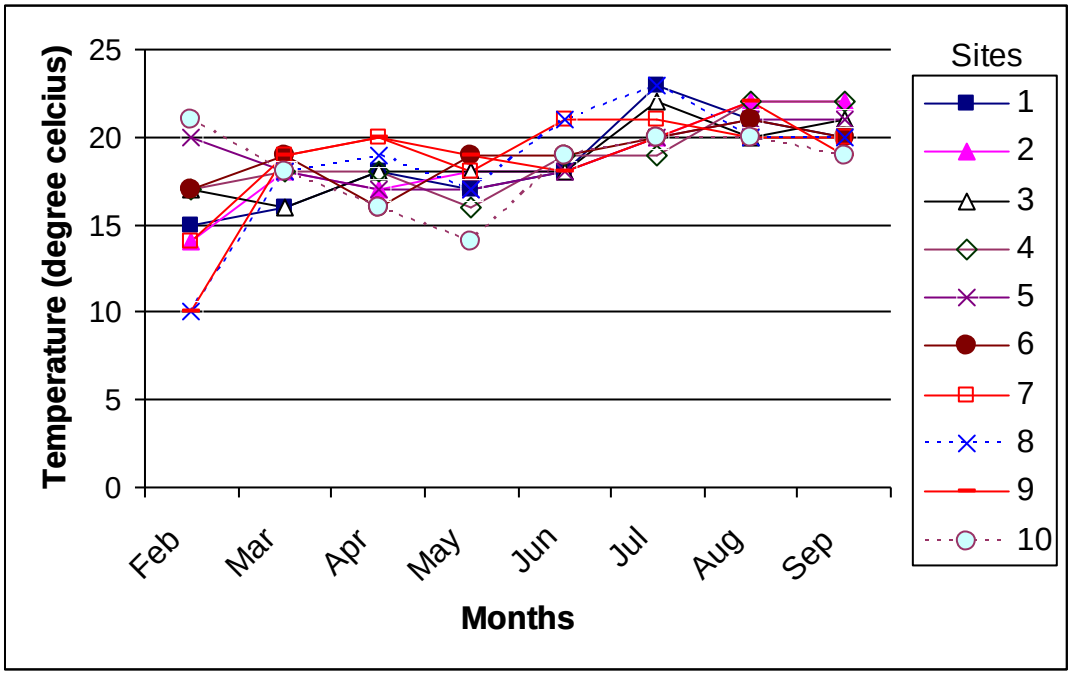

Figure 1.1: Seasonal variation of water temperature of the wells (1-10) over the period of eight months (2006)

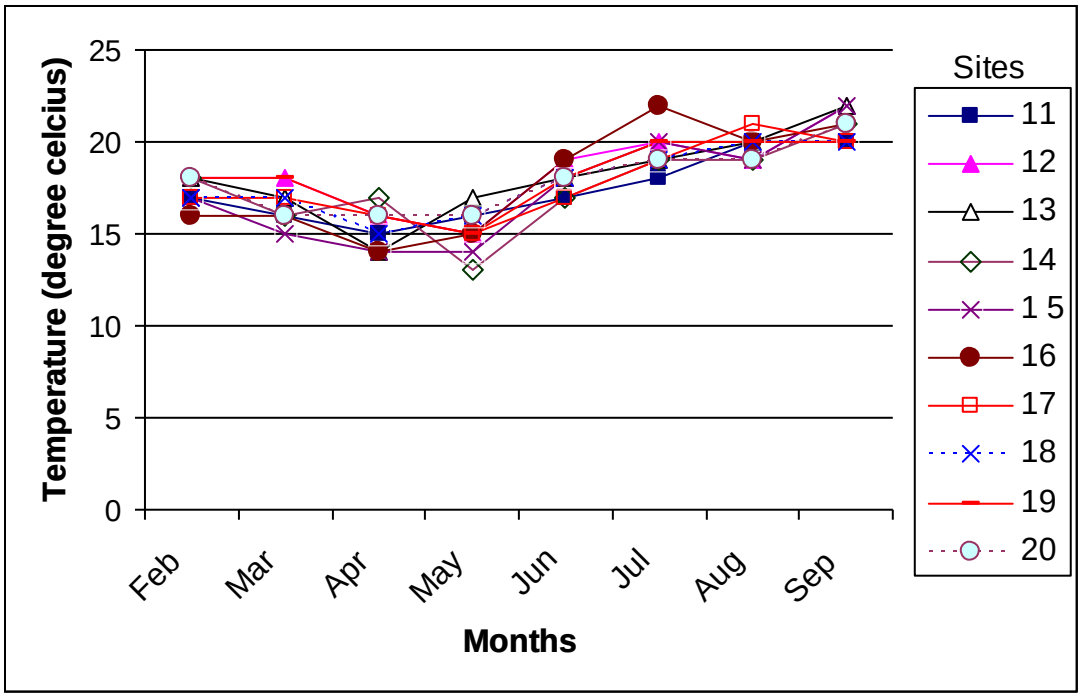

Figure 3.2: Seasonal variation of water temperature of the wells (11-20) over the period of eight months (2006)

The water temperature was found minimum in the month February in the most sites, increased and reached maximum in the month July. Water temperature fluctuated in the months August and September .Water temperature fluctuated in few sites.

The minimum temperature were recorded as 15 ^{0}C in February (site 1), 14 ^{0}C in February (site 2), 16 ^{0}C in March (site 3), 16 ^{0}C in May (site 4), 17 ^{0}C in May (site 5), 16 ^{0}C in April (site 6), 14 ^{0}C in February (site 7), 10 ^{0}C in February (site 8 & 9), 14 ^{0}C in May (site 10), 15 ^{0}C in April (site 11), 15 ^{0}C in May (site 12), 14 ^{0}C in April (site 13), 13 ^{0}C in May (site 14), 14 ^{0}C in April (site 15 & 16), 15 ^{0}C in May (site 17 & 19), 15 ^{0}C in April (site 18) and 16 ^{0}C in May (site 20).

The maximum temperature were recorded as 23 ^{0}C in July (site 1), 22 ^{0}C in August (site 2), 22 ^{0}C in July (site 3), 22 ^{0}C in August (site 4), 21 ^{0}C in August (site 5 & 6), 21 ^{0}C in June (site 7), 23 ^{0}C in July (site 8), 22 ^{0}C in August (site 9), 21 ^{0}C in February (site 10), 20 ^{0}C in August (site 11), 22 ^{0}C in September (site 12 & 13), 21 ^{0}C in September (site

14), 22 ^{0}C in September (site 15), 22 ^{0}C in July (site 16), 21 ^{0}C in August (site 17), 20 ^{0}C in August (site 18 & 19) and 21^{0}C in September (site 20).

The monthly variation of temperature of the well water is significant at 0.05 and 0.01 probability level (F = 29.830, d.f. = 159). But the spatial variation of temperature of the well water is not significant at 0.05 and 0.01 probability level (F =0.614, d.f. = 159).

On the average, water temperature were recorded as 19 ± 2.7 ^{0}C at site 1 & 2; 19 ± 2.1^{0}C at site 3; 19 ± 2.2 ^{0}C at site 4; 19 ± 1.69 ^{0}C at site 5; 18.9 ± 1.64 ^{0}C at site 6; 19 ± 2.3 ^{0}C at site 7; 19 ± 3.9 ^{0}C at site 8; 18.4 ± 3.58 ^{0}C at site 9; 19 ± 2.33 ^{0}C at site 10; 17.4 ± 1.85 ^{0}C at site 11; 18.4 ± 2.2 ^{0}C at site 12; 18.1 ± 2.36 ^{0}C at site 13; 17.5 ± 2.39 ^{0}C at site 14; 17 ± 2.9 ^{0}C at site 15; 18 ± 3 ^{0}C at site 16; 17.75 ± 2.05 ^{0}C at site 17; 18 ± 1.8 ^{0}C at site 18; 18 ± 1.9 ^{0}C at site 19 and 17.88 ± 1.80 ^{0}C at site 20 over the eight months of the present investigation period.

The amplitudes of water temperature variation over the eight months during the investigation period were 8 ^{0}C, 8 ^{0}C, 6 ^{0}C, 6 ^{0}C, 4 ^{0}C, 5 ^{0}C, 7 ^{0}C, 13 ^{0}C, 12 ^{0}C, 7 ^{0}C, 5 ^{0}C, 7 ^{0}C, 8 ^{0}C, 8 ^{0}C, 8 ^{0}C, 8 ^{0}C, 6 ^{0}C, 5 ^{0}C, 5 ^{0}C and 5 ^{0}C at sites 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19 and 20 respectively

6.1.2 pH

The seasonal variation of pH of the well water over the period of eight months (2006) are shown in the Figure 4.

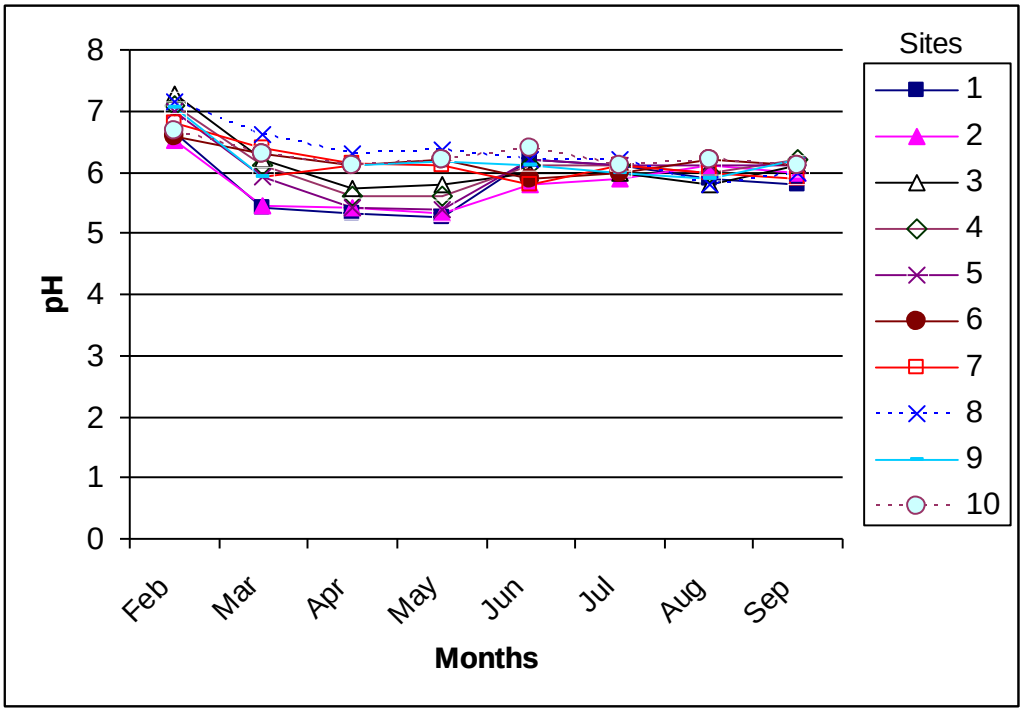

Figure 4.1: Seasonal variation of pH of well water (1-10) over the period of eight months (2006)

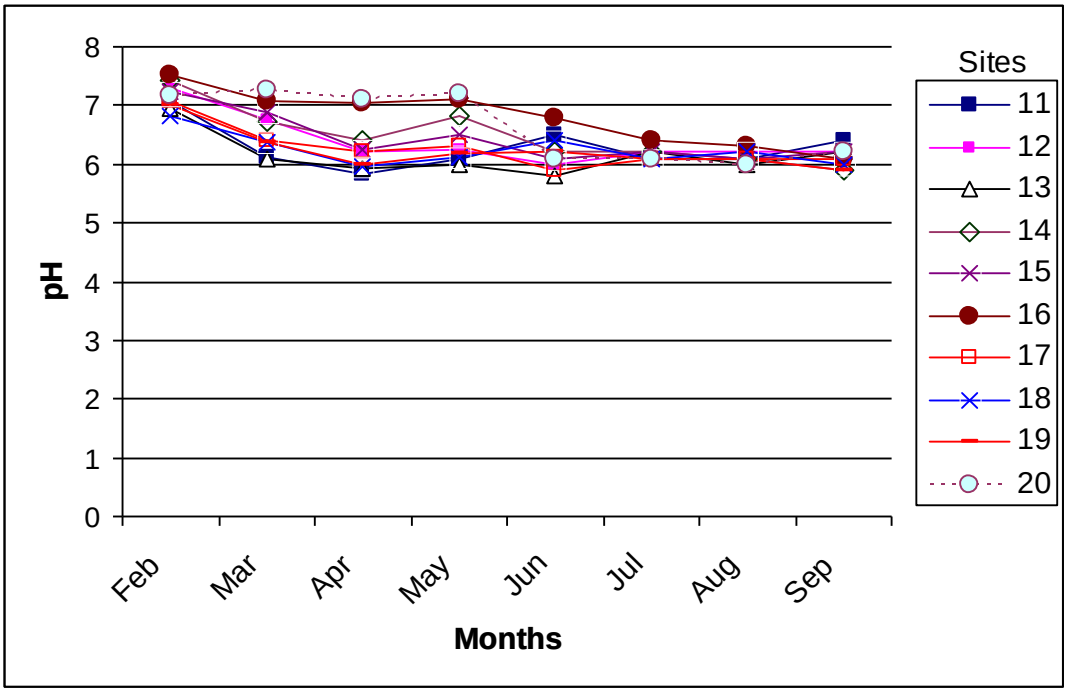

Figure 4.1: Seasonal variation of pH of well water (1-10) over the period of eight months (2006)

The minimum pH were recorded as 5.27 in May (site 1), 5.31 in May (site 2), 5.72 in April (site 3), 5.6 in April (site 4), 5.38 in May (site 5), 5.9 in June (site 6), 5.8 in June (site 7), 5.8 in August (site 8), 5.9 in August (site 9), 6.1 in September (site 10),5.82 in April (site 11), 6 in June (site 12), 5.8 in June (site 13), 5.9 in September (site 14), 6.1 in June (site 15), 6.1 in September (site 16), 5.9 in June (site 17), 6 in April (site 18), 5.9 in September (site 19) and 6 in August (site 20).

The pH was found maximum in the month February. The maximum pH were recorded as 6.64 (site 1), 6.52 (site 2), 7.26 (site 3), 7.1 (site 4), 7 (site 5), 6.58 (site 6), 6.79 (site 7), 7.15 (site 8), 7.06 (site 9), 6.67 (site 10), 7.08 (site 11), 7.3 (site 12), 6.95 (site 13), 7.43 (site 14), 7.3 (site 15), 7.53 (site 16), 7.09 (site 17), 6.8 (site 18), 7 (site 19), and 7.27 (site 20).

The monthly variation of pH of the well water is significant at 0.05 and 0.01 probability level ($F = 18.637$, d.f. = 159). The spatial variation of pH of the well water is significant at 0.05 and 0.01 probability level ($F = 2.621$, d.f. = 159).

On the average, pH were recorded as 5.83 ± 0.48 at site 1, 5.81 ± 0.41 at site 2, 6.11 ± 0.49 at site 3, 6.1 ± 0.46 at site 4, 6.03 ± 0.51 at site 5, 6.17 ± 0.21 at site 6, 6.16 ± 0.31 at site 7, 6.33 ± 0.41 at site 8, 6.18 ± 0.37 at site 9, 6.26 ± 0.19 at site 10, 6.28 ± 0.38 at site 11, 6.4 ± 0.4 at site 12, 6.15 ± 0.35 at site 13, 6.47 ± 0.49 at site 14, 6.4 ± 0.19 at site 15, 6.79 ± 0.49 at site 16, 6.28 ± 0.36 at site 17, 6.2 ± 0.3 at site 18 & 19 and 6.64 ± 0.59 at site 20 over the eight months of the present investigation period.

The amplitudes of pH variation over the eight months during the investigation period were 1.37, 1.21, 1.54, 1.5, 1.62, 0.68, 0.99, 1.35, 1.16, 0.57, 1.26, 1.3, 1.15, 1.53, 1.2, 1.43, 1.19, 0.9, 1.1 & 1.27 at sites 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19 and 20 respectively.

6.1.3. Dissolved Oxygen

The seasonal variation of dissolved oxygen (DO) of the well water over the period of eight months (2006) are shown in the Figure 5.

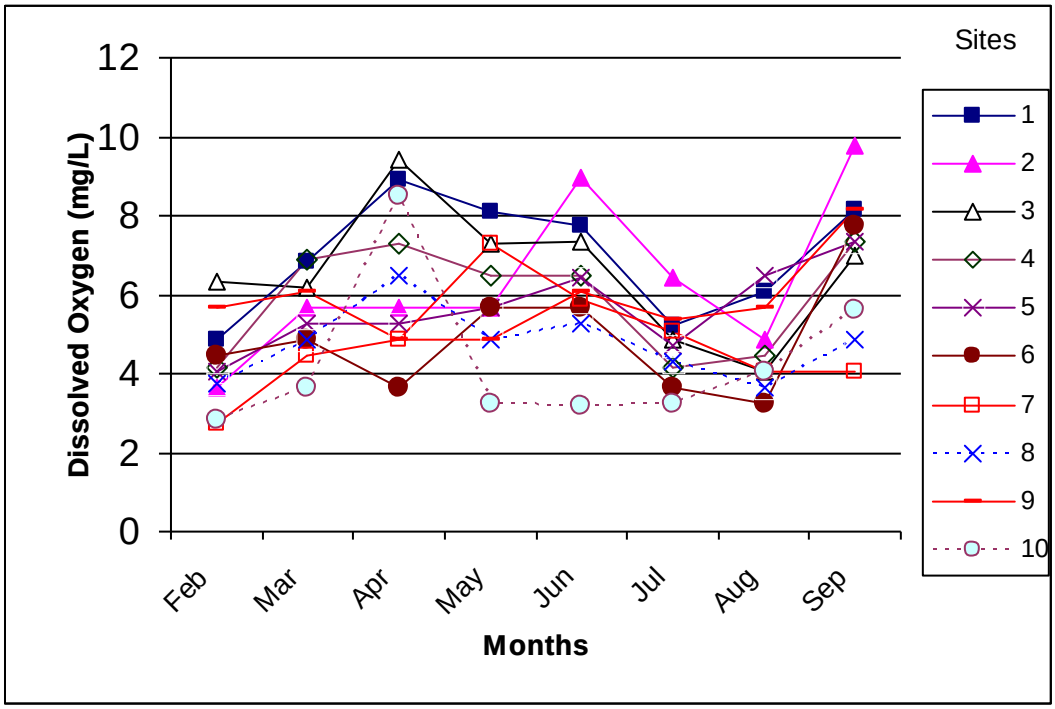

Figure 5.1: Seasonal variation of Dissolved oxygen (DO) of the wells (1-10) over the period of eight months (2006)

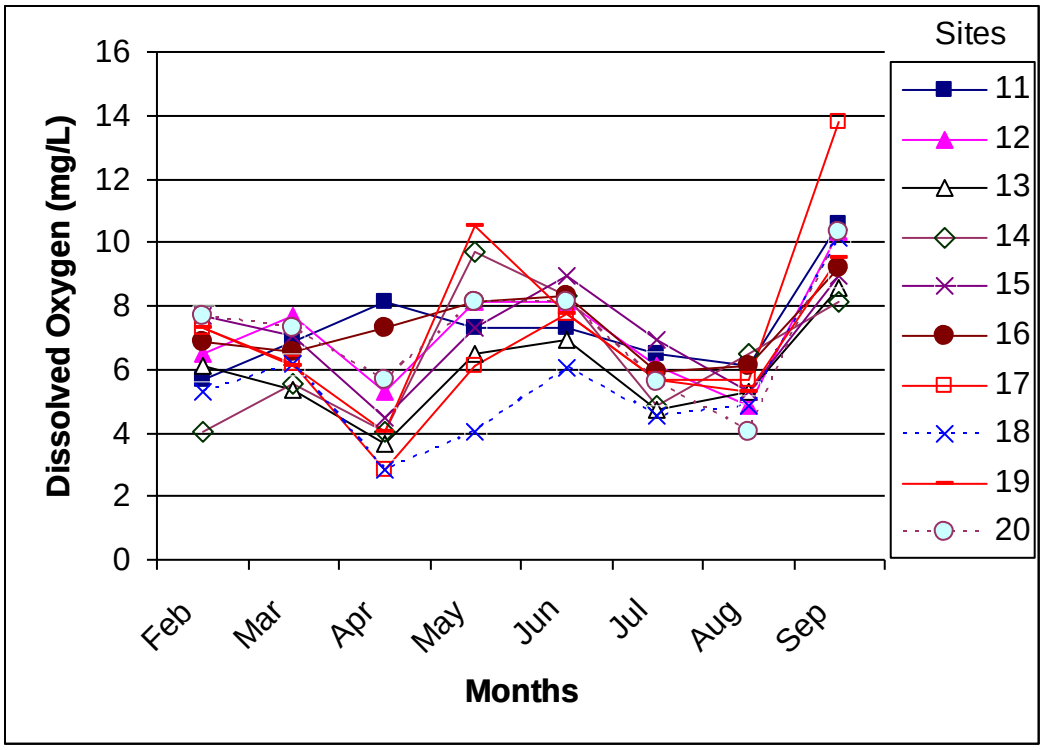

Figure 5.2: Seasonal variation of Dissolved oxygen (DO) of the wells (11-20) over the period of eight months (2006).

The minimum DO were calculated as 4.86 mg/L in February (site 1), 3.63 mg/L in February (site 2), 4.1 mg/L in August (site 3), 4.13 mg/L in February (site 4), 4.05 mg/L in February (site 5), 3.2 mg/L in August (site 6), 2.8 mg/L in February (site 7), 3.6 mg/L in August (site 8), 4.9 mg/L in May (site 9), 2.83 mg/L in February (site 10), 5.67 mg/L in February (site 11), 4.68 mg/L in August (site 12), 3.6 mg/L in April (site 13), 4.05 mg/L in February (site 14), 4.46 mg/L in April (site 15), 5.93 mg/L in July (site 16), 2.84 mg/L in April (site 17 & 18), 4.05 mg/L in April (site 19) and 4.05 mg/L in August (site 20).

The maximum DO were calculated as 8.92 mg/L in April (site 1), 9.76 mg/L in September (site 2), 9.4 mg/L in April (site 3), 7.32 mg/L in September (site 4 & 5), 7.7 mg/L in September (site 6), 7.3 mg/L in May (site 7), 6.5 mg/L in April (site 8), 8.1 mg/L in September (site 9), 8.51 mg/L in April (site 10), 10.6 mg/L September (site 11), 10.3 mg/L in September (site 12), 8.5 mg/L September (site 13), 9.73 mg/L in May (site 14),

8.94 mg/L in September (site 15), 9.19 mg/L in September (site 16), 13.8 mg/L in September (site 17), 10.2 mg/L in September (site 18), 10.5 mg/L in May (site 19) and 10.3 mg/L in September (site 20).

The monthly variation of DO of the well water is significant at 0.05 and 0.01 probability level (F = 11.184, d.f. = 159). The spatial variation of DO of the well water is significant at 0.05 and 0.01 probability level (F =2.397, d.f. = 159).

On the average, DO were calculated as 6.98 ± 1.48 mg/L at site 1, 6.33 ± 2.05 mg/L at site 2, 6.6 ± 1.6 mg/L at site 3, 5.9 ± 1.41 mg/L at site 4, 5.65 ± 1.06 mg/L at site 5, 4.9 ± 1.5 mg/L at site 6, 4.8 ± 1.4 mg/L at site 7, 4.8 ± 0.9 mg/L at site 8, 5.8 ± 1 mg/L at site 9, 4.29 ± 0.9 mg/L at site 10, 7.3 ± 1.53 mg/L at site 11, 7.12 ± 1.8 mg/L at site 12, 5.9 ± 1.5 mg/L at site 13, 6.39 ± 2.13 mg/L at site 14, 7.07 ± 1.58 mg/L at site 15, 7.29 ± 1.15 mg/L at site 16, 6.91 ± 3.15 mg/L at site 17, 5.49 ± 2.17 mg/L at site 18, 7.02 ± 2.19 mg/L at site 19 and 7.11 ± 1.94 mg/L at site 20 over the eight months of the present investigation period.

The amplitudes of DO variation over the eight months during the investigation period were 4.06 mg/L, 6.13 mg/L, 5.4 mg/L, 3.19 mg/L, 3.27 mg/L, 4.5 mg/L, 4.5 mg/L, 2.8 mg/L, 3.3 mg/L, 5.68 mg/L, 4.9 mg/L, 5.46 mg/L, 4.9 mg/L, 5.68 mg/L, 4.48 mg/L, 3.25 mg/L, 11 mg/L, 7.32 mg/L, 6.49 mg/L & 6.27 mg/L at sites 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19 and 20 respectively.

6.1.4 Free carbondioxide (CO_2)

The seasonal variation of free CO_2 of the well water over the period of eight months (2006) are shown in the Figure 6.

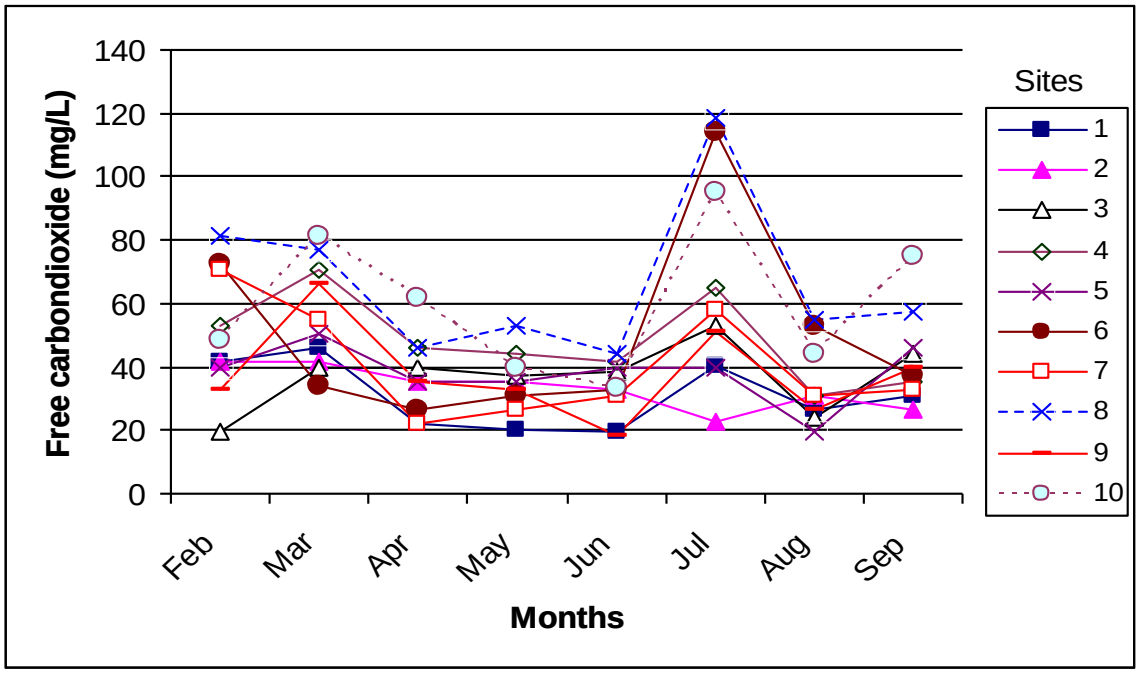

Figure 6.1: Seasonal variation of Free Carbon dioxide of the wells (1-10) over the period of eight months (2006)

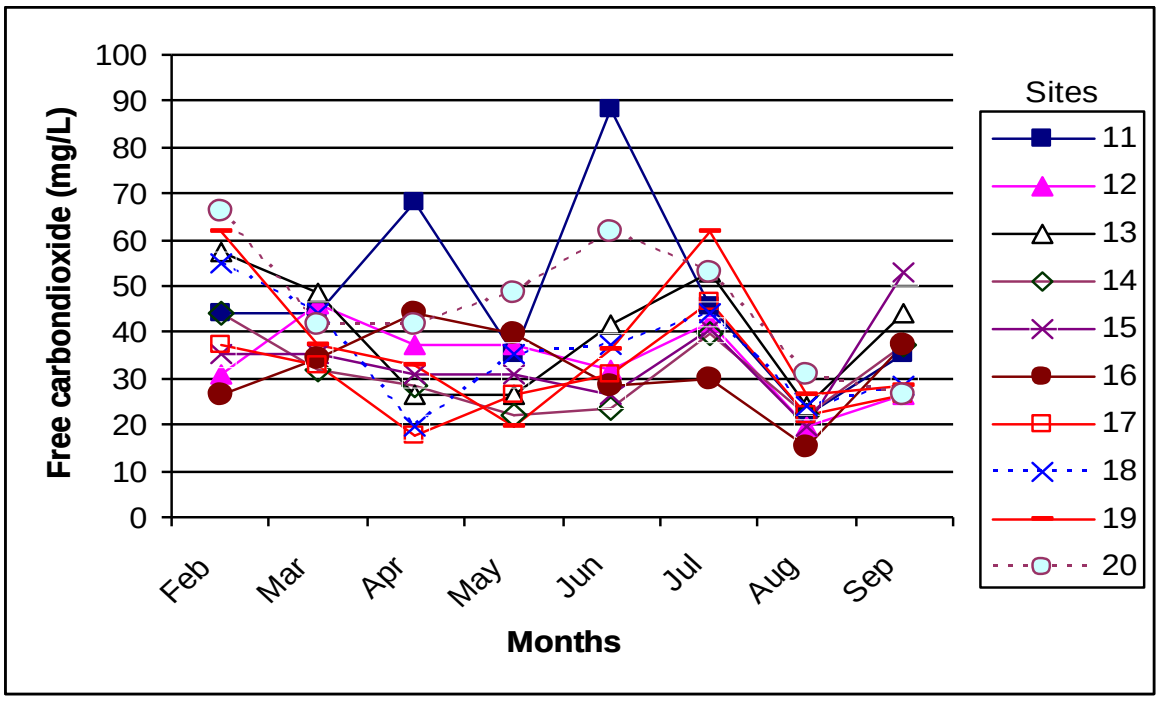

Figure 6.2: Seasonal variation of Free Carbon dioxide of the wells (11-20) over the period of eight months (2006).

The minimum free CO_2 were calculated as 19.8 mg/L in June (site 1), 22.9 mg/L in July (site 2), 19.8 mg/L in February (site 3), 30.8 mg/L in August (site 4), 19.8 mg/L in August (site 5), 26.4 mg/L in April (site 6), 22 mg/L in April (site 7), 44 mg/L in June (site 8), 18.5 mg/L in June (site 9), 33.4 mg/L in June (site 10), 22 mg/L in August (site11), 19.8 mg/L in August (site12), 24.2 mg/L in August (site13), 22 mg/L in August (site14), 19.8 mg/L in August (site15), 15 mg/L in August (site16), 17.6 mg/L in April (site17), 20 mg/L in April (site18), 19.8 mg/L in May (site 19) and 26 mg/L in September(site 20).

The maximum free CO_2 were calculated as 46.2 mg/L in March (site1), 41.8 mg/L in March (site2), 52.8 mg/L in July (Site 3), 70.4 mg/L in March (site4), 50.6 mg/L in March (site5), 114 mg/L in July (Site6), 70.4 mg/L in February (site 7), 119 mg/L in July (Site8), 66 mg/L in March (site9), 95 mg/L in July (Site10), 88 mg/L in June (site 11), 46.2 mg/L in March (site12), 57.2 mg/L in February (site13), 44 mg/L in February (site14), 52.8 in September (site 15), 44 mg/L in February (site16), 46.6 mg/L in July (Site17), 55 mg/L in February (site18), 61.6 mg/L in February (site19) and 66 mg/L in February (site20).

The monthly variation of free CO_2 of the well water is significant at 0.05 and 0.01 probability level ($F = 6.911$, d.f. = 159). The spatial variation of free CO_2 of the well water is significant at 0.05 and 0.01 probability level ($F = 3.319$, d.f. = 159).

On the average, free CO_2 were calculated as 27.6 ± 10.6 mg/L at site 1, 29.9 ± 6.7 mg/L at site 2, 33.2 ± 10.5 mg/L at site 3, 43.4 ± 13.8 mg/L at site 4, 34.53 ± 9.1 mg/L at site 5, 45.2 ± 30 mg/L at site 6, 37.1 ± 17.7 mg/L at site 7, 60 ± 25 mg/L at site8, 34.6 ± 14.8 mg/L at site 9, 54.3 ± 22.1 mg/L at site 10, 47.8 ± 22.9 mg/L at site 11, 34.0 ± 8.58 mg/L at site 12, 40.2 ± 12.9 mg/L at site 13, 31 ± 8.5 mg/L at site 14, 33.9 ± 9.84 mg/L at site 15, 32.0 ± 9.8 mg/L at site 16, 30.1 ± 9.14 mg/L at site 17, 36.0 ± 12.0 mg/L at site 18, 38.1 ± 15.6 mg/L at site 19 and 46.0 ± 14 mg/L at site 20 over the eight months of the present investigation period.

The amplitudes of CO_2 variation over the eight months during the investigation period were 26.4 mg/L, 18.9 mg/L, 33 mg/L, 39.6 mg/L, 30.8 mg/L, 88 mg/L, 48.4 mg/L, 74.8 mg/L, 47.5 mg/L, 61.6 mg/L, 66 mg/L, 26.4 mg/L, 33 mg/L, 22 mg/L, 33 mg/L, 29 mg/L, 29 mg/L, 35 mg/L, 41.8 mg/L & 40 mg/L at sites 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19 and 20 respectively.

6.1.5 Total alkalinity

The seasonal variation of total alkalinity of the well water over the period of eight months (2006) is shown in the Figure 7.

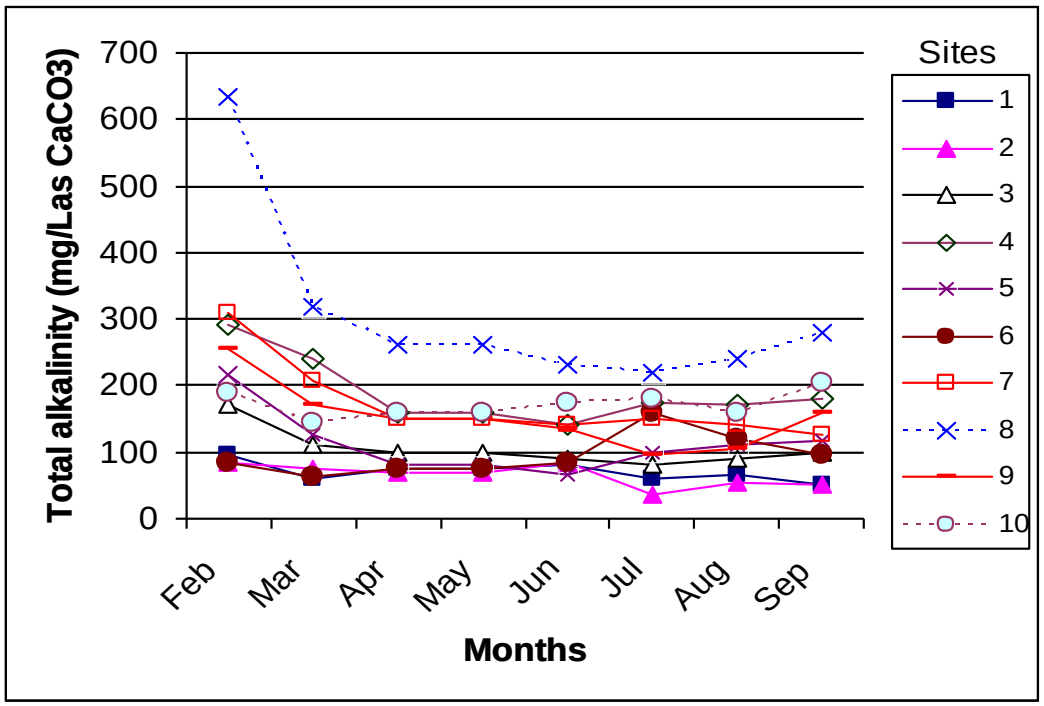

Figure 7.1: Seasonal variation of Total alkalinity of the wells (1-10) over the period of eight months (2006)

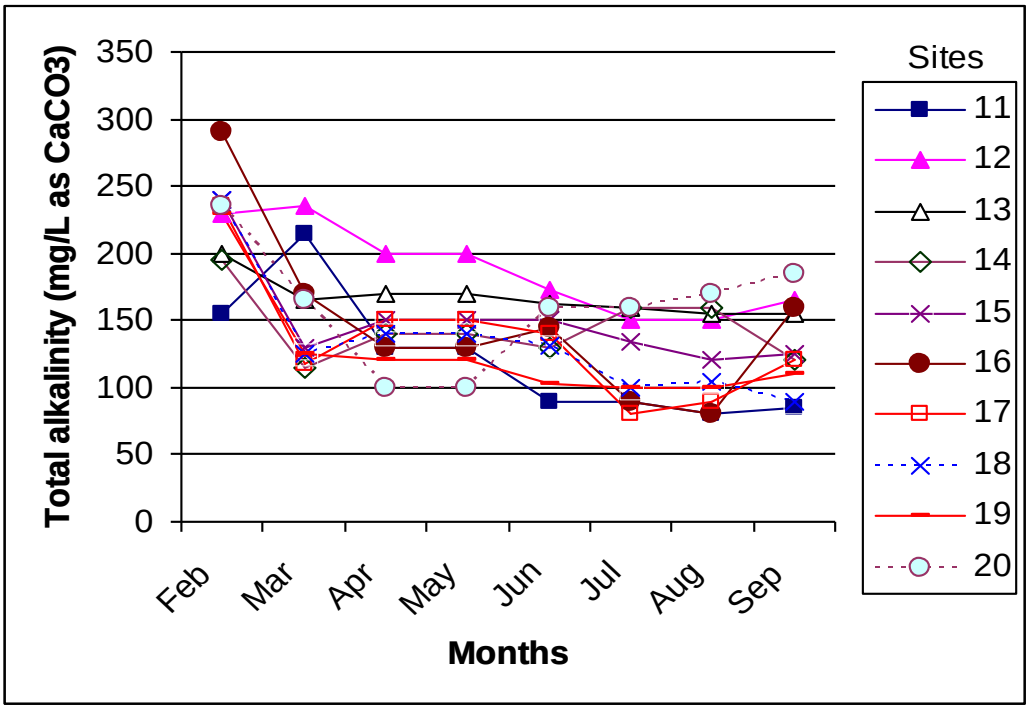

Figure 7.2: Seasonal variation of Total alkalinity of the wells (11-20) over the period of eight months (2006).

The minimum total alkalinity were calculated as 50 mg/L in September (site 1), 35 mg/L in July (site 2), 81 mg/L in July (site3), 140 mg/L in June (site4), 65 mg/L in June (site5), 62.5 mg/L in March (site 6), 125 mg/L in September (site7), 220 mg/L in July (site8), 95 mg/L in July (site9), 145 mg/L in March (site10), 80 mg/L in August (site 11), 150 mg/L in August (site 12), 155 mg/L in August (site 13), 115 mg/L in March (site14), 120 mg/L in August (site 15), 80 mg/L in August (site 16), 80 mg/L in July (site17), 90 mg/L in September (site18), 100 mg/L in July (site19) and 100mg/L in April (site 20).

The maximum total alkalinity was calculated in the month February in most sites except sites 6, 10, 11 and 12. The value were calculated as 98 mg/L (site1), 85 mg/L (site2), 170 mg/L (site3), 290 mg/L (site4), 215 mg/L (site5), 309 mg/L (site7), 635 mg/L (site8), 255 mg/L (site9), 200 mg/L (site13), 195 mg/L (site14), 240 mg/L (site15), 290 mg/L (site16), 235 mg/L (site17), 240 mg/L (site18), 230 mg/L (site19) 235 mg/L (site20), 160 mg/L in July (site6), 205 mg/L in September (site 10), 215 mg/L in March (site 11) and 235 mg/L in March (site 12).

The monthly variation of total alkalinity of the well water is significant at 0.05 and 0.01 probability level (F = 6.405, d.f. = 159). The spatial variation of total alkalinity of the well water is significant at 0.05 and 0.01 probability level (F =8.399, d.f. = 159).

On the average, total alkalinity were calculated as 70 ± 15 mg/L at site 1, 66 ± 17 mg/L at site 2, 105 ± 28 mg/L at site 3, 189 ± 50 mg/L at site 4, 112 ± 47 mg/L at site 5, 94.6 ± 31.5 mg/L at site 6, 171 ± 60.5 mg/L at site 7, 305.6 ± 136.5 mg/L at site 8, 153 ± 49 mg/L at site 9, 172 ± 19.4 mg/L at site 10, 122 ± 46 mg/L at site 11, 187.8 ± 33.6 mg/L at site 12, 167 ± 14.5 mg/L at site 13, 145 ± 26 mg/L at site 14, 150 ± 38.3 mg/L at site 15, 149 ± 64.8 mg/L at site 16, 135.3 ± 47.89 mg/L at site 17, 133.9 ± 46.8 mg/L at site 18, 126 ± 43.1 mg/L at site 19 and 159 ± 44 mg/L at site 20 over the eight months of the present investigation period.

The amplitudes of total alkalinity variation over the eight months during the investigation period were 48 mg/L, 50 mg/L, 89 mg/L, 150 mg/L, 150 mg/L, 97.5 mg/L, 184 mg/L, 415 mg/L, 160 mg/L, 60 mg/L,135 mg/L, 85 mg/L, 45 mg/L, 80 mg/L, 120 mg/L, 210 mg/L, 155 mg/L, 150 mg/L, 130 mg/L & 135 mg/L at sites 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19 and 20 respectively.

6.1.6 Total hardness

The seasonal variation of total hardness of the well water over the period of eight months (2006) is shown in the Figure 8.

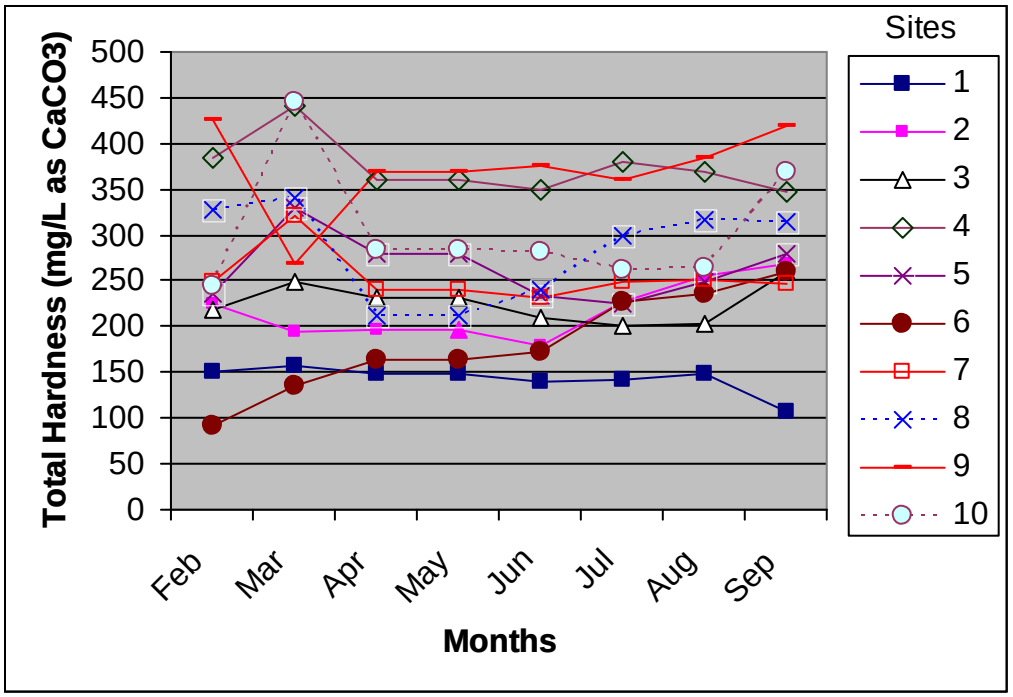

Figure 8.1: Seasonal variation of Total hardness of the wells (1-10) over the period of eight months (2006)

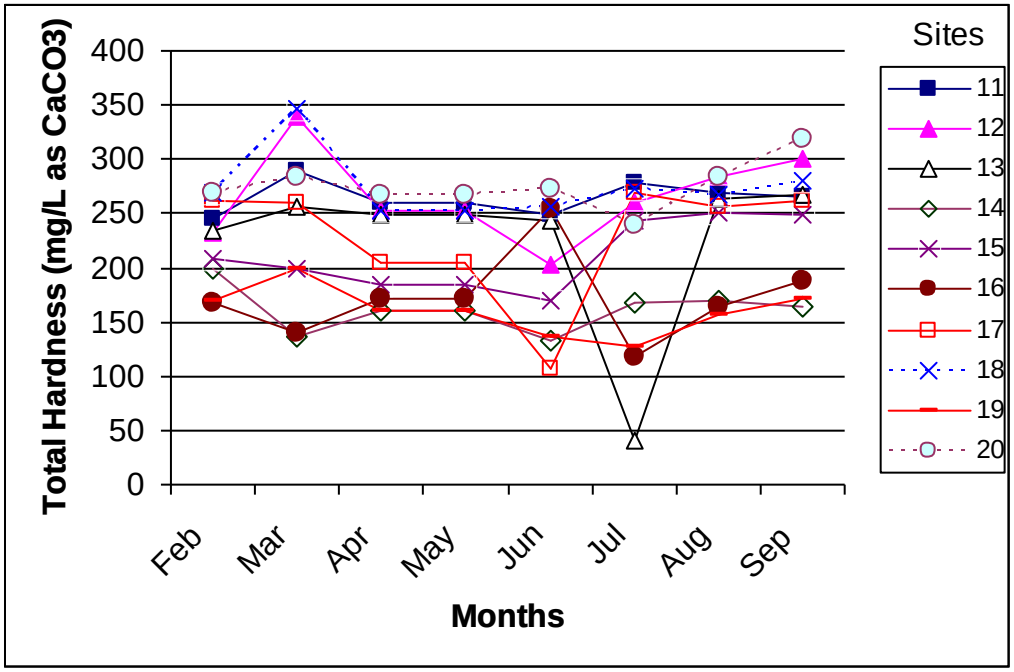

Figure 8.2: Seasonal variation of Total hardness of the wells (11-20) over the period of eight months (2006)

The minimum total hardness were calculated as 106 mg/L in September (site 1), 180 mg/L in June (site 2), 200 mg/L in July (site 3), 348 mg/L in September (site 4), 224 mg/L in July (site5), 92 mg/L in February (site 6), 232 mg/L in June (site 7), 212 mg/L in April (site 8), 268 mg/L in March (site 9), 244 mg/L in February (site 10), 246 mg/L in February (site 11), 202 mg/L in June (site 12), 40 mg/L in July (site 13), 132 mg/L in June (site 14), 170 mg/L in June (site 15), 118 mg/L in July (site 16), 106 mg/L in June (site 17), 252 mg/L in May (site 18), 128 mg/L in July (site 19) and 240 mg/L in July (site 20).

The maximum total hardness were calculated as 158 mg/L in March (site 1), 268 mg/L in September (site 2), 260 mg/L in September (site3), 440 mg/L in March (site 4), 330 mg/L in March (site5), 260 mg/L in September (site 6), 320 mg/L in March (site 7), 340 mg/L in March (site 8), 426 mg/L in February (site 9), 446 mg/L in March (site 10), 290 mg/L in March (site 11), 340 mg/L in March (site 12), 268 mg/L in September (site 13), 200 mg/L in September (site 14), 250 mg/L in August (site 15), 254 mg/L in June (site 16), 270 mg/L in July (site 17), 346 mg/L in March (site 18), 200 mg/L in March (site 19) and 318 mg/L in September (site 20).

The monthly variation of total hardness of the well water is not significant at 0.05 and 0.01 probability level ($F = 1.024$, d.f. = 159). The spatial variation of total hardness of the well water is significant at 0.05 and 0.01 probability level ($F = 20.515$, d.f. = 159).

On the average, total hardness were calculated as 143 ± 16 mg/L at site 1, 218 ± 32 mg/L at site2, 226 ± 21.7 mg/L at site3, 374 ± 30 mg/L at site 4 , 264 ± 35 mg/L at site 5, 181 ± 56 mg/L at site 6, 254 ± 28 mg/L at site 7, 283 ± 53 mg/L at site 8, 372 ± 48 mg/L at site 9, 305 ± 68 mg/L at site 10,265 ± 14.7 mg/L at site 11, 265 ± 42.5 mg/L at site 12, 225.3 ± 75.65 mg/L at site 13, 161.3 ± 21.14 mg/L at site 14, 211 ± 39.6 mg/L at site 15, 172 ± 39.6 mg/L at site 16, 228 ± 56 mg/L at site 17, 275 ± 31 mg/L at site 18, 160 ± 22.2 mg/L at site 19 and 276 ± 21.9 mg/L at site 20 over the eight months of the present investigation period.

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The amplitudes of total hardness variation over the eight months during the investigation period were 52 mg/L, 88 mg/L, 60 mg/L, 92 mg/L, 106 mg/L, 168 mg/L, 88 mg/L, 128 mg/L, 158 mg/L, 202 mg/L, 44 mg/L, 138 mg/L, 228 mg/L, 68 mg/L, 80 mg/L, 136 mg/L, 164 mg/L, 94 mg/L, 72 mg/L and 78 mg/L at sites 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19 and 20 respectively.

6.1.7 Calcium and Calcium hardness

Figures 9 and 10 show the seasonal variation of calcium and calcium hardness respectively of the well water over the period of eight months (2006) during the investigation period. The pattern of variation of calcium is similar to that of calcium hardness because calcium hardness is due to the presence of calcium and they have linear relationship.

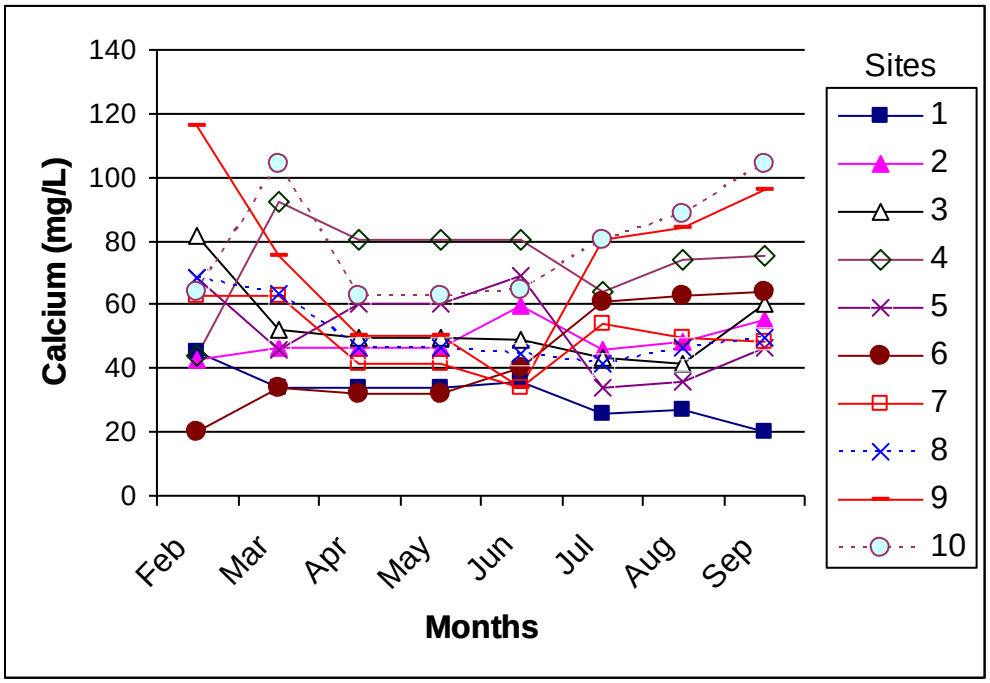

Figure 9.1: Seasonal variation of Calcium of the wells (1-10) over the period of eight months (2006)

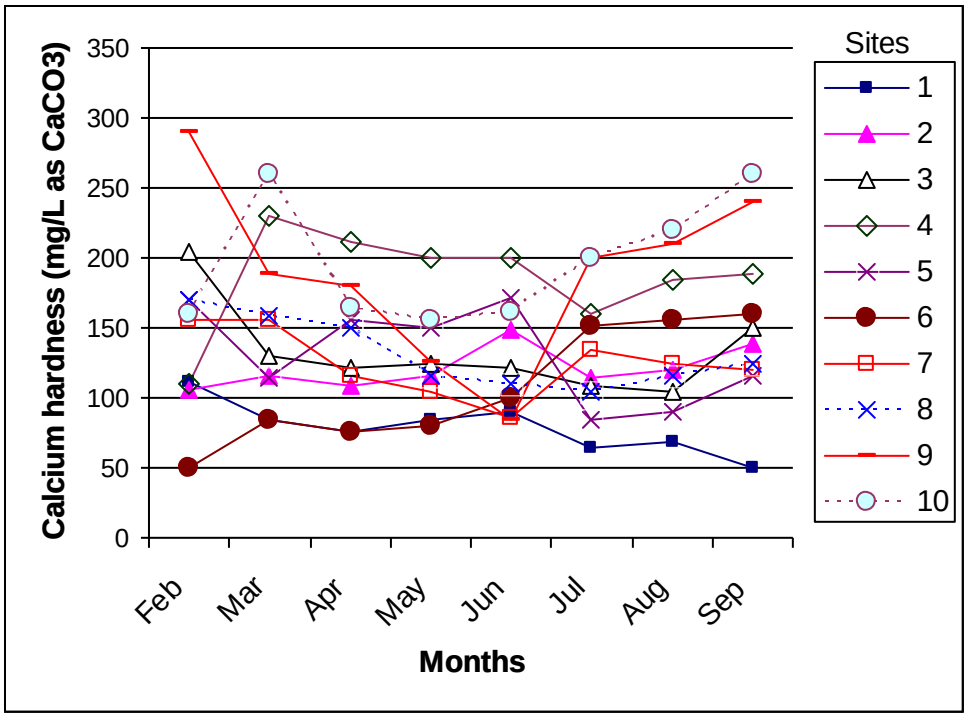

Figure 10.1: Seasonal variation of Calcium hardness of the wells (1-10) over the period of eight months (2006)

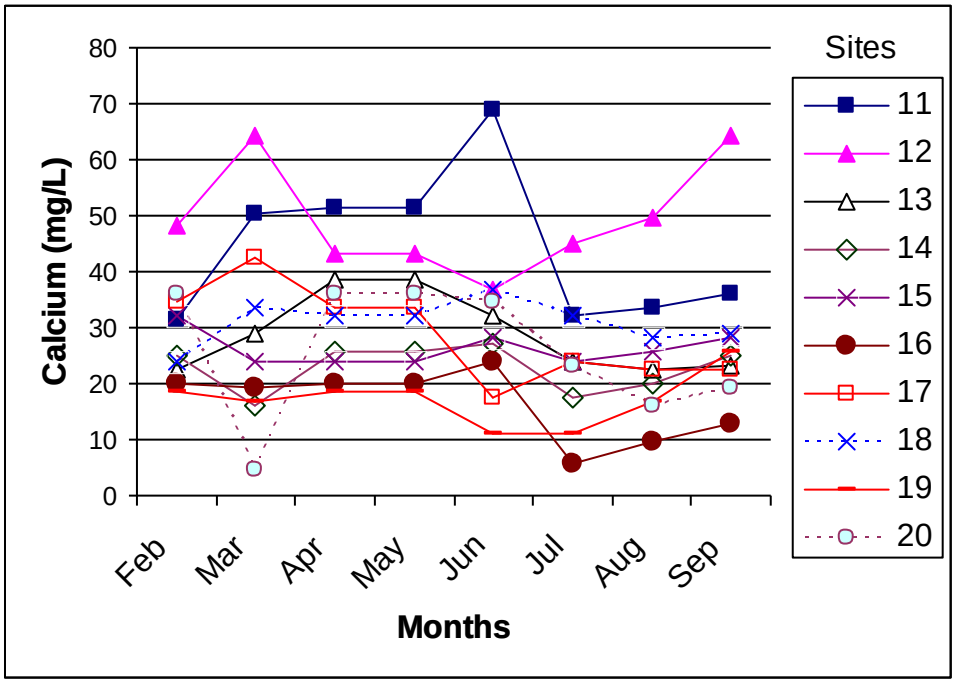

Figure 9.2: Seasonal variation of Calcium of the wells (11-20) over the period of eight months (2006)

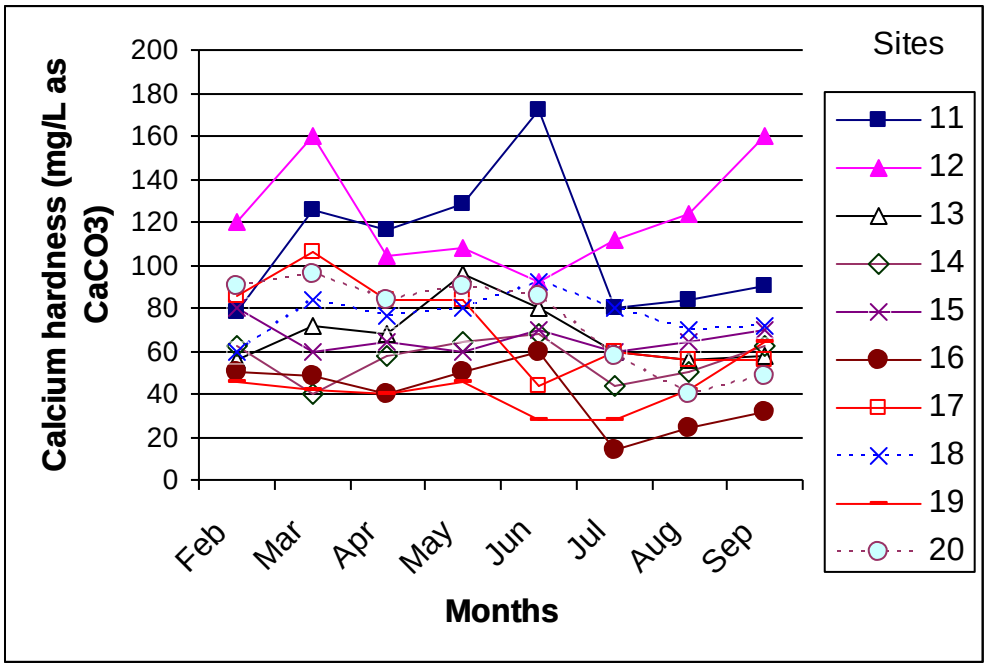

Figure 10.2: Seasonal variation of Calcium hardness of the wells (11-20) over the period of eight months (2006)

The minimum calcium content were calculated as 20.1 mg/L in September (site 1), 42.5 mg/L in September (site 2), 42 mg/L in August (site 3), 44 mg/L in February (site 4), 34 mg/L in July (site 5), 20.1 mg/L in February (site 6), 34 mg/L in June (site 7), 41.7 mg/L in July (site 8), 33.7 mg/L in June (site 9), 63 mg/L in April (site 10), 31.3 mg/L in February (site 11), 36.9 mg/L in June (site 12), 22.5 mg/L in February (site 13) , 16 mg/L in March (site 14), 24.1 mg/L in March (site 15), 5.6 mg/L in July (site 16), 17.6 mg/L in June (site 17), 24.1 mg/L in February (site 18), 11 mg/L in June (site 19) and 4.8 mg/L in March (site 20).

The minimum calcium hardness were calculated as 50 mg/L as $CaCO_3$ in September (site1), 106 mg/L as $CaCO_3$ in February (site 2), 104 mg/L as $CaCO_3$ in August (site 3), 110 mg/L as $CaCO_3$ in February (site 4), 84 mg/L as $CaCO_3$ in July (site 5), 50 mg/L as $CaCO_3$ in February (site 6), 85.2 mg/L as $CaCO_3$ in June (site 7), 104 mg/L as $CaCO_3$ in

July (site 8), 84 mg/L as $CaCO_3$ in June (site 9), 156 mg/L as $CaCO_3$ in May (site 10), 78 mg/L as $CaCO_3$ in February (site 11), 92 mg/L as $CaCO_3$ in June (site 12), 56 mg/L as $CaCO_3$ in February (site 13), 40 mg/L as $CaCO_3$ in March (site 14), 60 mg/L as $CaCO_3$ in March (site 15), 14 mg/L as $CaCO_3$ in July (site 16), 44 mg/L as $CaCO_3$ in June (site 17), 60 mg/L as $CaCO_3$ in February (site 18), 28 mg/L as $CaCO_3$ in April (site 19) and 40 mg/L as $CaCO_3$ in August (site 20).

The maximum calcium content were calculated as 44.9 mg/L in February (site 1), 59.3 mg/L in June (site 2), 82 mg/L in February (site 3), 92 mg/L in March (site 4), 69 mg/L in June (site 5) , 64.2 mg/L in September (site 6), 63 mg/L in February (site 7), 68.2 mg/L in February (site 8), 116 mg/L in February (site 9), 104 mg/L in March (site 10), 69 mg/L in June (site 11), 64.2 mg/L in September (site 12), 38.5 mg/L in May (site 13), 27.3 mg/L in June (site 14), 32.1 mg/L in February (site 15), 24 mg/L in June (site 16), 42.5 mg/L in March (site 17), 36.9 mg/L in June (site 18), 26 mg/L in September (site 19) and 36 mg/L in February (site 20).

The maximum calcium hardness were calculated as 112 mg/L as $CaCO_3$ in February (site 1), 148 mg/L as $CaCO_3$ in June (site 2), 204 mg/L as $CaCO_3$ in February (site 3), 230 mg/L as $CaCO_3$ in March (site 4), 172 mg/L as $CaCO_3$ in June (site 5), 160 mg/L as $CaCO_3$ in September (site 6), 156 mg/L as $CaCO_3$ in February (site 7), 170 mg/L as $CaCO_3$ in February (site 8), 290 mg/L as $CaCO_3$ in February (site 9), 260 mg/L as $CaCO_3$ in March (site 10), 172 mg/L as $CaCO_3$ in July (site 11), 160 mg/L as $CaCO_3$ in September (site 12), 96 mg/L as $CaCO_3$ in May (site 13), 68 mg/L as $CaCO_3$ in June (site 14), 80 mg/L as $CaCO_3$ in February (site 15), 60 mg/L as $CaCO_3$ in June (site 16), 106 mg/L as $CaCO_3$ in March (site 17), 92 mg/L as $CaCO_3$ in June (site 18), 64 mg/L as $CaCO_3$ in September (site 19) and 96 mg/L as $CaCO_3$ in March (site 20).

The monthly variation of calcium and calcium hardness of the well water is not significant at 0.05 and 0.01 probability level ($F = 0.375$ for calcium content and $F = 0.374$ for calcium hardness, d.f. = 159 for both). The spatial variation of calcium and calcium

hardness of the well water is significant at 0.05 and 0.01 probability level (F = 21.443 for calcium content and F = 21.451for calcium hardness, d.f. = 159 for both).

On the average, calcium and calcium hardness were calculated as 31.9 ± 7.53 mg/L and 78.5 ± 18.7 mg/L as $CaCO_3$ at site 1, 48.8 ± 5.6 mg/L and 121 ± 14.7 mg/L as $CaCO_3$ at site 2, 53 ± 13 mg/L and 133 ± 31.9 mg/L as $CaCO_3$ at site 3, 74 ± 14 mg/L and 186 ± 36.8 mg/L as $CaCO_3$ at site 4, 52 ± 14 mg/L and 132 ± 35 mg/L as $CaCO_3$ at site 5, 43.2 ± 17mg/L and 107 ± 42.7 mg/L as $CaCO_3$ at site 6, 49 ± 10 mg/L and 124 ± 24.3 mg/L as $CaCO_3$ at site 7, 50.9 ± 9.56 mg/L and 131 ± 24.7 mg/L as $CaCO_3$ at site 8, 73.4 ± 27.1 mg/L and 190 ± 63.7 mg/L as $CaCO_3$ at site 9, 79 ± 18 mg/L and 198 ± 44.5 mg/L as $CaCO_3$ at site 10, 44.4 ± 13.3 mg/L and 109 ± 32.6 mg/L as $CaCO_3$ at site 11, 49.3 ± 9.92 mg/L and 123 ± 25.1 mg/L as $CaCO_3$ at site 12, 28.8 ± 6.89 mg/L and 68.2 ± 14.1 mg/L as $CaCO_3$ at site 13, 22.8 ± 4.22 mg/L and 56 ± 10.1 mg/L as $CaCO_3$ at site 14, 26.3 ± 2.93 mg/L and 66 ± 7.01 mg/L as $CaCO_3$ at site 15, 16 ± 6.3 mg/L and 39.8 ± 15.4 mg/L as $CaCO_3$ at site 16, 28.9 ± 8.41 mg/L and 72 ± 21 mg/L as $CaCO_3$ at site 17, 31 ± 3.9 mg/L and 76.8 ± 9.68 mg/L as $CaCO_3$ at site 18, 17 ± 4.6 mg/L and 42 ± 11.4 mg/L as $CaCO_3$ at site 19 and 26 ± 12 mg/L and 74 ± 22 mg/L as $CaCO_3$ at site 20 over the eight months of the present investigation period.

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The amplitudes of calcium and calcium hardness variation over the eight months during the investigation period were 24.9 mg/L and 62 mg/L as $CaCO_3$, 16.8 mg/L and 42 mg/L as $CaCO_3$, 40 mg/L and 100 mg/L as $CaCO_3$, 48 mg/L and 120 mg/L as $CaCO_3$, 35 mg/L and 88 mg/L as $CaCO_3$, 44.1 mg/L and 110 mg/L as $CaCO_3$, 28 mg/L and 70.8 mg/L as $CaCO_3$, 26.5 mg/L and 66 mg/L as $CaCO_3$, 82.6 mg/L and 206 mg/L as $CaCO_3$, 42 mg/L and 104 mg/L as $CaCO_3$, 37.7 mg/L and 94 mg/L as $CaCO_3$, 27.3 mg/L and 68 mg/L as $CaCO_3$, 16 mg/L and 40 mg/L as $CaCO_3$, 11.2 mg/L and 28 mg/L as $CaCO_3$, 8.02 mg/L and 20 mg/L as $CaCO_3$, 18 mg/L and 46 mg/L as $CaCO_3$, 24.9 mg/L and 62 mg/L as $CaCO_3$, 12.8 mg/L and 32 mg/L as $CaCO_3$, 14 mg/L and 36 mg/L as $CaCO_3$ and 31 mg/L and 56 mg/L as $CaCO_3$ at sites 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19 and 20 respectively.

6.1.8 Magnesium

Figure 11 show the seasonal variation of magnesium content of the well water over the period of eight months (2006) during the investigation period.

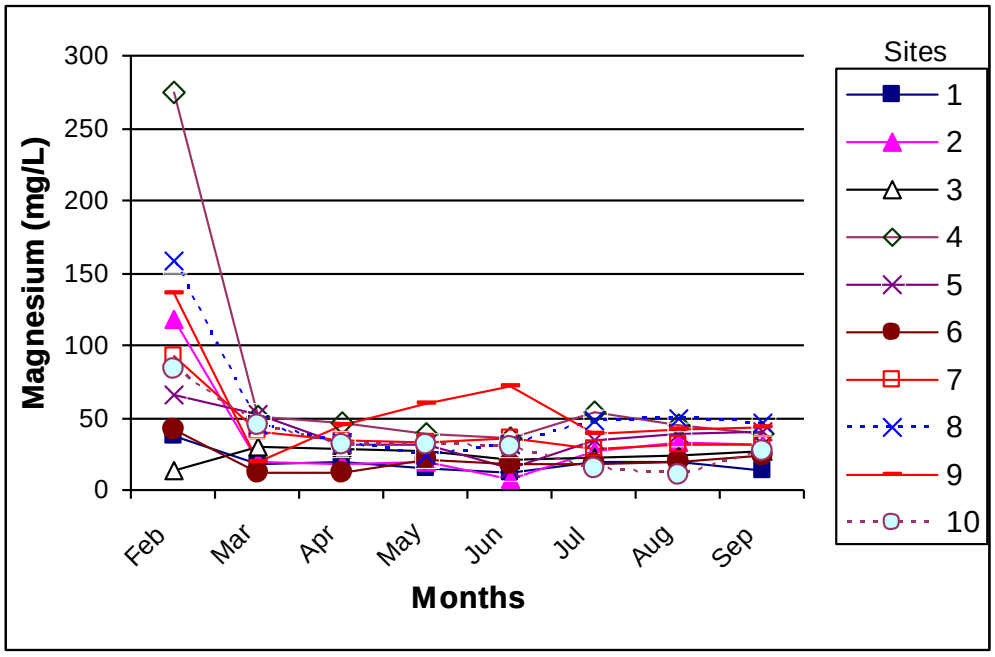

Figure 11.1: Seasonal variation of Magnesium of the wells (1-10) over the period of eight months (2006)

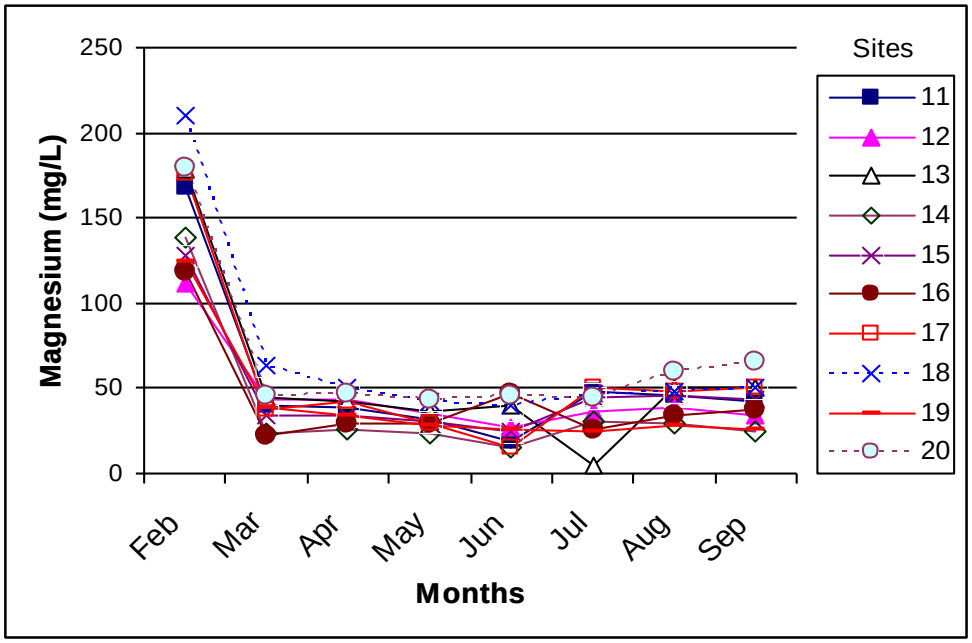

Figure 11.2: Seasonal variation of Magnesium of the wells (11-20) over the period of eight months (2006)

The minimum magnesium content were calculated as 12.2 mg/L in June (site 1), 7.78 mg/L in June (site 2), 14 mg/L in February (site 3), 36.5 mg/L in June (site 4), 15.1 mg/L in June (site 5), 12.64 mg/L in March (site 6), 28.2 mg/L in July (site 7), 23.3 mg/L in May (site 8), 19.4 mg/L in March (site 9), 10.7 mg/L in August (site 10), 18 mg/L in June (site 11), 26.7 mg/L in June (site 12), 4.9mg/L in July (site 13) , 15.6 mg/L in June (site 14), 24mg/L in June (site 15), 22.4 mg/L in March (site 16), 15.1mg/L in June (site 17), 40 mg/L in May (site 18), 24.3 mg/L in July (site 19) and 43.3 mg/L in May (site 20).

The maximum magnesium content were calculated as 38 mg/L in February (site 1), 118 mg/L in February (site 2), 29.2 mg/L in March (site 3), 274 mg/L in February (site 4),66 mg/L in February (site 5) , 42 mg/L in February (site 6), 92 mg/L in February (site 7), 158 mg/L in February (site 8), 136 mg/L in February (site 9), 84 mg/L in February (site 10), 168 mg/L in February (site 11), 112 mg/L in February (site 12), 178 mg/L in February (site 13), 138 mg/L in February (site 14), 128 mg/L in February (site 15), 118 mg/L in February (site 16), 176 mg/L in February (site 17), 210 mg/L in February (site 18), 124 mg/L in February (site 19) and 180 mg/L in February (site 20).

The monthly variation of magnesium content of the well water is not significant at 0.05 and 0.01 probability level (F = 1.152, d.f. = 159). The spatial variation of magnesium content of the well water is significant at 0.05 and 0.01 probability level (F =8.656, d.f. = 159).

On the average, magnesium content were calculated as19.4 ± 8.01mg/L at site 1, 34.3 ± 34.8 mg/L at site 2, 24.1 ± 4.93 mg/L at site 3, 73 ± 81.4 mg/L at site 4, 38.7 ± 15.2 mg/L at site 5, 20.9 ± 9.38mg/L at site 6, 40.6 ± 21.1 mg/L at site 7, 54 ± 43 mg/L at site 8, 56.9 ± 35.3 mg/L at site 9, 34.1 ± 22.7 mg/L at site 10, 54 ± 47 mg/L at site 11, 46.3 ± 27.1 mg/L at site 12, 55 ± 53 mg/L at site 13, 38.8 ± 40.3 mg/L at site 14, 48 ± 33 mg/L at site 15, 43 ± 31.3 mg/L at site 16, 56.1 ± 49.9 mg/L at site 17, 69 ± 57 mg/L at site 18, 41.1 ± 33.8 mg/L at site 19 and 66.2 ± 46.7 mg/L at site 20 over the eight months of the present investigation period.

The amplitudes of magnesium content variation over the eight months during the investigation period were 25.9 mg/L, 110 mg/L, 15.2 mg/L, 238 mg/L, 50.9 mg/L, 29.4 mg/L, 63.8 mg/L, 135 mg/L, 117 mg/L, 73.3 mg/L, 150 mg/L, 85.3 mg/L, 183 mg/L, 122 mg/L, 104 mg/L, 95.6mg/L, 161 mg/L,170 mg/L, 99.7 mg/L and 137 mg/L at sites 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19 and 20 respectively.

6.1.9 Chloride

Figure 12 show the seasonal variation of chloride content of the well water over the period of eight months (2006) during the investigation period.

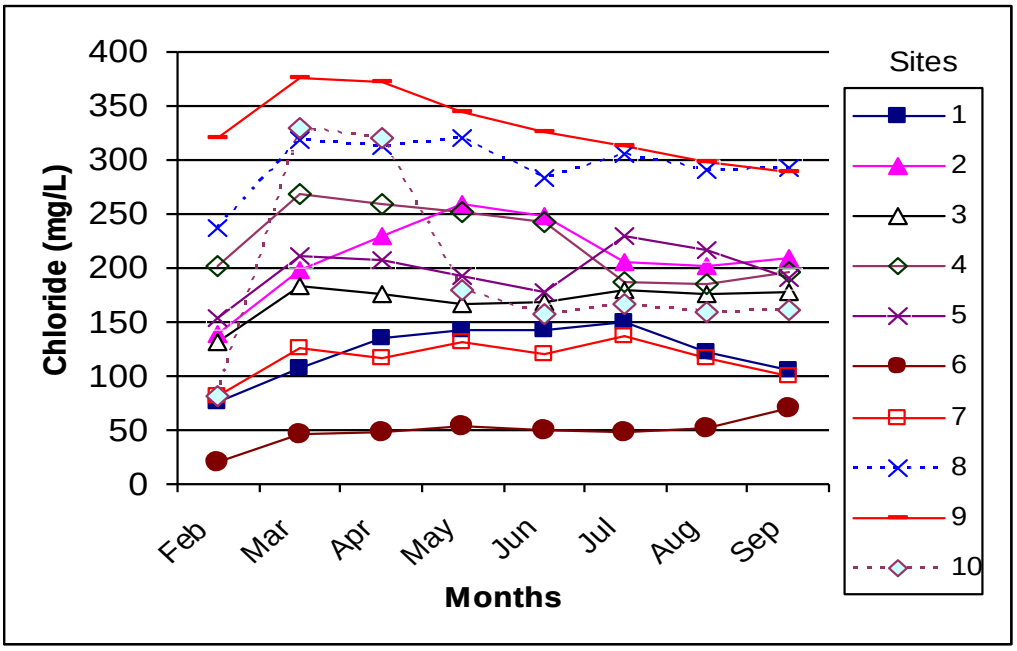

Figure 12.1: Seasonal variation of Chloride of the wells (1-10) over the period of eight months (2006)

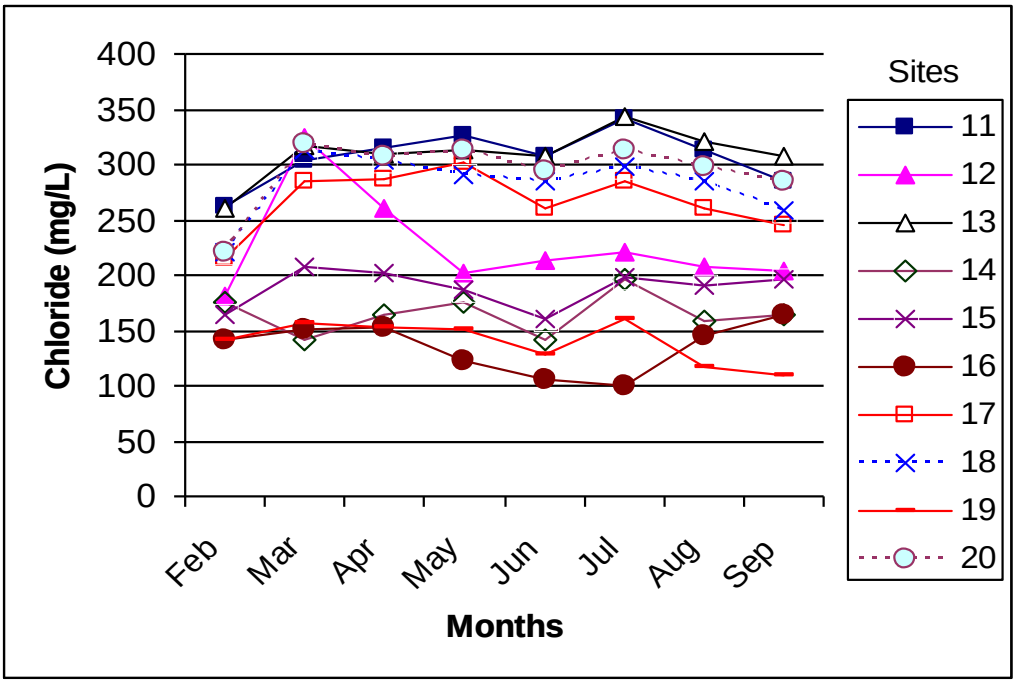

Figure 12.2: Seasonal variation of Chloride of the wells (11-20) over the period of eight months (2006)

The minimum chloride content were calculated as 75.26 mg/L in February (site 1), 139.2 mg/L in February (site 2), 132 mg/L in February (site 3), 185 mg/L in August (site 4), 153 mg/L in February (site 5), 19.9 mg/L in February (site 6), 82.4 mg/L in February (site 7), 237 mg/L in February (site 8), 290 mg/L in September (site 9), 82 mg/L in February, (site 10), 262.7 mg/L in February (site 11), 180 mg/L in February (site 12), 261 mg/L in February (site 13), 142 mg/L in March (site 14), 160 mg/L in June (site 15), 99.4 mg/L in July (site 16), 216 mg/L in February (site 17), 220 mg/L in February (site 18), 109 mg/L in September (site 19) and 21 mg/L in August (site 20).

The maximum chloride content were calculated as 149.1 mg/L in July (site 1), 258.4 mg/L in April (site 2), 183 mg/L in March (site 3), 268 mg/L in March (site 4),230 mg/L in July (site 5) , 71 mg/L in September (site 6), 138 mg/L in July (site 7), 320 mg/L in April (site 8), 376 mg/L in March (site 9), 329 mg/L in March (site 10), 340.8 mg/L in July (site 11), 325 mg/L in March (site 12), 344 mg/L in July (site 13), 196 mg/L in July (site 14), 207 mg/L in March (site 15), 165 mg/L in September (site 16), 301 mg/L in April (site 17), 312 mg/L in March (site 18), 160 mg/L in July (site 19) and 320 mg/L in March (site 20).

The monthly variation of chloride content of the well water is not significant at 0.05 and 0.01 probability level ($F = 1.235$, d.f. = 159). The spatial variation of chloride content of the well water is significant at 0.05 and 0.01 probability level ($F = 45.762$, d.f. = 159).

On the average, chloride content were calculated as 123 ± 25.74 mg/L at site 1, 251.4 ± 39.99 mg/L at site 2, 169 ± 16.1mg/L at site 3, 223 ± 344 mg/L at site 4, 195 ± 24 mg/L at site 5, 49.2 ± 14.1 mg/L at site 6, 118 ± 18.5 mg/L at site 7, 296 ± 27.6 mg/L at site 8, 326 ± 28 mg/L at site 9, 177 ± 69mg/L at site 10, 308.1 ± 25.21 mg/L at site 11, 219 ± 44.3 mg/L at site 12, 310 ± 22.9 mg/L at site 13, 166 ± 18.6 mg/L at site 14, 186 ± 16.5 mg/L at site 15, 131 ± 22.9 mg/L at site 16, 269 ± 29.3 mg/L at site 17, 280 ± 28.4 mg/L at site 18, 139 ± 19 mg/L at site 19 and 259 ± 102 mg/L at site 20 over the eight months of the present investigation period.

The amplitudes of chloride content variation over the eight months during the investigation period were 73.84 mg/L, 119.3 mg/L, 51.1 mg/L, 84 mg/L, 76.7 mg/L, 51.1 mg/L, 55.4 mg/L, 82.4 mg/L, 87 mg/L, 247 mg/L, 78.1 mg/L, 145 mg/L, 82.4 mg/L, 54 mg/L, 46.9 mg/L, 65.3 mg/L, 85.2 mg/L,92.3 mg/L, 51 mg/L and 299 mg/L at sites 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19 and 20 respectively.

6.1.10 Nitrate-nitrogen

The seasonal variation of nitrate-nitrogen concentration of the well water over the period of eight months (2006) is shown in the Figure 13.

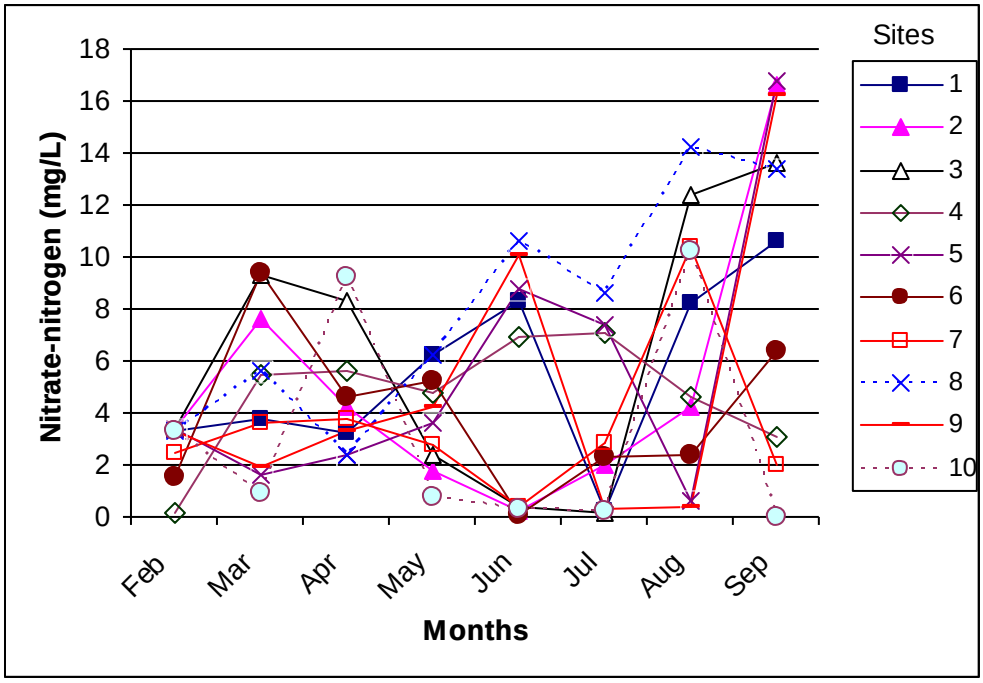

Figure 13.1: Seasonal variation of Nitrate-nitrogen of the wells (1-10) over the period of eight months (2006)

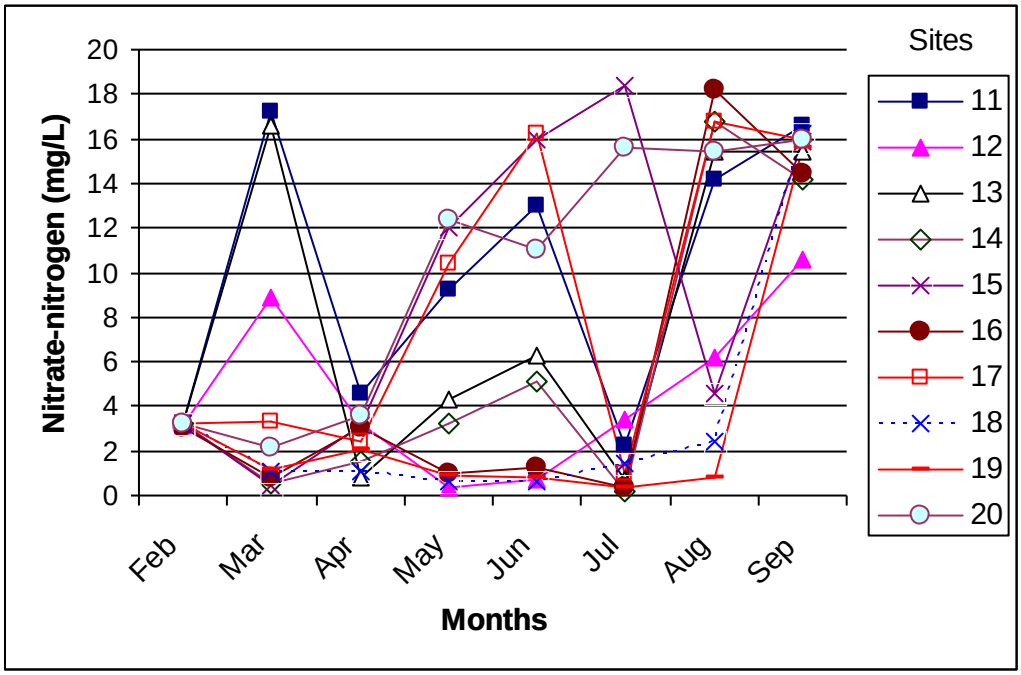

Figure 13.2: Seasonal variation of Nitrate-nitrogen of the wells (11-20) over the period of eight months (2006)

The minimum nitrate-nitrogen concentration were calculated as 0.22 mg/L in July (site 1), 0.2 mg/L in June (site 2), 0.15 mg/L in July (site 3), 0.18 mg/L in February (site 4), 0.6 mg/L in August (site 5), 0.05 mg/L in June (site 6), 0.4 mg/L in June (site 7), 2.4 mg/L in April (site 8), 0.3 mg/L in July (site 9), 0 mg/L in September, (site 10), 2.2 mg/L in July (site 11), 0.4 mg/L in May (site 12), 0.7 mg/L in July (site 13), 0.2 mg/L in July (site 14), 0.45 mg/L in March (site 15), 0.4 mg/L in July (site 16), 1.0 mg/L in July (site 17), 0.6 mg/L in June (site 18), 0.4 mg/L in July (site 19) and 2.15 mg/L in August (site 20).

The maximum nitrate-nitrogen concentration were calculated as 10.6 mg/L in September (site 1), 16.6 mg/L in September (site 2), 13.6 mg/L in September (site 3), 7.1 mg/L in July (site 4),17 mg/L in September (site 5) , 9.4 mg/L in March (site 6), 10.4 mg/L in August (site 7), 14.2 mg/L in August (site 8), 16 mg/L in September (site 9), 10 mg/L in August (site 10), 17.2 mg/L in March (site 11), 10.6 mg/L in September (site 12), 16.6 mg/L in March (site 13), 16.8 mg/L in August (site 14), 18.4 mg/L in July (site 15), 18.2

mg/L in August (site 16), 16.8 mg/L in August (site 17), 16.2 mg/L in September (site 18), 16.0 mg/L in September (site 19) and 16.0 mg/L in September (site 20).

The monthly variation of nitrate-nitrogen of the well water is not significant at 0.05 and 0.01 probability level (F =9.789, d.f. = 159). But the spatial variation of nitrate-nitrogen of the well water is not significant at 0.05 and 0.01 probability level (F =1.462, d.f. = 159).

On the average, nitrate-nitrogen concentration were calculated as 5.48 ± 3.42 mg/L at site 1, 5.0 ± 5.18 mg/L at site 2, 6.24 ± 5.34 mg/L at site 3, 4.72 ± 2.24 mg/L at site 4, 5.6 ± 5.3 mg/L at site 5, 3.98 ± 3.02 mg/L at site 6, 3.54 ± 2.97 mg/L at site 7, 8.05 ± 4.42 mg/L at site 8, 5.0 ± 5.5 mg/L at site 9, 3.1 ± 4.2 mg/L at site 10, 10.0 ± 6.08 mg/L at site 11, 4.58 ± 3.96 mg/L at site 12, 7.83 ± 6.85 mg/L at site 13, 5.59 ± 6.36 mg/L at site 14, 9.21 ± 7.1 mg/L at site 15, 5.28 ± 6.95 mg/L at site 16, 8.68 ± 6.92 mg/L at site 17, 3.33 ± 5.28 mg/L at site 18, 3.33 ± 5.28 mg/L at site 19 and 9.93 ± 5.99 mg/L at site 20 over the eight months of the present investigation period.

The amplitudes of nitrate-nitrogen concentration variation over the eight months during the investigation period were 10.38 mg/L, 16.4 mg/L, 13.5 mg/L, 6.92 mg/L, 16.0 mg/L, 9.35mg/L, 10.0 mg/L, 11.8 mg/L, 16.0 mg/L, 10.0 mg/L, 15.0 mg/L, 10.2 mg/L, 15.9 mg/L, 16.6 mg/L, 18.0 mg/L, 17.8 mg/L, 15.8 mg/L, 15.6 mg/L, 15.0 mg/L and 13.9 mg/L at sites 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19 and 20 respectively.

6.1.11 Ortho-phosphate

The seasonal variation of ortho-phosphate concentration of the well water over the period of eight months (2006) is shown in the Figure 14.

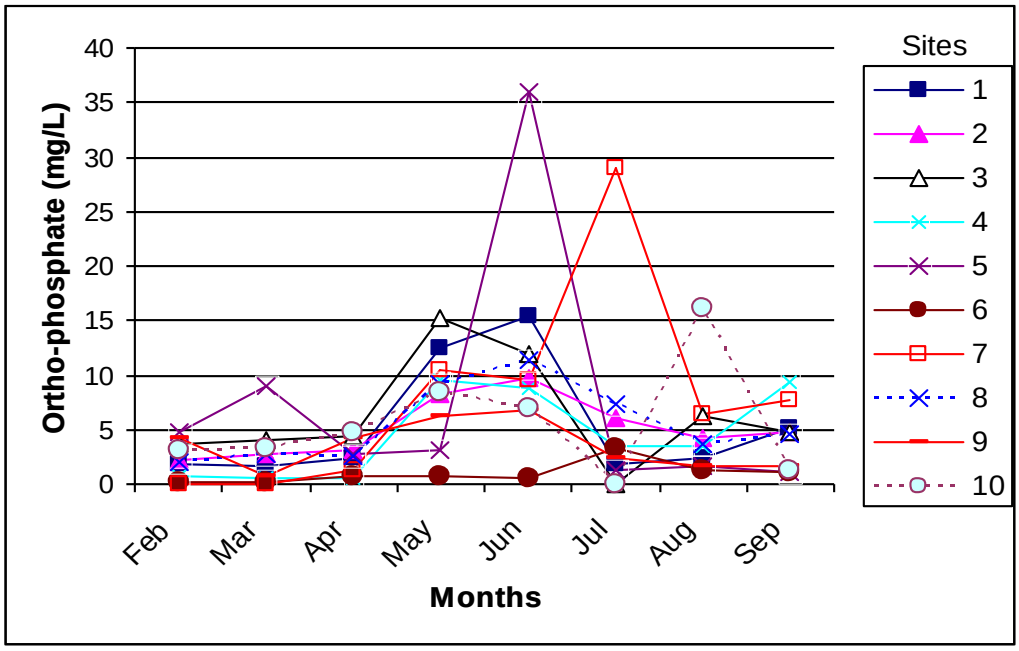

Figure 14.1: Seasonal variation of Ortho-phosphate of the wells (1-10) over the period of eight months (2006)

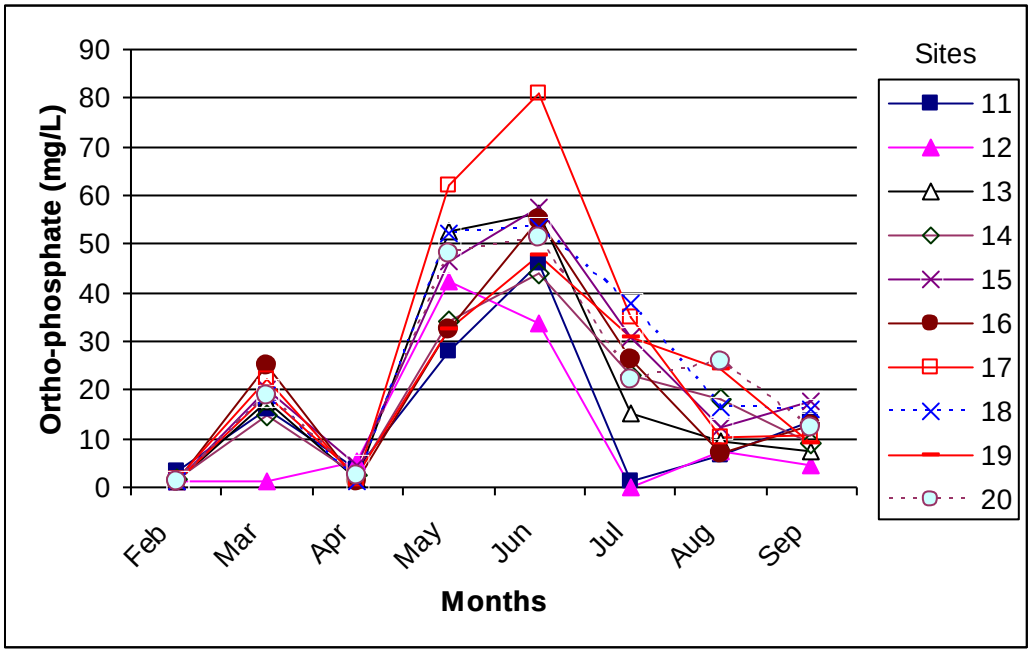

Figure 14.2: Seasonal variation of Ortho-phosphate of the wells (11-20) over the period of eight months (2006)

The minimum ortho-phosphate concentration were calculated as 1.72 mg/L in March (site 01), 2.2 mg/L in February (site 2), 0.02 mg/L in July (site 3), 0.6 mg/L in March (site 4), 1.13 mg/L in September (site 5), 0.2 mg/L in February (site 6), 0.05 mg/L in March (site 7), 2.04 mg/L in February (site 8), 0.75 mg/L in March (site 9), 0.06 mg/L in July, (site 10), 1.3 mg/L in July (site 11), 0.13 mg/L in July (site 12), 1.34 mg/L in February (site 13), 1.52 mg/L in February (site 14), 1.42 mg/L in February (site 15), 1.1 mg/L in February (site 16), 1.64 mg/L in February (site 17), 1.12 mg/L in April (site 18), 1.4 mg/L in February (site 19) and 1.4 mg/L in February (site 20).

The maximum ortho-phosphate concentration were calculated as 15.4 mg/L in June (site 1), 9.7 mg/L in June (site 2), 15.2 mg/L in May (site 3), 9.6 mg/L in May (site 4),36 mg/L in June (site 5) , 3.3 mg/L in July (site 6), 29 mg/L in July (site 7), 11.4 mg/L in June (site 8), 6.7 mg/L in June (site 9), 16.2 mg/L in August (site 10), 46.0 mg/L in June (site 11), 42.4 mg/L in May (site 12), 56.5 mg/L in June (site 13), 44.0 mg/L in June (site 14), 57.5 mg/L in June (site 15), 55.0 mg/L in June (site 16), 81.0 mg/L in June (site 17), 53.5 mg/L in June (site 18), 47.5 mg/L in June (site 19) and 51.5 mg/L in June (site 20).

The monthly variation of ortho-phosphate concentration of the well water is significant at 0.05 and 0.01 probability level ($F = 14.319$, d.f. = 159). The spatial variation of ortho-phosphate concentration of the well water is significant at 0.05 and 0.01 probability level ($F = 1.856$, d.f. = 159).

On the average, ortho-phosphate concentration were calculated as 5.4 ± 5.42 mg/L at site 1, 5.13 ± 2.66 mg/L at site 2, 6.3 ± 4.91 mg/L at site 3, 4.58 ± 4.04 mg/L at site 4, 7.5 ± 11.8 mg/L at site 5, 1.0 ± 1.0 mg/L at site 6, 8.06 ± 9.44 mg/L at site 7, 5.45 ± 3.47 mg/L at site 8, 3.46 ± 2.21 mg/L at site 9, 5.51 ± 5.13 mg/L at site 10, 15.0 ± 15.0 mg/L at site 11, 11.9 ± 16.4 mg/L at site 12, 20.2 ± 21.9 mg/L at site 13, 18.39 ± 14.97 mg/L at site 14, 23.9 ± 19.8 mg/L at site 15, 20.2 ± 18.5 mg/L at site 16, 28.0 ± 29.4 mg/L at site 17, 24.7 ± 20.8 mg/L at site 18, 20.8 ± 16.1 mg/L at site 19 and 22.9 ± 18.8 mg/L at site 20 over the eight months of the present investigation period.

The amplitudes of ortho-phosphate concentration variation over the eight months during the investigation period were 13.7 mg/L, 7.5 mg/L, 15.2 mg/L, 9.0 mg/L, 34.9 mg/L, 3.1 mg/L, 29.0 mg/L, 9.36 mg/L, 5.95 mg/L, 16.1 mg/L, 45.0 mg/L, 42.3 mg/L, 55.2 mg/L, 42.48 mg/L, 56.1 mg/L, 53.9 mg/L, 79.4 mg/L, 52.4 mg/L, 46.1 mg/L and 50.1mg/L at sites 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19 and 20 respectively.

6.1.12 Iron

The seasonal variation of Iron content of the well water over the period of eight months (2006) is shown in the Figure 15.

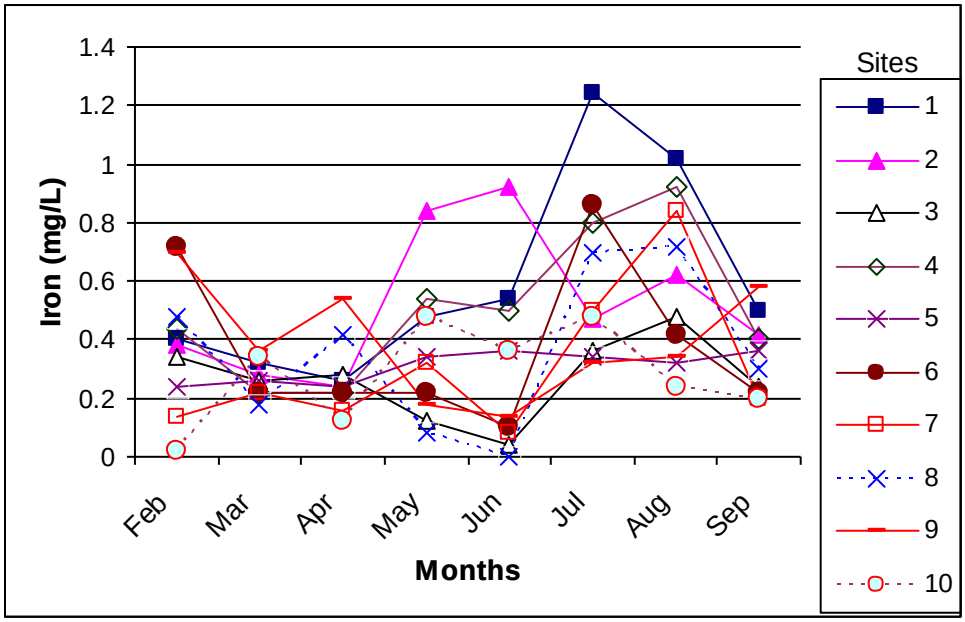

Figure 15.1: Seasonal variation of Iron of the wells (1-10) over the period of eight months (2006)

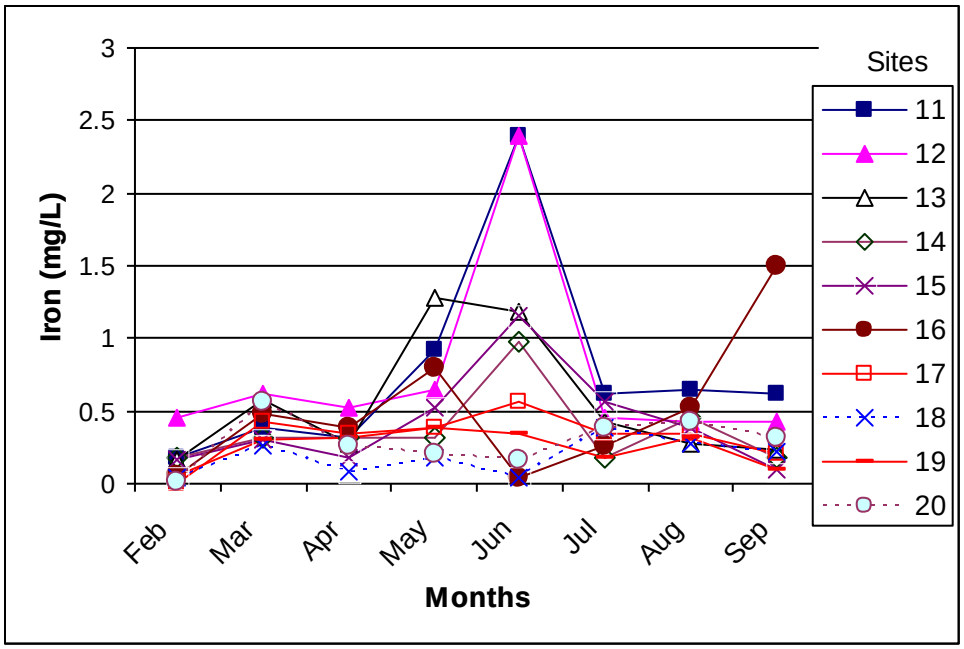

Figure 15.2: Seasonal variation of Iron of the wells (11-20) over the period of eight months (2006)

The minimum iron content were calculated as 0.26 mg/L in April (site 1), 0.2 mg/L in April (site 2), 0 mg/L in June (site 3), 0.2 mg/L in March (site 4), 0.2 mg/L in February (site 5), 0.1 mg/L in June (site 6), 0.08 mg/L in June (site 7), 0 mg/L in June (site 8), 0.14 mg/L in June (site 9), 0.02 mg/L in February, (site 10), 0.18 mg/L in February (site 11), 0.42 mg/L in August (site 12), 0.16 mg/L in February (site 13), 0.18 mg/L in February (site 14), 0.1 mg/L in September (site 15), 0 mg/L in June (site 16), 0 mg/L in February (site 17), 0.04 mg/L in February (site 18), 0.06 mg/L in February (site 19) and 0.02 mg/L in February (site 20).

The maximum iron content were calculated as 1.24 mg/L in July (site 1), 0.9 mg/L in June (site 2), 0.5 mg/L in August (site 3), 0.9 mg/L in August (site 4),0.4 mg/L in June (site 5) , 0.86 mg/L in July (site 6), 0.84 mg/L in August (site 7), 0.72 mg/L in August (site 8), 0.7 mg/L in February (site 9), 0.48 mg/L in May (site 10), 2.4 mg/L in June (site 11), 2.4 mg/L in June (site 12), 1.28 mg/L in May (site 13), 0.98 mg/L in June (site 14), 1.16 mg/L in June (site 15), 1.5 mg/L in September (site 16), 0.56 mg/L in June (site 17), 0.38 mg/L in July (site 18), 0.38 mg/L in May (site 19) and 0.56 mg/L in March (site 20).

The monthly variation of iron content of the well water is not significant at 0.05 and 0.01 probability level (F =2.647, d.f. = 159). The spatial variation of iron content of the well water is not significant at 0.05 and 0.01 probability level (F =1.856, d.f. = 159).

On the average, iron content were calculated as 0.6 ± 0.35 mg/L at site 1, 0.5 ± 0.3 mg/L at site 2, 0.3 ± 0.1mg/L at site 3, 0.5 ± 0.3 mg/L at site 4, 0.3 ± 0.1 mg/L at site 5, 0.37 ± 0.27 mg/L at site 6, 0.31 ± 0.25 mg/L at site 7, 0.36 ± 0.27 mg/L at site 8, 0.4 ± 0.2 mg/L at site 9, 0.28 ± 0.17 mg/L at site 10, 0.76 ± 0.7 mg/L at site 11, 0.74 ± 0.68 mg/L at site 12, 0.55 ± 0.44 mg/L at site 13, 0.36 ± 0.26 mg/L at site 14, 0.42 ± 0.34 mg/L at site 15, 0.5 ± 0.5 mg/L at site 16, 0.32 ± 0.16 mg/L at site 17, 0.19 ± 0.12 mg/L at site 18, 0.25 ± 0.12 mg/L at site 19 and 0.29 ± 0.17 mg/L at site 20 over the eight months of the present investigation period.

The amplitudes of iron content variation over the eight months during the investigation period were 0.98 mg/L, 0.7 mg/L, 0.4 mg/L, 0.7 mg/L, 0.1 mg/L, 0.76 mg/L, 0.76 mg/L, 0.72 mg/L, 0.56 mg/L, 0.46 mg/L, 2.22 mg/L, 1.98 mg/L, 1.12 mg/L, 0.8 mg/L, 1.06 mg/L, 1.5 mg/L, 0.56 mg/L,0.34 mg/L, 0.32 mg/L and 0.54 mg/L at sites 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19 and 20 respectively

6.1.13 Electrical conductivity

The seasonal variation of electrical conductivity of the well water over the period of eight months (2006) is shown in the Figure 16.

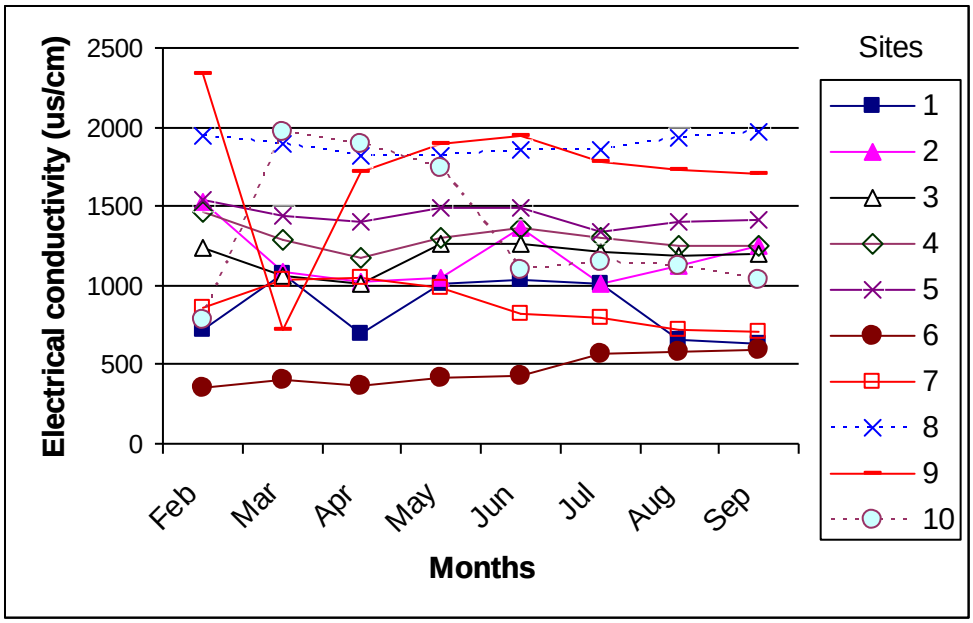

Figure 16.1: Seasonal variation of Electrical conductivity of the wells (1-10) over the period of eight months (2006)

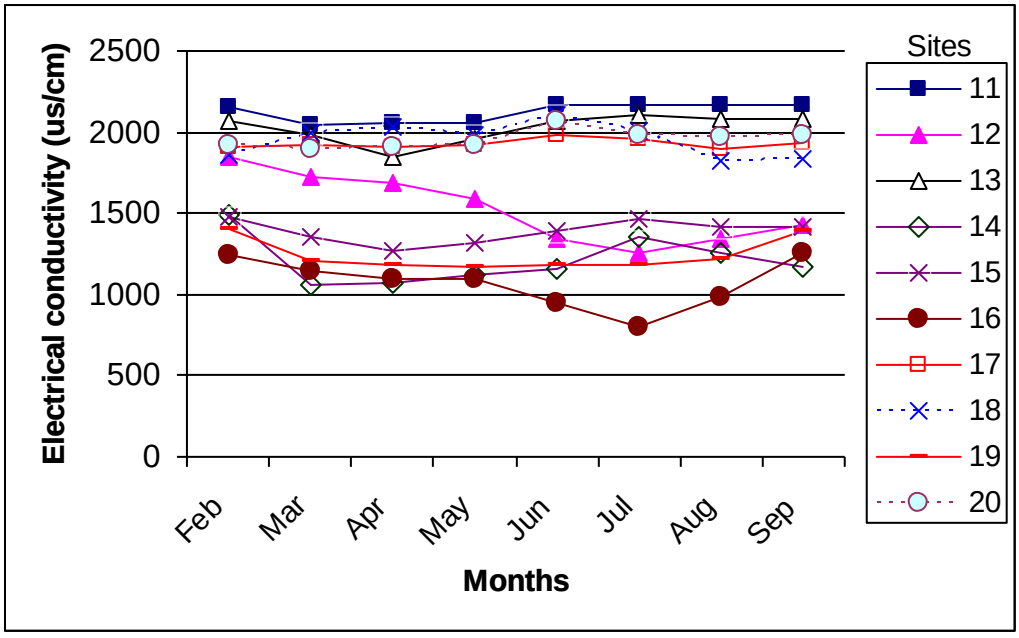

Figure 16.2: Seasonal variation of Electrical conductivity of the wells (11-20) over the period of eight months (2006)

The minimum electrical conductivity were calculated as 626 µS/cm in September (site 1), 1015 µS/cm in July (site 2), 1012 µS/cm in April (site 3), 1175 µS/cm in April (site 4), 1342 µS/cm in July (site 5), 354 µS/cm in February (site 6), 702 µS/cm in September (site 7), 1816 µS/cm in May (site 8), 716 µS/cm in March (site 9), 784 µS/cm in February, (site 10), 2040 µS/cm in March (site 11), 1258 µS/cm in July (site 12), 1852 µS/cm in April (site 13), 1058 µS/cm in March (site 14), 1264 µS/cm in April (site 15), 802 µS/cm in July (site 16), 1892 µS/cm in August (site 17), 1824 µS/cm in August (site 18), 1164 µS/cm in May (site 19) and 1901 µS/cm in March (site 20).

The maximum electrical conductivity were calculated as 1076 µS/cm in March (site 1), 1525 µS/cm in February (site 2), 1265 µS/cm in May (site 3), 1465 µS/cm in February (site 4),1536 µS/cm in February (site 5) , 592 µS/cm in September (site 6), 1054 µS/cm in April (site 7), 1966 µS/cm in September (site 8), 2330 µS/cm in February (site 9), 1965 µS/cm in March (site 10), 2172 µS/cm in July (site 11), 1845 µS/cm in February (site 12), 2105 µS/cm in July (site 13), 1491 µS/cm in February (site 14), 1482 µS/cm in February (site 15), 1258 µS/cm in September (site 16), 1982 µS/cm in June (site 17), 2105 µS/cm in June (site 18), 1401 µS/cm in February (site 19) and 2065 µS/cm in June (site 20).

The monthly variation of electrical conductivity of the well water is not significant at 0.05 and 0.01 probability level (F = 0.112, d.f. = 159). The spatial variation of electrical conductivity of the well water is significant at 0.05 and 0.01 probability level (F = 2.647, d.f. = 159).

On the average, electrical conductivity were calculated as 854 ± 195 µS/cm at site 1, 1182 ± 185 µS/cm at site 2, 1179 ± 91.8 µS/cm at site 3, 1298 ± 85.5 µS/cm at site 4, 1439 ± 62.7 µS/cm at site 5, 464 ± 101 µS/cm at site 6, 870 ± 138 µS/cm at site 7, 1887 ± 56.9 µS/cm at site 8, 1726 ± 457 µS/cm at site 9, 1348 ± 448 µS/cm at site 10, 2123 ± 58.3 µS/cm at site 11, 1527 ± 214 µS/cm at site 12, 2026 ± 86.6 µS/cm at site 13, 1210 ±

149 µS/cm at site 14, 1389 ± 74.1 µS/cm at site 15, 1070 ± 154 µS/cm at site 16, 1928 ± 28.4 µS/cm at site 17, 1956 ± 103 µS/cm at site 18, 1241 ± 95.8 µS/cm at site 19 and 1960 ± 54.9 µS/cm at site 20 over the eight months of the present investigation period.

The amplitudes of electrical conductivity variation over the eight months during the investigation period were 450 µS/cm, 510 µS/cm, 253 µS/cm, 290 µS/cm, 194 µS/cm, 238 µS/cm, 352 µS/cm, 150 µS/cm, 1614 µS/cm, 1181 µS/cm, 132 µS/cm, 587 µS/cm, 253 µS/cm, 433 µS/cm, 218 µS/cm, 456 µS/cm, 90 µS/cm, 281 µS/cm, 237 µS/cm and 164 µS/cm at sites 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19 and 20 respectively.

6.1.14 Total Dissolved Solids (TDS)

The seasonal variation of TDS of the well water over the period of eight months (2006) is shown in the Figure 17.

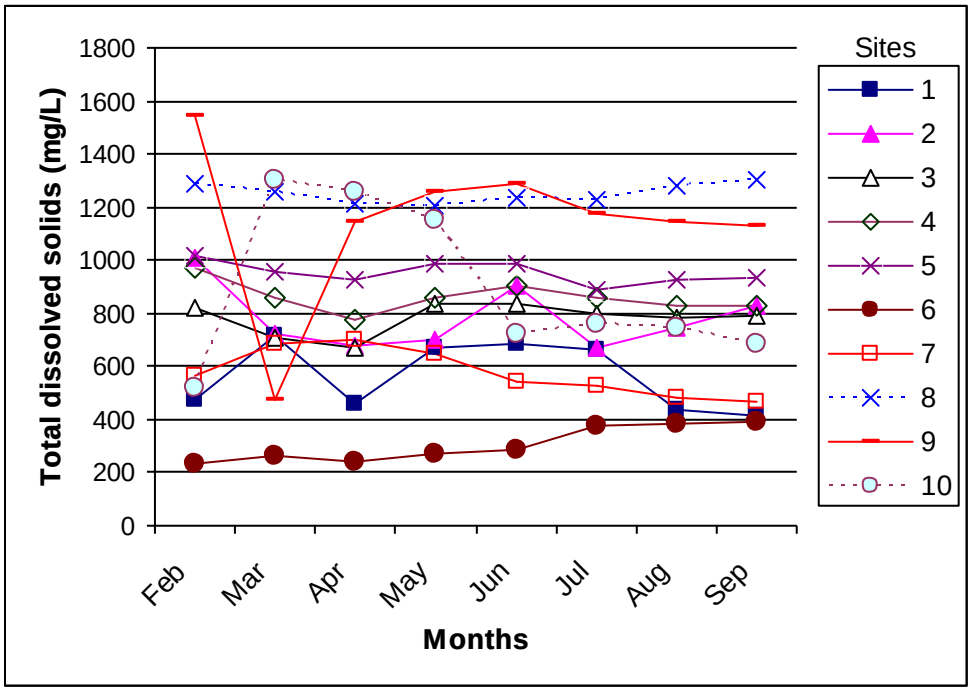

Figure 17.1: Seasonal variation of Total dissolved solids of the wells (1-10) over the period of eight months (2006)

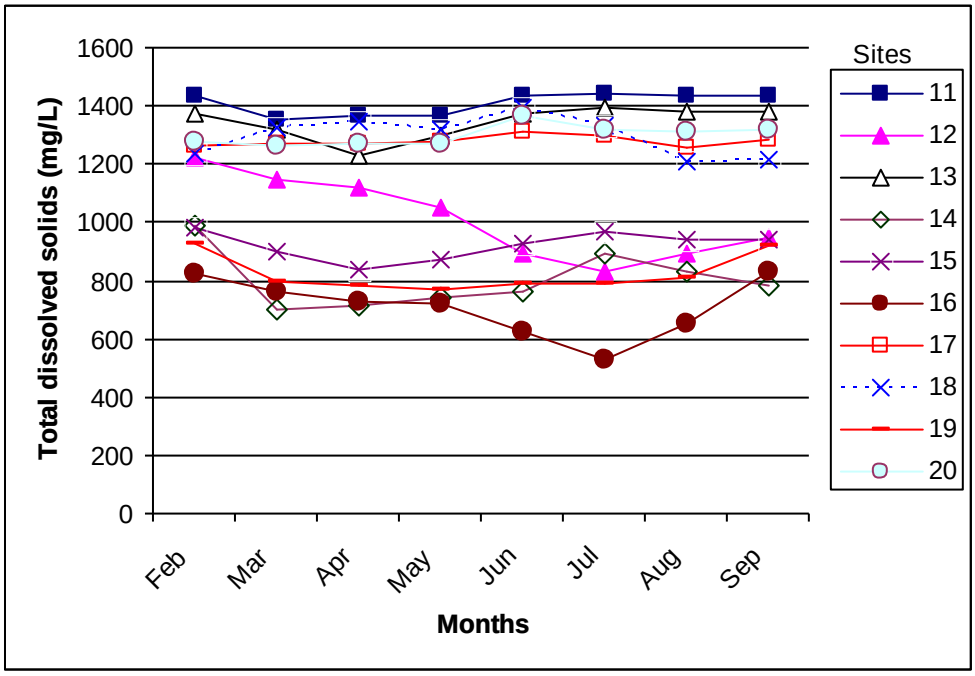

Figure 17.2: Seasonal variation of Total dissolved solids of the wells (11-20) over the period of eight months (2006)

The minimum TDS were calculated as 415 mg/L in September (site 1), 672.9 mg/L in July (site 2), 671 mg/L in April (site 3), 779 mg/L in April (site 4), 890 mg/L in July (site 5), 234.7 mg/L in February (site 6), 465 mg/L in September (site 7), 1204 mg/L in May (site 8), 475 mg/L in March (site 9), 520 mg/L in February, (site 10), 1353 mg/L in March (site 11), 834 mg/L in July (site 12), 1228mg/L in April (site 13), 701 mg/L in March (site 14), 838 mg/L in April (site 15), 532 mg/L in July (site 16), 1254 mg/L in August (site 17), 1209 mg/L in August (site 18), 772 mg/L in May (site 19) and 1260 mg/L in March (site 20).

The maximum TDS were calculated as 713.4 mg/L in July (site 1), 1011.1 mg/L in June (site 2), 839 mg/L in August (site 3), 971 mg/L in August (site 4), 1018 mg/L in June (site 5) , 392.5 mg/L in July (site 6), 699 mg/L in August (site 7), 1303 mg/L in August (site 8), 1545 mg/L in February (site 9), 1303 mg/L in May (site 10), 1440 mg/L in July (site 11), 1223 mg/L in February (site 12), 1396 mg/L in July (site 13), 989 mg/L in

February (site 14), 983 mg/L in February (site 15), 834 mg/L in September (site 16), 1314 mg/L in June (site 17), 1396 mg/L in June (site 18), 929 mg/L in February (site 19) and 1369 mg/L in June (site 20).

The monthly variation of total dissolved solids of the well water is not significant at 0.05 and 0.01 probability level (F = 0.112, d.f. = 159). The spatial variation of total dissolved solids of the well water is significant at 0.05 and 0.01 probability level (F = 49.194, d.f. = 159).

On the average, TDS were calculated as 566 ± 129.5 mg/L at site 1, 783.67 ± 122.36 mg/L at site 2, 782 ± 60.9mg/L at site 3, 861 ± 56.7 mg/L at site 4, 954 ± 41.6 mg/L at site 5, 307.4 ± 66.77 mg/L at site 6, 577 ± 91.5 mg/L at site 7, 1251 ± 37.7 mg/L at site 8, 1144 ± 303 mg/L at site 9, 893 ± 297 mg/L at site 10, 1407 ± 38.6 mg/L at site 11, 1013 ± 142 mg/L at site 12, 1343 ± 57.4 mg/L at site 13, 802 ± 98.8 mg/L at site 14, 921 ± 49.1 mg/L at site 15, 710 ± 102 mg/L at site 16, 1279 ± 18.9 mg/L at site 17, 1297 ± 68 mg/L at site 18, 823 ± 63 mg/L at site 19 and 0.29 ± 0.17 mg/L at site 20 over the eight months of the present investigation period.

The amplitudes of TDS variation over the eight months during the investigation period were 298.4 mg/L, 338.13 mg/L, 168 mg/L, 192 mg/L, 129 mg/L, 157.8 mg/L, 233 mg/L, 99.5 mg/L, 1070 mg/L, 783 mg/L, 87.5 mg/L, 389 mg/L, 168 mg/L, 287 mg/L, 145 mg/L, 302 mg/L, 59.7 mg/L, 186 mg/L, 157 mg/L and 109 mg/L at sites 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19 and 20 respectively.

6.2 Microbiological features

6.2.1 Membrane Filter Test

All the Well waters the faecal coliform count per 100 ml were found to be greater than 300/ 100 ml of sample.

6.2.2 MPN Test

MPN Tests were carried out in only 10 Well water samples. MPN Index/100 ml were calculated as 240, 4, 20, 31, 2, 7, 16, 130, 22 and 1600 in sites 1, 2, 4, 6, 7, 10, 12, 18, 19 and 20 respectively.

CHAPTER SEVEN

7. DISCUSSION

7.1 Physico-chemical features

The temperature of well water of the Madhyapur Thimi Municipality was observed with low in winter season (February) i.e. 10 ^{0}C to 17 ^{0}C and high in summer (July/August) i.e. 20 ^{0}C to 23 ^{0}C. There is more or less fluctuation in temperatures of well water. The seasonal variation of temperature of the well water is significant at 0.05 and 0.01 probability level. Whereas the spatial variation of temperature of the well water is not significant at 0.05 and 0.01 probability level ($F = 1.596$, d.f. = 159). Water bodies undergo temperature variation along with normal climatic fluctuations and seasonal variation. Temperature of water is influence by latitude, altitude, season, time of day, air circulation, cloud cover and the depth of water body. A rise in temperature of the water leads to the speeding up of the chemical reaction in water, reduces the solubility of gases, enhanced growth of microorganisms and amplifies the tastes, odour and corrosion problem however there is no standard guideline value regarding the temperature.

The pH of the well water varied between 5.27 and 7.53 throughout the investigation period. Among all the sites, minimum pH was found in site 1 (May) and maximum pH was found in site 15 (February). The observed monthly variation of pH in the well water is significant at 0.01 probability level whereas the spatial variation of pH is significant at 0.05 probability level and not significant at 0.01 probability level. The drinking water quality standard for pH in WHO standard is below 8 (WHO, 1993) and Nepal Water Quality Standard is between 6.5 to 8.5. Thus, all the waters are suitable for drinking from pH point of view. In drinking water, acidic pH may cause corrosion of metal and alkaline pH adversely affects the disinfection process.

Dissolved oxygen (DO) is considered as one of the most important parameters in water quality assessment. The minimum DO was calculated as 2.8 mg/L in site 7 (February) and maximum DO was calculated as 10.6 mg/L site 11 (September). The observed monthly variation of DO in the well water is significant at 0.01 probability level whereas the spatial variation of DO is significant at 0.05 probability level and not significant at 0.01 probability level.

Carbon dioxide in the water is usually found as free carbon dioxide (CO_2) and combined CO_2 (i.e. carbonate & bicarbonate) (APHA, 1995). The minimum free CO_2 was calculated as 15.0 mg/L in site 16 (August) and maximum free CO_2 was calculated as 119 mg/L in site 8 (July). The observed monthly variation of DO in the well water is significant at 0.01 probability level and the spatial variation of DO is significant at 0.01 probability level.

Alkalinity of water is its acid-neutralizing capacity. It is the sum of all the titrable bases such as carbonates, bicarbonates, hydroxides, phosphates, nitrates, silicates, borates etc. However, in natural waters carbonates, bicarbonates and hydroxide are considered to be predominant bases. Thus, the total alkalinity (combining carbonates, bicarbonates and hydroxides) can be expressed (APHA, 1995; Saxena, 1987 and Trivedi and Goel, 1986). The minimum total alkalinity was calculated as 35 mg/L in site 2 (July).The maximum total alkalinity was calculated as 635 mg/L in site 8 (February). The observed monthly variation of total alkalinity in the well water is significant at 0.01 probability level and the spatial variation of total alkalinity is significant at 0.01 probability level.

Hard water consumes more soap to produce lather. Hardness refers to the sum of calcium and magnesium concentrations both expressed as calcium carbonate, in mg/L. Polyvalent ions of some other metals like strontium, iron, aluminium, Zinc, manganese etc. are also capable of precipitating the soap and thus contributing to the hardness. However, the concentration of these ions is very low in natural water, therefore, hardness is generally measured as concentration of only calcium and magnesium (as calcium carbonate), which are far higher in quantities over other hardness producing ions (Trivedi and Goel, 1986).

Studies carried out so far do not reveal direct and conclusive health effect due to hardness in water. Increase in hardness has found to be beneficial to human health in some studies. The WHO guideline value for hardness is 500 mg/L as $CaCO_3$ (WHO, 1993). The hardness of the well water ranges from 40 mg/L to 446 mg/L as $CaCO_3$ throughout the study period. Thus all waters are suitable for drinking from hardness point of view. The observed monthly variation of total hardness in the well water is not significant at 0.01 probability level whereas the spatial variation of total hardness is significant at 0.01 probability level.

The calcium content of the river water had the similar trend of fluctuations as that of calcium hardness because calcium hardness is due to the presence of calcium content and they have linear relationship (APHA, 1995).The calcium concentration and calcium hardness were higher in late winter (February) /early spring (March). The calcium concentration and calcium hardness were low in the September. The observed monthly variation of calcium concentration and calcium hardness in the well water is not significant at 0.01 probability level whereas the spatial variation of calcium concentration and calcium hardness is significant at 0.01 probability level.

Magnesium is a common constituent of natural water and its concentration is generally lower than calcium (Trivedi and Goel, 1986 and Saxena, 1987). Because of this, lower magnesium content was recorded in every station during the investigation period. The observed monthly variation of magnesium concentration in the well water is not significant at 0.01 probability level whereas the spatial variation magnesium concentration is significant at 0.01 probability level.

Chloride occurs naturally in all types of waters. In natural freshwater, however, its concentration remains quite low and generally less than that of sulphates and bicarbonates. Chloride can be an indicator of pollution. Usually the higher concentration of chloride along with nitrate or ammonium show that the water is contaminated by the domestic sources. Chloride in drinking water originates from natural sources, sewage and

industrial effluents, urban runoff containing de-ionising salts and saline intrusion (WHO, 2004). Chloride in the form of chloride (Cl^-) ion, is the major inorganic anions in water and wastewater. In potable water, the salty taste produced by chloride concentration is variable and dependent on the chemical composition of water (APHA, 1985). High concentration of chloride gave a salty taste to water and beverages. Chloride was found low in site 6. It may be due to the site situated near the agricultural land and have less contamination with domestic wastes. Chloride was found high in sites 8 & 9. It may be due to the site situated in human settlement and contaminated with domestic wastes. Site 8 is situated near the pond.

The WHO guideline value as well as Nepal Drinking water standard for chloride is 250 mg/L. The chloride content of well water varied between 19.9 mg/L to 376 mg/L. Out of 20 sites the average value of chloride content for 7 sites are greater than WHO value. The observed monthly variation of chloride content in the well water is not significant at 0.01 probability level whereas the spatial variation chloride content is significant at 0.01 probability level.

Nitrogen is essential for living organisms as an important constituent of proteins, including genetic material. Nitrogen is present in organic and inorganic form in the water. Inorganic nitrogen, in the order of decreasing oxidation states are nitrate (NO_3^-), nitrite (NO_2^-), ammonium ion (NH_4^+) and molecular/elemental nitrogen (N_2). (UNESCO, 1996; APHA, 1995). Nitrate is the common form of combined nitrogen found in natural waters. Nitrate contained in drinking water is the indicator of organic pollution. Nitrate is the product of oxidation of organic nitrogen by the bacteria present in soil and water in presence of sufficient oxygen. Nitrate itself is not toxic. The effects are hazardous when nitrate is converted to nitrite. Consumption of water with high level of nitrate is deleterious to health, especially to infants who may develop a disease called methaemoglobianemia (blue baby syndrome) in which there is reduction of transportation of oxygen by blood. Investigation indicates that nitrate content higher than 200 mg/L increase the risk of stomach cancer. (ENPHO, 2000). Nitrate in excess of 45 mg/l (or in excess of 10 mg/l if reported as nitrate-nitrogen) is of health significance to pregnant

women and infants under 6 months. Considerably higher nitrate content apparently is tolerated by most adults (Self, 1994). According to ENPHO (1999), dug well of Marutole (Thimi) contain nitrate-nitrogen above 30 mg/L. This well was not included in the present study.

The WHO guideline value of nitrate for drinking water is 50 mg/L (WHO, 1993) whereas the Canada standard for Nitrate-nitrogen for drinking water is 10 mg/L. The nitrate-nitrogen content of the well water varied from 0 mg/L to 18.4 mg/L. So all the waters are suitable for drinking from WHO point of view for nitrate-nitrogen. High range of nitrate nitrogen may be due to domestic pollution as all sites are located in core of human settlement except site 6.The observed monthly variation of nitrate-nitrogen content in the well water is not significant at 0.01 probability level whereas the spatial variation nitrate-nitrogen content is significant at 0.01 probability level.

Phosphorus is an essential nutrient for living organisms and exists in water bodies as both dissolved and particulate species. Phosphorus is found in natural rocks, domestic sewage and decaying vegetable matter. In natural water and waste water, phosphorus occurs mostly as dissolved orthophosphates and polyphosphates, and organically bound phosphates (UNESCO, 1996 and APHA, 1995). Phosphate has no direct health impact. Phosphorus is a limiting factor and causes eutrophication in surface waters. High phosphorus concentration in shallow water can originate from domestic pollution. But high concentration of phosphate in ground water may be due to the underlying geochemistry and weathering of phosphorus-bearing rocks. Jha et.al. (1997) also found high levels of ammonia and phosphate in deep ground water. Throughout the investigation period the PO_4^{---}- P of the well water fluctuated between 0.02 mg/L to 57.5 mg/L. The observed monthly variation of Ortho-phosphate concentration in the well water is significant at 0.01 probability level whereas the spatial variation Ortho-phosphate concentration is significant at 0.01 probability level. Phosphorus as such is not harmful to the human but its analysis is useful for pollution study.

Iron can be present in water naturally and due to pollution also. Iron in higher concentrations can be aesthetically unpleasant and can stain clothes, hair and nails. WHO guideline value of iron is 0.3 mg/L and is not a health based value. According to Jha et. al. (1997), high iron contain in deep wells is a natural property. The iron content of well water varied from 0 mg/L to 2.4 mg/L. The observed monthly variation of iron content in the well water is significant at 0.05 probability level and the spatial variation of iron content is significant at 0.05 probability level. Sites 1, 2, 4, 9, 11, 12, 13, 15, and 16 crosses the WHO limit for iron content.

Electrical conductivity or simply conductivity is a measure of the ability of an aqueous solution to carry an electric current. This ability depends upon the presence of ions, on their total concentration, mobility and valence; and on the temperature of measurement (APHA, 1995). It doesn't have a direct health effect however, high conductivity most of the time indicate addition of some pollutants to it. The electrical conductivity value of well water ranged from 354 µS/cm to 2330 µS/cm. The observed monthly variation of electrical conductivity in the well water is not significant at 0.01 probability level and the spatial variation of electrical conductivity is significant at 0.01 probability level. High conductivity may be due to pollution in dug wells and natural property in deep wells. (ENPHO, 1999).

The TDS and conductivity of water showed the similar trends of fluctuation because conductivity and TDS have generally linear relationship as most of the salts in the water are present in the ionic forms and capable of conducting current (Trivedi and Goel, 1986). The TDS is 0.55 to 0.9 times the conductivity of water (APHA, 1995) and as a general rule; the TDS is 0.65 times the conductivity of water because the dissolved solids in the highly mineralized water are usually more than 65 % of the conductivity. This is true within the conductivity value of 50, 000 µS/cm (Trivedi and Goel, 1986). The TDS for drinking water should be within the limit 1000 mg/L as per WHO Guideline value and Nepal drinking water quality standard. Except sites 1, 6, and 7 all sites cross the WHO limit for conductivity.

7.2 Microbiological features

Water may contain disease-causing pathogens if it is contaminated with human or warm blooded animal excreta. Sources of such pathogens include septic tank, pet wastes, urban runoffs, sewage etc. The disease-causing organisms are accompanied by other common types non-pathogenic bacteria found in animal intestines such as faecal coliform bacteria, *enterococci* bacteria and *Escherichia coli* (E. Coli) bacteria. Presence of these organisms in water means there is chance of having disease-causing organisms, hence these organisms are considered as indicator organisms.

WHO guideline value for Faecal Coliform is 0 colony/100 ml of water. From MF Test all Well waters contained faecal coliform per 100 ml of water sample greater than 300. So, all Wells are contaminated with faecal coliforms. But from MPN Test, out of 10 sites in which MPN Test were performed maximum coliforms were found in site 20 (1600/100ml) and minimum were found in site 7 (2/100 ml). All the well water samples gave positive completed coliforms test confirming the detection of coliform bacteria in the water sample, indicating the faecal contamination of water except site 7. Thus, all well waters are considered as nonpotable. Necessary treatment should be done before drinking such waters.

CHAPTER EIGHT

8. CONCLUSION AND RECOMMENDATIONS

8.1 Conclusion

Madhyapur Thimi Municipality covers an area of 11.47 sq. km. It is situated exactly in between three major cities of Kathmandu Valley -Kathmandu, Lalitpur and Bhaktapur. It has total population of 47751 (CBS 2001). The physico-chemical features such as pH, electrical conductivity, total dissolved solids, dissolved oxygen, free carbondioxide, total alkalinity, total hardness, calcium, magnesium, chloride and phosphate vary significantly from sites 1 to 20 whereas the monthly variation of water temperature, pH, dissolved oxygen, free carbondioxide, total alkalinity, nitrate and phosphate were significant over the investigation period. The Nitrate-nitrogen content of all Well water samples were found within WHO limit during the investigation period. The iron content of Sites 1 (Kumhalachi), 2 (Bahanani), 4 (Gungachiwa), 9 (Tigani), 11 (Tahanani), 12 (Bhulankhel), 13 (Bramhanani), 15 (Tachutole), and 16 (Bamune tole) crosses the WHO limit for iron content. The maximum iron content was found in site 11 in the month June during the investigation period. Similarly, the electrical conductivity of sites 2 (Bahanani), 3 (Dhwakasi), 4 (Gungachiwa), 5 (Kasmatuthi), 8 (Nachutole), 9 (Tigani), 10 (Lokanthali), 11 (Tahanani), 12 (Bhulankhel), 13 (Bramhanani), 14 (Tulanani), 15 (Tachutole), 16 (Bamune tole), 17 (Parsikomarga), 18 (Gachen marga), 19 (Shiva tole) and 20 (Chode marga) crosses the WHO limit for electrical conductivity. The maximum electrical conductivity of 2330 µS/cm was found in site 9. From MF Test all Well waters contained faecal coliform per 100 ml of water sample greater than 300. So, all Wells are contaminated with faecal coliforms. But from MPN Test, out of 10 sites in which MPN Test were performed maximum coliforms were found in site 20 (1600/100ml) and minimum were found in site 7 (2/100 ml). All the well water samples gave positive completed coliforms test confirming the detection of coliform bacteria in the water sample, indicating the faecal contamination of water except site 7. Thus, all well waters are considered as nonpotable from microbial point of view. Necessary treatment should be done before drinking such waters.

8.2 Recommendations

Due to various constrains and time limitation, the present study is preliminary. Followings are some recommendations regarding this study.

1. Regular water quality monitoring should be carried out to check up the degree of pollution and its causes.

2. Public should be trained about simple water treatment methods such as boiling, filtration, chlorination etc.

3. Personal hygiene should be maintained during handling of drinking water.

4. Traditional Wells should be protected and conserved.

5. Open Wells should be covered with lid for the protection of contamination from atmosphere and dust.

6. Septic tanks and waste water drainage should not be made near by Wells.

7. Regular cleaning and maintenance of Wells should be done like in Sithi nakha.

8. Least number of parameters of water has been examined in this study. To ensure the potability of water more parameters should be examined.

9. Need of launching of environmental hygiene basic education programs and activities to raise public consciousness and support for the improvement of water quality

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