ENVIRONMENTAL ANALYSIS:
WATER AND SOIL SAMPLES
IN VARIOUS SELECTED AREAS OF
CALICUT DISTRICT

THESIS

submitted to the University of Calicut for the Degree of

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Forwarded

By

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CERTIFICATE

This is to certify that this thesis entitled "Environmental analysis: water and soil samples in various selected areas of Calicut District" is an authentic record of work carried out by Jesiamma Joseph under my supervision and guidance, in partial fulfillment of the requirements for the award of the degree of Doctor of Philosophy in Chemistry under the Faculty of Science, University of Calicut. No part of this thesis has been presented before for any other degree.

Geetha

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Date: 27.01.2005

DECLARATION

I, Jesiamma Joseph do hereby declare that this thesis entitled **"Environmental analysis: water and soil samples in various selected areas of Calicut District"** submitted by me to the University of Calicut for the award of the degree of Doctor of Philosophy under the Faculty of Science is the result of the bonafide research carried out by me under the guidance of Dr. Geetha Parameswaran, Retired Professor, University of Calicut. I further declare that the results presented in this thesis have not been submitted previously for any degree.

Station: Calicut University,

Date: 31.01.2005

Jesiamma Joseph

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PREFACE

The great Geologist Nobel aureate Szent Geory called water as "the Matrix of life". After air, water is the most important necessity for life. Water is not only essential for life but is predominant in organic constituents of living cell. It makes up about 65% of the body weight of the adult human.

Human beings use water for many purposes like drinking, irrigation, industrial processes, power generation with fossil and nuclear fuels, transportation, recreation and waste disposal etc.

In the past the study related to water was not serious except maintaining the quantity. But rapid population growth, technological developments, increasing living standards, industrialization, etc. resulted in greater demand of good quality water. On the other hand the pollution of water resources is increasing steadily. Since the public health depends to a great extent on the quality of drinking water continuous monitoring of drinking water is necessary.

The present study was aimed at evaluating and studying the extent of pollution of ground water and soil in selected areas of Calicut District. An attempt has also been made to improve their quality.

Based on the six following objectives the work was carried out from May 2000 to May 2003

(i) to evaluate the quality of drinking water in the wells in a selected area

(ii) to see whether the quality of these waters meets the drinking water quality standards

(iii) to study the seasonal and spatial variations in the quality of the well waters

(iv) to identify the contaminants, their sources and concentration

(v) to get comprehensive picture of pollution of soil from the surrounding areas of the wells.

(vi) to utilize selected aquatic organisms for water quality improvement.

The work is presented in 8 chapters.

Chapter **one** gives an introduction of the subject, review and spells out the aims and scope of the present study. The basic concepts of hydrology, groundwater and wells are presented and the natural and man made contamination of groundwater and salinity intrusions are also briefly described in this chapter.

Chapter **two** gives the details of the area under investigation and information on sampling procedures and various techniques employed in the analysis of the different constituents.

Chapter **three** describes the analysis of seasonal and spatial variations of different physico-chemical parameters.

In chapter **four** an attempt has been made to calculate Water Quality Index of various samples. Fluctuation in chemical parameters with respect to rainfall also has been studied.

In chapter **five** results of bacteriological analysis have been discussed in detail.

Chapter **six** deals with the traditional water treatment as well as treatment using aquatic organisms.

Chapter **seven** includes soil analysis.

Conclusion and suggestions are presented in the **last** chapter.

The results and salient features of the studies conducted are summarized and supplemented by a list of references. The values of the various parameters measured are given in tables, which are appended at the end while the corresponding figures are incorporated in the text itself.

Chapter 1

INTRODUCTION AND REVIEW

Water is one of the most essential components for survival of life on earth. Endowed with many physical and chemical properties, water is the only compound existing naturally in all the three basic states –gaseous, liquid and solid. In 1995 The World Bank vice president Ismail Serageldin said, "If the wars of this century were fought over oil, the wars of the next century will be fought over water". About 70% of earth's surface is covered with water with depth ranging from 0 to11km. Yet with each passing day our deepest worry is the future of the planets' fresh water supply. Why? Scientific data gives the answer to this. Out of the total water resources about 97.2% is salt water. Only 2.8% is available as fresh water at any time on the planet .Of which 99% is located underground, much of it is more than 900m deep (CWRDM, 1993).

Apart from sustaining life, water finds its application in domestic, agricultural and industrial activities, which requires water in large quantities and at various qualities. Water can dissolve in it, a wide range of elements and compounds leading to significant changes in its quality. The quality of water determines its suitability. Drinking water must be pure to the possible extent. It must be free from disease causing microorganisms or any other harmful chemical substances.

The important sources of drinking water are surface waters (lakes and rivers) and ground water from wells and springs. In towns and cities where there is public water supply, water from the rivers is treated, disinfected and supplied.

In rural areas, however ground water is the important source of drinking water. Deforestation and changes in land use pattern have led to drastic changes in the global rainfall, resulting in prolonged droughts in many areas of the world. Ultimately the pressure has increased on the groundwater, which is a reliable fresh water resource. Indiscriminate application of fertilizers and insecticides in fields has resulted in the pollution of run off waters. Upon entering water bodies these chemicals can cause significant changes in the quality of water. The industrial effluents are also discharged into the water bodies, in most of the cases without or with partial treatment. These harmful pollutants can enter the groundwater table, and impart physical and chemical changes or both. These changes in quality make it unfit for its intended use.

It has been assumed traditionally that groundwater is safer for consumption without treatment because the soil acts as a natural efficient filter to remove pollutant as the water percolates through the soil matrix. As a result private wells do not generally receive treatment (Nair, 1996). Handa (1994) has carried out ground water contamination studies in various parts of the country and disagrees on the fact that 'the groundwater is safe (free from pathogenic bacteria), does not contain harmful constituents and is free from suspended matter in comparison to surface water'. The studies have shown that such an assumption need not be correct under all circumstances (Cole, 1974; Furinam and Barton, 1971; Miller *et al.*, 1974; Scalf *et al.,* 1973). Since then, the quality of water gained equal importance with that of its quantity. Protection of drinking water sources from contamination and their elimination have therefore become important. Improvements in water supplies are believed to reduce the transmission of pathogens and thus improve children's growth rate and concomitantly reduce mortality rates (Esrey and Habicht, 1986; Blum and Feachem, 1983). Considering the multiple causes of disease and death, it is therefore essential to look at all these problems in an integrated water management fashion (Geldof *et al.*, 1994; Egboka *et al.*, 1989).

The period 1981 – 1991 has been declared as International Drinking Water Supply and Sanitation Decade (IDWSSD 1981-91). The goal of this decade was that all people should have an access to adequate water supply and a satisfactory means of excreta disposal in order to reduce the incidence of water and excreta related diseases.

To provide good quality of drinking water, the existing quality of the fresh water resources must be studied and documented. With this in mind the year 2003 has been declared as the International Year of Fresh Water. This stimulates governments, communities and external supporting agencies to release water resources for the development of water supplies and sanitation.

As a nation India has become deeply concerned about water availability in the future. The modern economy of a country is directly linked with its water resources. As population grows it puts strain on the available water potential of a place and even drinking water has become a major problem in many parts of the country. High population density, rapid growth in industry, explosive growth of urban countries, exploitation of natural resources and improper disposal of industrial waste have led to depletion and degradation of fresh water resources.

The largest available source of fresh water is beneath the ground. Even today most of Indian rural population (77 % of the population) depends on ground water for drinking and irrigation purposes. Of the 2, 27000 villages experiencing water problem the majority suffer from pollution due to biological and chemical contamination of the consumable water. (Lokesh *et al.*, 1995).

Salt-water intrusion in the unconfined and confined aquifers along various coastal belts of Indian union is being increasingly reported. The problems are particularly severe in the coastal belts of Tamil Nadu, Kerala and Gujarat (Nazimuddin and Basak, 1995). Due to increasing demand of potable water resources caused by increased population and raised industrial activities, the limited ground water resources of this sensitive zone are being more extensively utilized compared to what used to be a decade back.

Taking the case of Kerala, which is a narrow fertile coastal strip, blessed with 41 west flowing and 3 east flowing rivers, it is paradoxical that Kerala suffers from drinking water scarcity during the summer season in spite of an average precipitation of 3000 mm.

Fresh water is used for three main purposes in the state, i.e. for agriculture, industry and for domestic purposes. Its major demand is for irrigation followed by that for drinking water needs. About 70 percent of the population of Kerala depends on homestead open wells for drinking water.

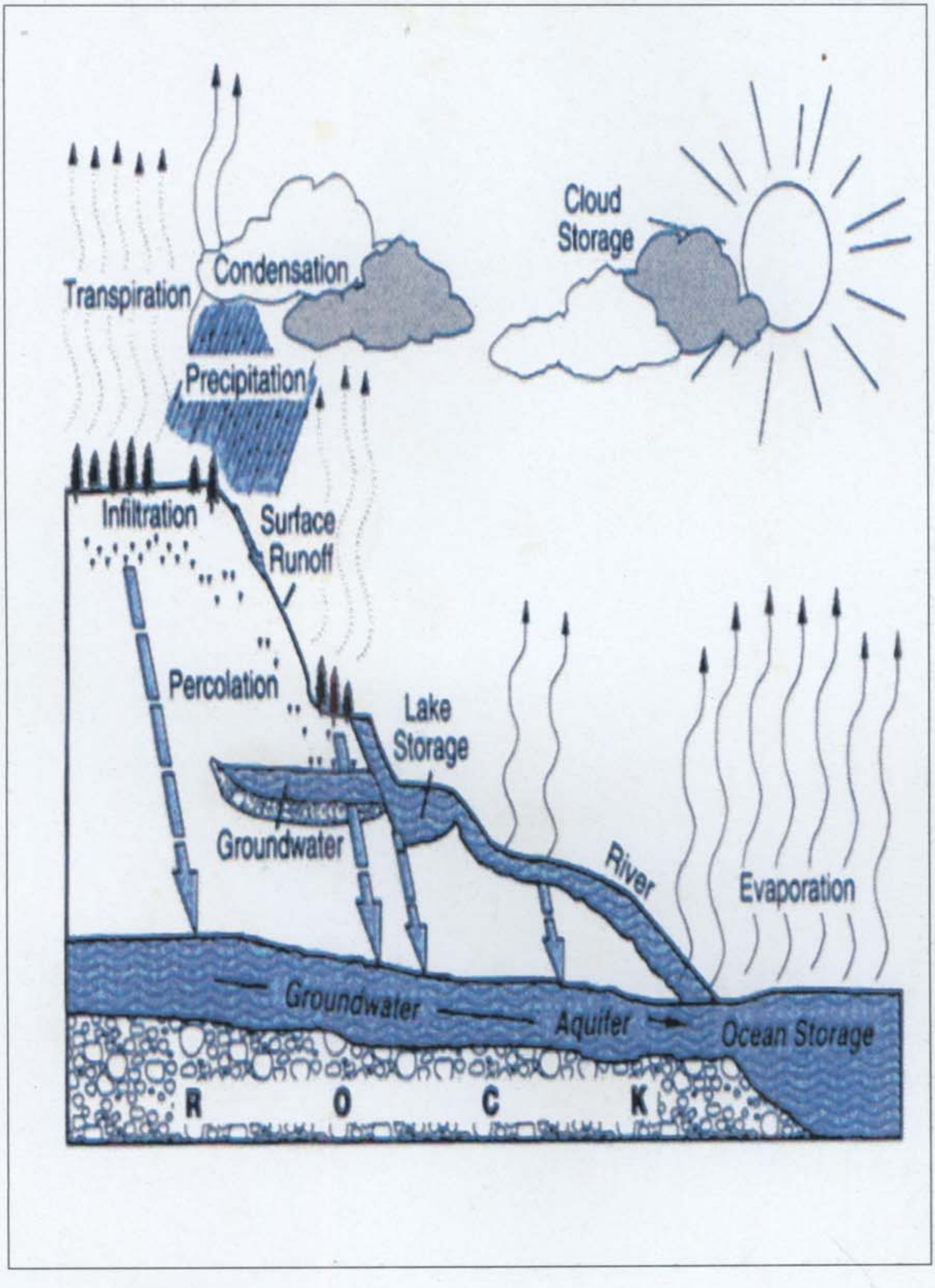

Figure 1.1 The hydrologic cycle

General characteristic of ground water

Hydrologic Cycle

Undoubtedly without water there is no possibility of life at all. This water has been given in bounteous proportion by nature by the perennial hydrological cycle of evaporation, condensation and precipitation.

The hydrologic cycle is the continuous unsteady circulation of the water resource from the atmosphere to and under the land surface and by various processes back to the atmosphere (Fig.1.1). About 1/3 of the solar flux absorbed by the earth surface is used to drive the hydrologic cycle (Berner *et al.*, 1987). It is dynamic in that the quantity and quality of water at a particular location may vary greatly with time, temporal variations may occur in the atmosphere, on the land surface, in surface waters and in the ground waters of an area. The forces involved in this process include radiation, molecular attraction and capillarity. Within the hydrologic cycle water may appear in all three of its states solid, liquid and gas. It consists of various unsteady processes occurring in the atmosphere and beneath the earth's surface.

The important processes are

(1) **Precipitation**: If enough droplets combine, they become too heavy to stay air borne and fall to the earth as drizzle or as rain. If enough ice crystals are formed they become very heavy and they too fall to the earth as sleet, hail or snow. This process is called precipitation. The world's fresh water supply is constantly being redistributed by precipitation.

(2) **Interception:** The amount of precipitation that wets and adheres to above ground objects-primarily vegetation until it is evaporated back into the atmosphere is called interception. The annual amount of interception in a particular area is affected by factors such as the amount and type of precipitation, the extent and type of vegetation and wind.

(3) **Snow melt:** It is precipitation that is temporarily stored as snow pack, much of which eventually melts and moves on or into the ground.

(4) **Infiltration and percolation:** Infiltration is the passage of water through the air soil interface. The movement of water through layers of soil and voids of rocks is called percolation. Infiltration rates are affected by factors such as time since the rainfall event began, soil porosity and permeability, antecedent soil, moisture conditions and presence of vegetation. During infiltration water enters from surface storage into voids via the combined effects of gravity and capillary forces. The capillary forces are inversely proportional to the diameter of pores. As the process continues, the pore space becomes filled and the capillary tension decreases, under saturated conditions flow is mostly due to gravity. Infiltration is one of the most difficult elements of the hydrologic cycle to quantify. Both these processes occur in the region known as zone of aeration

(5) **Evaporation and transpiration:** Water moves from the earth to the atmosphere in two ways - one is **evaporation**. It is a process whereby water is transformed from the liquid or solid state into the gaseous states. Another way by which water becomes water vapour and is transferred to the air is **transpiration**. In this process water from the earth is absorbed by the roots of plants such as grasses, bushes and trees. This water then moves up through vegetation and is transferred to the air.

(6) **Surface run off:** When the surface soil can hold no more water, it is said to be **saturated**. Any excess precipitation then begins to flow downhill over the surface. This process is called overland runoff or **surface runoff.** Most of the surface runoff then flows to water body such as river or lake, and much of it eventually reaches the oceans.

(7) **Inter flow or subsurface flow:** It is the process whereby water moves essentially laterally beneath the land surface but above the groundwater table. It occurs until water enters a surface water channel.

(8) **Groundwater flow:** – It is referred to as **base flow** - It is water moving laterally beneath the water table toward and into natural or artificial channels, lakes and other receiving waters.

Due to the permanent movement of water under the action of solar energy and gravity water appears on earth in phases, which forms a cycle. The recovery periods of the various water storages vary widely. Whereas on average atmospheric water renewed every 8 days and river water every 16 days, the renewal of water contained in glaciers, large lakes, ground water reservoirs, seas and ocean may take hundreds or thousands of years.

It was estimated that about 95000 cubic miles of water are evaporated from oceans, lakes, streams, earth's soil and transpiration from leaves of plants. The entire amount is precipitated out of which 24000 cubic miles falls on earth yearly. This is the source of fresh water. The statistics of water distribution on the earth's surface is shown below

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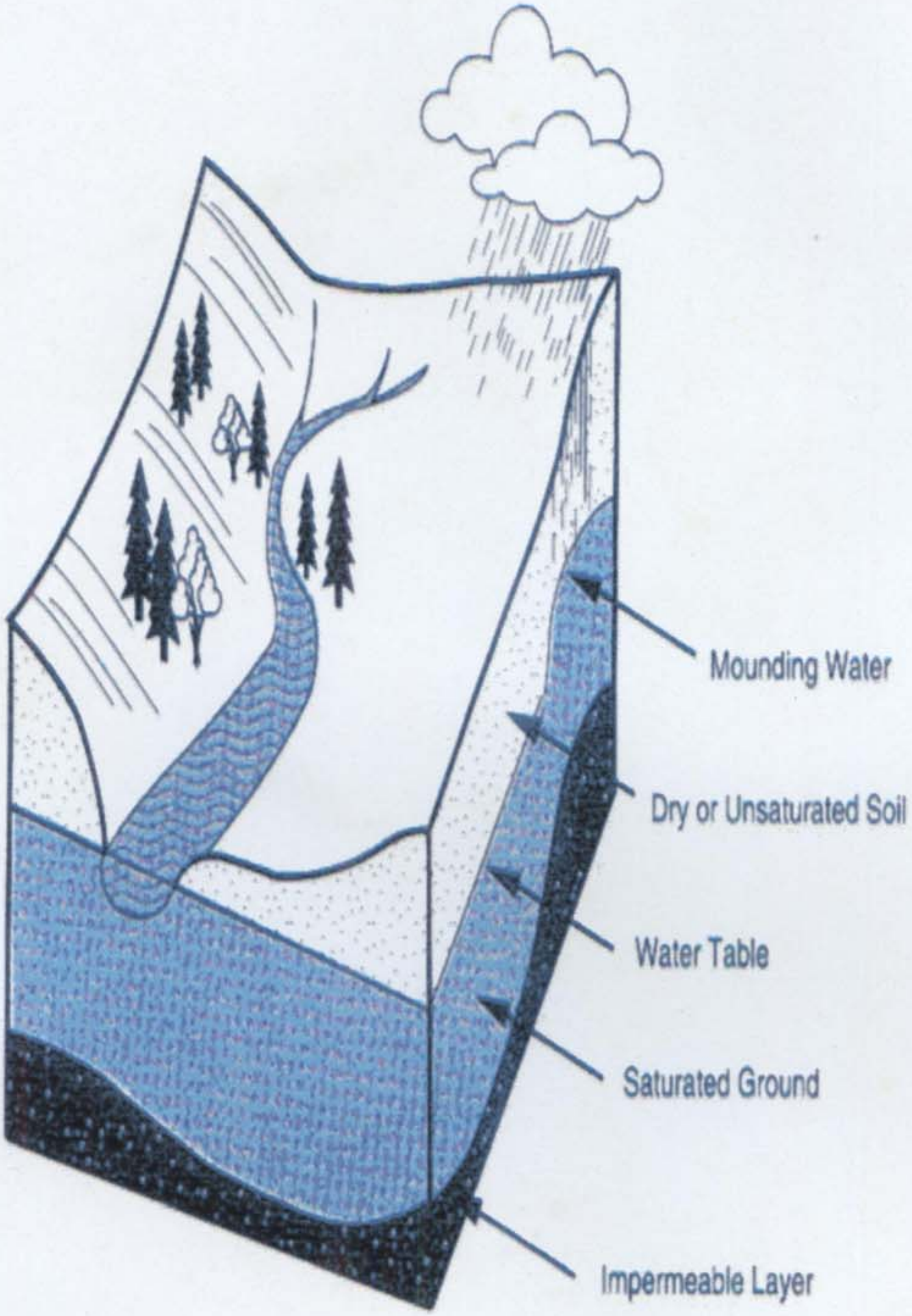

Figure 1.2 Formation of ground water in nature

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Table 1.1 Statistics of water distribution on the earth's surface.

Reservoir	Volume (106 km3)	Percent of Total
Oceans	1370	97.25
Ice caps and glaciers	29	2.05
Deep ground water (750-4000m)	5.3	0.38
Shallow groundwater (<750m)	4.2	0.32
Lakes	0.125	0.01
Soil moisture	0.065	0.005
Atmosphere	0.013	0.001
Rivers	0.0017	0.0001
Biosphere	0.0006	0.00004
Total	**1408.7**	**100**

Ground Water

Groundwater is the water occurring below the earth's surface in open spaces including fractures, joints, faults or other open spaces between rock particles below the water table (Fig.1.2), where the water table is defined as the upper surface of the completely saturated ground (Raudkivi, 1979).

To be specific, the water available in the saturated zone is termed as **ground water** while the water entering the saturated zone is termed as the **recharge** (Freeze and Cherry, 1979). It is the largest reservoir of fresh water available to humans. The amount of groundwater is strongly influenced by the amount of infiltration, which in turn can be affected by the other paths taken by precipitation in the hydrologic cycle.

The order of availability of fresh water on earth: ice sleets and glaciers, groundwater, lakes and reservoirs, and river water.

Groundwater is important as:

- source of water for human use
- medium of waste disposal (deep well disposal)
- recharge for rivers (effluent rivers - springs)

Kinds of groundwater

1. **Connate**: Entrapped brackish water found in the open spaces in the rocks
2. **Juvenile**: Water originating directly from magma
3. **Meteoric**: Fresh circulating water in the open spaces in rocks and is the type we often refer to as "the groundwater".

Most streams or lakes are in direct communication with ground water that saturates the available pores or flow channels. Between those land surfaces that are not continually covered with water and the underlying ground water body there is an intermediate zone where openings and pore spaces are filled mainly with air. Periodically water is added to this zone by rainfall, irrigation, etc. and the portion that is not returned by evapotranspiration to the atmosphere can move downward toward the ground water table. If water is plentiful it moves faster, if the water table is very low movement may be very slow. Movement of the solute will be still slower.

In most sediment the horizontal permeability is greater than the vertical permeability. This inhibits vertical movement of water and water in a particular stratum may develop chemical characteristics that are substantially different from water in strata above or below.

The earth's surface consists of alternate pervious and impervious soils. The pervious layers are those through which water can easily pass and through impervious layer water cannot easily pass. A portion of the rainfall on the ground percolates into the soil and reaches the impervious layer. It then moves in a lateral direction towards some outlet. The pervious layer in which water moves laterally is called an **aquifer**. Aquifer has the property of storing water and yielding the stored water readily and economically to wells. Aquifers are geologic formations, which contain ground water, and they are permeable to transmit and yield water in usable quantities. Various geologic formation acts as aquifers. In general, if a formation is capable of yielding enough water to support a well or spring, it is called an aquifer.

The types of geologic material from which the formation originally was made, influence its ability to hold and transmit water. For example, sands and gravels allow water to flow through easily. By comparison, shale, which originated from compacted layers of mud and clay, generally allows very little water to flow through it unless the shale is highly fractured. To be an aquifer, a geologic formation must contain pores or open spaces that are filled with water. 90% of all developed aquifers consist of unconsolidated rocks, chiefly gravel and sand. These aquifers can be visualized as large underground storage reservoirs. The entry of water is from natural or artificial recharge and it flows out by wells, as well is constructed to penetrate the earth into the saturated zone from which water can be extracted.

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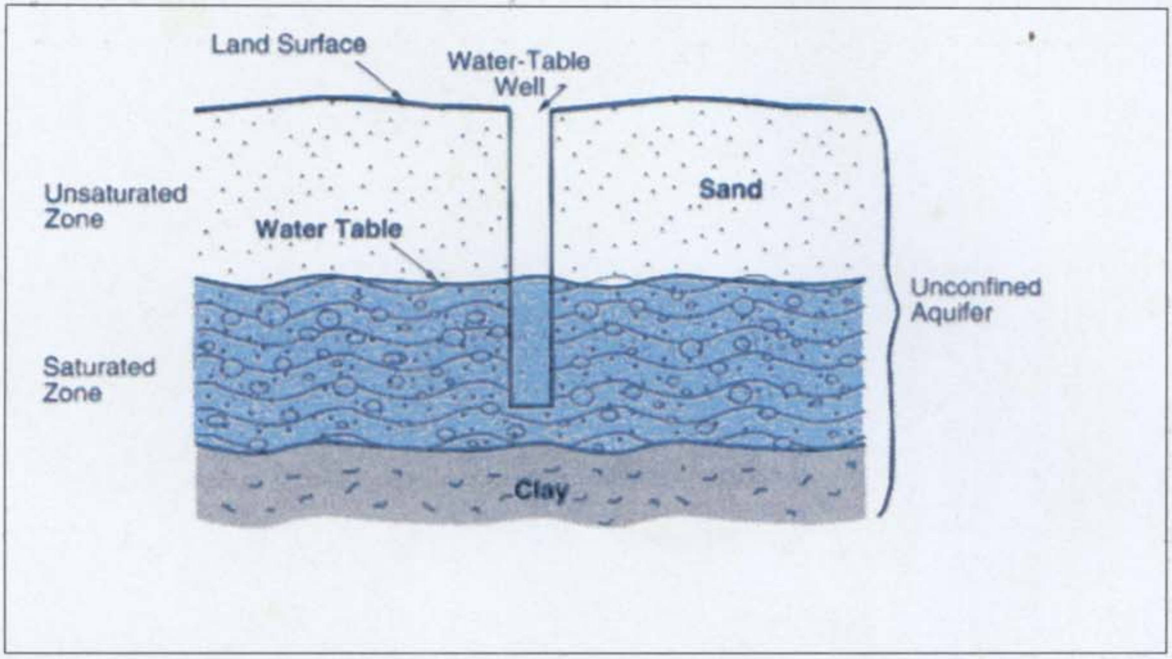

Figure1.3 Cross section of an unconfined aquifer

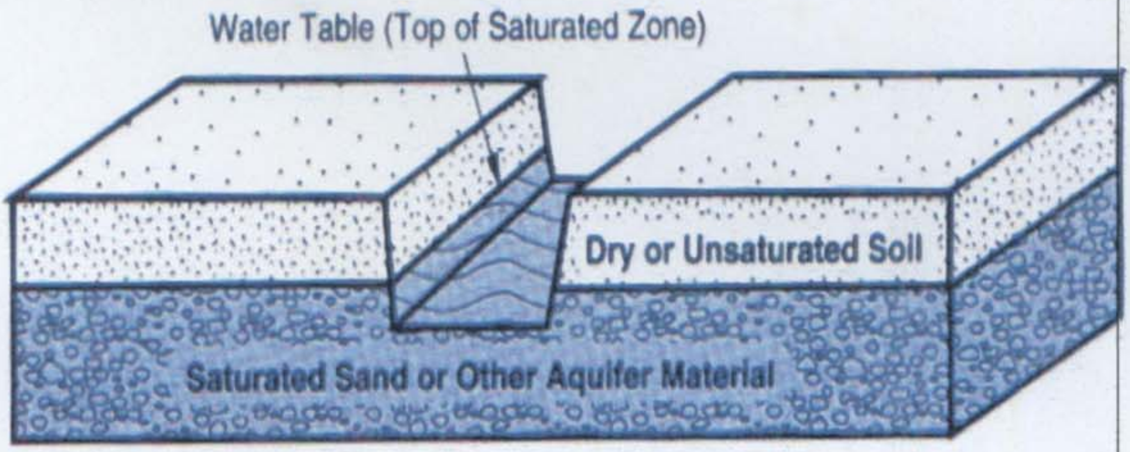

Figure1.4 Illustration of water table

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Water can exist in aquifers under two different conditions. The most common condition is when the water table is exposed to the atmosphere through openings on the overlying regolith. (Regolith is a geologic term used to describe the loose and discontinuous blanket of decayed rock debris overlying solid bedrock. The term soil is sometimes used for this unconsolidated material but soil is only the very uppermost part of the regolith where chemical and physical weathering is most active. Water is introduced to the regolith by precipitate and stream flow). This type of aquifer is referred to as an unconfined aquifer (Fig.1.3) or water table aquifer.

Groundwater also occurs under confined conditions. Confined ground water is isolated from the atmosphere at the point of discharge by impermeable geologic formation and the confined aquifer is generally subjected to pressures higher than atmospheric pressure. Under unconfined conditions the water table is free to rise and fall. During periods of drought the water table may drop 3 to 7 ft. or more. If heavy precipitation persists for many months or years the ground table may rise above its established mean level. Underground water sources are generally found in the form of springs, wells, infiltration wells and infiltration galleries. The free surface of water in the aquifer is known as water table.

Ground water resources: Scientists have estimated that there is an annual incidence of 24,000 cubic miles of water every year on the land surface of the earth alone, which consists of 36 million acres. But this bountiful supply had got its two phases of manifestation, surface water and ground water. Fig. (1.4) shows how a water table might actually occur in nature. When rain falls on the watershed, some of the rain percolates downward to the water table. A mound of

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Figure1.5 Groundwater movement

water within the aquifer is then built up above the level of the rest of the water table. The water aquifer is then built up above the level of the rest of the water table. The water within this mound slowly flows down gradient, increasing the level of the water table slightly and if the water table is high enough, draining into the stream channel. The movement of groundwater is illustrated further in fig. (1.5). The movement of water is faster in sand or gravel, but slow in clay; faster in large cracks (Beiser *et al.*, 1978).

The subsurface soil is mainly classified as unsaturated and saturated ones. In the former, the voids are filled by water and air but the latter contains water only. A clear demarcation of water in these zones is difficult, however the unsaturated zone lies over the saturated zone. Hence groundwater in that portion of water beneath the wells through drainage galleries or that flows naturally to the earth's surface via seeps or springs. When a hole is dug there may be moist soil but water will not flow freely. The groundwater is reached only when water begins to flow into the hole, i.e. the pressure of the groundwater is greater than that of the atmospheric pressure.

Aquifer functions: The opening and pores in a water bearing formation is like a net work of inter connected pipes through which water flows at very slow rates from areas of pipes provide both storage and flow or conduit functions in an aquifer.

Storage function: Storage function is related to the porosity to specific yield of the aquifer material. **Porosity** is an index of how much ground water can be stored in a saturated medium and is usually expressed as percentage of the bulk volume of the material. (Gibson and Singer, 1983). For example if 1m^3 of sand contains

$0.3m^3$ of open space, its porosity is 30%. μ= (Volume of pore space) / (Volume of bulk solid)

Specific yield is defined as the volume of water released from a unit volume of the aquifer material when allowed to drain freely by gravity. The remaining volume of water not removed by gravity drainage is called specific retention.

Porosity = specific yield + specific retention (η= Sy + Sr).

Flow (Conduit) function: The property of an aquifer related to its conduit function is known as the permeability. Permeability is a measure of the capacity of an aquifer to transmit water or in other words it is defined as the flow per unit cross sectional area of the formation when subjected to a unit hydraulic head per head unit length of flow and has the dimension of velocity that is length /time. Porosity is an important factor that affects the capacity of an aquifer for yielding water.

Ground water recharge: The recharge of ground water is mainly due to the movement of subsurface water. Sources of natural recharge include precipitate stream flow lakes and reservoirs. Other sources known as artificial recharge occur from excess irrigation seepage, from canals. Even seawater can enter underground along coasts (Todd, 1959). In humid areas during spring months when evapotranspiration is small and soil moisture is maintained at or above field capacity by frequent rains only a small fraction of the annual precipitate percolates downwards to the water table. A large portion of it runs overland to streams or is discharged by the process of evapotranspiration before it reaches aquifers (Walton, 1970). Several factors control the amount of precipitate that reaches the zone of saturation. They are the character and thickness of the soil, and other deposits above and below the water table, the topography and other factors such as vegetal cover, land use, soil moisture contact, the depth of the water table, the intensity, duration and seasonal distribution of rainfall, the occurrence of precipitate as rain, the temperature and other meteorological factors like humidity, wind, etc.

The vertical head differentials can influence the vertical downward movement of ground water. Their recharge is done by vertical leakage of which the following are important. Permeability and thickness of the deposits, the head differential between the sources of water and the aquifer and the area through which leakage occurs. Deeply buried aquifers are recharged by the vertical leakage of water.

Groundwater in its natural state is in motion although the velocities may be very small (Todd, 1959; Bouwer, 1978). The driving phenomena of water flow in the ground are the hydraulic potential or head. The cause of the movement is the difference of potential.

If the fluid is at the same head everywhere, there is no flow and if there exists a difference of head in space, water flows on the direction of decreasing heads (Fried, 1978). The normal speed of flow is between one meter per year and one meter per day. But the flow can be faster or slow depending upon the nature of the material through which the water moves and rates as high as 30 meter per day have been measured.

Ground water contamination

During the last decade, ground water pollution has become a major issue in the management of this vital natural resource and the protection of environment. As nearly one-fifth of all the water used in the world is obtained from ground water resources and in many areas ground water is the only fresh water source available; protection of ground water quality has become a high priority management goal (Rao and Yadiah, 1996).

Ideally groundwater should be characterized by clarity, bacterial purity, constant temperature and chemical quality and should require very little treatment prior to its use. However increased usage of groundwater resources and general increase of inputs of surface pollution into groundwater zones have caused contamination and general deterioration of groundwater quality in many areas of the world. Water even while falling as rain picks up small amounts of gases, ions, dust and particulate matter from the atmosphere. Then as it flows over or through the surface layers of the earth, it dissolves and carries with it some of almost everything it touches, including that which is dumped into it by man. They include industrial and commercial solvents, metal and acid salts, sediments, pesticides, herbicides, plant nutrients, radioactive materials, road salts, decaying animal and vegetable matter and living microorganisms such as algae, bacteria and viruses.

Groundwater contamination is a socio- economic problem that receives considerable attention in modern industrialized societies. The Environmental Protection Agency of U.S. between 1971 and 1974 documented ground water pollution during their background quality study of ground water (Wellings, 1982).

Groundwater can be contaminated by the following ways: improper disposal of liquid wastes, defective well construction, failure to seal the abandoned wells, deep percolation from intensively farmed fields, point sources such as septic tanks, garbage disposal sites, cemeteries, mine spoils, and oil spills, or any other accidental entry of pollutants into groundwater environment (Bouwer, 1978; Raghunath, 1988). These sources can be classified as environmental, industrial, agricultural and domestic (Camp *et al.*, 1974; Fried, 1978; Epstein, 1982 and Tchobanoglous and Schroeder, 1985).

Environmental: The environment through which the flow of groundwater takes place is responsible for environmental type of pollution. Even under undisturbed conditions, and without man's intervention, groundwater already contains a certain amount of dissolved matter, sometimes reaches levels which render the water unsuitable for certain usage.

Domestic: Accidental breaking of sewers, percolation from septic tanks, rain infiltrating through sanitary landfill and artificial recharge of aquifers by sewage water are identified as the major sources of domestic pollutants

Agricultural: Agricultural contamination is due to irrigation water and rainwater dissolving and carrying fertilizers. Salts, herbicides, pesticides, etc. as they infiltrate through the ground surface, travel through the unsaturated zone and replenish the aquifer. The uneven distribution of applied irrigation, non – uniformity of vegetative cover has contributed to the spatial variability of nitrates. (Mehran and Mohsen, 1997).

Industrial: Effluent discharges containing toxic organic and inorganic substances and heavy metals, intentional and unintentional disposal of raw or treated industrial wastes etc. by land are the industrial sources of contamination (Wood *et al.*, 1984).

In some cases, the groundwater resources, which are recharged by surface waters, might be polluted by influent seepage (wherever permeable beds are cut across by streams) resulting in contamination of ground water drawn from such aquifers (Subramanyam, 1969). Another main problem of groundwater storage is the salinity of many rock strata by which water becomes unfit for use. This is a critically important problem in arid areas.

Agriculture is the greatest user of water, accounting for 80% of all consumption. Some 15% of world's cropland is irrigated by ground water. In India 60 million hectares are irrigated of which about 40% is from ground water (Raghunath,1988). In areas dominated by agricultural activities there is the additional risk of diffuse contamination by agrochemicals. (EEA, 1999, Goss *et al.* (1998), Spalding *et al.* (1993).

Because of the filtering capacity of the soil, suspended material is seldom a constituent of ground water (Peavy *et al.* (1987); Nolan, (2000). Contaminated groundwater may appear clear and yet contain pathogenic organisms. The depth of the water table below the ground level is a governing factor in determining pollution. As the water table is near the surface, risk of contamination is greater; the shallow groundwater aquifers can be contaminated by bacteria from the liquid effluents from septic tanks, cess pools, etc. (Raghunath, 1988). Faecal coli forms, nitrates, and phosphates present in septic tank effluent are responsible for diseases like typhoid fever, gastroenteritis, blue baby syndrome (National Research Council, 1998).

When contamination has occurred by downward movement of polluted water sources from the surface like deep percolation from agricultural fields, leachate from garbage disposal areas or septic tanks etc, the concentration of the pollutants will be highest at the top of the groundwater, whereas brines and other solutions with a significantly higher density than the ground water will move to the bottom of the aquifer (Bouwer, 1978). Contaminants moving through aquifers are not subjected to rapid dilution because of its slow movement (Page, 1987). The generally low velocity of ground water movement, tending to inhibit mixing and diffusion in a ground water basin is one of the principal factors influencing ground water quality.

This slow rate of groundwater movement results in lapse of many years after the start of pollution, before the affected water shows in a well. This is also the reason why many years may be required to rehabilitate contaminated aquifers, though the source of pollution has been estimated, and there can be another possibility that the pollution source may have disappeared by the time the contamination is discovered and even the geology or hydrologic patterns in the immediate area may have changed. Therefore making the prevention of contamination is the best alternative than any other alternative sources. This slow movement also has an advantage i.e. those biodegradable pollutants and bacteria and viruses can decompose, or die with time. Various contaminants differ greatly in their subsurface behaviour. Many of them decay or are absorbed and almost all contaminants lose some of their potency by dilution in ground water. The potency of others decreases by their aeration above the water table. (Pettyjohn and Wayne, 1972). The effect persists for very long period, sometimes several decades (Prashanthi *et al.*, 1997).

The infiltration of urban roof runoff into well permeable subsurface material has adverse effects on the ground water quality and endangers drinking water resources. Adrian *et al.* (2003) observed a fast infiltration flow during natural rainfall.

In India the impact of pollution is generally due to the haphazard urban development without adequate attention to sewage and waste disposal, rapid industrialization without proper treatment and disposal of waste products, sanitary dumping of refuse and other solid wastes near aquifers, excessive use of fertilizers and pesticides for agricultural development and poor drainage in agricultural soils (Pitchaiah, 1995). Goyal *et al.* (1981) reported that 23.5% of ground water of Panjab showed varying degree of salinity.

Industrial wastes have resulted in pollution of ground water with high nitrate build-up, and metals and cyanides (Nolan *et al.*, 1996). This is due to the disposal of effluents on the surface creating stagnant pools. The rainwater dissolves these metals and percolates into the soil and ground water. The electroplating, wool drying, engineering and distilleries were the main polluters (Goyal *et al.*, 1981; Singh and Dogra, 1981; Kakar and Bhatnagar, 1981. Naram (1981) reported that textile mills and tanneries have polluted the ground water in Warrangal (A.P.) even in wells situated 125m from the polluting source. Krishnaswamy and Haridas (1981) studied the quality along Palar river course and nearby wells (Madras) and reported that wells were grossly polluted. The important pollutants were salinity and hardness. Mallick and Banerjee (1981) reports nitrate pollution of ground water as a result of industrialization and extensive use of nitrogen fertilizers in the Indo-Ganga Plain.

Varadarajan and Purandara (2003) studied the chemical characteristics of ground water in Malaprabha Sub- basin of Belgaum, Karnataka during pre monsoon and post monsoon seasons. It was observed that the quality of groundwater in the upstream region of the sub-basin is quite acceptable for use whereas in the downstream region various parameters exceed the acceptable limits due to excessive irrigation by excess application of fertilizers and pesticides. They also observed fluoride in excess along the down stream region of the sub basin. Moti R.Sharma (2004) studied the suitability of ground water for drinking purposes in Hamirpur area in Himachal Pradesh and found that though the water is very hard and highly alkaline there is no major pollution hazard in the ground water. Subramanyam and Reddy (1891) conducted extensive studies on the quality of ground water in Andhra Pradesh. Sarma and Samy (1981) and (1986) have sampled about 130 wells in the Vishakhapatnam Basin. Contamination has occurred due to natural geological formation, industrial effluents, irrigation or urbanization. Malini *et al.* (2003) collected ground water samples from the vicinity of Mysore, Karnataka and these samples were analysed for inorganic constituents. They found that the groundwater was over saturated with respect to calcite and to lesser extent with dolomite. Sixty percent of the ground water samples had nitrate concentration higher than the WHO limit. Gupta (1981) evaluated the quality of well waters in Udaipur district of Rajasthan.

Ramasesha *et al.* (2002) carried out a detailed study to asses the ground water quality in and around Dindigal, Tamil Nadu. The analytical results revealed that the ground water in the major part of the area is highly mineralised with high concentration of nitrate and fluoride. Out of 110 ground water samples analysed 68 samples were found to have nitrate concentration more than 45mg/L. Jeyram *et al.* (1981) assessed the ground water quality in Faridabad, Haryana. Tanwar (1981) reported large variation in the ground water quality in Faridabad after analysing 3000 well water samples.

Taqveem Ali Khan *et al.* (2003) studied hydrochemical parameter of the ground water in the Dibai Block of Bulandshahar District (U.P.) by taking 18 dug well samples. Qualitatively the ground water was potable, hard, and alkaline in reaction and slightly mineralized.

Das and Kidwai (1981) reported high values of chlorides, sulphates and nitrates in the wells in the river basin of Betwa, (M.P). They attributed this change to human animal excreta pollution. Rajmohan *et al.* (2003) tried to find out the general hydrochemistry and quality of ground water of Royapuram area, Chennai. The chemical analysis shows that sodium and chloride are the dominated ions in those samples and the ground water in these areas is hard to very hard category. A study on subsurface water quality in Kalayarkoil Panchayat union of Sivaganga District in Tamil Nadu has been carried out by Ramesh and Mahendran (2000). They analysed the trend and spatial distribution of various chemical parameters affecting the subsurface water in pre monsoon and post monsoon seasons. It was reported that concentrations of the parameters show an increasing trend in both the seasons but it was more in post monsoon season, indicating the increasing rate of leachate into subsurface water during monsoon period.

Kakar (1981) observed nitrate levels exceeding 500mg/L at shallow depths at several places in southern and southwestern Haryana. Das (1985) reported the high fluoride in deep ground waters of Betwa Basin, Madhya Pradesh, with concentration ranging from 0.25mg/L to 10.25mg/L. Jain *et al.* (2000) carried out a hydrochemical study of the ground water of Sagar District, Madhya Pradesh to examine the suitability of water for drinking and irrigation purposes. It was reported that the ground water of the area falls under the category of low sodium hazards. Pickering (1985) studied the mobility of soluble fluoride in soils. Noss (1985) reported the mobility of soluble fluoride in ground water contamination. Infiltration of water by rainfall, water already present in the waste or water generated by bio-degradation causes the leachate to leave the land fill site laterally or vertically and find its way into the groundwater, causing contamination.

Kumaravel *et al.* (2003) tested the quality of ground water around the dumping sites located at Villianur, Mettupalayam, Chidambaram (T.N.). The results of chemical test of ground water showed higher amount of contamination by the dumping located in sandy bed and less contamination of ground water by dumping located in clayey soil. Gasoline and petroleum products were found in the wells near by industrial waste disposal sites. Rao *et al.* (1986) analysed 70 samples from different dug and bore wells located at 21 places in the Nuzvid Town (A.P.) and reported that nearly 50% of the wells had high values of dissolved solids. Physico- chemical characteristics of bore wells of industrial areas of Vishakhapatnam were monitored by Srinivas *et al.* (2002). The Water Quality

Index varied from 50- 97.41 indicating level of nutrient load and pollution in the bore waters. The quality of ground water in Venkatagiri Taluq, Nellore District, A.P. has been assessed by analysing one hundred and twenty ground water samples. Lingeswara Rao (2001) revealed that 5 factors were responsible for total variance in the quality of ground water. Conductivity, sodium, carbonate, potassium and magnesium account for 81.0% of the total variance. Mishra *et al.* (2003) observed that the water pollution on the mining areas is mainly due to the presence of a large amount of suspended solids in the effluents of mines. Sarma & Sarmah (1990) found that the quality of ground water has exceeded the prescribed limits in the Guwahati area. 7 open wells and 13 bore wells were investigated for their water quality. It was found that the open wells were heavily contaminated than bore wells with coliforms (Dhanaselvi and Samy, 1990).

In some parts of India sewage effluents are used for irrigation. This also can be one of reasons for ground water pollution. In Roorkee area sewage irrigation is being practiced since 1975. Singhal *et al.* tried to assess the impact of sewage irrigation on the ground water quality of that area with reference to the physico- chemical and bacteriological characteristics and selected heavy metals. The result showed that slight deterioration on the overall quality of ground water in the shallow aquifer in the vicinity of the irrigated area (Singal, 2001). Ballukraya and Ravi (1999) studied the characterization of groundwater in the unconfined aquifers of Chennai City. He concluded that quality of ground water in this region is controlled by topography and lithology apart from other factors like land use pattern and paleo-environmental conditions. Gnanasundar and Elango (1998) studied the groundwater quality of a coastal urban aquifer and suggested that groundwater quality affected by polluted canal water and clay deposits.

Hydrological conditions and Groundwater pollution sources in Kerala

Kerala state lies as a narrow stretch of land bordering the Lakshadeep Sea on the western side and Tamil Nadu and Karnataka on the eastern side. It lies between north latitudes 8°18' and 12°48' and longitudes 74°52' and 77°22'.

The occurrence and movement of ground water is mainly controlled by the physiographical /geological setting.

The state is divided into three major physiographic units viz. the coastal plains, the midlands and the hill ranges. The length of the coastal zone is about 560kms and the zone covers about 10% of states' area. The coastal plains have an elevation of less than 6m whereas the elevation of the midland ranges from 6 to 80 m and that of the hill ranges is more than 80 m above mean sea level. Water is one of the primary natural resources on which the sustenance and eco-development of Kerala are largely dependent (State Water Policy, 1992).

Kerala is situated in the humid tropics and has unique geomorphology, geology, meteorology, land use and cropping pattern. These factors considerably influence the water resources and its management (Nambudiripad, 1998). There are 44 rivers that originate in the Western Ghats and cut across the state with their innumerable tributaries and branches. Out of the 44 rivers, 41 flow towards the west and join the Kaveri system and finally into the Bay of Bengal. The annual discharge from all the rivers of Kerala is estimated to be 77900 million m^3 (James, 1998).

Laterites are the most widely distributed lithological unit in the state and the thickness of this formation varies from a few meters to about 30m.The depth to water level in the formation ranges from less than a meter to 25 mbgl. The occurrence and movement of ground water in the laterites are mainly controlled by the topography. Laterite is a highly porous rock. Due to this porous nature, groundwater is drained from elevated places and slopes at shortest duration after monsoon due to which scarcity is experienced in the elevated places and slopes. This is the most extensive hydrogeologic unit in the state.

In Kerala nearly 40 % of the rural area is covered by protected water supply. Hence the bulk of the rural population depends on ground water sources for multipurpose activities. The state with a ground water potential of 6000 Mm^3, the open dug wells are capable of yielding an average of 10 –20 cubic meters per day. Kerala has highest density of wells in the world. (Martin, 1989).

Generally, the ground water problems in Kerala are due to the presence of excess salinity, iron, fluoride, hardness and coliforms. Seawater intrusion, domestic sewage, mineralogical origin and agricultural and industrial activities are the major causes for ground water pollution (Remani and Harikumar, 1998). Low pH, high iron content, high hardness, high TDS and salinity are common quality problems in the coastal areas (Nazimuddin and Basak, 1995). Excess chloride concentration has also been reported from the coastal zone (CWRDM, 1997).

Contaminated groundwater in the midland region is generally found to have high iron, fluoride and chloride concentration and abnormal values of pH and electrical conductivity. Mineralogical contamination is another ground water problem in this region. Maintenance of ground water quality at acceptable levels is a major requirement for successful use of a ground water resource. Joseph (1982), sampled 11 wells in Eloor, Cochin twice in June, 1982. They analysed the waters for pH, conductivity and chemical parameters. The relation between pollutant discharge into rivers and their presence in nearby ground water was confirmed by Von Gunten Kull (1986). The ground waters of Trivandrum were characterized by Basak and Nazimuddin (1983). Kamaalkshan Kokkal *et al.* (2002) studied the quality of well water near KSRTC bus stand, Kaserkod. It was reported that the water from those wells is bacteriologically highly polluted. KSRTC septic tank, washout from the cattle shed, wastewater from the hotel and their own toilet were the sources of pollution in that place. Nazimuddin et al. has identified major sources of pollution in different parts of Kerala. (Nazimuddin *et al.*, 2003).

Problems of ground water management of Kozhikode District

Kozhikode district has 4 major rivers and are west flowing and drain into Arabian Sea. The average rainfall for the whole district is about 3424mm.CWRDM has investigated several cases in Calicut district. In Mavoor a number of open wells around the buried pipelines along 11km stretch were found to be affected. Another investigation of wells in West Hill revealed that pollutants from sewerage drain took 34 years to reach well which was only 30m away from the drain (Nazimuddin *et al.*, 2003).

Wells

A well can be defined as vertical cylindrical opening, which extends from the surface of the ground into the water bearing formation of the aquifer. The chemical nature of the groundwater is one of the major factors, which determine a well's suitability.

In ancient times ground water resources were tapped from drinking supply and irrigation. Wells were digged to supplement water obtained from springs and rivers. Well water is mentioned in Rig Veda. Wells were also constructed in Greece and Persia (Duggal, 1984). Deep wells around 100m were constructed in China at least 3000 years ago and they were lined with bamboo castings. The Indus Valley civilization (3000B.C) also had wells to meet their water supply. Well are classified as shallow wells, deep wells and tube wells (Driscoll, 1986).

Shallow wells: They are constructed in the uppermost layer of the earth surface. They draw water from the pervious layer overlying the first impervious layer. They are generally less than 50 feet in depth. Based on the type of construction they are classified as bore or driven and jetted wells of which the dug wells are the oldest and simplest. They can furnish large quantities of water from shallow ground water sources. The well is permanently lined with a casing (often called as curb) of wood staves, brick, rock, concrete or metal. The liners in contact with the water bearing layers are perforated to allow water to enter. If the aquifer is sandy material a layer of gravel is placed around the curb as a sand barrier An open well is capable of yielding an average of 10 –20 cubic meters of water per day. Though it can easily be operated it is susceptible to dry up in years of drought. And deep-seated aquifers cannot be economically tapped. Ground water from a shallow origin is particularly susceptible to contamination from a combination of point and diffuse sources (Fuest *et al.*, 1998).

Deep wells are wells that are dug into pervious layer below the first impervious stratum. The yield from deep wells is much better than the shallow wells. Fairly sustained yield of water can be obtained even in years of scanty rainfall. The deep wells are contained in lower embedded aquifer and so it is available at a pressure greater than atmospheric pressure. So deep wells are also known as pressure wells. Deep wells contain more minerals.

Well Yield

The actual yield of a well, in gallons per minute (gpm), will vary considerably depending on the age and depth of the well, the diameter of the casing, well construction, pump capacity and age and most importantly, properties of the geologic formation. The exact yield and depth of each well will depend on the properties of the geologic formation at the specific location of the well. The water level in any well typically does not remain constant but changes depending upon the proximity of adjacent wells and surface streams and natural rainfall. Ground-water discharge and recharge greatly affect water levels in wells.

Chapter 2

MATERIALS, METHODS AND INSTRUMENTS

Topography of the study area

Calicut is an important centre of Kerala. It is situated in the northern part of Kerala between $11^0 10'$-$11^0 15'$ north latitude and $75^\circ 45'$-$75^\circ 52'$ east longitude. It has total area of $2344km^2$ and a population of 26.2 lakhs, which is about 9% of the total population of the state. The relative areas of the different physiographic units in the district are lowland -$362.8km^2$, midland -$1344.7km^2$ and highland-$625.8km^2$. Calicut city is spread over an area of 84.2km with a human population of about 419831. It is situated on the Malabar Coast. The area falls under midland region of Kerala, with the highest elevation being approximately 65 meters above sea level. The major rivers flowing through this district are Korappuzha, Chaliyar and the Kallai river and their tributaries. The last two join at the Beypore estuary.

The soil is typically lateritic. It is deep red in colour and is observed mainly in the tropics. It has developed on bedrock of mafic igneous rock. A soil horizon associated with laterite soils is iron-rich, humus, poor mixture of clay, quartz and other diluents. This material called plinthite, dries irreversibly with repeated wetting and drying with strong sunlight. The hard, dried rock like material is hardened plinthite and is commonly referred to as ironstone or laterite (Raychaudhuri, 1996).

Most of the people depend on homestead open wells for domestic purposes. The density of open wells in the district is 258 per km^2. It is estimated

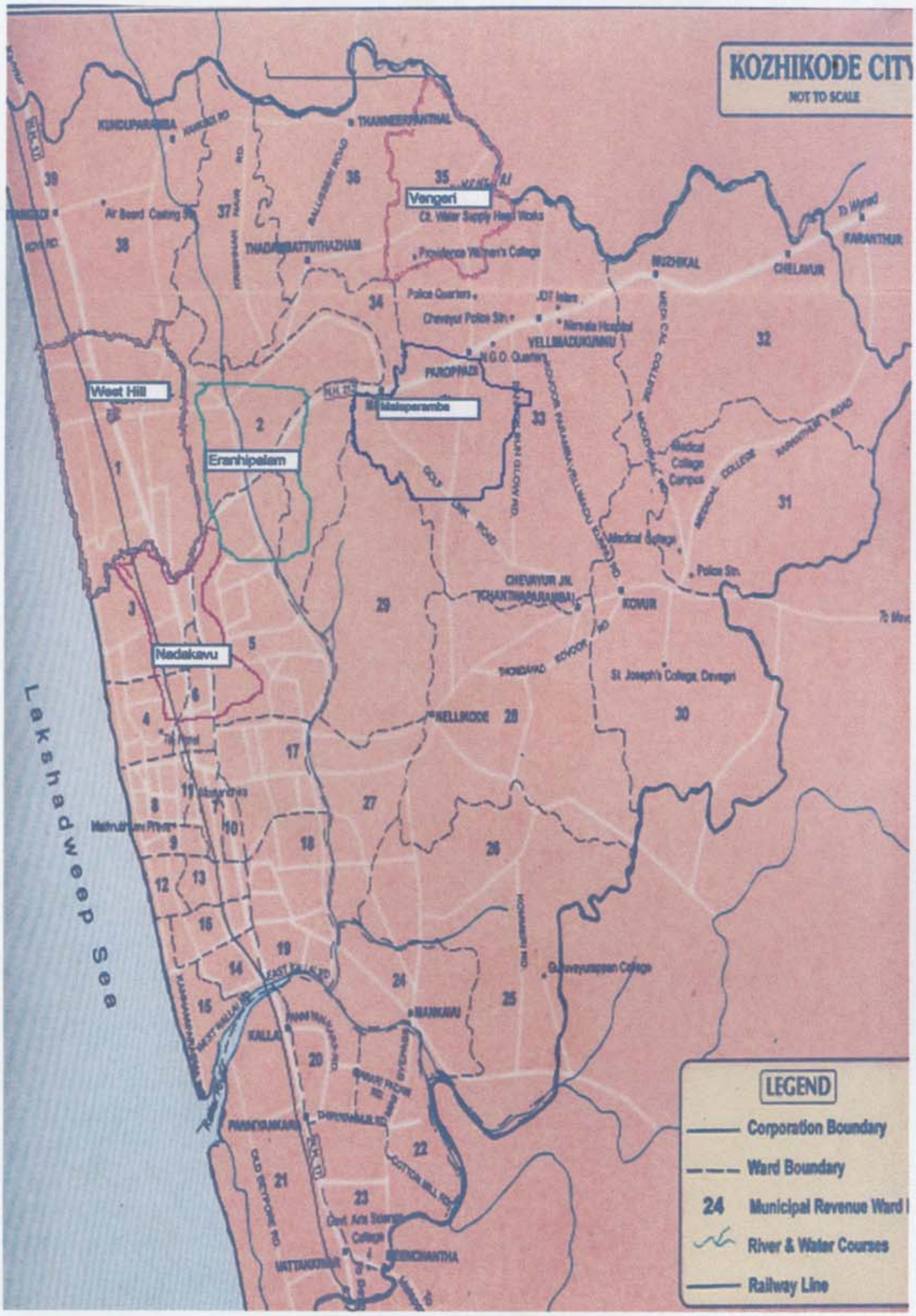


Figure 2.1 Location of the wells

that 50% of the population of the city depend on wells (Karma, 1994). A detailed ground water survey of the location of wells was conducted. 20 wells were selected in different parts of Calicut district. All the wells served the purpose of drinking water source. Locations of the wells include agricultural area, industrial area and area which are pruned to saline water intrusion (Table 2.1). The locations are given in fig. 2.1.

Materials

Reagents and chemicals

All the chemicals used were of analytical grade BDH, Glaxo, E. Merck or Qualigens. Standard solutions and reagents for analysis were prepared as follows:-

Sulphuric Acid (0.02N): Sulphuric acid solution for total alkalinity determination was prepared by diluting concentrated acid. The solution was standardised using 0.02 N sodium carbonate solution.

EDTA solution (0.01 M): 3.723 g. of A.R. grade EDTA was dissolved in distilled water and diluted to 1000ml. The Molarity was checked by titrating against standard calcium carbonate solution using murexide indicator.

Silver nitrate solution (0.0282 N) 4.7 g silver nitrate is dissolved in redistilled water and diluted to one litre and stored in brown bottle. Concentration of the solution was checked by titrating with sodium chloride (0.0282 N) using potassium chromate indicator.

Barium chloride solution: 2.443 g A.R. barium chloride was weighed and dissolved in distilled water and made up to one litre in a volumetric flask.

Nessler's reagent: 100g HgI_2 and 70g KI were dissolved in a small quantity of water. A cold solution of sodium hydroxide (160g in 500ml distilled water) is added with stirring and diluted to 1000ml.

Stock ammonium solution: 3.819 ammonium chloride was dissolved in distilled water and made upto 1000ml.

Manganous sulphate: 480g of manganous sulphate tetrahydrate were dissolved in 1000ml distilled water.

Alkali iodide azide solution: 500g of potassium hydroxide and 135g KI were dissolved in distilled water. After adding sodium azide (10g in 400ml distilled water) it was made up to 1000ml.

Sodium thiosulphate solution: 24.83g of sodium thiosulphate was dissolved in 1000ml of distilled water.

Phenol disulphonic acid: 75g of pure white phenol was dissolved in 300ml of pure sulphuric acid slowly with stirring. It was then heated for two hours in a boiling water bath.

Stock solution for Spectrophotometric determinations

Iron solution: For constructing calibration curve for the estimation of iron, a stock solution was prepared by dissolving 0.864g hydrated ferric ammonium sulphate in distilled water in the presence of 10ml of con. HCl acid and made up to one litre. Thus 1 ml. of this solution contains 0.1 mg of iron.

Fluoride solution: Dissolved 221.0 mg of anhydrous sodium fluoride in distilled water and diluted to 1000 ml. Thus one ml of the solution is equivalent to 100 microgram or 100ppm fluoride.

Standard phosphate solution:

Dissolved 219.5mg anhydrous potassium dihydrogen phosphate in distilled water and diluted to 1000ml. 1 ml of this solution contains 50ppm phosphate.

Stock solutions for flame photometric determination

Standard sodium solution: Dissolved 2.541g analar sodium chloride in distilled water and made up to 1000ml.

Standard potassium solution: Dissolved 1.907g analar potassium chloride in distilled water and made up to 1000ml.

Buffer solutions

Ammonia buffer for EDTA titration: Ammonium chloride (16.9g) was dissolved in 143 ml concentrated ammonia of specific gravity 0.8 and then added 1.25g of magnesium salt of EDTA and diluted to 250 ml with distilled water.

Indicators

Eriochrome Black-T indicator: The solid indicator 0.5g was ground with analar sodium chloride (100g) in a mortar and stored in air tight bottle.

Phenolphthalein indicator: Dissolved 1g phenolphthalein in 100ml of 95% alcohol and added 100ml of distilled water then added 0.02N NaOH until a faint pink colour appears.

Methyl Orange indicator: Dissolved 0.5g of methyl orange in one litre of distilled water.

Murexide indicator: Mixed solid murexide indicator and analar sodium chloride in the ratio 1:500 by weight in a mortar, ground well and kept the powder in a dry bottle.

Potassium chromate solution: Dissolved 50g potassium chromate in a little distilled water. Silver nitrate solution was added till a definite red precipitate was formed. Allowed the solution to stand for12 hours. Filtered and diluted the filtrate to one litre with distilled water.

Starch indicator: 0.5 g of starch was made into a paste with distilled water and it was then added into 100ml water and boiled for few minutes and cooled.

Special reagents:

1.Acid Zirconyl SPADNS reagent:

a) SPADNS solution: Dissolved 968 mg SPADNS (2- Parasulphophenylazo1,8-dihydroxy,3,6-naphthalene disulphonate) also called 4,5-dihydroxy-3-(para sulpho phenylazo) -2,7-naphthalein disulphonic acid trisodium salt, in distilled water and diluted to 50 ml.

b)Zirconyl acid reagent: Dissolved 133mg zirconyl chloride octahydrate $ZrOCl_2$ $8H_2O$ in about 25ml distilled water and added 350ml conc. HCl, further diluted to 500ml with distilled water.Then mixed equal volumes of SPADNS solution and zirconyl acid reagent for preparing acid zirconyl SPADNS reagent.

c) Ammonium molybdate reagent:

Dissolved 25g ammonium molybdate in 175ml distilled water; cautiously added 280ml of concentrated H_2SO_4 to 400ml distilled water. Cooled and added the molybdate solution and diluted to one litre.

d) Stannous chloride reagent:

Dissolved 2.5g of fresh stannous chloride reagent in 100ml glycerol. Heated in a water bath and stirred well to hasten the dissolution.

Instruments

Instruments used in the investigation are

A Systronics Digital **pH meter** 335 was employed for all pH measurements. Standard buffer solutions of pH 4 and 7 were used for calibration.

Elico CM 180 **conductivity meter** was used for measuring specific conductivity.

A Shimadzu model 1601 **UV-Visible Spectrophotometer** was used for estimation of iron.

Flame Photometer:

Alkali metals are excited by the relatively low excitation energy of a flame. The solution under test is atomized and finely sprayed into the flame where it imparts colour whose wavelength is characteristic of the element present in the sample. The intensity or the colour varies with the concentration of the metallic ions in the solution. Air at a certain pressure is blown into the atomizer where the sample solution is broken into fine particles and is carried with the compressed air into the flame. In the mixing chamber, the compressed air meets the fuel gas coming at a certain pressure and the mixture thus formed is fed into the burner for producing the flame. Radiation from the flame passes through a lens, a slit and a filter and then falls on a photocell. The current developed in the photocell is measured by the galvanometer. Flame was produced by liquid petroleum gas. Analysis of sodium and potassium were done by this method.

Atomic Absorption Spectrophotometer

To detect copper, zinc, cadmium, mercury and lead Atomic Absorption Spectrophotometer was used.

The principle of Atomic Absorption Spectrophotometer is based on the absorption of photons by an atomic vapour in ground state. The element of interest in the sample is dissociated from its chemical bonds and placed into an unexcited, unionized ground state. The dissociation is achieved by supplying thermal energy to the sample. The element is then capable of absorbing radiation of discrete lines of narrow bandwidth. The wavelength at which absorption occurs is characteristic of the element and the degree of absorption is a function of the concentration of atoms in the vapour.

Line radiation from suitable source is passed through atomic vapour by means of suitable optics to a wavelength selector. The latter isolates the wavelength that can be absorbed by the test material from other spectral lines emitted by the source. A photosensitive detector measures the light flux after passage through the wavelength selector.

The source of radiation is a hollow cathode lamp. Atomic vapour is produced in an atomizer. Thermal energy in the form of flame or electrical heat is supplied to provide free atomic environment. In flame type atomizer, the pre-heated sample is aspired into air- acetylene flame or nitrous oxide- acetylene flame depending on the element to be determined. Air- acetylene flame gives a temperature of about 2000°C and is suitable for the determination of metals like silver, cadmium, cobalt, chromium, copper, iron, manganese, lead and zinc.

METHODS

Water sampling and the determination of various physical and chemical parameters were carried out according to standard methods (APHA, 1998; R.G.Bates, 1973).

Sampling

Samples from the wells were collected from a few feet below the water surface. Samples from the bore well were taken after thorough flushing.

Temperatures, pH, electrical conductivity, colour and appearance of all the water samples were noted on the site.

Water samples were carefully collected in a 300ml capacity BOD bottle. Winkler A and B solutions were added on the spot and the samples were thus fixed. The measurement of dissolved oxygen was made later at the laboratory.

Samples for Physico-chemical analysis

Water samples of about 2 liters were collected in clean plastic can using plastic funnel after rinsing the container with sample.

Samples for Bacteriological analysis

For bacteriological analysis 250 ml of water was collected in glass stupider sterilized glass bottle. The stopper of the bottle was protected using a parchment paper.

Analysis

Colour and Appearance

Colour is a common constituent of many natural waters and it is caused by metallic substances, such as iron and manganese compounds, humus materials, tannin, algae, weeds and protozoa.

The colour of the water was noted visually.

Temperature

The ambient temperature of the water was noted immediately on the site itself to avoid changes caused by air temperature and manipulation of the sample.

The thermometer was immersed directly in the water collected in sample bottle for a period of time sufficient to permit constant reading. Temperature was recorded in Celsius scale.

Total Dissolved Solids

100 ml of the sample was filtered to a previously weighed dish and evaporated to dryness in an oven, cooled in a desiccator and weighed again. From the difference in weight total dissolved solids were calculated.

pH

The instrument was allowed to warm for 30 minutes followed by calibration of the electrode system against standard buffer solutions of known pH 4 and 7. The glass electrode of the pH meter was washed with distilled water having specific conductance less than 2 micro mhos and a pH of 5.6 – 6.0; the temperature was set at 25°C. This was then placed in the water sample taken in a 100ml beaker and the pH was read directly. In sampling care was taken to avoid agitation of the sample because loss of CO_2 may change the actual pH value. CO_2 dissolves in water to form carbonic acid. Since the solubility of CO_2 changes with pressure and temperature the pH in turn will also change. pH may change appreciably during transport and storage of water samples. Therefore pH was determined at the site itself.

Electrical Conductivity

The electrical conductivity of any sample depends on the electrolytes dissolved in it. The conductivity is proportional to the amount of such substances dissolved in the water provided the solution is very dilute. Conductivity cell was washed with deionised water and placed in potassium chloride solution (0.01N) after rinsing, the reading was adjusted to 1409 mhocm^{-1} (standardization).

Then the sample was taken in a 100 ml beaker and specific conductivity was measured after washing the cell with deionised water and rinsing with the sample. The conductivity meter directly measures the electrical conductivity. The unit is micro mhos per cm at 25^{0} C.

Total Alkalinity

100ml of the water sample was titrated against sulphuric acid (0.02N) solution using methyl orange indicator. The results are expressed in mg/L of calcium carbonate. Phenolphthalein alkalinity in all the samples was found to be zero.

Total Hardness

Total hardness was determined by EDTA – titrimeric method. In alkaline condition, disodium salt of ethylene diamine tetra acetic acid dehydrate reacts with calcium and magnesium to form a soluble chelated complex

$$CaCl_2 + 2EDTA \rightarrow Ca\,(EDTA)_2 + 2NaCl$$

Calcium and magnesium develop a wine red colour with Eriochrome black T. pH is maintained at 10. As magnesium can be first precipitated as $Mg(OH)_2$ titer value gives the amount of calcium only. Murexide indicator forms a pink colour with Ca^{++} and becomes complexed in a change from pink to purple which indicates the end point of the reaction.

100ml of the water sample was titrated against standard EDTA (0.01M) solution using Eriochrome black-T as the indicator at a pH of 10 (ammonia buffer was used). The results are expressed in ppm or mg/L of calcium carbonate.

Calcium Hardness

To 100ml of the sample murexide is added after adding 2ml sodium hydroxide to increase the pH. It is then titrated against EDTA solution till the violet solution turned to blue and the value of calcium hardness is calculated.

Dissolved Oxygen

The experiment is based on the addition of divalent manganese solution followed by strong alkali to the sample in a glass stoppered bottle. Dissolved oxygen present rapidly oxidises an equivalent amount of the dispersed divalent manganous hydroxide to hydroxides of higher valancy states. In the presence of iodide ions and acidification, the oxidized manganese converts to the divalent state, with the liberation of iodine equivalent to the original DO content in the sample. The iodine is then titrated with a standard solution of thiosulphate.

Water was siphoned into the sample bottle. Precautions were taken to reduce the contact of the water with air. The tip of the siphon tube was allowed to reach the bottom of the sample bottle and water was allowed to flow turbulently during siphoning. The water was allowed to overflow the top of the sample bottle so that water which has been in contact with the air is displaced. Then the siphon was gently removed and the stopper was dropped in the bottle after making sure that no air bubbles were trapped in the bottle. Then 1 ml of manganese sulphate solution followed immediately by 1 ml of alkali azide reagent was pipetted into the solution. The reagents were added at the bottom of the sample. Great care was taken to ensure that no air was bubbled into the water when the reagents were added. The stopper was inserted and the bottle was carried to the laboratory. 2ml of concentrated sulphuric acid was added just below the surface of the sample and the bottle was rotated after replacing the stopper. 50 ml of the aliquots was transferred into a conical flask and the liberated iodine was titrated against sodium thiosulphate solution using starch indicator.

Oxygen absorbed

100ml of the sample was treated with 0.0152N potassium permanganate solution and sulphuric acid. Allowed it to react for 4 hours and titrated it against standard sodium thiosulophate solution using starch indicator.

Carbon dioxide

100ml of the water sample was pipetted out into a conical flask without agitating the water. It was titrated against 0.023N NaOH solution after adding 10 drops of phenolphthalein till a permanent pink shade was obtained.

Ammonia

Nesslerization method: 500ml of the water sample was taken and 10ml of phosphate buffer was added and distilled it. 50ml of the distillate was taken and 2ml of Nessler solution was added and mixed. After 10-12 minutes, concentration of ammonia was found out using a colorimeter.

Nitrite –Nitrogen

1ml of suphanilic acid was added to 50ml of the sample and was shaken well for 4 - 5 minutes. Then 1ml of naphthylamine hydrochloride and 1ml of sodium acetate buffer were added and adjusted the pH to 2 - 2.6. After allowing it to stand for half an hour, reading was taken at 520nm using colorimeter. The experiment was repeated using standard sodium nitrite solution.

Nitrate- Nitrogen

Pipetted out 1ml of the water sample into a test tube. 1.5ml of diluted reagent (80 ml of distilled water was added to 200ml strong phenol disulphonic acid) was added along the side of the test tube so that a layer was formed at the bottom. It was then placed in boiling water bath. After cooling, it was made up to 25ml using ammonium citrate solution (25g in 1 litre of distilled water) in a 25ml flask and colour absorption was read against a blank. (Distilled water and acid treated as above).

Albuminoid nitrogen

50ml of the distilled sample was taken and 50ml of alkaline $KMnO_4$ (0.533%) was added and distilled again. 50ml of the distillate was collected. 2ml of the Nessler solution was added. After keeping for 10-12 minutes the amount of albuminoid was found out using a colorimeter.

Chloride

Since pH of all the samples were around 7, argentometric method (Mohr's) was employed for the determination of chloride. 100ml of the water sample was titrated against standard silver nitrate solution (0.282N) using potassium chromate as indicator. The results are expressed in ppm. The reactions involved are

$$AgNO_3 + Cl^- \rightarrow AgCl\downarrow + NO_3^-$$

$$2Ag\,NO_3 + K_2CrO_4 \rightarrow Ag_2CrO_4\downarrow + 2KNO_3.$$

Sulphate

Titrimetric EDTA method was employed for determining sulphate content of the water sample. 100ml of the water sample was taken in a beaker, added few drops of methyl orange indicator and slight excess of nitric acid. Boiled to expell carbon dioxide. 10ml of the standard barium chloride solution was added to the boiling solution. Cooled the mixture and allowed the barium sulphate precipitate to settle. 50ml of supernatant liquid was pipetted and added 1ml ammonia buffer and Eriochrome black-T indicator were added and titrated against standard EDTA solution until a blue colour is produced.

Sodium and Potassium

The determination of metal ions in natural waters by classical method is difficult because of the low concentrations of most ions and because of interferences. Flame methods for water analysis were first applied by West *et al.* (1950) to the alkali and alkaline earth metals. West *et al.* determined Na, K and Ca at the microgram per milliliter level by flame emission. The flame photometric method is the most rapid and sensitive and generally more accurate method for measuring sodium and potassium.

The filter was set for readings at 589nm. The compressor was started and the burner of the flame photometer lighted. Kept the air pressure at 5lb. and adjusted the gas feeder was adjusted to have a blue sharp flame. Then different stock solutions were used within the ranges 0-1, 0-10 and 0-100mg of sodium per litre one by one recorded the emission value for each plotted a standard curve between concentration and emission of standard sodium solution. Adjusted the zero value of the meter by feeding distilled water. Filtered the sample through a filter paper and fed it into the flame photometer. Noted the readings with the standard curve. The results are expressed in ppm.

For the determination of potassium the filter of the flame photometer was set for readings at 769 nm and preceded for determination of potassium content in the sample by following the method described for the determination of sodium.

Calcium and Magnesium

Titrimetric EDTA method was employed for determining calcium and magnesium content of the samples. The titre value obtained for total hardness using Eriochrome black-T at pH 10 amounts to the total calcium and magnesium. The titration was repeated using murexide as indicator at a pH of 12-13 using sodium hydroxide solution. This titre value corresponds to the amount of calcium in the sample. The difference between first and second titration was used for calculating the magnesium concentration in the sample. The results are expressed in ppm.

Iron

Total Iron content in the water samples were determined spectrophotometrically by potassium thiocyanate method. 50 ml of the water samples were treated with 6ml 5N Hydrochloric acid and 10 ml 10% potassium solution and made up to 100ml. A calibration graph was also constructed using different concentration of standard iron solutions. The concentration of iron in samples is expressed in ppm.

Flouride

The colourimetric method is based on the reaction between fluoride and a zirconium dye lake (the term lake refers to the colour produced when zirconium ion is added to SPADNS dye. Fluoride reacts with reddish color Dye Lake dissociating a portion of it into a colourless complex anion ZrF_6^- and the yellow colour dye. As the amount of fluoride is increased the colour becomes progressively higher and of a different colour. This bleaching action is directly proportional to fluoride ion concentration. Either a spectrophotometer or a filter photometer may be used to measure sample absorbance for comparison against a standard curve.

Phosphate

Phosphate concentration in the water samples were determined by spectroscopically. Here the molybdophosphoric acid formed is reduced to intensely colouerd blue complex by stannous chloride. Here 50ml of the sample was treated with 4 ml ammonium molybdate reagent and 0.5 ml stannous chloride reagent, the solution was thoroughly mixed after each addition. After 10 minutes, measured the colour photometrically at 696nm and compared with a standard calibration curve.

Copper, Cadmium, Mercury, Lead and Zinc

Copper is one of the most commonly determined trace metals in natural water. Zinc, Cadmium, Mercury and Lead were detected using atomic absorption spectrophotometer.

Chapter 3

PHYSICO- CHEMICAL PARAMETERS

Quality of drinking water

Potable or drinking water can be defined as the water delivered to the consumer that can be safely used for drinking, cooking and working. Water quality of drinking water is to be maintained for the protection of public health and thus elimination or reduction to a minimum of constituents that are known to be hazardous to health and well being of people. The basic requirement of the drinking water according to Elmendorf and Buckles (1980) are

- Free from pathogenic organisms
- Containing no compound that have an adverse effect, acute or long term on human health.
- Fairly clear
- Containing no compounds that cause an effective taste or smell
- Not causing corrosion or encrustation of the water supply system nor staining clothes washed in it.

Agents that alter the quality of water as it moves over or below the surface of the earth may be classified under four major headings.

Physical: Physical characteristics relate to the quality of water for domestic use and are usually associated with the appearance of the water, its color or turbidity.

Chemical: chemical composition of the groundwater is related to the soluble products of rock weathering and composition and changes with respect to time and space (Raghunath, 1988, Raudkivi, 1979).

Biological: Biological characteristics correspond to the plants and animals, both dead and alive, which are found in water. They include algae, viruses, bacteria, and other forms of aquatic life as well as animals and plant contaminations.

Algae: Algae are examples of aquatic plants that can seriously affect the quality of surface water and shallow ground water. Some algae cause taste and odour problems; others clog sand filters. They are present to some extent in almost all surface water.

Bacteria and Viruses: Various types of bacteria can clog well screens or cause taste and odor problems. Of particular concern are bacteria and viruses that can cause disease in humans. These organisms do not ordinarily live in the water; they enter it through human or animal contact with the source water.

Microscopic animals: They are some disease causing microscopic animals that are not naturally found in water but can survive for a period of time after being deposited by humans or animals. An example is *Giardia lamblia* a protozoan that causes an intestinal disease in humans.

Biological agents are very important in their relation to public health and may also be significant in modifying the physical and chemical characteristics of water.

Radiological: Radionuclide can occur in water supplies either from natural sources or as a result of human activities. Naturally occurring radionuclides include radium 226, radium 228 and radon. Radon is a gas most often present in granite formations. If the water flows through the fractures in the rock to an aquifer that ground water may contain Radon. Radiological factors must be considered in areas where there is a possibility of water to come in contact with radioactive substances.

The quality of ground water is described by its physical, chemical and microbiological properties. These characteristics are interlinked. Therefore, interpretation of coefficient between water quality parameters gives good idea about the quality of water and facilitates rapid monitoring methods. Kumar et *al.* (1994) studied quality and correlationship among water quality parameters of ground water samples from different parts of India and developed linear regression equations for different water quality parameters. The authors concluded that electrical conductivity could be used to predict the concentrations of calcium, magnesium, hardness, alkalinity, sulphate and chloride in close proximity to real values in drinking waters in different regions of India in spite of wide variations in different groundwater quality. Similar studies were also carried out for Musnur mandal (Rao, K.S., 1994) and Reddigudem mandal (Krishna J.S.R. (1995) in Krisha district of Andhra Pradesh.

Several investigations have been conducted regarding correlations between variations of parameters for the rapid monitoring of water quality. Singh (1996) made a study of correlations among 14 water quality parameters by taking 35 locations in Jhunghunu district of Rajasthan and obtained neither perfect positive nor perfect negative correlation between any two parameters with 0.895 between calcium and total hardness. Singh and Choudhary (1999) attempted to obtain some correlation among physic-chemical parameters of Nagpur district and concluded saying that positive correlation between chloride and total dissolved solids, and electrical conductivity at 25°Cand total dissolved solids with less value for other parameters were obtained. Mariappan *et al.* (2001) have studied the correlation between total dissolved solids and other chemical parameters of groundwater of Kannankudi block in Sivagangai district, Tamil Nadu by grouping the data of 49 borewells according to depth and climatic seasons and have concluded that neither exact positive nor perfect negative relationships exist between total dissolved solids and rest of the chemical parameters except between chloride and total dissolved solids. Patil and Khaire (2004) did statistical analysis of physico-chemical parameters of ground water. He tried to correlate 55 pairs of parameters and found that there is positive correlation between 2/3 of the total number of pairs.

The quality criteria of water for each specific use differ from one another. The domestic water qualities will be different from the industrial and irrigation uses. In the domestic supply itself potable water must have high quality. Individual countries impose acceptable water quality standards. To achieve this, internationally accepted standards are also provided by WHO. Common drinking water quality parameters and their WHO and BIS standards are given in table 3. In the quality studies many physical and chemical factors are considered. An attempt has been made to correlate various parameters using statistical analysis. Important significant correlations among various parameters are indicated. Detailed values are noted in Table 3.21.

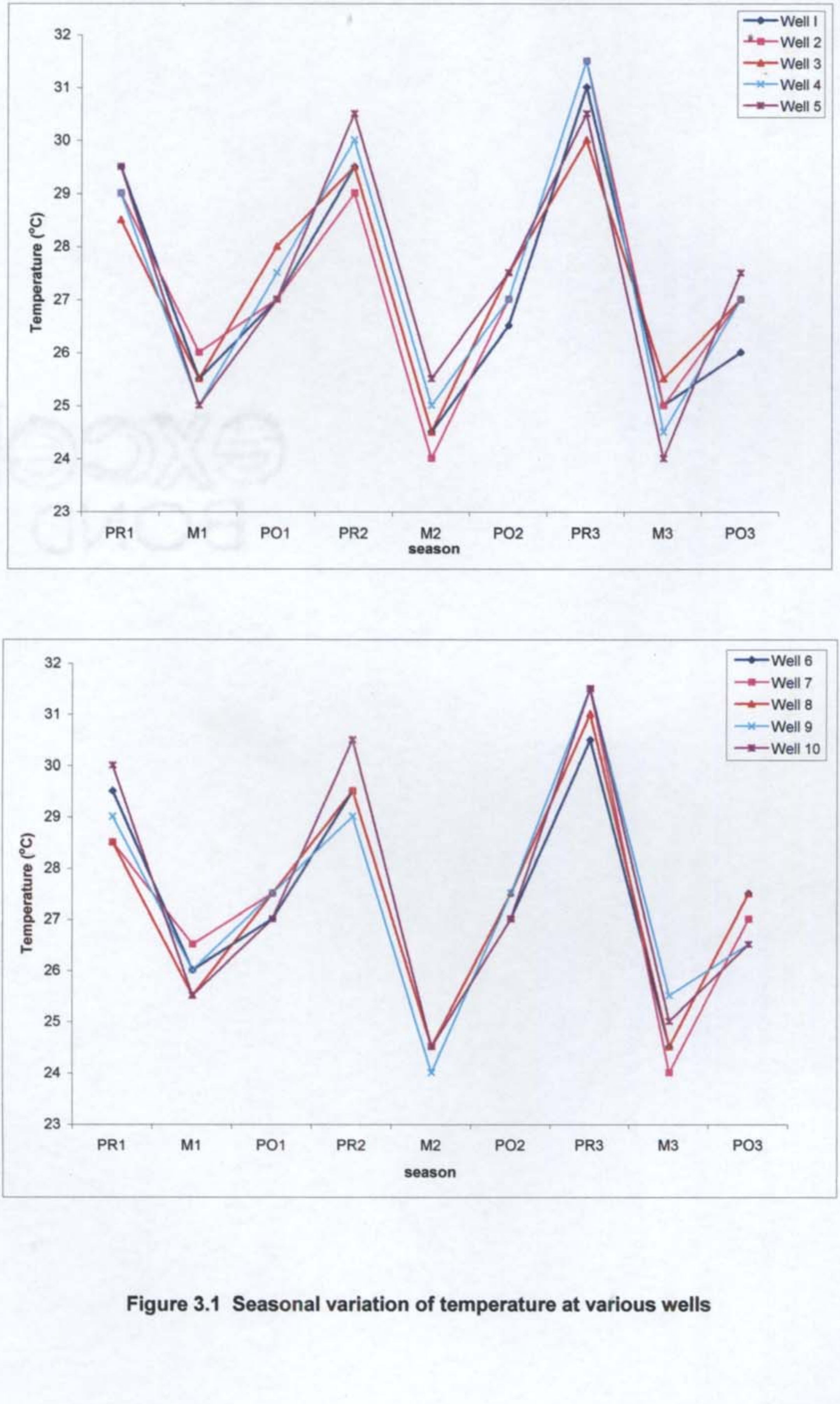
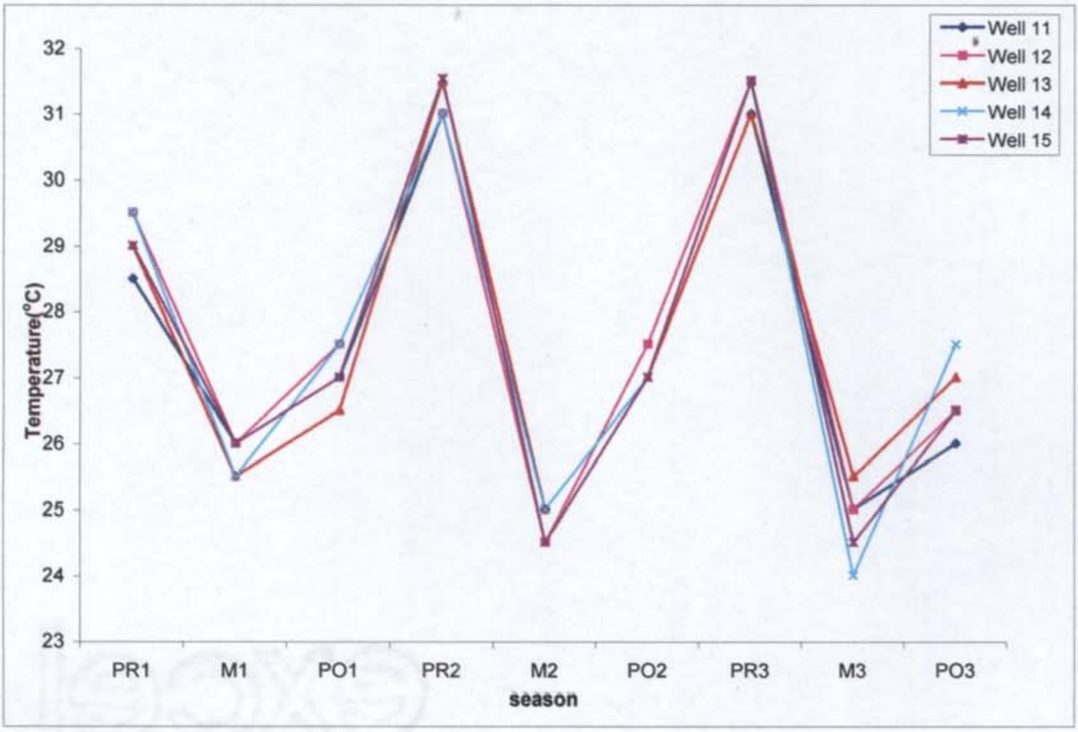


Figure 3.1 Seasonal variation of temperature at various wells

53 B



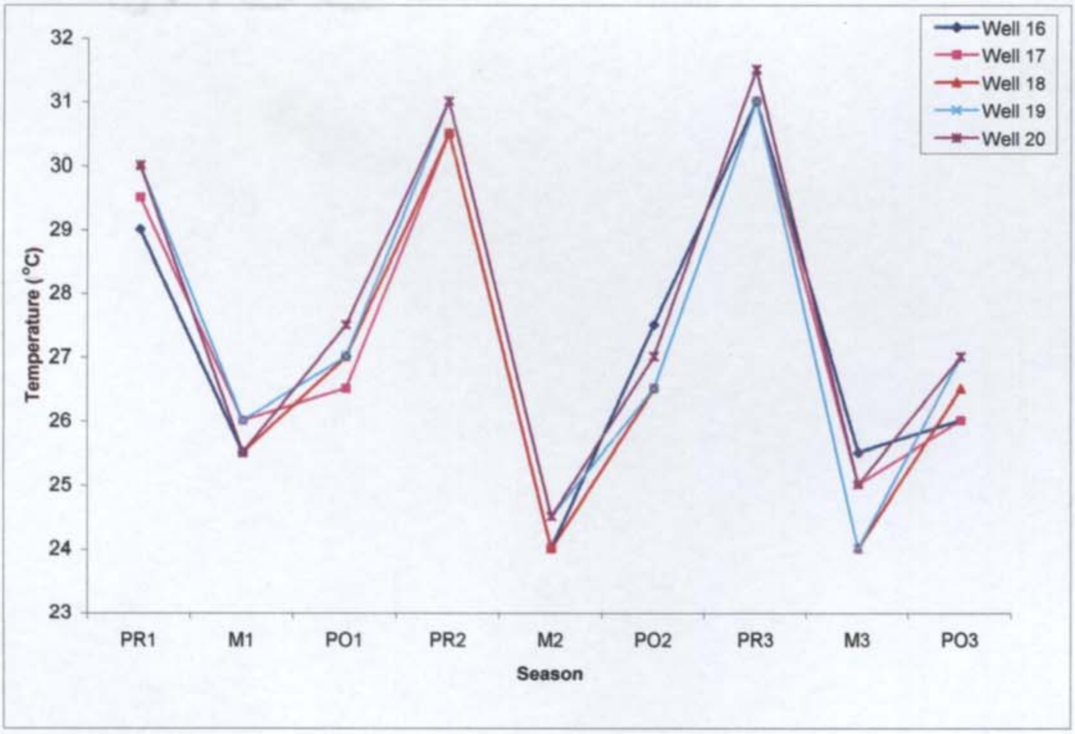


Figure 3.2 Seasonal variation of temperature at variuos wells

Physical Parameters

Temperature

An ideal water supply should have at all times an almost constant temperature or one with minimum variation. Temperature values are not normally standardized by public health criteria because of the insignificant health effects.

Consumers agree that cold water is more potable (psychologically associating with running water also due to lower detectability of taste and odour)

Chemical and bacteriological reactions increase with increase in temperature. Trichloromethane formation and corrosion increases with increase in temperature.

The depth of the source of ground water could be gauged from the temperature of the water. Temperature results may lead to the delivery of an unexpected source of pollution. The warmer the water, the less gas it can absorb. It is an important factor influencing the palatability and desirability of drinking water. Ground water temperature for the first hundred feet below ground water is approximately that of the local average annual air temperature but it is lower than the surface water and remains almost constant. Brown *et al.* (1967) pointed out that fluctuation in temperature depends on the type and concentration of polluted matter especially during summer.

The temperatures of different samples are given in table 3. 1. Seasonal variation of temperature is given in graph 3.1 and 3.2. There is significant variation in temperature between seasons ($P < 0.01$), but variation between wells is insignificant ($P > 0.05$).

To study the significance of variation of temperature with other parameters correlation coefficient also was calculated (Table 3.20). Considering all the seasons and all the wells, temperature and dissolved oxygen are correlated ($P < 0.01$). There is no significant correlation between temperature and any other parameters ($P > 0.05$).

Odour

It is recognized as a quality factor affecting acceptability of drinking water, tainting of fish and other aquatic organisms and esthetics of recreational waters. Most organic and inorganic chemicals contribute taste or odour.

Because some odorous materials are detectable when present in only a few nanograms per liter it is usually impractical and often impossible to isolate and identify the odour-producing chemical. The human nose is the practical odour-testing device used in this method. Odour tests are performed to provide qualitative measurements of odour intensity. The water collected from all the wells was odourless.

Turbidity

It is the measure of the fine suspended matter in water mostly caused by colloidal matter such as clay, silt, nonliving organic particulates, plankton and other microscopic organisms in addition to suspended organic and inorganic matter. Because of the filtering capacity of the soil, suspended material is seldom

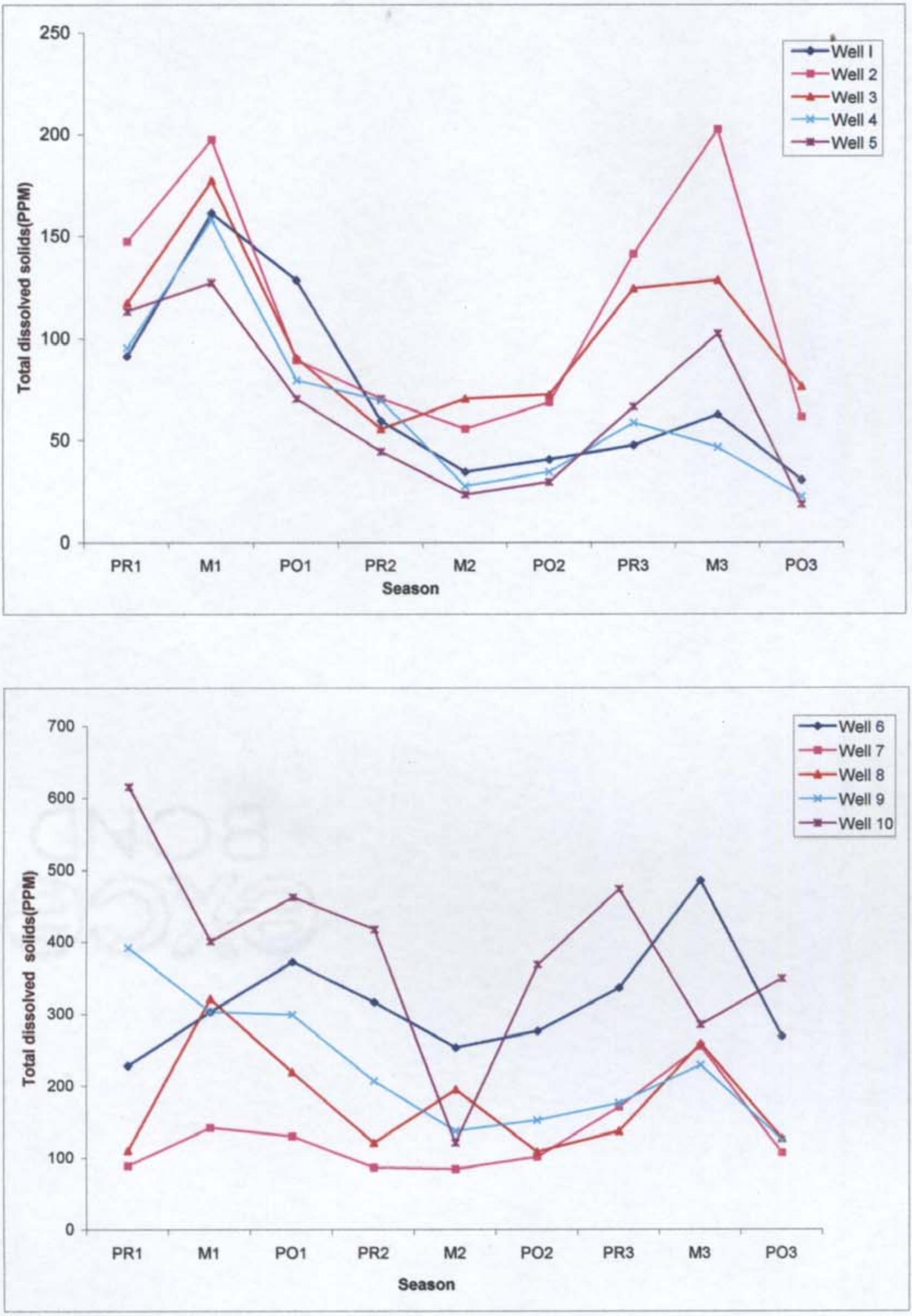
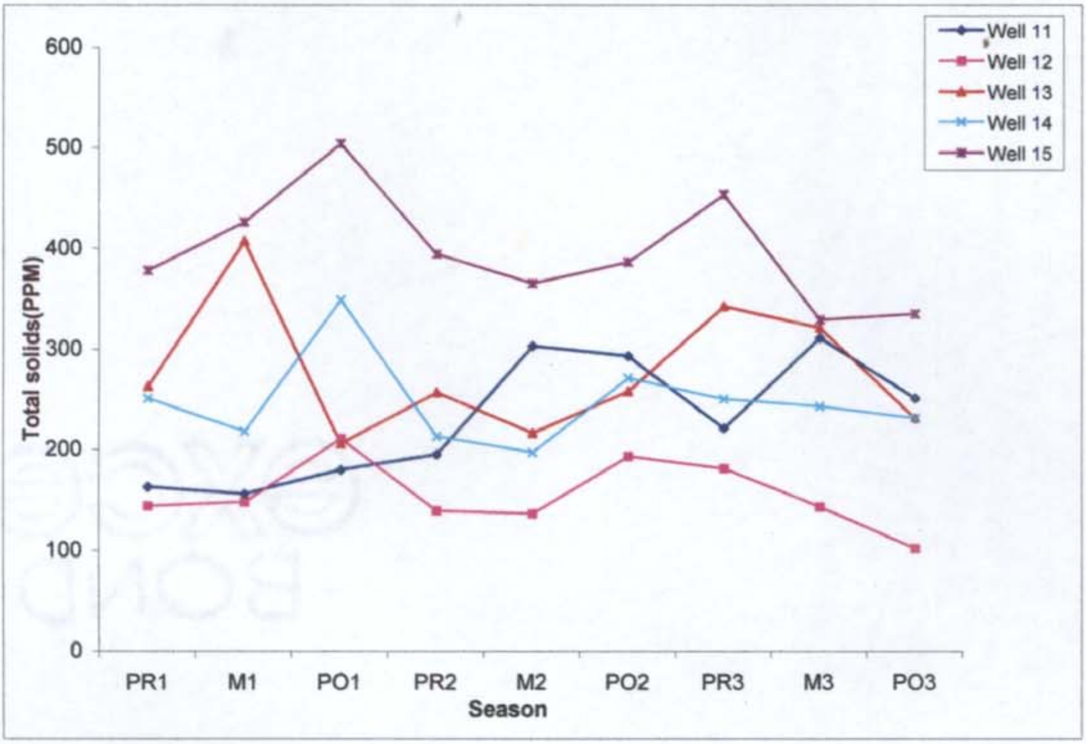


Fig 3.3 Seasonal variation in Total Dissolved Solids at various wells

55B



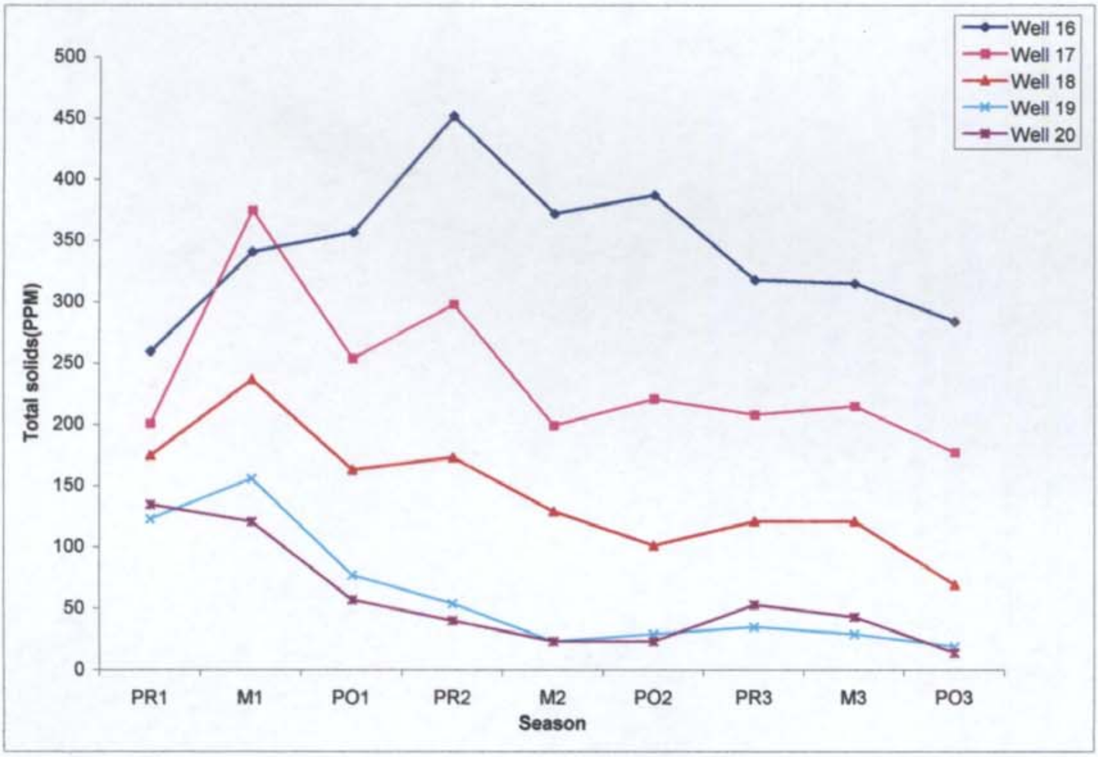


Figure 3.4 Seasonal variation in Total Dissolved Solids at various wells

a constituent of groundwater. (Peavy *et al.*, 1987). All the water samples were clear and there were no suspended impurities.

Total Dissolved Solids

Total dissolved solids refer to any minerals, salts, metals, cations or anions dissolved in water. Total dissolved solids (TDS) comprise inorganic salts (principally calcium, magnesium, potassium, sodium, bicarbonates, chlorides and sulphates) and some small amounts of organic matter that are dissolved in water.

In general the total dissolved solids concentration is the sum of the cations and anions in the water. Therefore the total dissolved solids test provides a qualitative measure of the amount of dissolved ions but does not tell us the nature or ion relationships. In addition the test does not provide us insight into the specific water quality issues such as: elevated hardness, salty taste or corrosiveness. Therefore, the total dissolved solids test is used as an indicator test to determine the general quality of the water. An elevated total dissolved solids (TDS) concentration is not a health hazard. The TDS is regulated because it is more of an aesthetic rather than a health hazard. An elevated TDS indicates the concentration of the dissolved ions that may cause the water to be corrosive, salty or brackish taste, result in scale formation. It also gives an idea about the elevated level of nitrate, arsenic, aluminium, copper, lead etc.

For aesthetic reasons a limit of 500 mg/L (milligrams per litre) has been established as part of the secondary drinking water standards. In the present study TDS in all the wells were within the permissible limit (Table 3.2) Seasonal variations of the TDS are given in graph 3.3 and 3.4.

ANOVA table shows that there is no significant variation between the seasons. The correlation between TDS and other parameters were also studied. When all the wells are considered there is significant correlation between TDS and alkalinity, calcium, calcium hardness, chloride, total hardness, potassium, magnesium, pH and sulphate and DO ($p<0.01$). Same correlation was found during all the three seasons.

Hydrogen ion concentration (pH or potential hydrogenii)

Water entering ground water zones from atmospheric precipitation is generally acidic. Under the normal conditions of unpolluted atmosphere pH of precipitation is in equilibrium with the saturated CO_2 concentrations in the atmosphere. The partial pressure of CO_2 in the earth's atmosphere is approximately 0.0003 bars, which will result in the normal pH of unpolluted precipitation of 5.6.

In soils due to CO_2 production by soil bacteria from decomposing soil organic matter, the partial pressure of CO_2 can reach values up to 10^{-1} bars. This can result in pH values of soil and ground water significantly below 5. In unpolluted water pH is controlled by the balance between dissolved CO_2 and the bicarbonate and carbonate ions. The pH of water body can change widely by the addition of pollutants. It may be used as an indicator of pollution.

Raw water examined for potential use as drinking water has an expected pH value between 4 and 9 but more than likely, encountered values will be between 5.5 and 8.6.

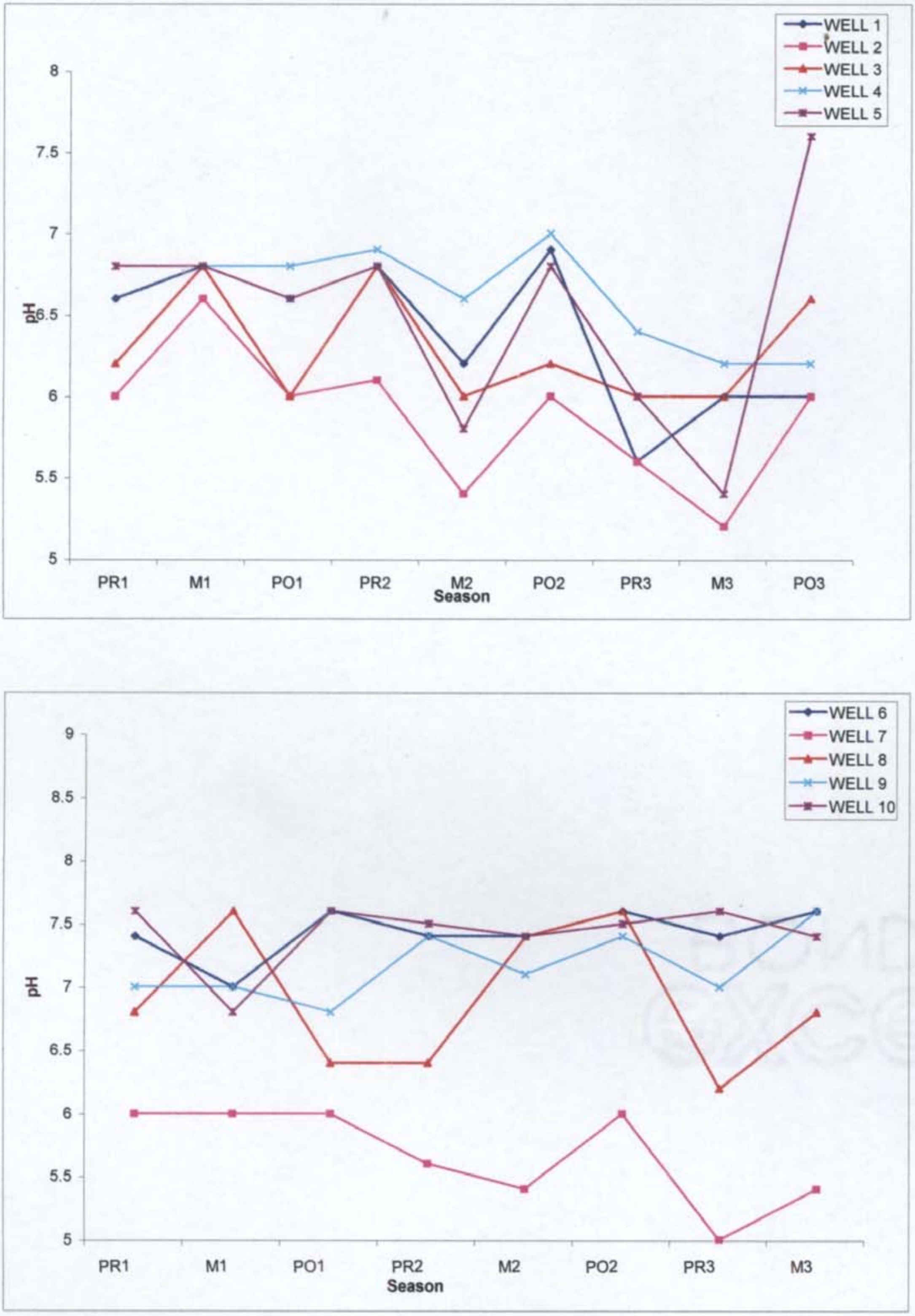
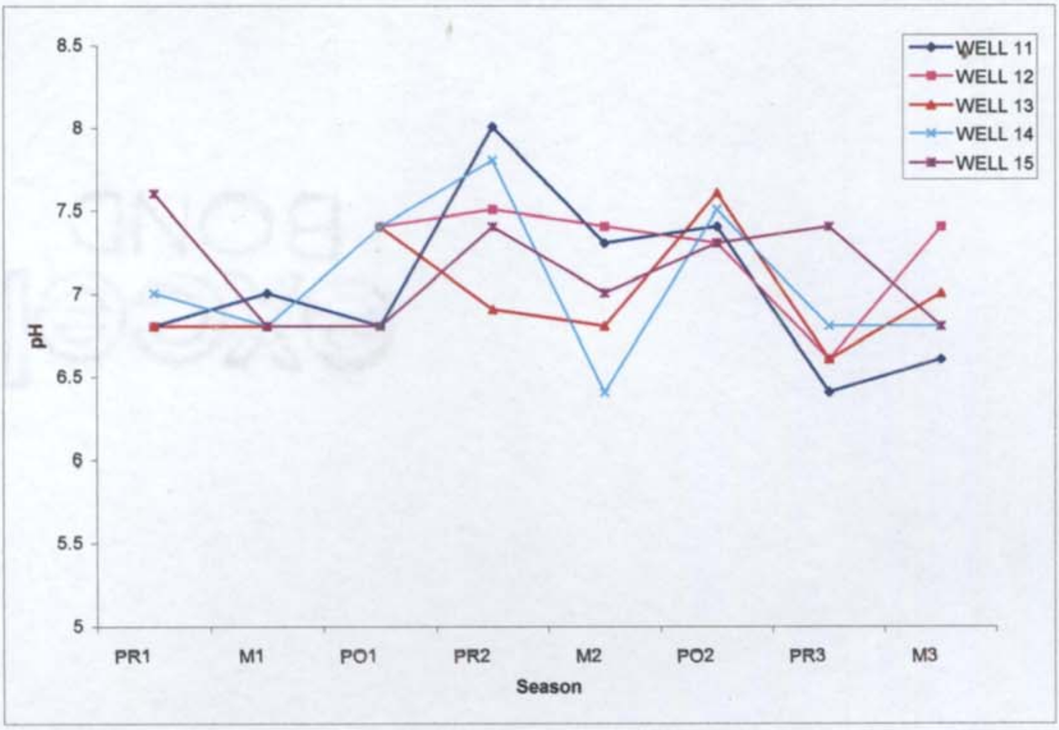


Figure 3.5 Seasonal variation in pH at various wells



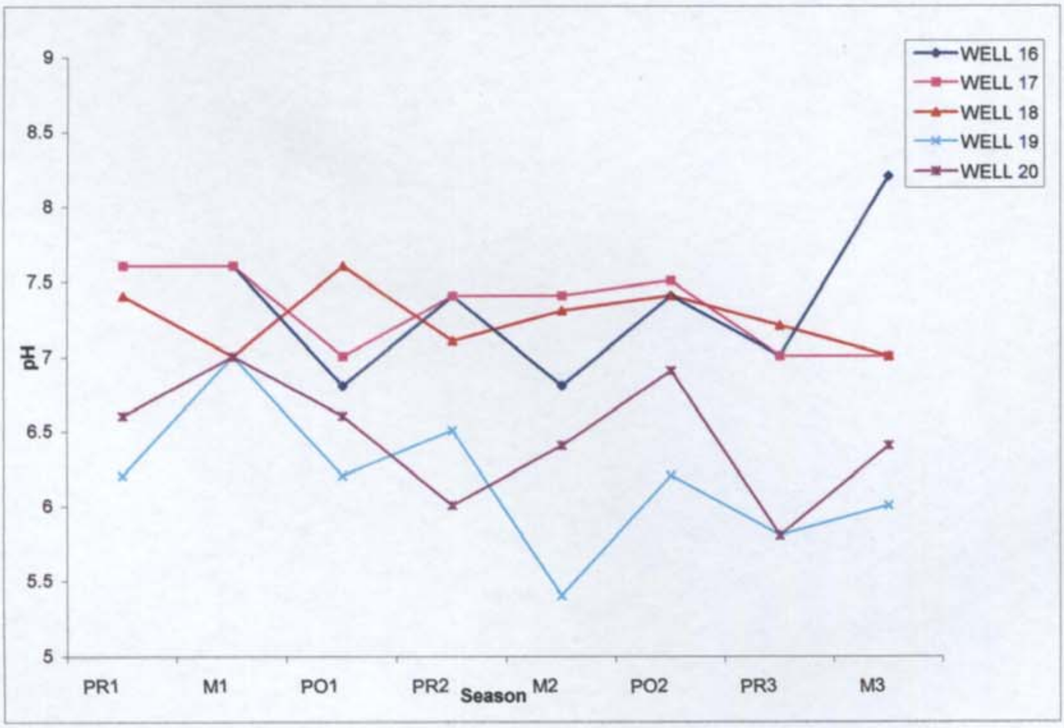


Figure 3.6 Seasonal variation in pH at various wells

Values higher than 7 are normally expected in raw water due to the presence of carbonate and bicarbonate (contact with rocks and stones) but acid rain may lower pH to values under 7. Water slightly below 7 is bacteriologically purer than alkaline water.

Even mildly acidic water influences the corrosive action of water in the distribution system. The minimum and maximum allowable pH range for potability is 6.5- 8.5 (WHO, 1984. ICMR, 1975).

For wells No1, 2, 3, 4, 5, 7, 19 and 20 the pH values were slightly less than the range specified (Table 3.3). No regular variations in pH were observed in any wells. Seasonal distribution pattern of pH is given in graph 3.5 and 3.6. Significant variation in pH is observed between wells ($P<0.01$). pH has high positive correlation with alkalinity, calcium, calcium hardness, sulphate, chloride, magnesium, total hardness and total dissolved solids in all the seasons($P<0.01$).

Bore well sample showed a higher value and it may be due to dissolved carbonates. In other cases value of pH is 7 or slightly less than 7 but within the permissible limit. Though, pH has no direct effect on human health, all biochemical reactions are sensitive to the variation of pH.

Electrical Conductivity

It is the measure of the ability of an aqueous solution to carry an electric current. This ability depends on the presence of ions, on their total concentration mobility and valency and on the temperature of measurement. Solutions of most inorganic compounds since they are in the ionized form are relatively good

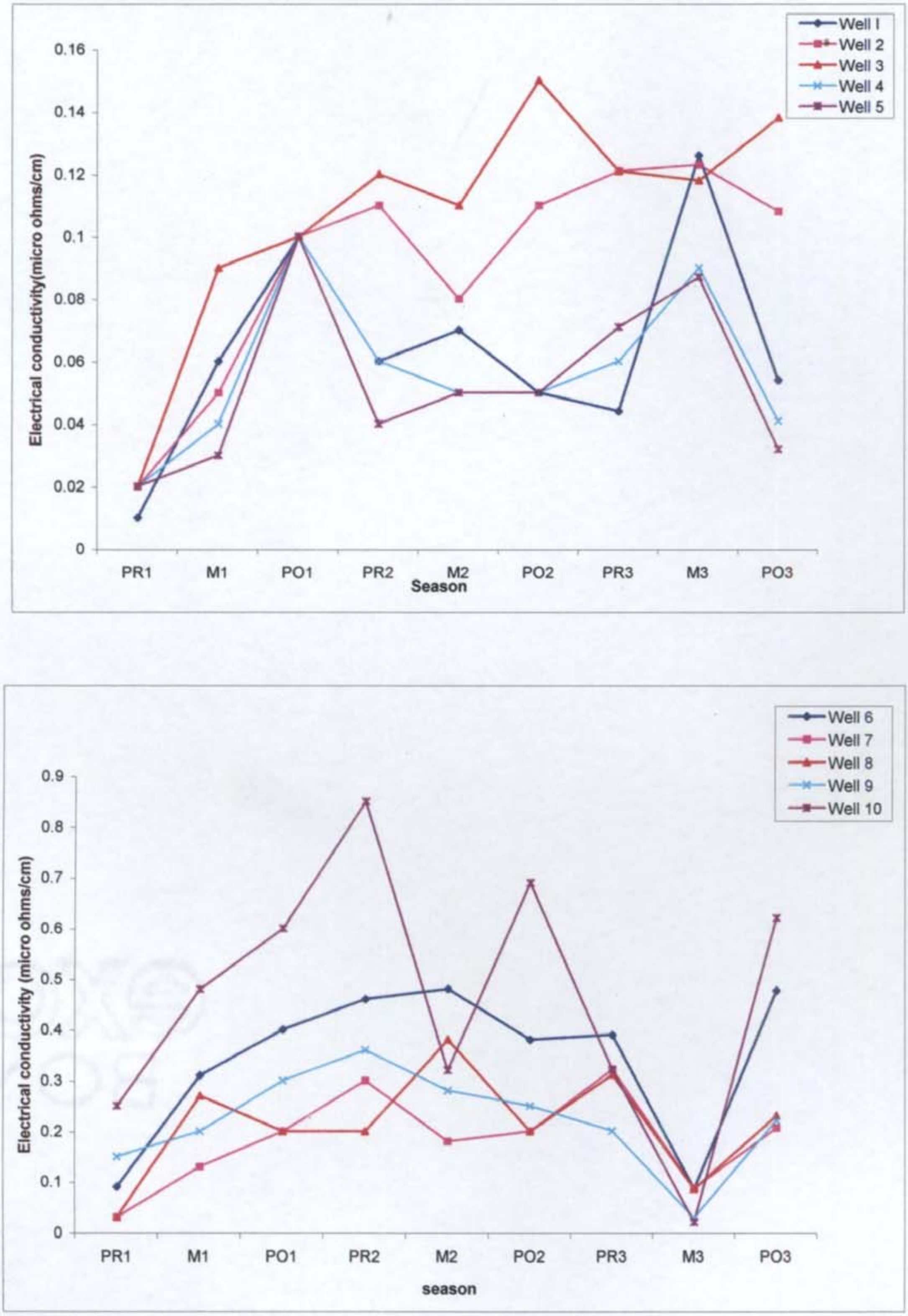


Fig 3.7 Seasonal variation in Electrical conductivity at various wells

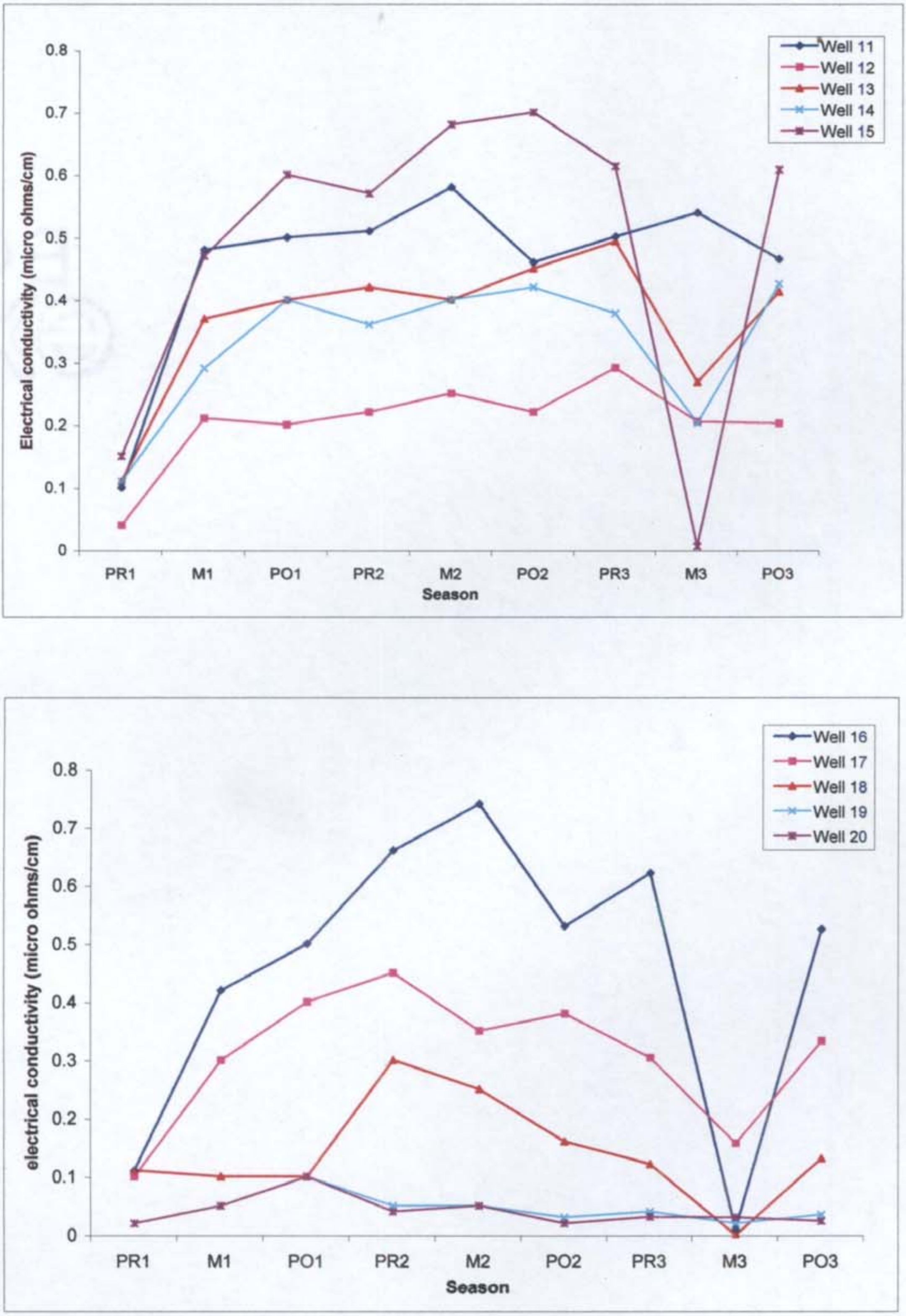


Fig. 3.8 Seasonal variation in Electrical conductivity at various wells

conductors and molecules of organic compounds that does not dissociate in aqueous solution conduct very poorly.

Conduction G = 1/R. (R in ohm and G in ohm^{-1}/mho); but G= K [A/L] (A- surface area cm^2; L- distance between the electrode (cm); K- conductivity or specific conductance).

Electrical conductivity is a very important parameter for determining the water quality for drinking and agricultural purpose. A common way to obtain a quick estimate of the concentration of dissolved solids in water is to measure the electrical conductivity (EC) of the water. Theoretically, water free of any contaminants will not conduct electricity. However most natural substances dissolved in water allow water to conduct electricity- the greater the concentration, the greater the electrical conductivity. Electrical conductivity values are directly related to the content of dissolved sodium and potassium salts and total dissolved solids. Electrical conductivity is often used as a rapid method of estimating the concentration of total dissolved ionizable solids. The relation between this concentration and conductivity depends on the nature of the ionized species present and will vary from one water sample to another.

The value in the study area is from 0.1 to 1.9 millimhos (Table 3.4) and variation in electrical conductivity is given in graph 3.7 and 3.8 The ideal value of electrical conductivity is <2.4 millimhos.

There is no significant variation in electrical conductivity between seasons and between wells ($P>0.05$). When all the wells and all the season are considered there is positive correlation between electrical conductivity and alkalinity, calcium, calcium hardness, chloride, sulphate, total dissolved solids, total hardness ($P<0.01$). During pre monsoon and post monsoon seasons also positive correlation between electrical conductivity and these parameters were significant ($P< 0.01$).

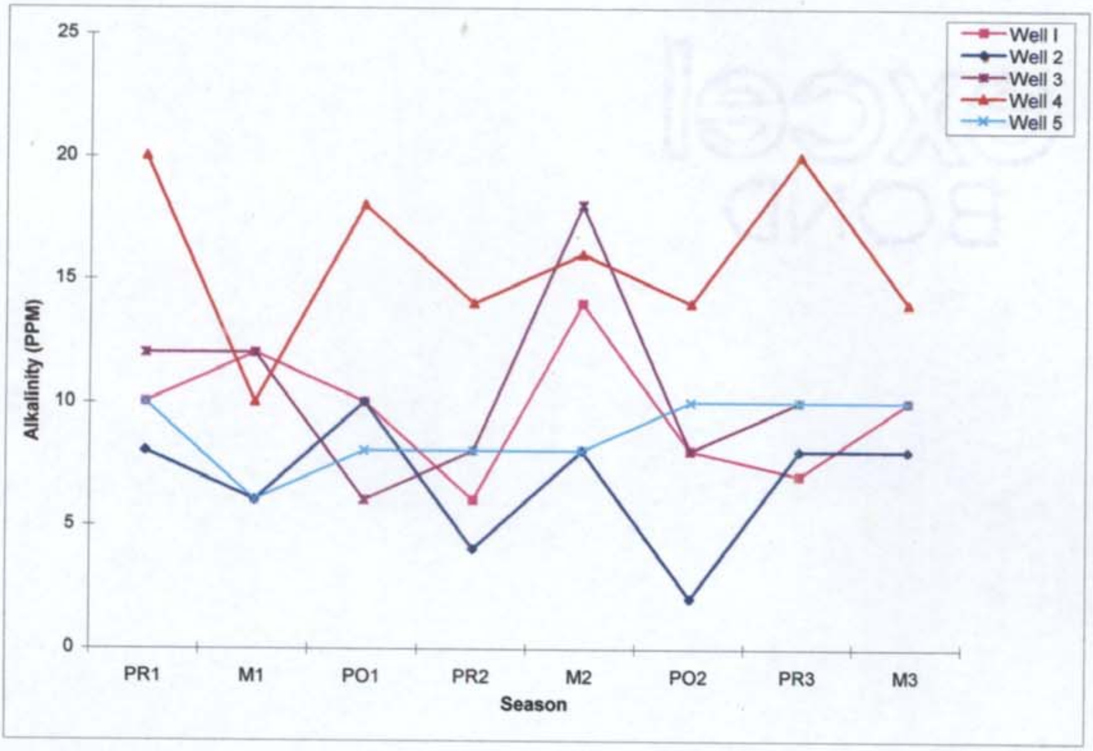
Chemical Parameters

Alkalinity

Alkalinity of water is its acid neutralizing capacity. It is a measure of an aggressive property of water and can be interpreted in terms of specific substances only when the chemical composition of the sample is known. Most natural waters contain substantial amounts of dissolved CO_2, which is the principal source of alkalinity. Undissociated dissolved CO_2 contributed to acidity rather than to titrable alkalinity and also be determined by titration using a basic solution. In most of the cases alkalinity is primarily a function of CO_3^{2-}, $HCO_3^-$and OH^- content and hence it is taken as an indicator of the concentration of those constituents. But because of the action of CO_2 on basic materials of soil bicarbonate will be the major component. The measured value may include contribution from borates, phosphates, silicates or other bases if they are present. Alkalinity of raw water may contain salts formed from organic acids such as humic acid.

From the potability view point alkalinity is not a significant parameter. Alkalinity in itself is not harmful to human beings. Variation of concentration from 5 to 125 mg/L is expected. Raw waters normally contain alkalinity in the form of carbonate of soda or bicarbonate of calcium and magnesium. Alkalinity also may be due to the contamination by leaching process through the surface

60A



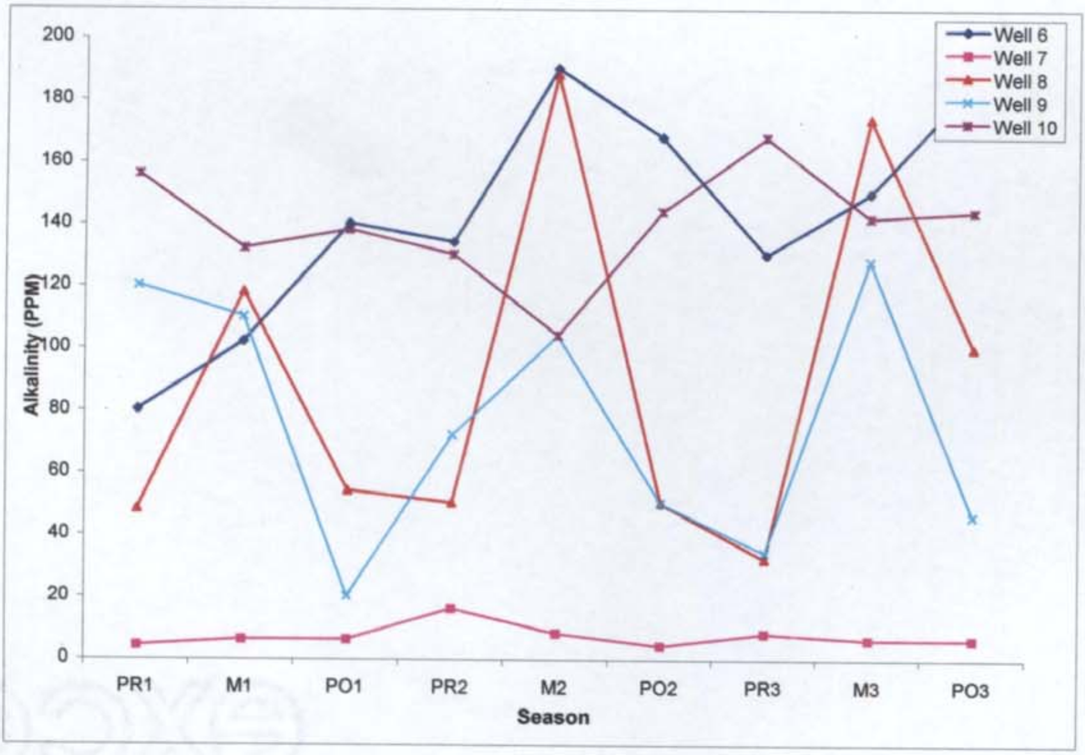
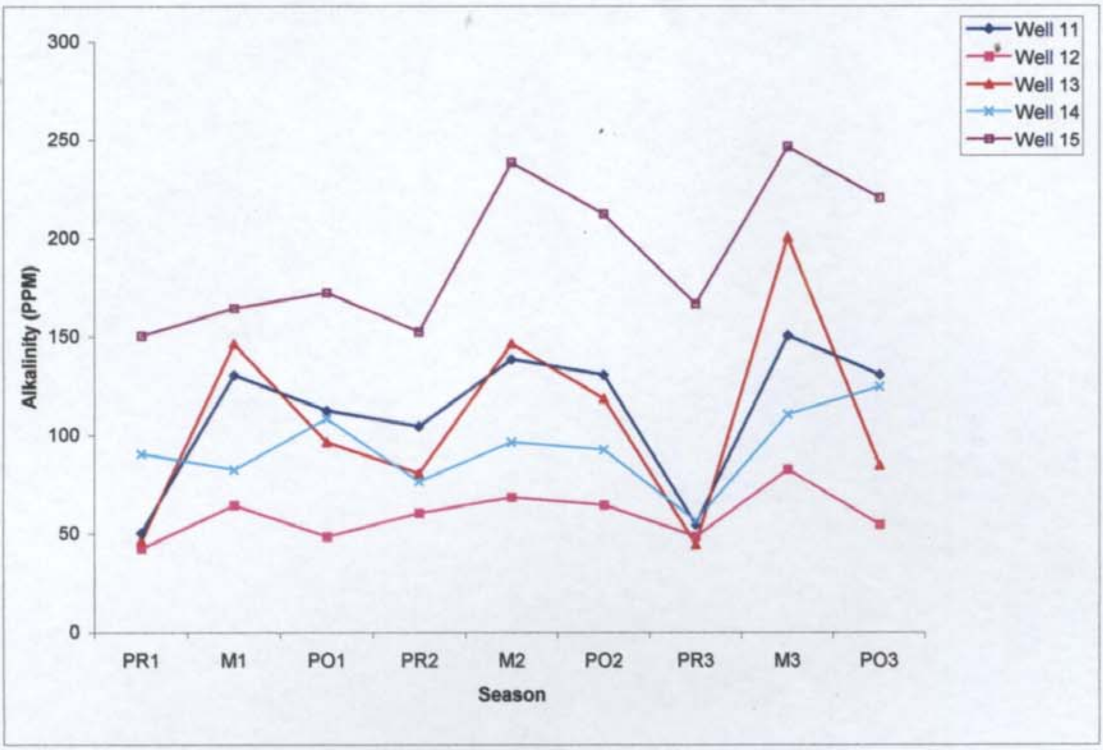


Figure 3.9 Seasonal variation in Alkalinity at various wells



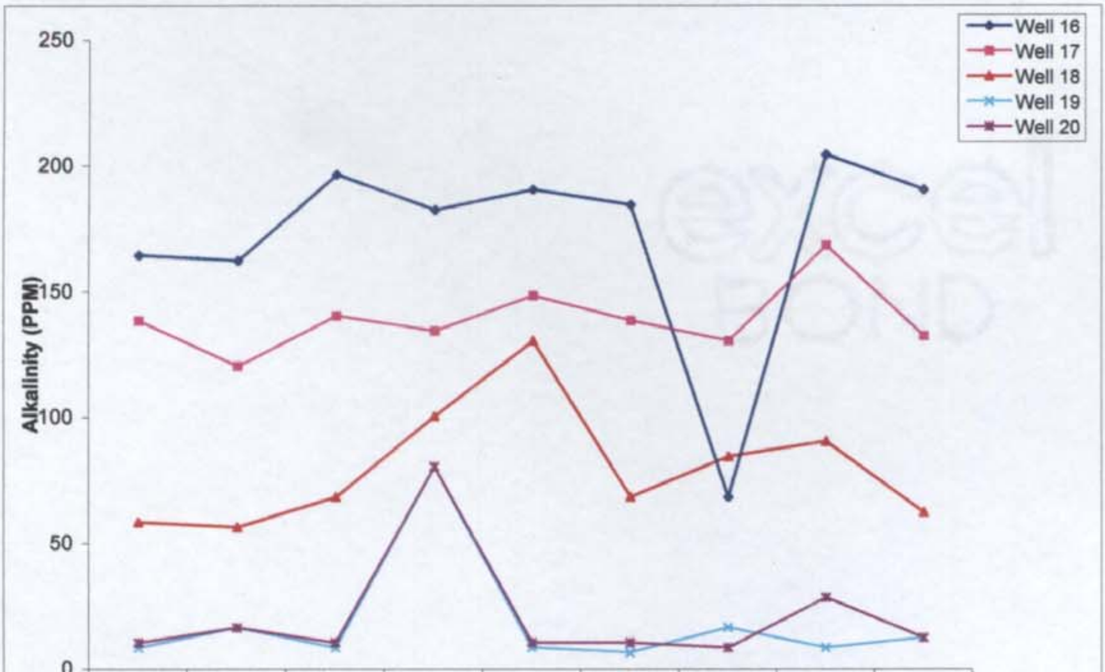


Figure 3.10 Seasonal variation in Alkalinity at various wells

water during rainy season. (Singh *et al.* (1999). Alkalinity is also produced by the action of water on limestone.

$$CaCO_3 + H_2O + CO_2 \rightarrow Ca(HCO_3)_2$$

Since in all the samples phenolphthalein alkalinity is zero, the alkalinity is only bicarbonate alkalinity; hydroxide and carbonate alkalinity is zero. The desirable limit of alkalinity is 200mg/L beyond which taste becomes unpleasant. Well Nos.6, 9, 10, 16, 17 and 18 were found to be alkaline (Table 3. 5). There is significant variation in alkalinity in different seasons and in different wells ($P < 0.01$). High positive correlation is observed between alkalinity and calcium, calcium hardness, pH, sulphate, magnesium, potassium, electrical conductivity, total dissolved solids, total hardness and chloride when all the wells and all the seasons were considered ($P < 0.01$). This high positive correlation is significant during all seasons also. The variations in alkalinity of different wells are given in graph 3. 9 and 3.10.

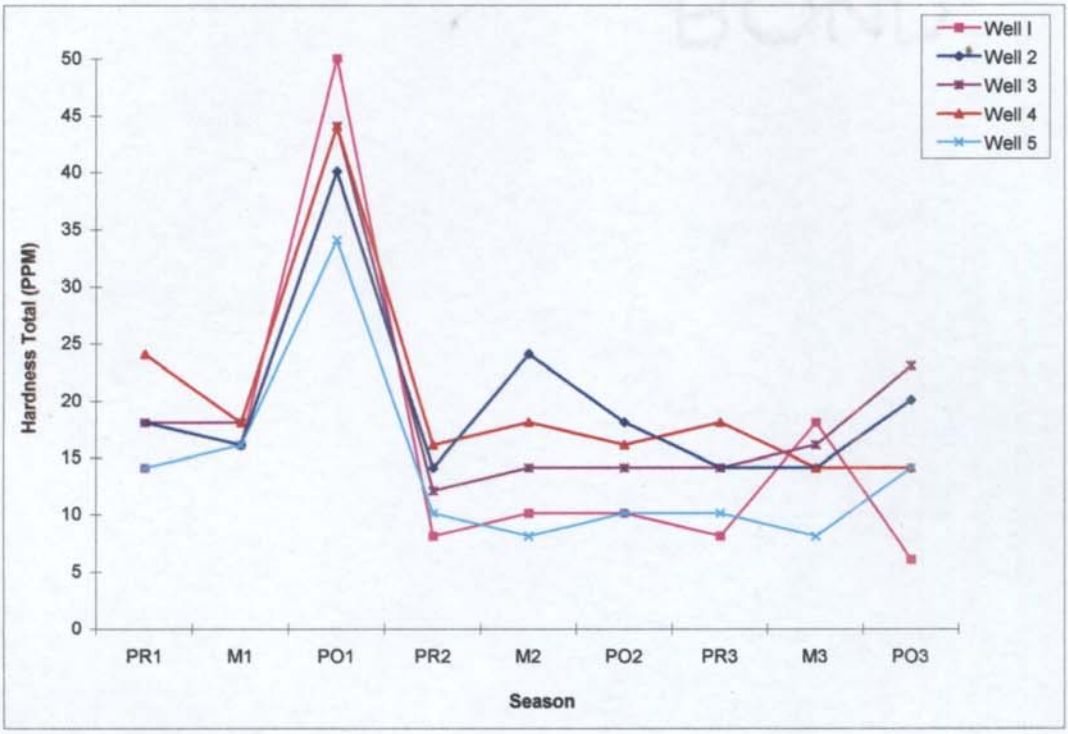
Total Hardness and Calcium Hardness

Hardness is imparted to water by the presence of cations mainly Ca and Mg. Other cations like Cr, Fe and Mn also contribute to hardness. It is the property of water, which prevents lather formation with soap and increases the boiling point of water. Anions responsible for hardness are mainly bicarbonates, carbonates, sulphates, chlorides, nitrates and silicates. Hardness caused by bicarbonate is referred to as temporary as it can be removed by boiling. Permanent hardness is caused mainly by sulphates and chlorides of the metals.

Hardness has no adverse effects on health, however some evidences have been given to indicate its role in heart disease. A study in Great Britain reveals that mortality from stroke and ischemic heart disease was found to be strongly related to water hardness (Pocock *et al.*, 1980). A variety of other diseases are correlated with the hardness of water. These include certain nervous system defects, anencephaly and various types of cancer.

Total hardness is defined as the sum of the calcium and magnesium concentration both expressed as $CaCO_3$ in milligrams per liter. When hardness is numerically greater than the sum of carbonate and bicarbonate alkalinity that amount of hardness equivalent to the total alkalinity is called carbonate hardness and the amount of hardness in excess of this is called non-carbonate hardness. When the hardness is numerically equal to or less than the sum of carbonate and bicarbonate alkalinity all hardness is carbonate hardness and non-carbonate hardness is absent. The hardness may range from zero to hundreds of milligrams per liter, depending on the source and treatment to which the water has been subjected. The hardness of water varies considerably from place to place. Generally groundwater is harder than surface water. According to the degree of hardness waters are classified commonly as follows

Hardness as $CaCO_3$ in mg/L	**Classification**
0-40	Soft
41-100	Moderately hard
101-300	Hard



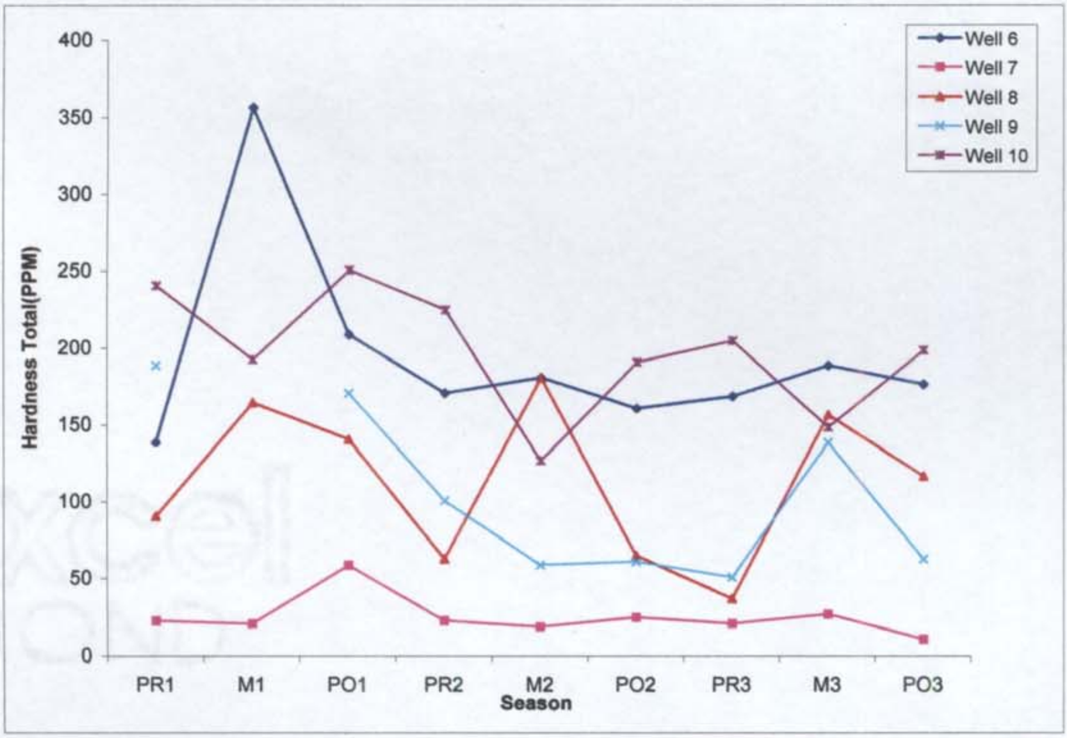


Figure 3.11 Seasonal variation of Total hardness at various wells

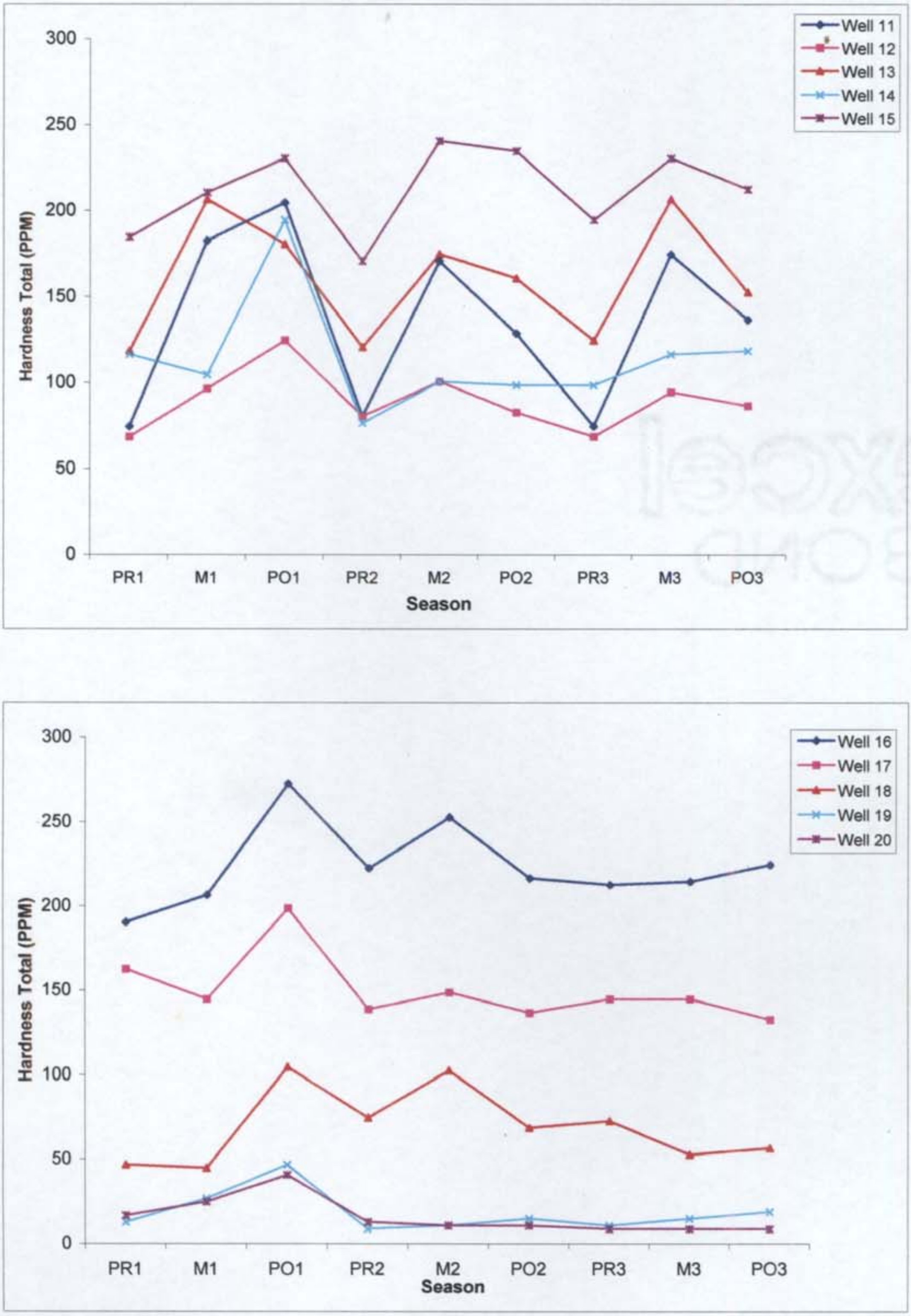
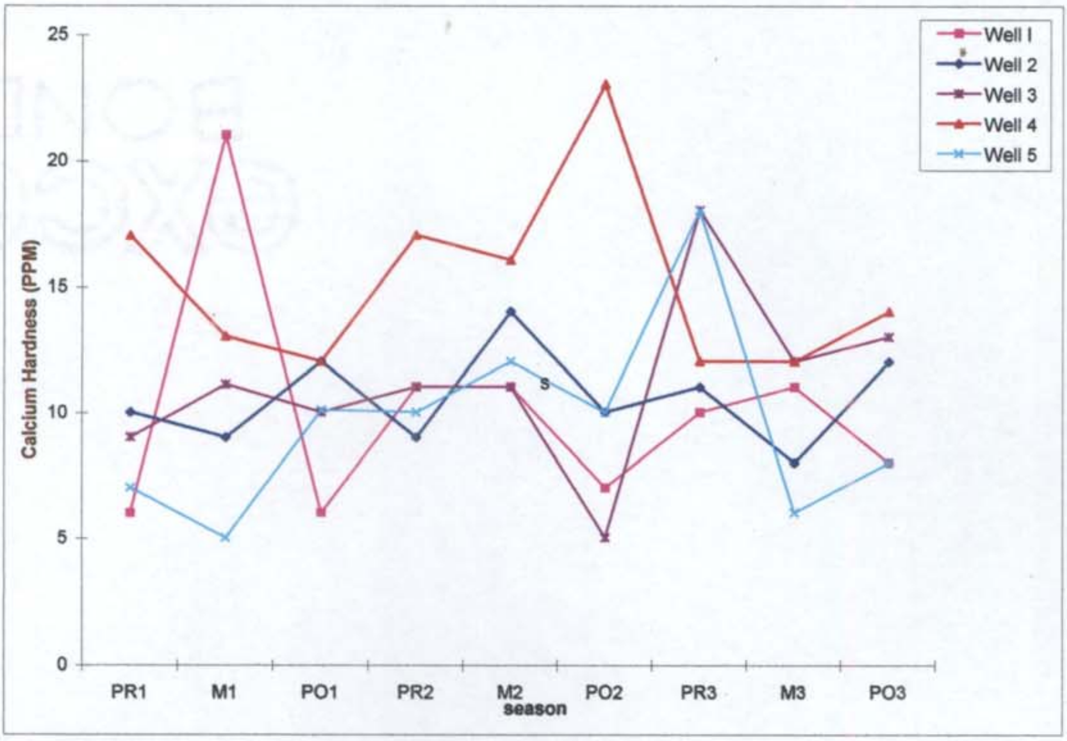


Figure 3.12 Seasonal variation of total hardness at various wells

62 c



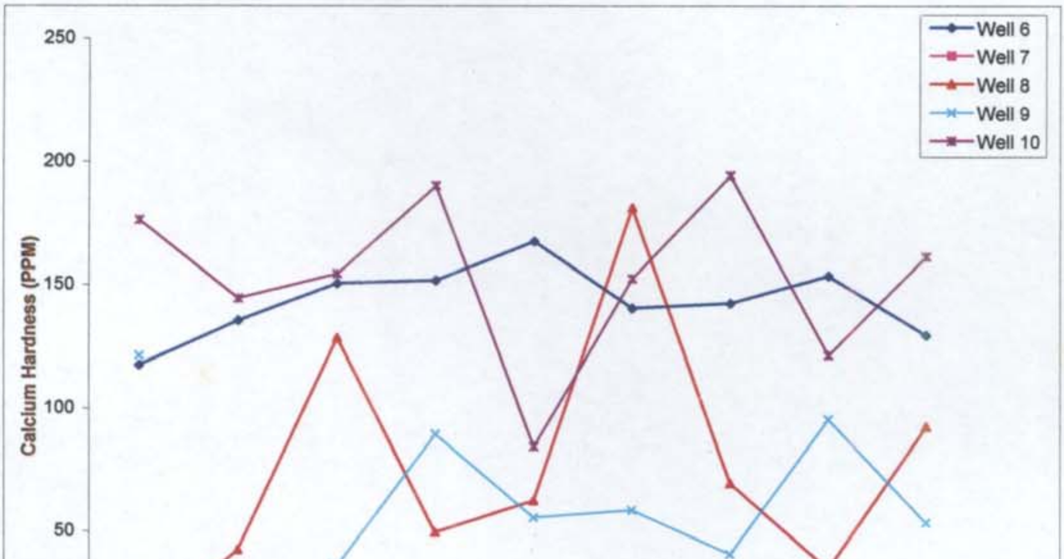


Figure 3.13 Seasonal variation in calcium hardness at various wells

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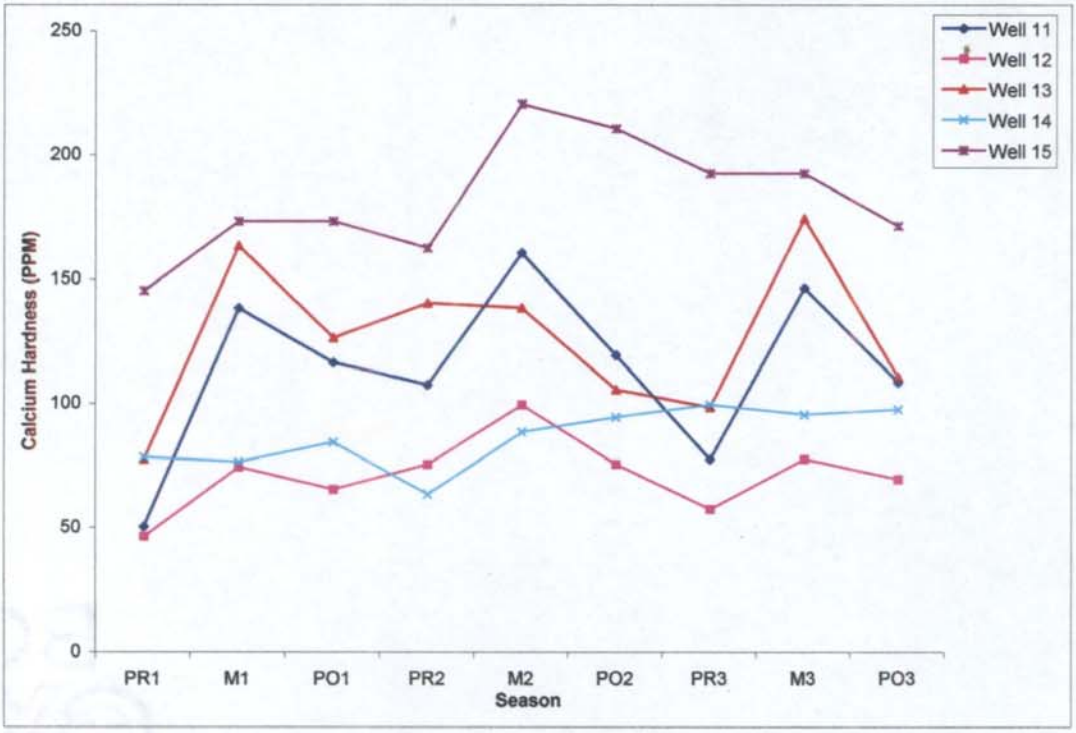


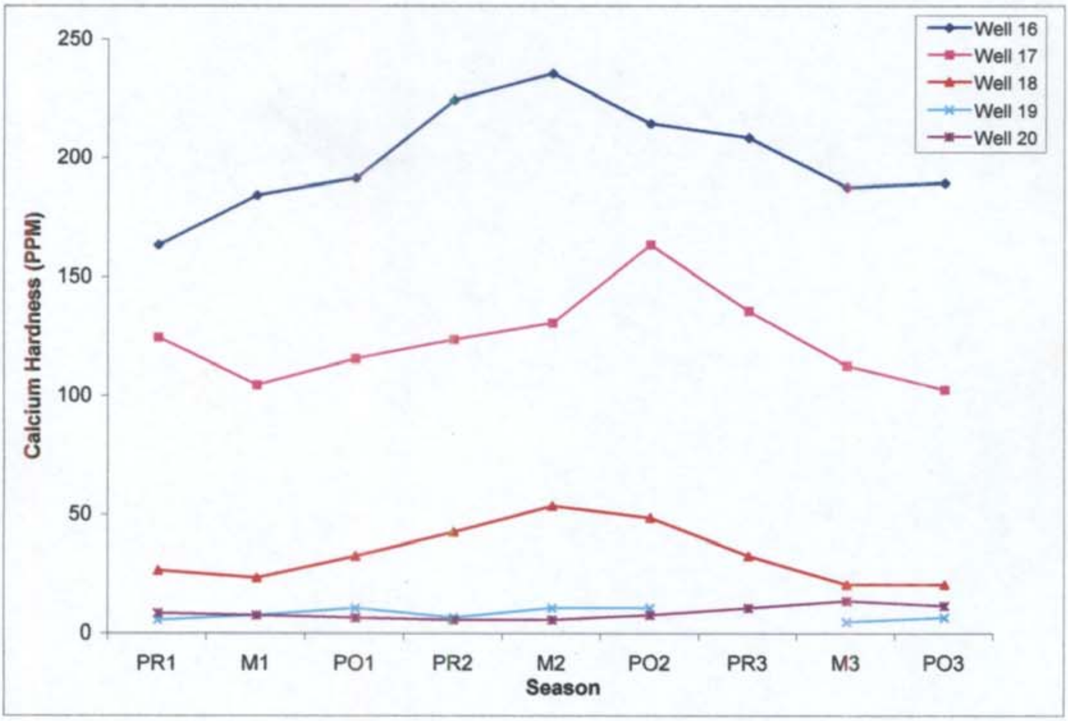


Figure 3.14 Seasonal variation in calcium hardness at various wells

26

301-500	Very hard
501-1000	Extremely hard

Very soft waters having hardness less than 30mg/L are likely to be corrosive. The total hardness in the study area varied from 8 - 272 mg/L. Variations of total hardness is shown in graph 3.11 and 3.12. Wells 6, 10, 13, 15, 16 and 17 are found to be hard. None of the wells belong to very hard category or extremely hard category. Well 1, 2, 3, 4, 5, 7, 19 and 20 are soft while 8, 9, 11, 12 and 14 show variation according to the seasons (Table 3.6). It is may be due to the mixing up of rainwater with the well water. The calculated value for calcium hardness is given in Table 3.7.

There is significant variation in total hardness between seasons and between wells ($P< 0.01$). But there is no significant variation in calcium hardness between seasons. The seasonal variation in calcium hardness at various wells is shown in graph 3.13 and 3.14. Positive correlation is found between total hardness and alkalinity, calcium, calcium hardness, chloride, sulphate, potassium, magnesium, pH, total dissolved solids and electrical conductivity ($P< 0.01$). Same correlation was found in case of calcium hardness also ($P< 0.01$).

Dissolved Oxygen

Dissolved oxygen (DO) is an important water quality parameter in water quality assessment. It is derived from the air and from the oxygen given off in the process of photosynthesis by aquatic plants. Dissolved oxygen present in drinking waters adds taste and is highly fluctuating factor in water. (Indirabai and Seenamma, 2002).

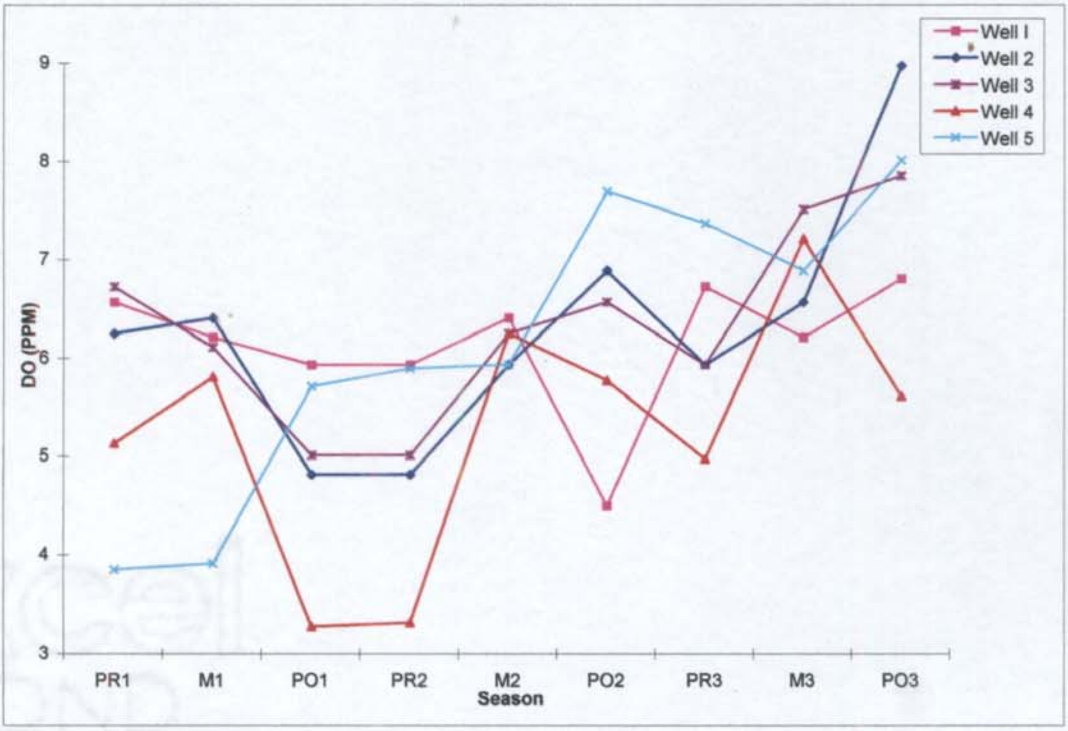


Figure 3.15 Seasonal variation in DO at various wells

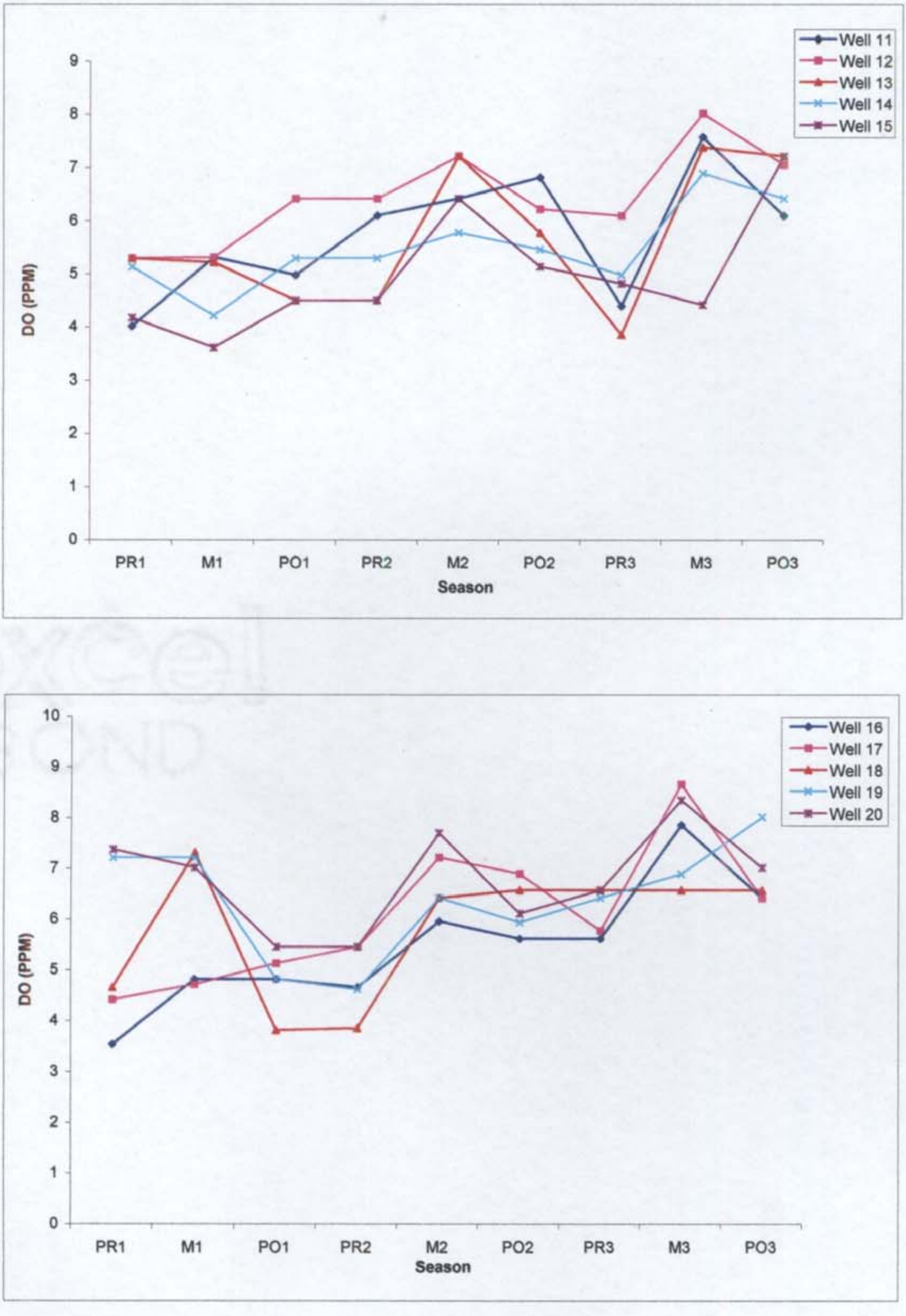


Figure 3.16 Seasonal variation in DO at various wells

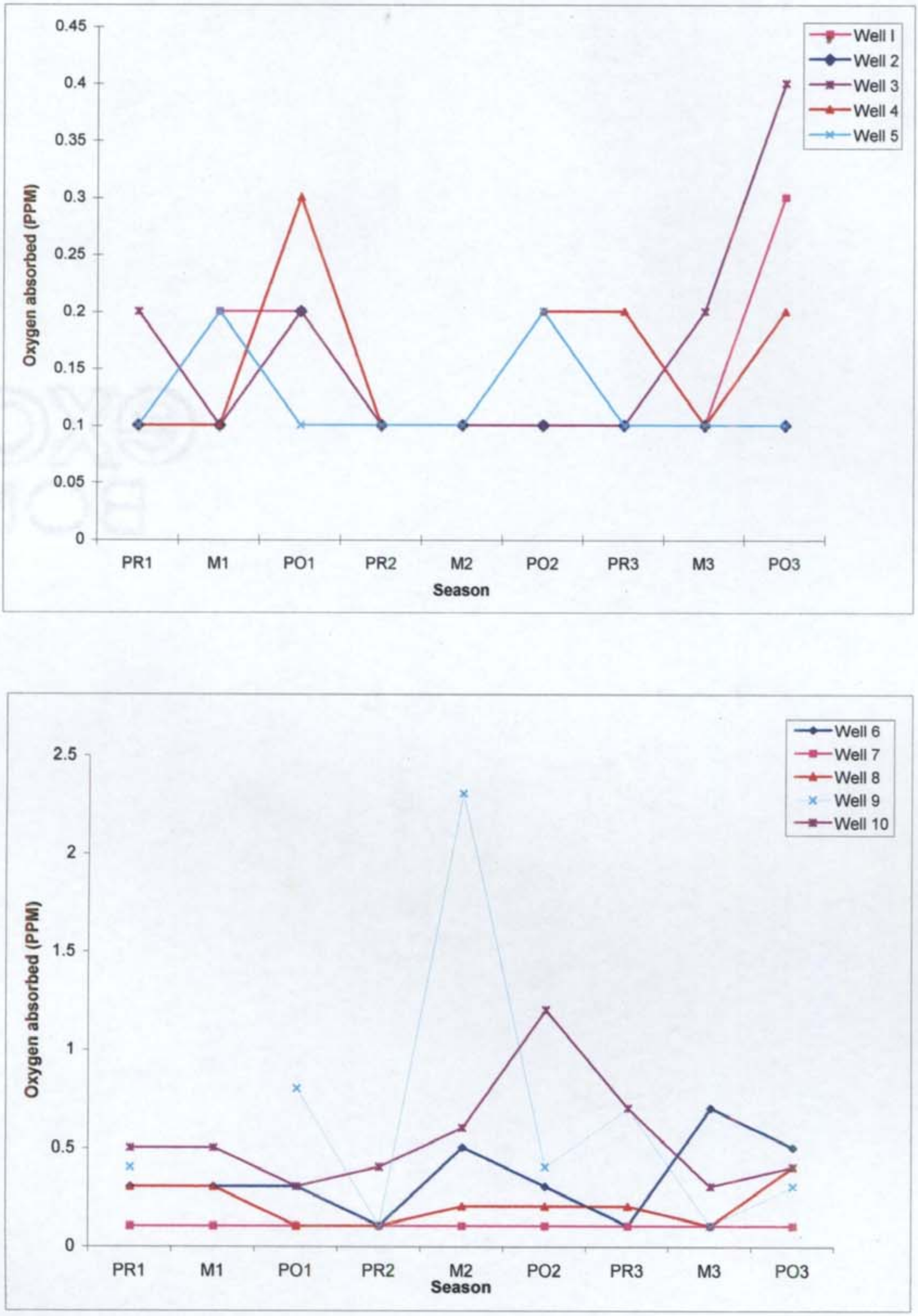


Fig. 3.17 Seasonal variation of Oxygen absorbed at various wells

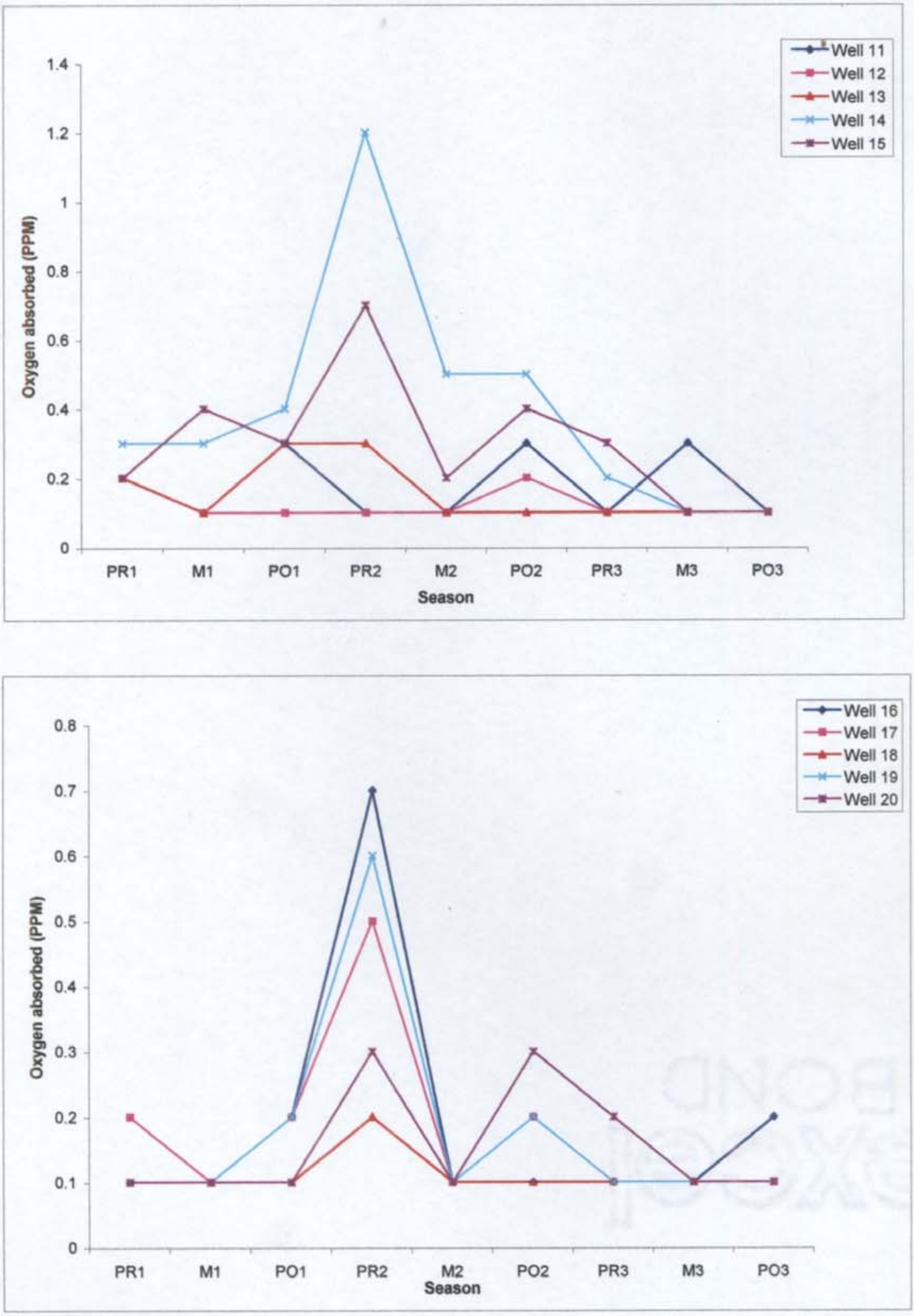


Figure 3.18 Seasonal variation in oxygen absorbed at various wells

Solubility of atmospheric oxygen in fresh water is low, only 10.66 mg/L at 10°C and 7.13mg/L at 30°C under normal atmospheric pressure. The solubility of oxygen in water depends on the partial pressure of oxygen in air, the temperature of the water and the mineral content of the water. DO in water affects the oxidation - reduction state of many other chemical compounds such as nitrate and ammonia, sulphate and sulphite and ferrous and ferric ions. The oxygen content of natural water varies with temperature, salinity, turbulence, photosynthetic activity of algae and higher plants and the atmospheric pressure. The DO has no adverse effect on water used for domestic purposes and increases the palatability of water. The high level of dissolved oxygen observed during monsoon season could be due to the mixing of rainwater rich in oxygen (Mathew Koshy and Vasudevan Nayar (1999). High values of dissolved oxygen indicate the absence of microorganisms. The values of DO in the study area in found to be between 3.26- 12 (Table 3. 8).

Significant variations of dissolved oxygen were observed between seasons ($P<0.01$). Variation of DO is given in graph 3.15 and 3.16. Variations of DO between wells were insignificant ($P>0.05$). Correlation between DO and temperature is highly significant.

Absorbed oxygen

If the absorbed oxygen is >1ppm it is a sure indication that organic pollutants are present in the water. In the present study all the wells except well no. 9 during monsoon (year II) are free from organic pollutants (Table 3.9). The values obtained are shown in fig 3.17 and 3.18. Variation between wells and between seasons was found to be highly insignificant. No significant correlation is found between oxygen absorbed and other parameters. ($P< 0.01$).

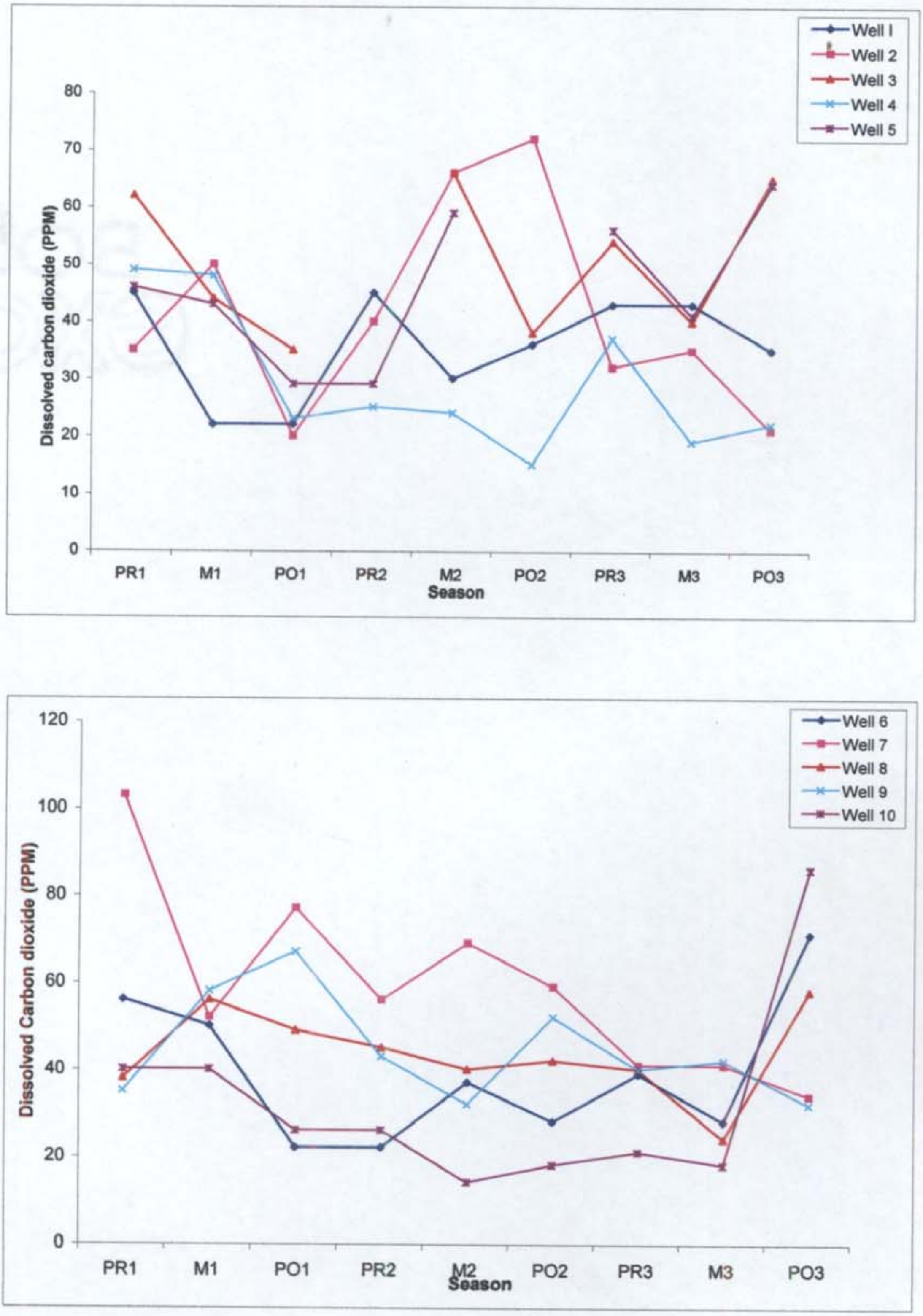
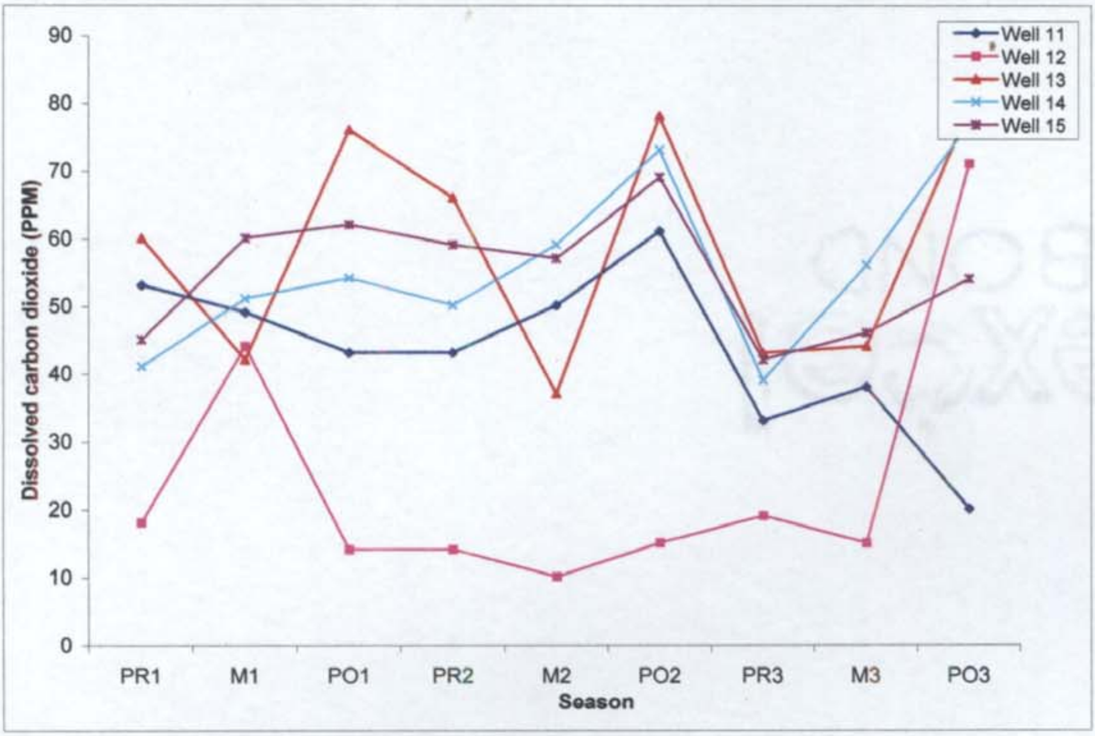


Figure 3.19 Seasonal variation of dissolved CO_2 at various wells



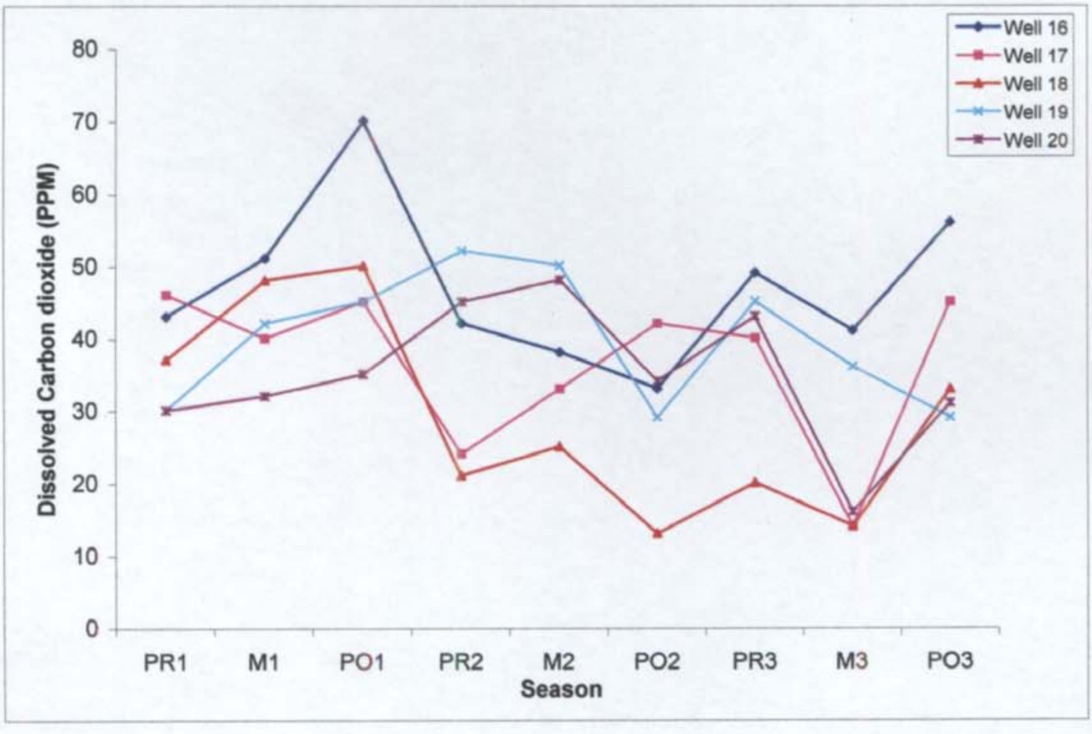


Figure 3.20 Seasonal variation of dissolved CO_2 at various wells

Carbon dioxide

Carbon dioxide is the chief cause of acidity or low pH values in ground water. CO_2 is relatively soluble in water and forms carbolic acid when it is dissolved. The carbolic acid in turn dissociates and produces more hydrogen ions than the pure water would do. Thus lowers their pH values. Generally the amount of free CO_2 present in groundwater together with the total alkalinity of water determines its pH value. Water with 50ppm of CO_2 and a total alkalinity of 100ppm would have a pH value of 6.6. This would be corrosive. If the free CO_2 were 20ppm and the total alkalinity 300 ppm then the pH value would be 7.5 and the water would not be corrosive. It is obvious that those three factors CO_2, alkalinity and pH are interrelated to the extent that any two of them are known, the third can be calculated. The measured CO_2 values are given in Table 3.10. Variations of CO_2 in different seasons are given in graph 3.19 and 3.20.

Significant variations of absorbed CO_2 are observed when all the wells are considered ($P< 0.05$); but variation of absorbed CO_2 is insignificant with respect to all the seasons ($P> 0.01$). There is no correlation between absorbed CO_2 and other parameters.

Ammonia

The most important source of ammonia is the ammonification of organic matter. Sewage disposal tends to increase the ammonia content of the waters as sewage has large quantities of nitrogenous matter. Occurrence of ammonia in the water can be accepted as the chemical evidence of organic pollution.

The presence of ammonia in ground water is quite generally a result of natural degradation processes. Ammonia in higher concentration is harmful to fish and other biota. It is also toxic to man at high concentration. In the present study ammonia was not present in any of the samples.

Nitrite

Nitrite is used in fertilizers and is found in sewage and wastes from humans and/or farm animals and may get into drinking water by runoff into surface water or by leaching into groundwater. While excessive amounts of nitrite in drinking water have not been observed, other sources of nitrite have caused serious illness and sometimes death in infants less than six months of age. The serious illness in infants is caused because nitrite interferes with the oxygen-carrying capacity of the child's blood. Symptoms include shortness of breath and blueness of the skin. USEPA has set the drinking water standard at 1 mg/L for nitrite to protect against the risk of adverse effects. USEPA has also set a drinking water standard for nitrate (converted to nitrite in humans) at 10 mg/L and for the sum of nitrate and nitrite at 10 mg/L. drinking water that meets the USEPA standard is associated with little to none of this risk and is considered as safe with respect to nitrite. In all the samples nitrite was absent or present in trace amount only.

Nitrate

Nitrate represents the highest oxidised form of nitrogen. Nitrate is the frequently introduced pollutant into ground water systems (Spalding and Exner, 1993). The most important source of the nitrate is biological oxidation of organic nitrogenous substances, which come from sewage and industrial wastes or produced indigenously in the water. Domestic sewage contains very high amounts of nitrogenous compounds. Run off from agricultural fields is also high in nitrate. Irrigation of land using sewage effluent also can be another source (Keeney, 1986, Bouchard *et al.*, 1992, Echhardt and Stackelberg, 1995, Mc Lay *et al.*, 2001, Insaf S Babiker *et al.*, 2004).

Atmospheric nitrogen fixed into nitrates by the nitrogen-fixing organism is also a significant contribution to nitrate in the water.

Many ground water have significant quantities of nitrates due to leaching of the nitrate with the percolating water. Ground water can also be contaminated by sewage and other wastes rich in nitrates. The adverse health effects of high nitrate levels in drinking water are well documented (Walton, 1951; Fan *et al.*, 1987; Gangolli *et al.*, 1994; Ward *et al.*, 1994; Fan and Sterinberg, 1996). When nitrate concentration exceeds 40mg/L it results in disease called methaemoglobinaemia (Shearer *et al.*, 1972). Other diseases caused by excess of nitrate are gastric cancer, and non- Hodgkin's lymphoma and goiter (Manivasakam, 1996). The nitrate content in the wells varied from.0 ppm to 6 ppm. The maximum was observed in well no 2, 7, 8 and 11during monsoon. It may be due to the percolation of polluted water. Well 2, 7, 8 are situated close to the septic tank (<10meter). Well No.11 is close to the domestic sewage.

Groundwater with concentration exceeding the threshold of 3 mg/L NO_3^- - N or 13 mg/L NO_3^- is considered contaminated due to human activities the so called human affected value (Eckhardt and Stackelberg, 1995). However the permissible limit of nitrate prescribed by ISI for drinking water is 20 mg/L with an excessive limit of 50mg/L. The criteria for bathing / recreation are 25 mg/L. The problem of nitrate pollution is a contemporary one and is not so clearly defined. However there are at least two ways in which nitrate pollution is suspected to be a threat to health. Nitrate pollution is basically the result of intensive cultivation.

The most common contaminant identified in ground water is dissolved nitrogen in the form of nitrate, due to agricultural activities and disposal of sewage on or beneath the land surface. Dissolved nitrogen also occurs in the form of NH_4^+, NH_3 - nitrite, NO_2^- - nitrogen (N_2), nitrous oxide N_2O and organic nitrogen. The process of conversion of organic nitrogen to NH_4^+ is known as ammonification. Through the process of nitrification $NH4^+$ is converted to NO_3^- by oxidation. This occurs in soil zone where organic matter and oxygen are abundant NO_3^- moves with the ground water with no transformation and or no retardation.

Nitrate is usually derived from geochemical composition of ground water, thunderstorm, manure, organic pool of the soil and from infiltration of surface runoff. Sodium nitrate & calcium nitrate are found in minerals occurring in arid zones and are highly soluble in water. Ammonium is bound on the lattice of silicates in a non-exchangeable form and is released only if the rocks get decayed. The nitrogen compound goes into surface water mainly through the introduction of the commercial, agricultural and industrial waste waters, through the rain water and through the washing away of agriculturally used surface. Average distribution of contamination from each source may be represented as follows

Commercial fertilizers	31%
Manure	19%

Soil nitrogen	46%
Rain	4%

The nitrate itself has no effect on health. But nitrate gets reduced to nitrite, which has a definite toxic effect at the concentration of 0.1 mg/L.

The nitrite oxidises hemoglobin of blood to methaemoglobin in which case the hemoglobin is not in a position to transport O_2. In case, large rates of conversions are involved inner suffocation may occur which can be recognized by the grey blue, colouring of skin and mucous membrane. In case of infants the conversion of hemoglobin can occur at double speed as such they are more susceptible to methaemoglobinaemia. Nitrate is an oxidizing agent and it readily oxidizes hemoglobin (Hb) into methaeomoglobin (MeHb) a blue coloured pigment and gets reduced to nitrite (NO_2). The oxidized Hb impairs the oxygen carrying capacity of the blood and thus causes hypoxia, which may have fatal consequences in anemic individuals and infants. Infants have greater exposure to the disease, as their total fluid intake per unit of body weight is approximately three times more than that of adults. And the pH of the stomach fluids in infants is higher (5-7) than in adults (<4) which allows nitrate reducing bacteria to grow in the upper gastrointestinal tract from which nitrite is absorbed (Royal Commission on Agricultural Pollution, 1979). In adults, as the stomach fluid is more acidic, the nitrate reducing bacteria live in the lower intestine, where absorption of nitrite to the blood stream does not occur. Gastrointestinal illness and diarrhea may allow the bacteria responsible for conversion of nitrate to nitrite, to migrate from lower intestine to upper intestine and stomach and increase the chances of nitrite formation prior to absorption in small intestine. Many cases of methaemoglobinaemia have been associated with bacteria contaminated wells, which may be a source of nitrate reducing bacteria and cause of gastrointestinal illness (ISCWQT, 1974). The MeHb formed in the infant's blood gives a characteristic blue hue to the skin and mucous membrane, thus giving the name blue baby disease or methaemiglobinaemia. This condition is particularly important in the case of infants because the infant and fetal Hb which is a_2g_2 type have greater affinity for oxygen than infants because adult Hb which is a_2b_2 type. More over the pH of the stomach fluids in infant (5-7) is higher than.that in adults (<4). That is in adults stomatic fluid is more acidic. High pH allows nitrate-reducing bacteria to grow in the upper gastrointestinal tract from which nitrate is absorbed (Royal Commission Agricultural Pollution 1979). This condition may also result by birth due to the deficiency of enzyme known as methaemoglobin reductace in fetal blood. Besides methaemoglobinaemia, which is characterised as secondary toxicity there is possibility of tertiary toxicity due to the formation of nitrosamines. Nitrite formed from the reduction of nitrate may react with some amino acids in the intestinal tract and stomach to form nitrosamines that are potential carcinogens. Chronic consumption of high nitrate waters may cause cancer and hence cause adverse effects on cardiovascular system and central nervous system. The nitrate can be reduced to nitrites with the help of bacteria

- in water distributing line
- by means of reduction of bacteria in food stuffs and drinks
- in the stomach and small intestine
- in dental cavities.

In India in recent survey 1290 ground water samples from different states were found to be having nitrate content more than 45 mg/L. Most of them are also found to have high dissolved solid content (Rajasthan, Tamil Nadu, Gujarat, Andhra Pradesh, Hariyana and Karnataka).

As nitrates are often associated with high TDS the standard technologies applied for desalination viz. reverse osmosis and electro dialysis can also achieve the removal of nitrates as in the case of fluoride and other undesirable salts. The method of natural decomposition of nitrates by bacteria can be successfully applied for removal of nitrates. The prerequisite for the course of denitrification are the partly oxidized conditions optimum pH value and temperature and sufficient supply of reduction agent for microorganism. Depending on the microorganism used; either hydrogen (autotrophic bacteria) or an organic carbon compound (heterotrophic bacteria) is added as reducing agent. For denitrification within a short time, highly concentrated bacteria on a suitable carrier are used. To reduce nitrate in water for drinking purposes any of the following methods also can be used.

-Procurement of water from other sources totally or partially

-New tapping of ground water

-Elimination by high nitrate consuming vegetation

-Physicochemical methods.

According to Nolan and Ruddy (1996) poorly drained soils can reduce the risk of nitrate contamination to ground water because the waterlogged soils

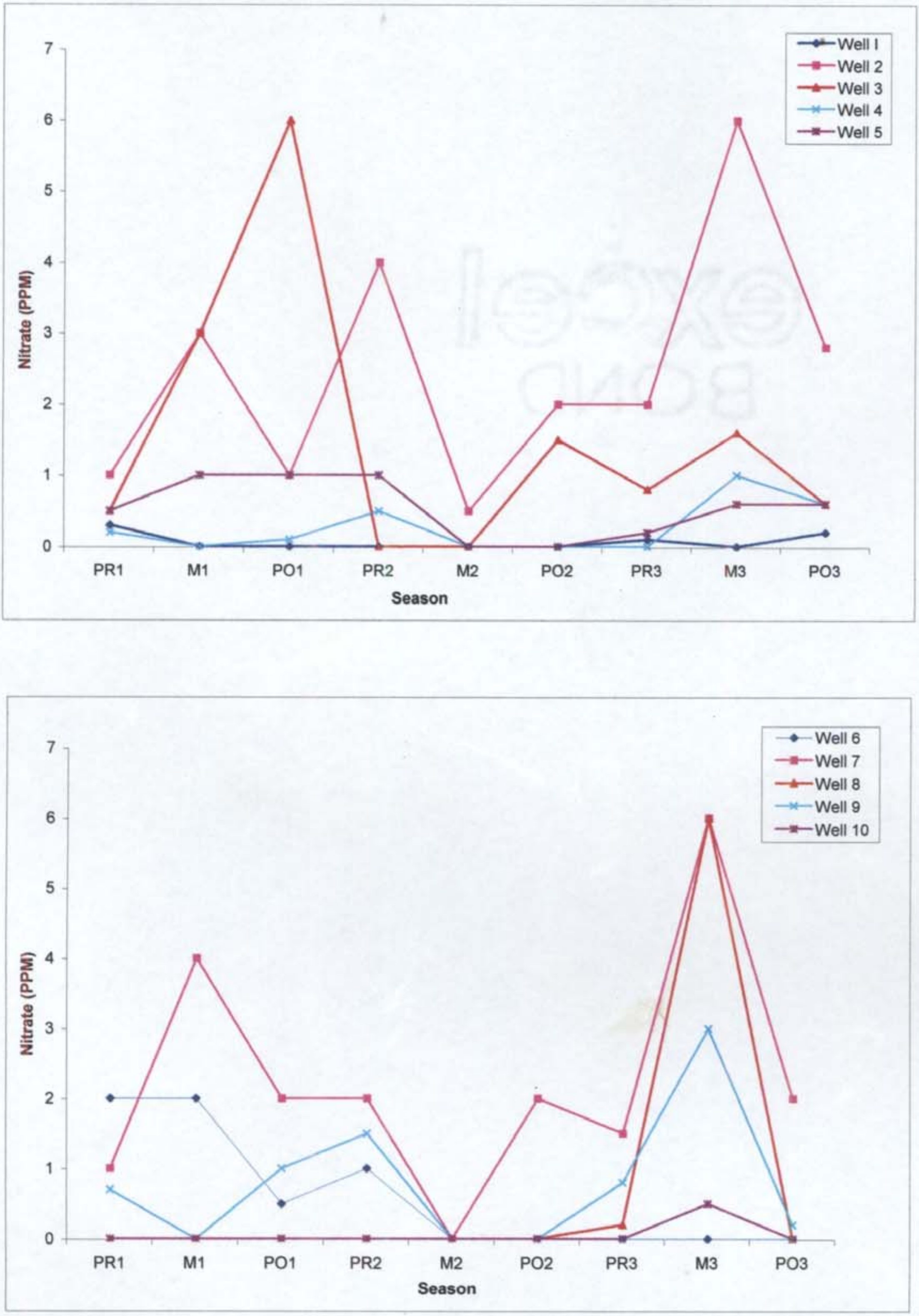
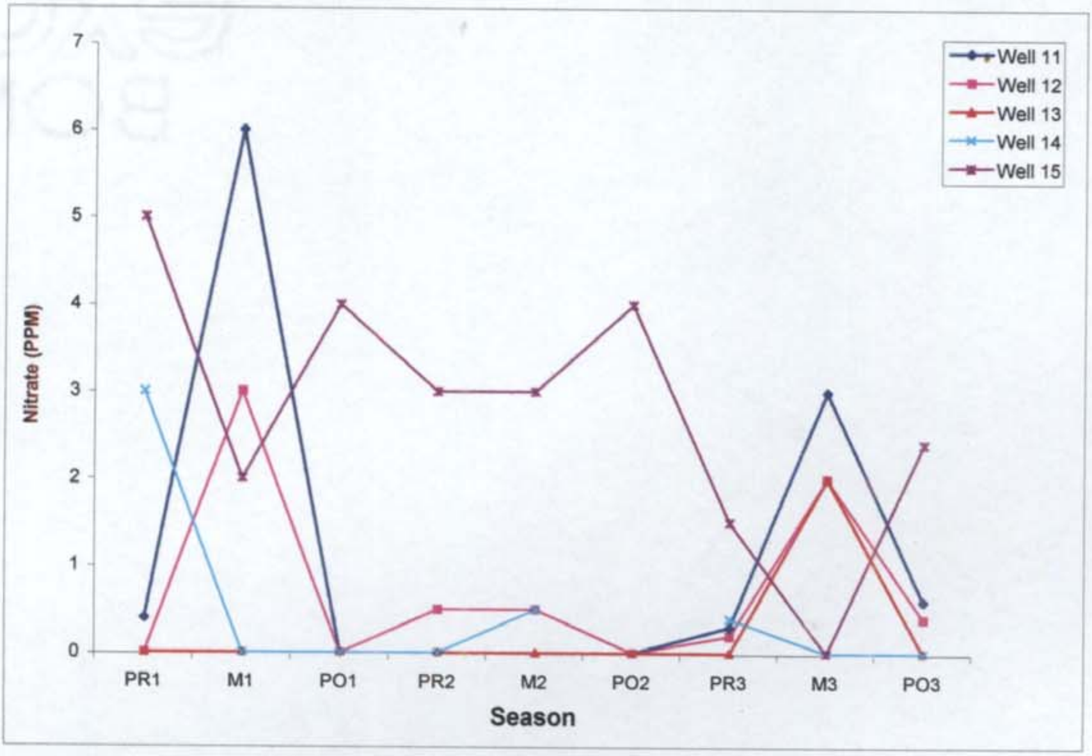


Figure 3.21 Seasonal variation in Nitrate at various wells



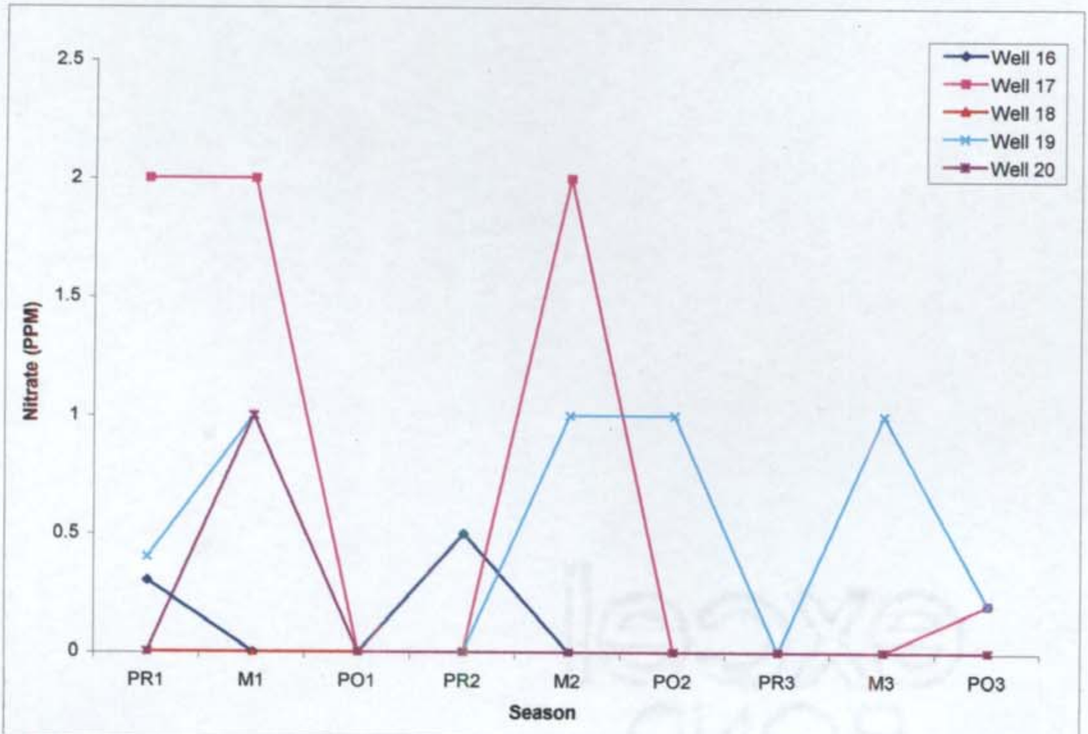


Figure 3.22 Seasonal variation in Nitrate at various wells

restrict the movement of nitrates of the water table. The nitrate concentration in the study area varied between 0-6mg/L.

There is significant variation in nitrate between seasons ($P < 0.05$) and between wells ($P < 0.01$). No correlation is found between nitrate and other parameters ($P > 0.05$). The observed values are given in Table 3.11 and the seasonal variations are shown in the graph (3.21, 3.22).

Chloride

Chloride occurs naturally in all types of water. In natural fresh water however its concentration remains quite low. The most important source of chloride in the waters is the discharge of domestic sewage and man and other animal excreta, which contains very high quantities of chloride together with nitrogenous compounds. A person per day excretes about 8-15 gm of NaCl. Therefore the chloride concentration serves as an indication of pollution by sewage. Industries are also important sources of chlorides. It is harmless up to 1500mg/L. concentration, but produce salty taste at 250-500mg/L levels and sometimes a high concentration causes laxative effect in human beings. It may affect persons who already suffer from diseases of the heart or the kidney (Saxena1, 1997).

Since there is free influence of saline water into the well comparatively high chloride values were obtained throughout all the seasons in well No. 10 (Table 3.12). Significant variations in chloride are found between the wells ($P < 0.05$). Variation in chloride between the seasons was also significant ($P < 0.05$). High positive correlation is found between chloride and alkalinity, calcium,

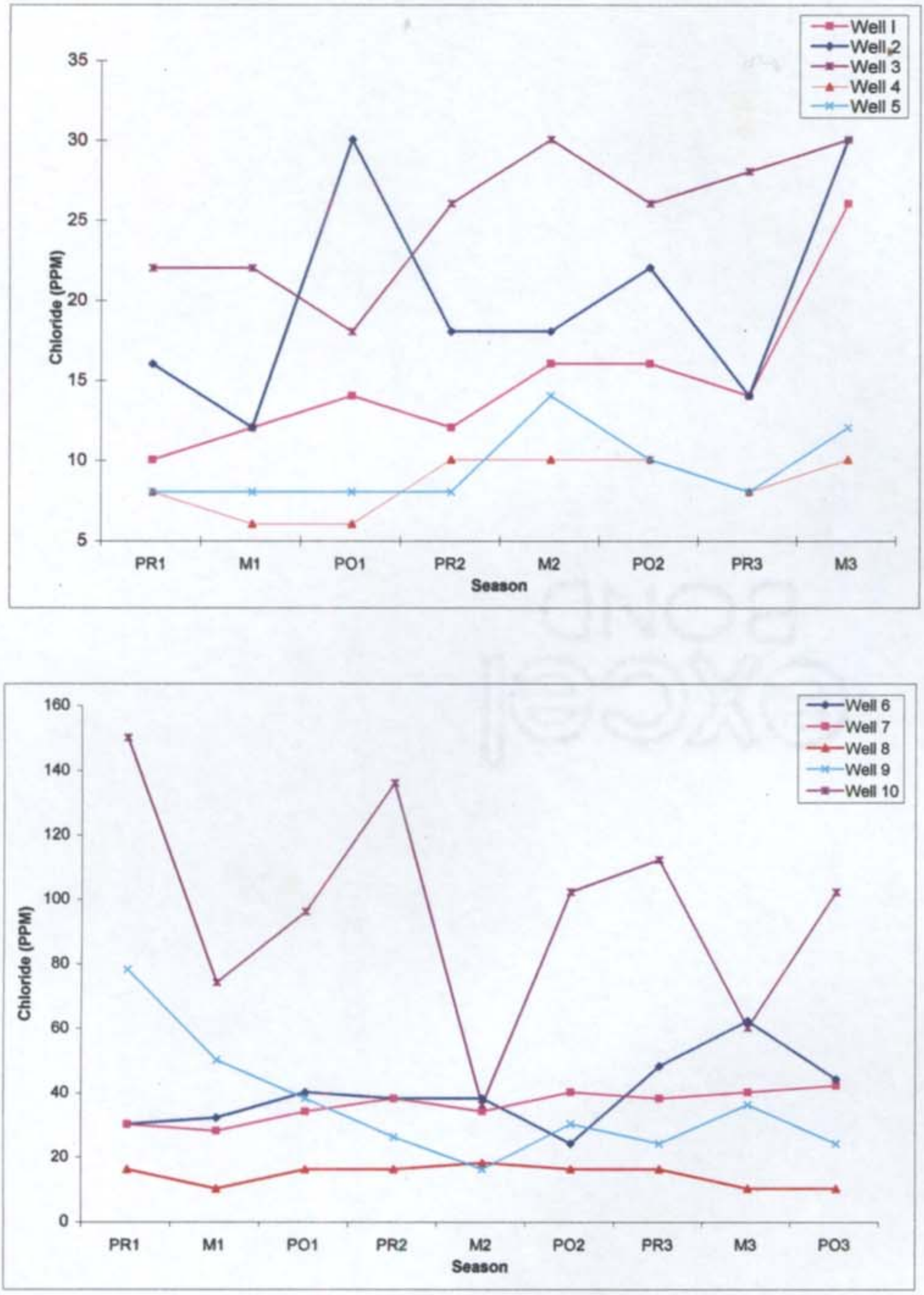
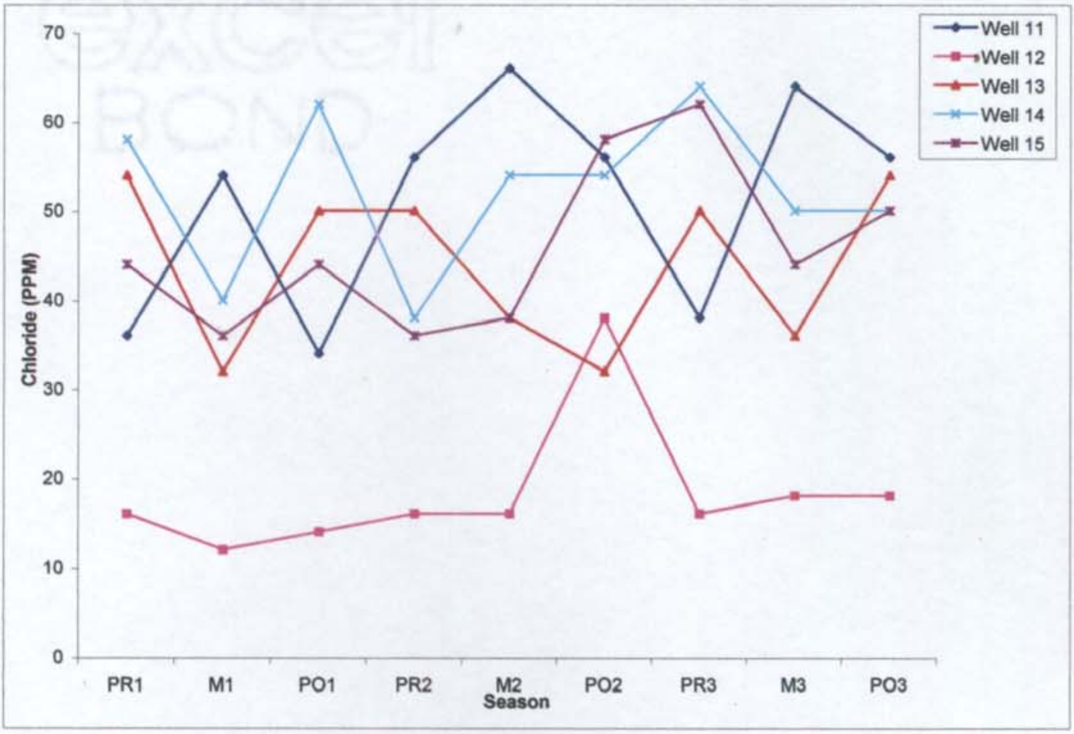


Figure 3.23 Seasonal variation in Chloride at various wells

72B



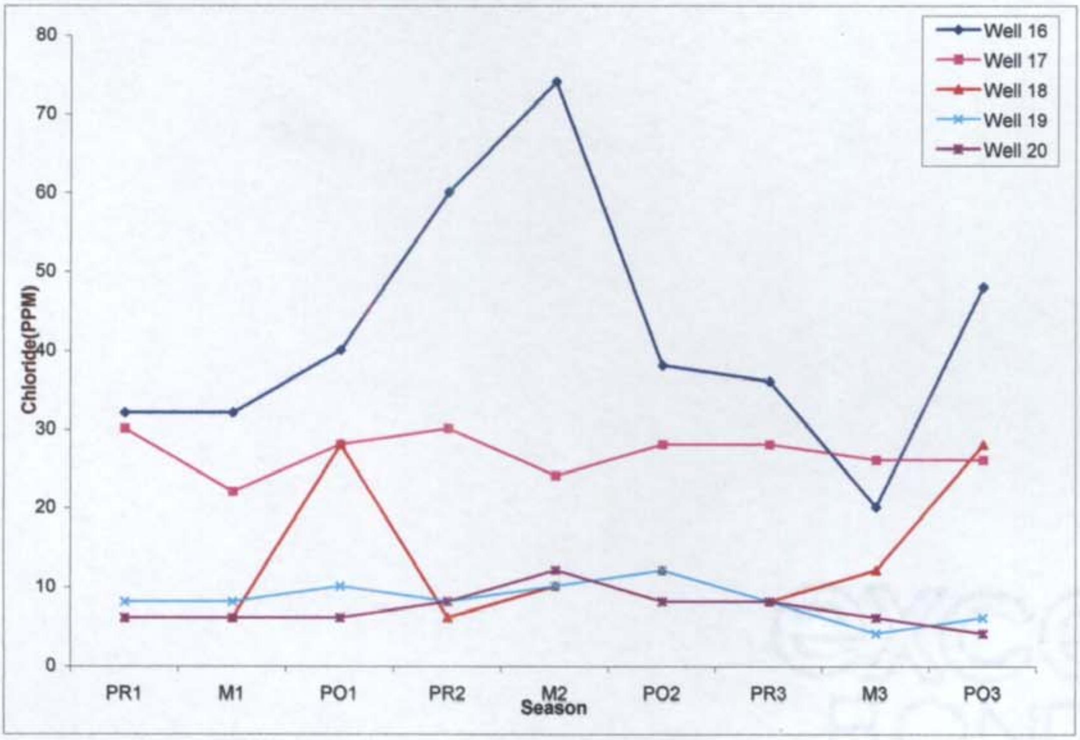


Figure 3.24 Seasonal variation in Chloride at various wells

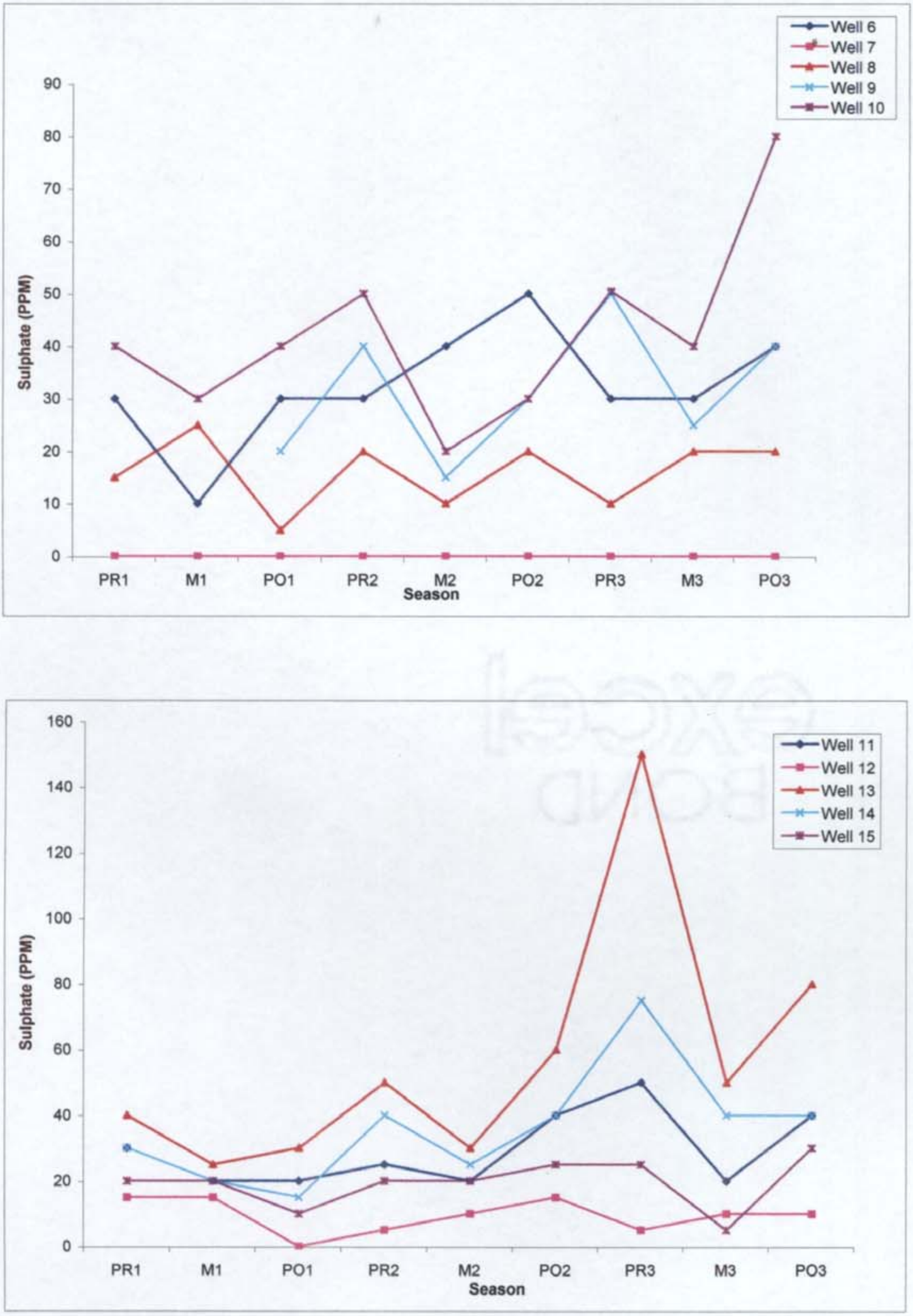


Figure 3.25 Seasonal variation in Sulphate at various wells

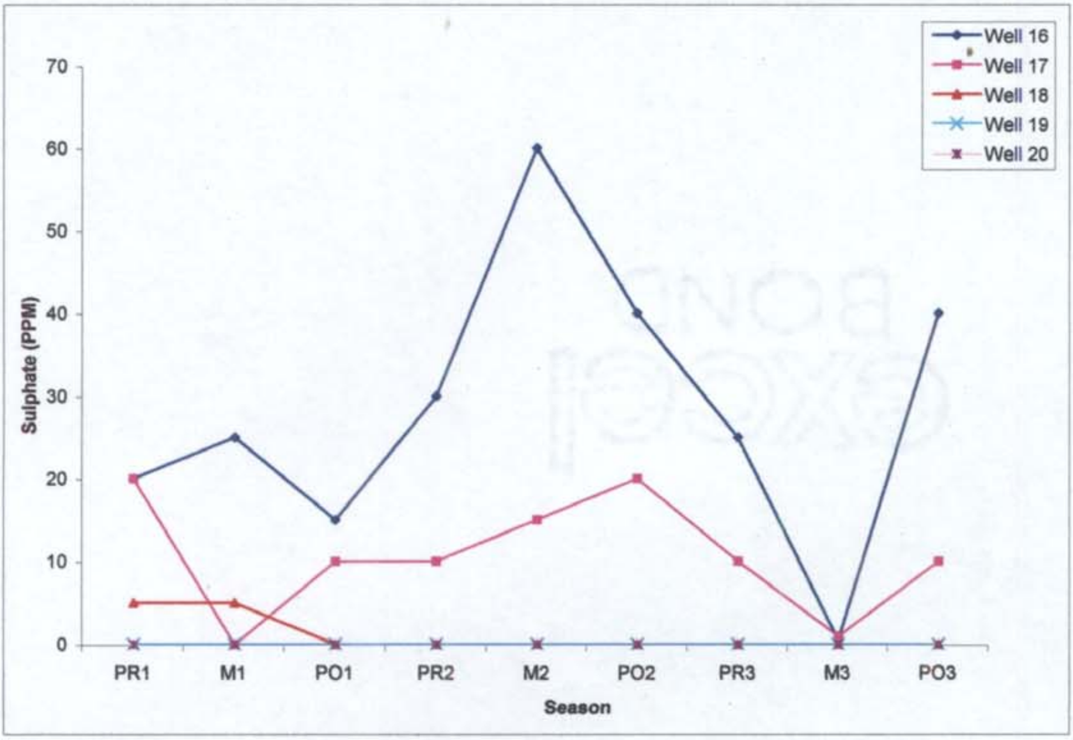


Figure 3.26 Seasonal variation in Sulphate at various wells

calcium hardness, total hardness, sulphate, total dissolved solids, potassium and magnesium and electrical conductivity. Seasonal variations in the concentration of chloride are shown in the graph (3. 23 and 3.24).

Sulphate

It is naturally occurring anion in all kinds of natural water. Rainwater has quite high concentration of sulphate particularly in the areas with high atmospheric pollution. Discharge of industrial wastes and domestic sewage in water tends to increase its concentration. Most of the salts of sulphate are soluble in water and imparts hardness. It undergoes transformations to sulphur and H_2S depending upon the redox potential of the water (Manivasakam, 1996). A limit of 150mg/L is recommended as safe for drinking purposes (ISI, 1983). Concentrations in excess of 250 ppm may have laxative and cathartic effect on persons unaccustomed to the water. Waters with about 500mg/L sulphates have a bitter taste and those with 1000 mg/L or more cause intestinal disorders (Saxena, 1997). It will also form a hard scale in boilers and heat exchangers.

The sulphate ion concentration in the entire study area varied from 0-150mg/L (Table 3.13), which is within the permissible limit. There is significant variation in sulphate between seasons and between wells ($P<0.05$). Variations of sulphate during different seasons are given in graph 3.25 and 3.26. (For wells1-5 sulphate ion concentration was found to be zero). Positive correlation found between sulphate and alkalinity, calcium, calcium hardness, electrical conductivity, total hardness, potassium, magnesium and total dissolved solids ($P<0.05$).

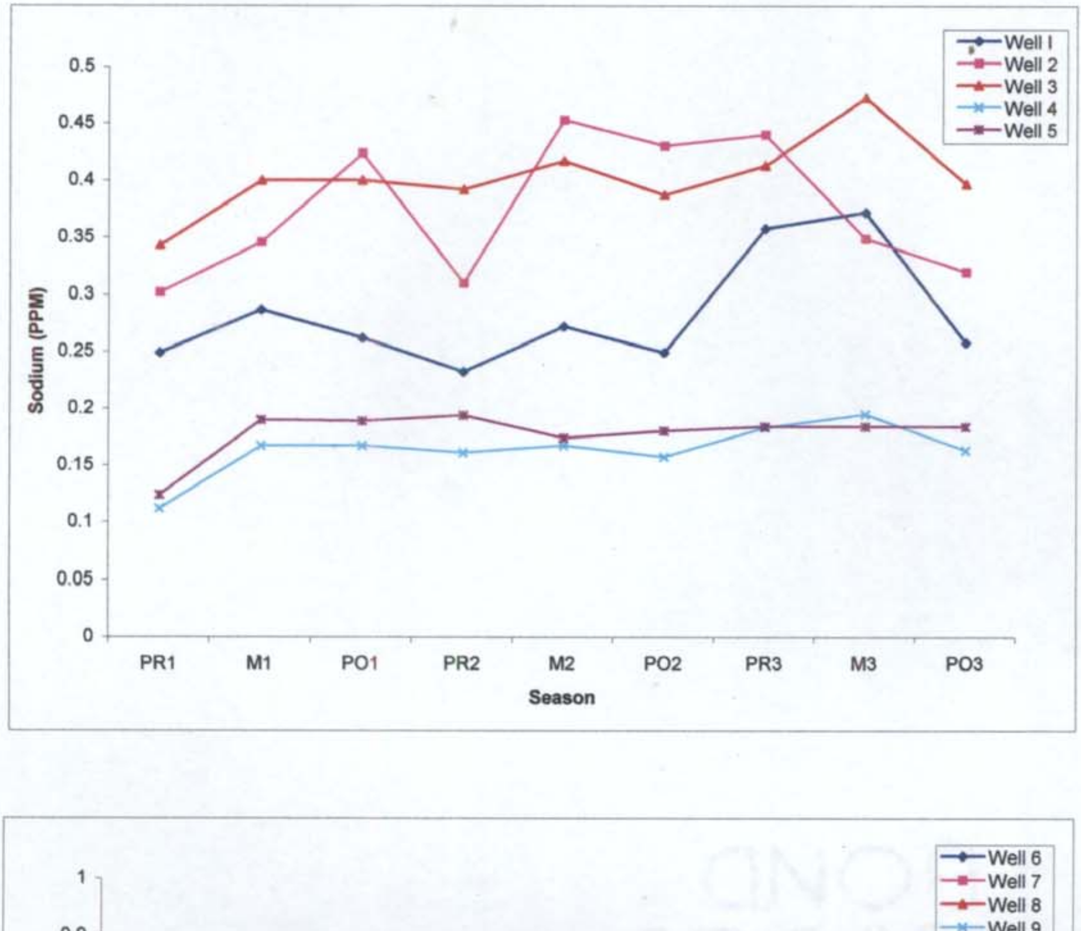
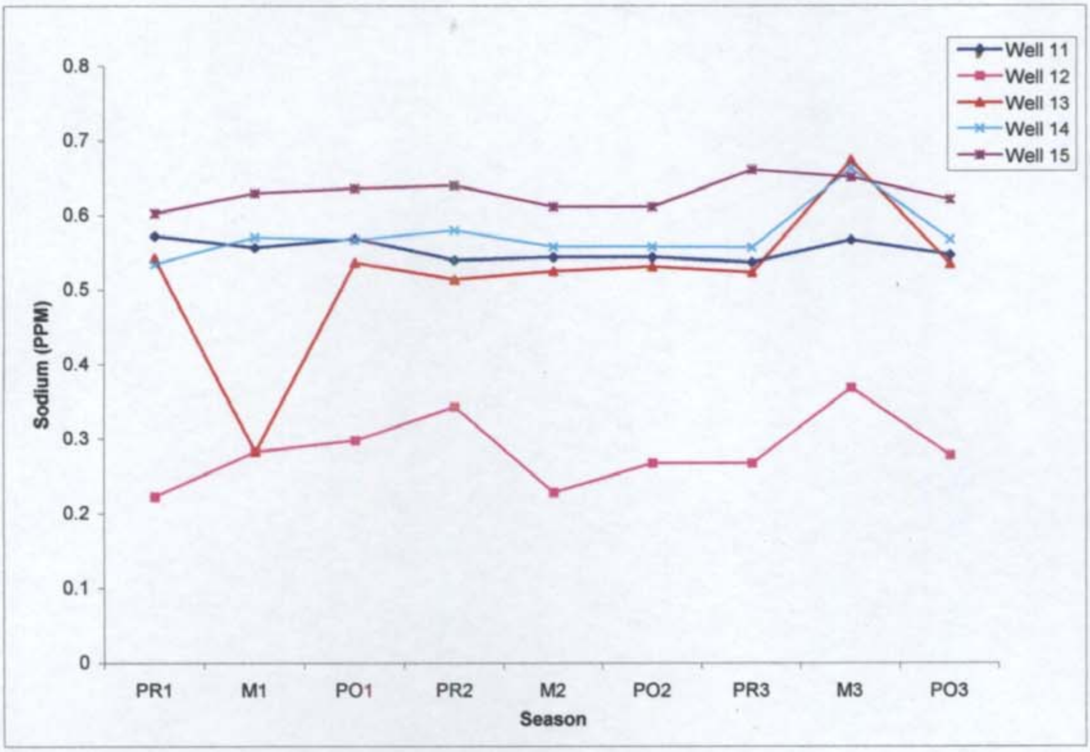


Figure 3.27 Seasonal variation in Sodium at various wells

73B



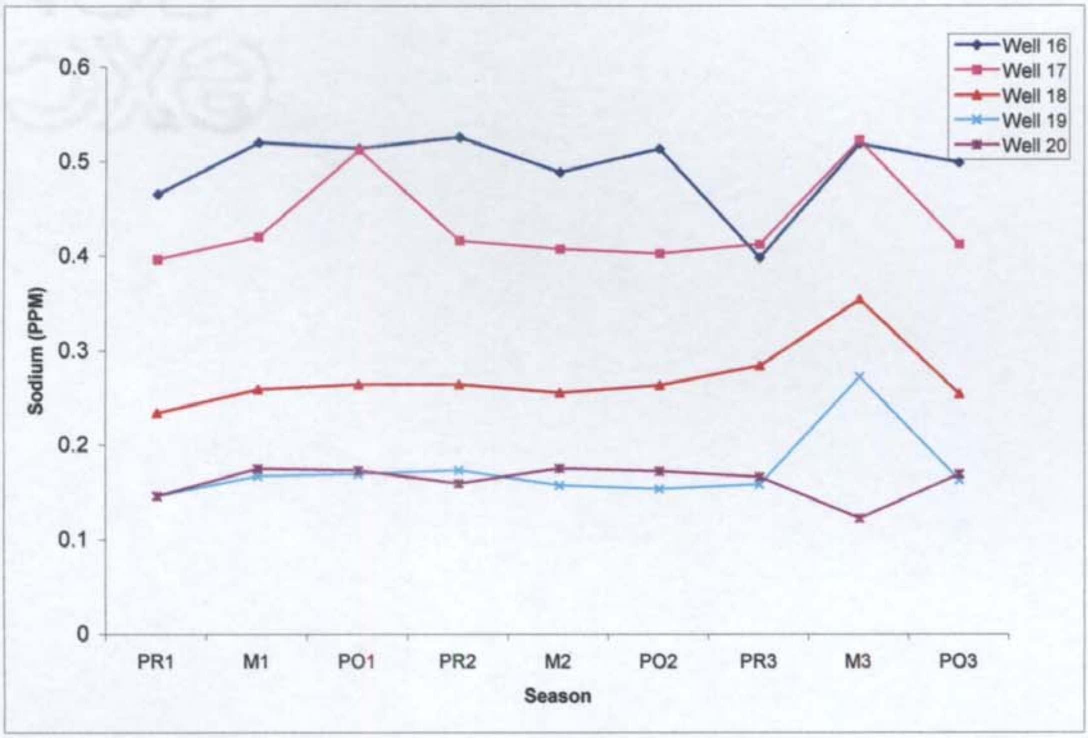


Figure 3.28 Seasonal variation in Sodium at various wells

Sodium

It is a naturally occurring cation. Its concentration in natural fresh water is lower than that of Ca and Mg. The source of sodium in natural waters is weathering of rocks. Disposal of domestic sewage and industrial waste increase the concentration of sodium in natural waters. In natural softening of water sodium is exchanged by Ca and Mg and thus its concentration increase in some ground water. Low concentration of Na has no adverse effects on the health. According to the National Academy of Science (1977, 1980) the higher concentration of Na can be related to cardiovascular diseases, hypertension and in women Toxemia associated with pregnancy (Guthrie, 1968). Intake of 100 mg/L of Na is known to raise pressure in children (Calabrese and Tuthil, 1977). High concentration of Na in association with chlorides and sulphates make the water salty and unpalatable.

In the present study it was found that during pre monsoon concentration of sodium was comparatively high (Table 3.14) and variation in Na between seasons and between wells are insignificant ($P>0.05$). There is significant correlation between sodium and chloride, total dissolved solids, hardness total, electrical conductivity and alkalinity ($P<0.01$) especially during pre monsoon. The data obtained are shown in graph 3.27 and 3.28.

Potassium

It is also a naturally occurring element, however its concentration remains lower than Na, Ca and Mg .The major source in natural fresh water is weathering of the rocks but the quality increases in the polluted water due to disposal of

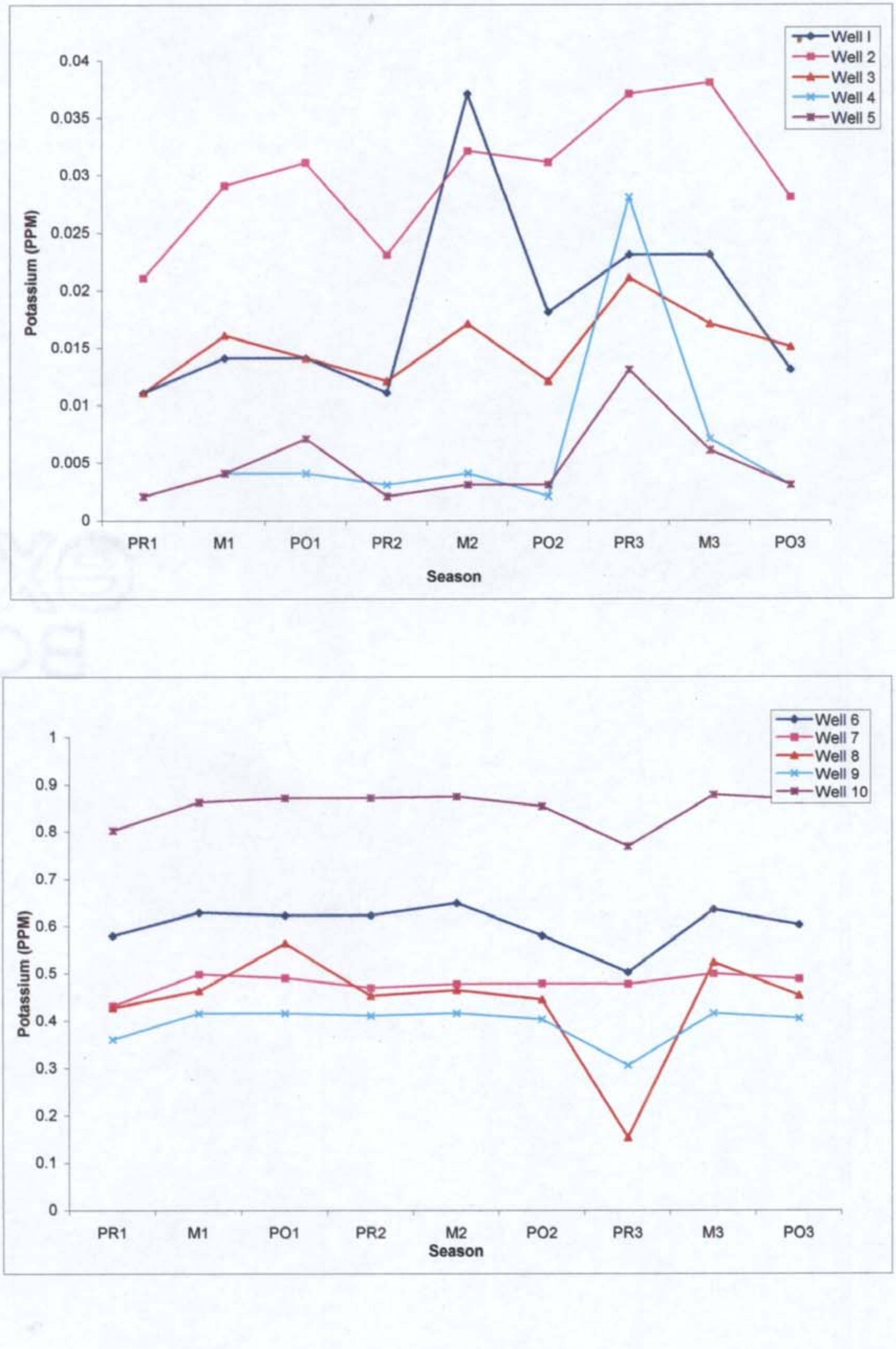
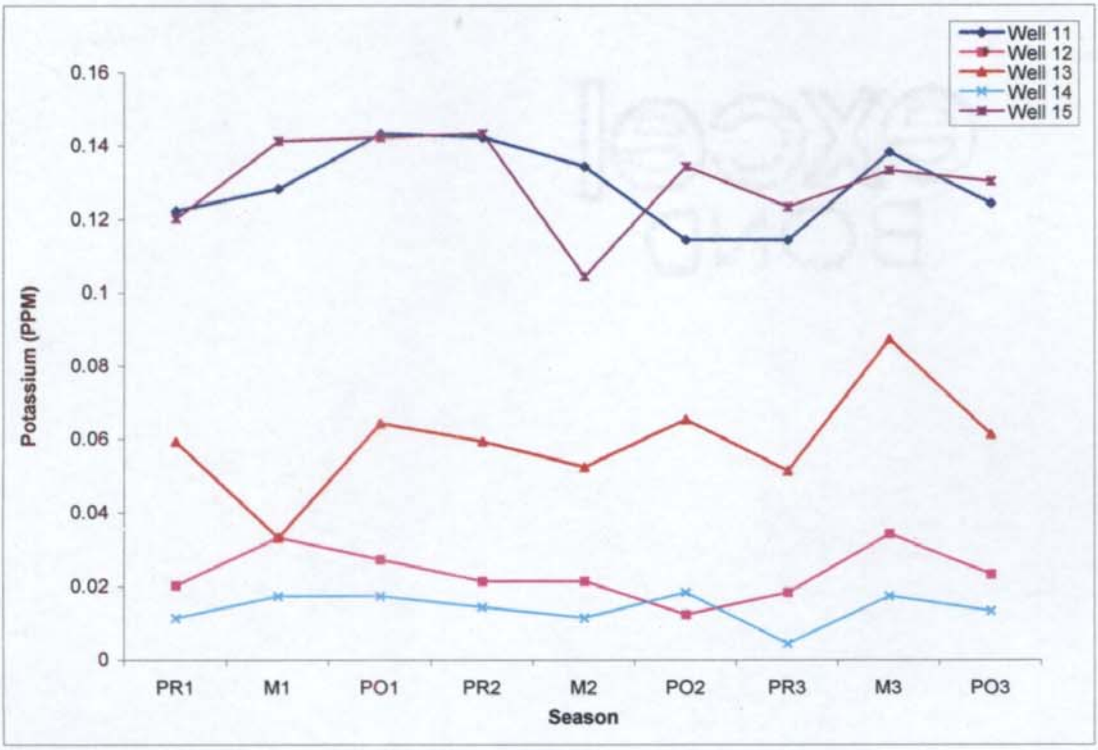


Fig 3.29 Seasonal variation in Potassium at various wells



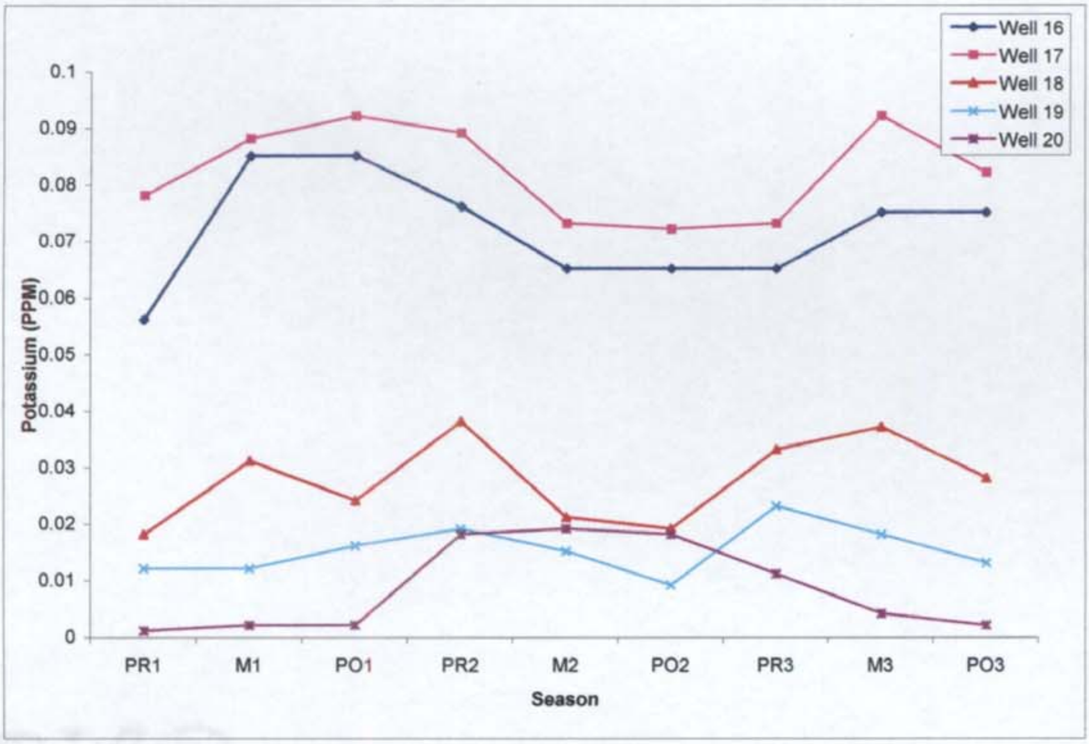


Figure 3.30 Seasonal variation in Potassium at various wells

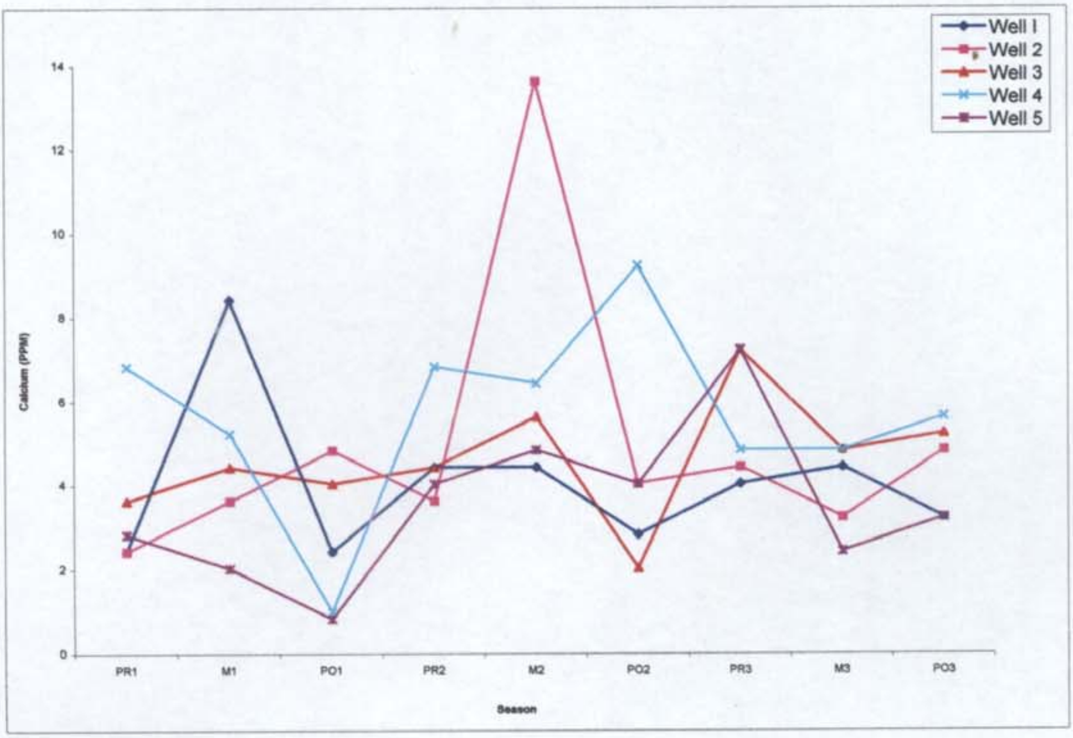
wastewater. As such from the health point of view it is not very much significant but large quantities may be laxative. Like Na, K is also highly soluble and therefore is not easily removed from water except by ion exchange. Although the abundance of K in the earth's crust is similar to that of Na its concentration in ground water is usually less than tenth of that of Na. Most ground water contains less than 10 mg /L of K.

In all the well water samples presence of potassium was negligible. (Graph 3.29 and 3.30). Variation in K between seasons ($P<0.05$) and between wells is significant ($P<0.05$). There is significant correlation between potassium and sulphate, calcium, pH, magnesium, calcium hardness, total dissolved solids, hardness total and alkalinity ($P<0.01$). Data are given in table 3.15.

Calcium

Calcium is one of the most abundant substances of the natural waters. Being present in high quantities in the rocks it is leached from there to contaminate the water. The quantities in natural waters generally vary from 10 to 100 mg/L depending upon the types of the rocks. Disposal of sewage and industrial waters are also important sources of Ca. Ca is taken up by ground water largely from the limestone in the earth's surface. Limestone is $CaCO_3$ and is soluble in H_2O only upto about 13ppm but when the water contains CO_2 the limestone is changed into calcium bicarbonate. Calcium in the form of bicarbonate is soluble in quantities upto about 1000ppm. This forms alkalinity and temporary hardness. Calcium is also taken up by water from gypsum ($CaSO_4$), which can be dissolved in pure water as large amount as 2000ppm. This does not cause alkalinity but forms permanent hardness. $CaCl_2$ is also highly soluble in water but

75A



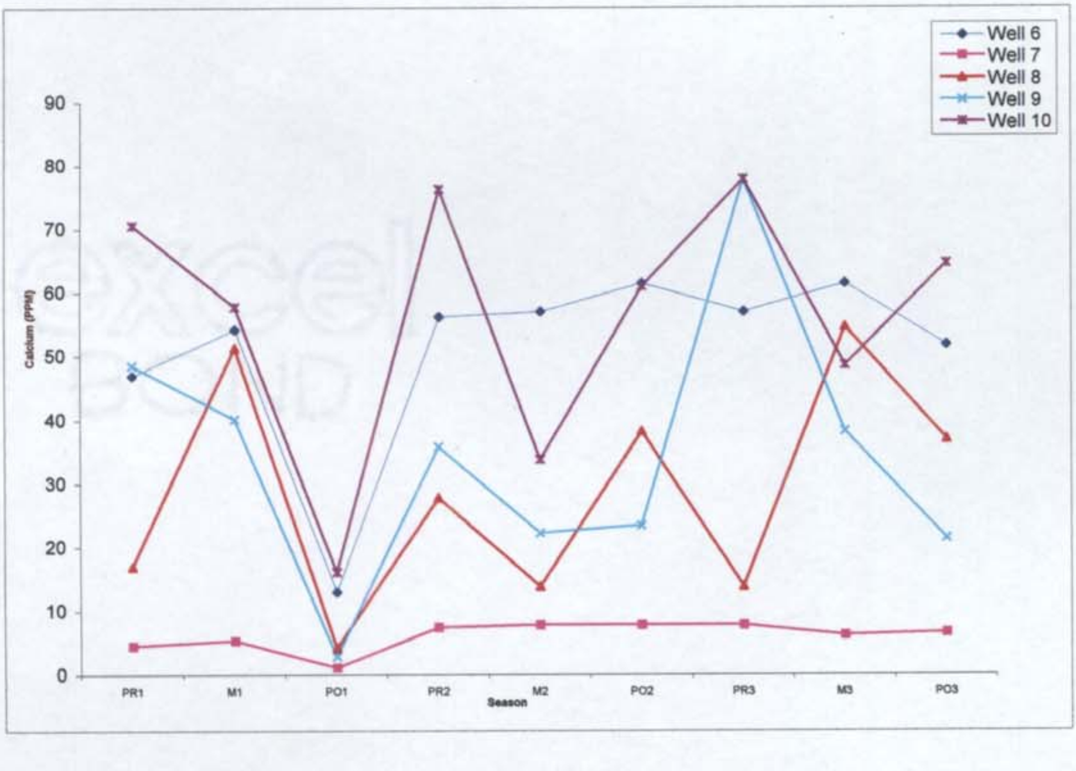
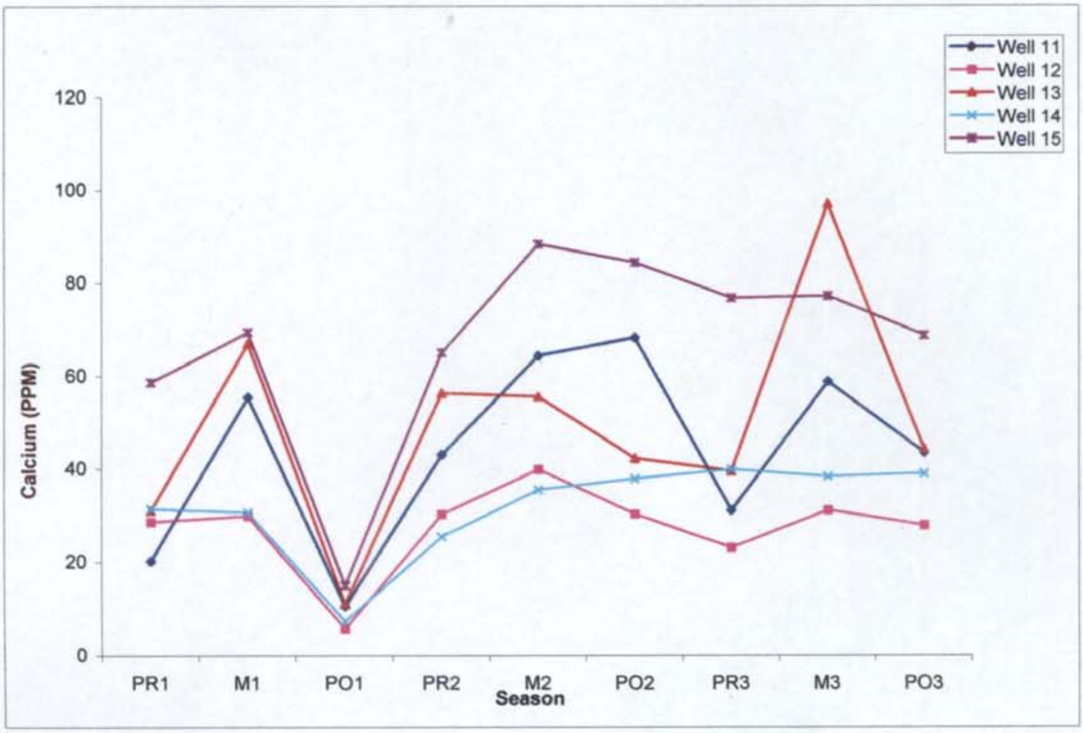


Figure 3.31 Seasonal variation in Calcium at various wells

75 B



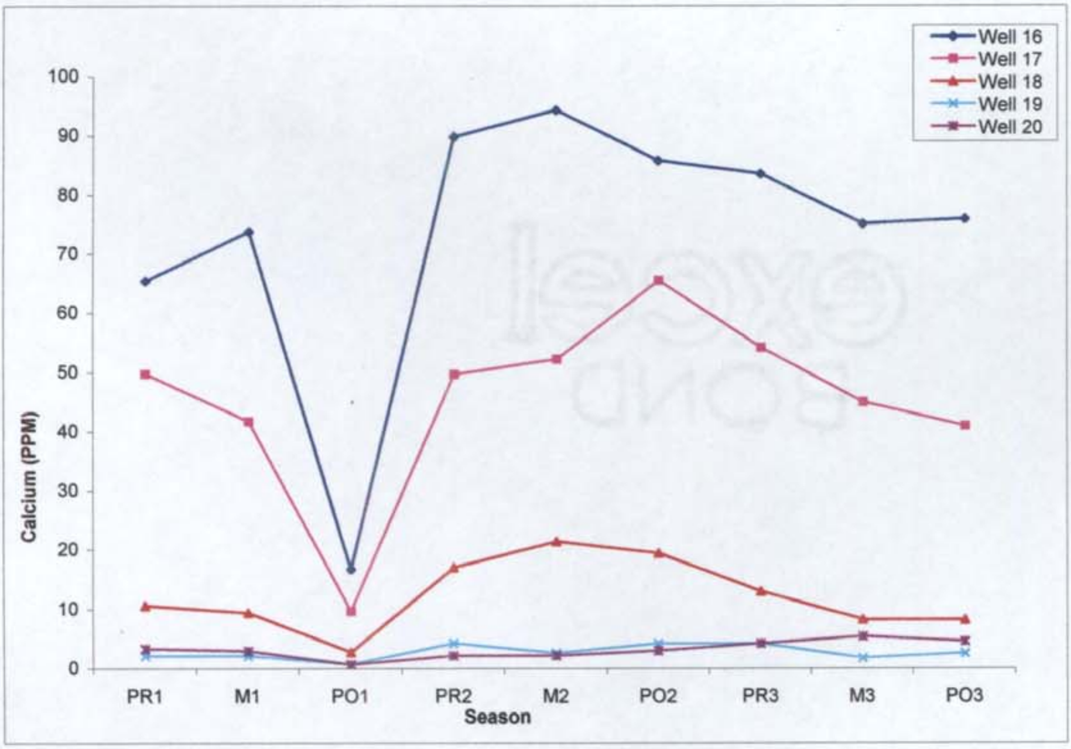


Figure 3.32 Seasonal variation in Calcium at various wells

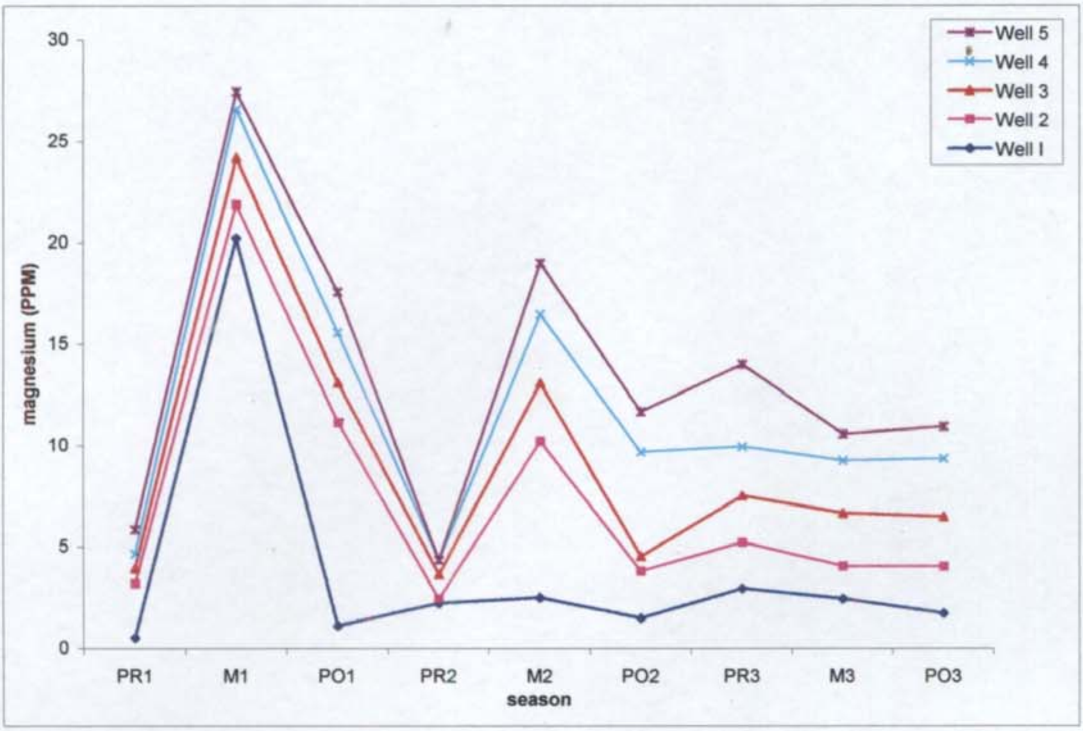
it is not often encountered in the ground water. Concentration of the Ca is reduced at higher pH due to its precipitation as $CaCO_3$. Calcium as such has no hazardous effects on human health. The highest desirable level of calcium in the drinking water is 75ppm and maximum permissible limit is 200ppm (WHO, 1984 and ICMR, 1975). It is an important nutrient required by the organisms. Concentrations up to 1800mg/L have been found not to impair any physiological reaction in man. The concentration of calcium in water samples ranges between 0.48- 75.7ppm. (Table 3.16). Thus the calcium concentration is low in the groundwater of the study area.

There is significant variation in calcium between wells and between seasons ($P<0.05$). Variations of calcium at different seasons are given in graph 3.31 and 3.32. Positive correlation between calcium and alkalinity, calcium hardness, electrical conductivity, total dissolved solids, chloride, potassium, magnesium and sulphate is significant ($P<0.05$) in all the seasons. Same correlation is found in all the wells.

Magnesium

The common sources of magnesium are dolomite, olivine, serpentine, talc etc. They also occur along with calcium minerals. The solubility is controlled by CO_2 despite the higher solubilities of most of its compounds. Magnesium is generally found in lesser concentrations than calcium. This difference is probably due to the slow dissolution of dolomite and the greater abundance of calcium. Common concentration of magnesium ranges from 1- 40 ppm. It also occurs in natural water with calcium. Sewage and industrial wastes are also important contributors of magnesium. It is supposed to be non-toxic at the concentrations

76A



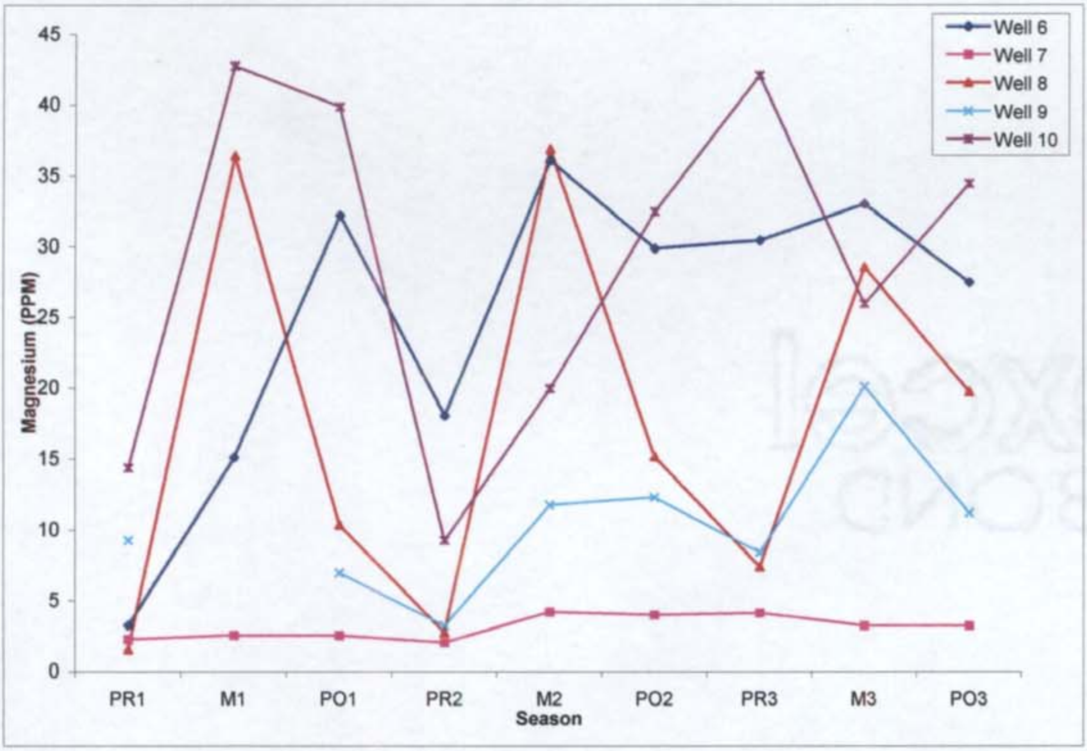


Figure 3.33 Seasonal variation in magnesium at various wells

146

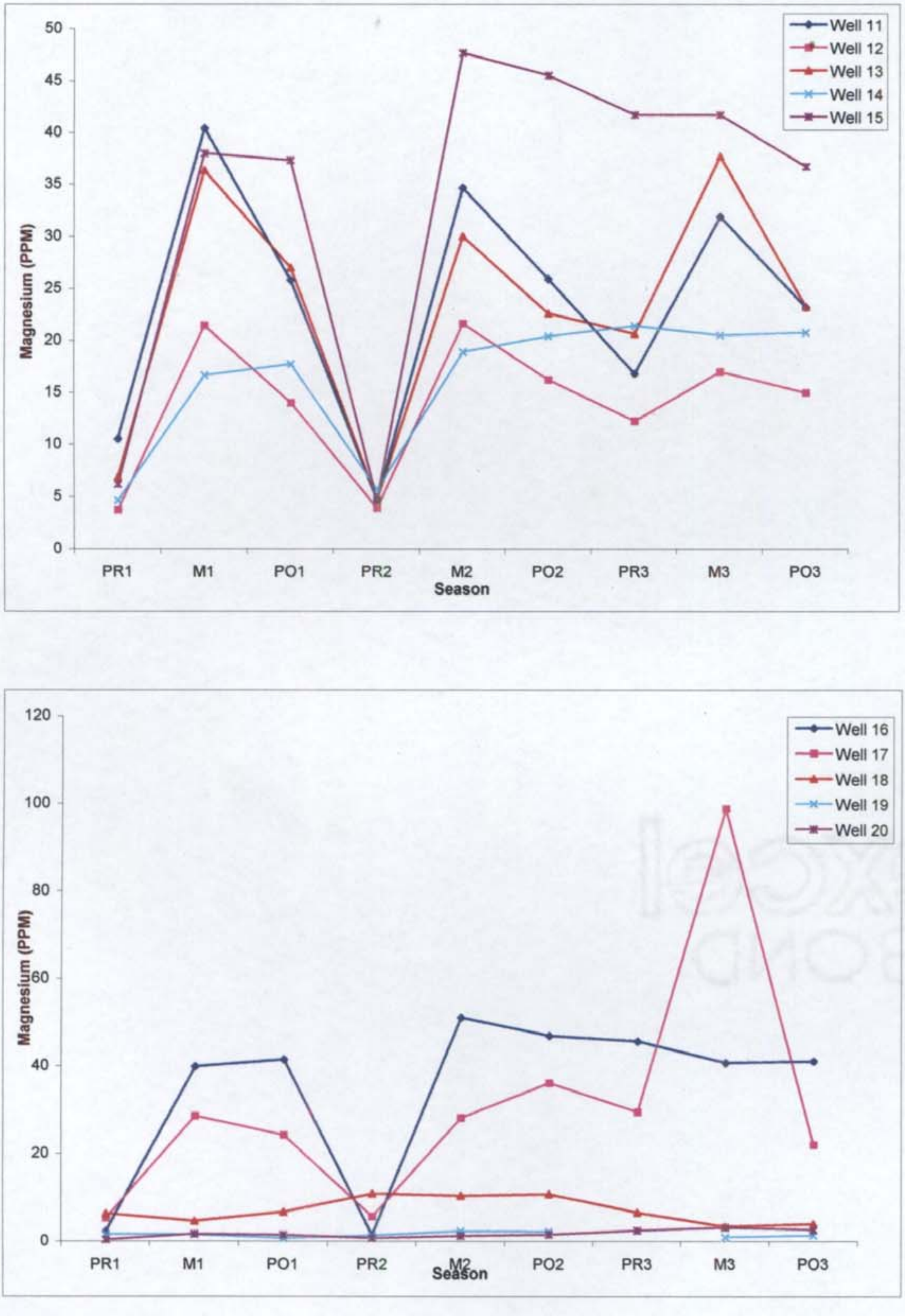


Figure 3.34 Seasonal variation of magnesium at various wells

generally met in natural waters. High concentration (>125mg/L) may be cathartic and diuretic for the initial user but a tolerance is developed in short time. High concentration combined with SO_4^{2-} acts as laxative to human beings. Concentration as high as 500mg/L imparts an unpleasant taste. Magnesium adds to the hardness of the water and with calcium poses the problem of scale formation in the boilers. The concentration of magnesium was found to vary from 0.2 to 47.5ppm. Its variation is represented in graph 3.33 and3.34. The data obtained for different wells are given in table 3.17.

The variation of magnesium between wells and between seasons is significant ($P<0.01$). There is significant correlation between magnesium and total hardness, total solids, alkalinity, sulphates, chlorides, calcium, pH and calcium hardness ($P<0.01$).

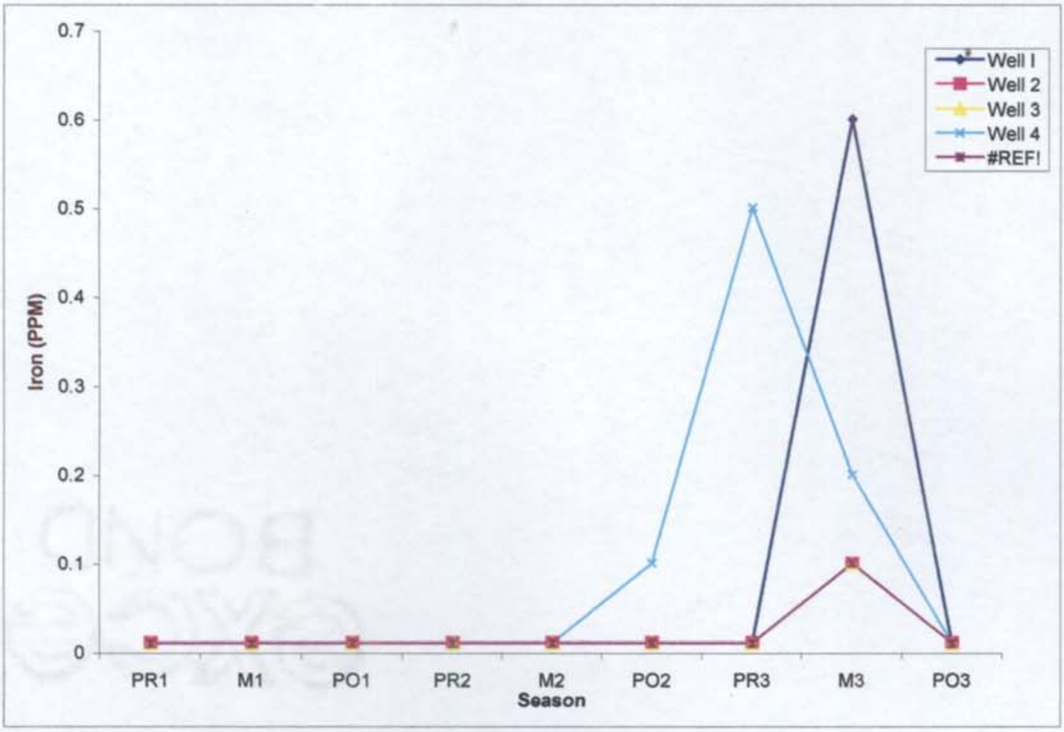
Iron

Iron is the fourth most abundant by weight in the earth's crust. It is one of the most abundant elements of the rocks and soil. Fayalite ($FeSiO_4$) hematite (Fe_2O_3) and magnetite (Fe_3O_4) are present in igneous rock. Organic complexes containing iron are present in important amounts in some water. All kinds of waters have appreciable quantities of iron and the quantity may vary from 0.5 to 100mg/L (Ernst, 1991). ISI (1983) and WHO (1984) have set a desirable limit of 0.3 mg/L and maximum permissible limit of 1.0 mg/L for drinking purpose. In the present study iron was not present in most of the samples. Groundwater contains sufficient quantities of dissolved or suspended iron. Some microorganisms utilize ferrous iron as energy source and convert ferrous into ferric hydroxide (Saxena, 1997).

In ground water most of the iron remains in Fe (II) state due to general lack of oxygen. But it slowly oxidises to ferric hydroxide in the presence of dissolved oxygen. This precipitate imparts turbidity to the water. In alkaline conditions in ground water the iron is mostly ferrous bicarbonate $Fe(HCO_3)_2$ which is colourless substance. When the ground water with higher concentration of iron is tapped, it quickly oxidises to ferric state in the form of insoluble ferric hydroxide, a brown substance .In appreciable quantities if $Fe(HCO_3)_2$ are present in ground water and they come in contact with oxygen at surface, the hydroxide are formed, CO_2 is released and hence it increases the pH facilitating the oxidation process.

The metabolic activities of the so called iron bacteria *Crenothrix* and *heptothrix* may influence the iron content of water. This involves the oxidation of ferrous iron to $Fe(OH)_3$ as these are aerobic bacteria. Fe^{2+} has octahedral hydration shell of six water molecules. Ferric iron forms inorganic solution which complexes with many anions besides OH^-. The chloride, fluoride, sulphate and phosphate complexes may be important in some natural systems. It has more solubility at acidic pH. Therefore large quantities of iron are leached out from the soil by acidic water. (acid mine drainage).

Although iron has only little concern as a health hazard, it is still considered as a nuisance in excessive quantities. Excess iron in water causes corrosion of tube wells and water supply installation and encourages growth of bacteria. It creates an aesthetic problem because of its taste and odour. Concentrations greater than 0.3ppm may cause rust-colored stains on laundry, plumbing fixtures and sinks. Metallic taste may be present and may affect the taste



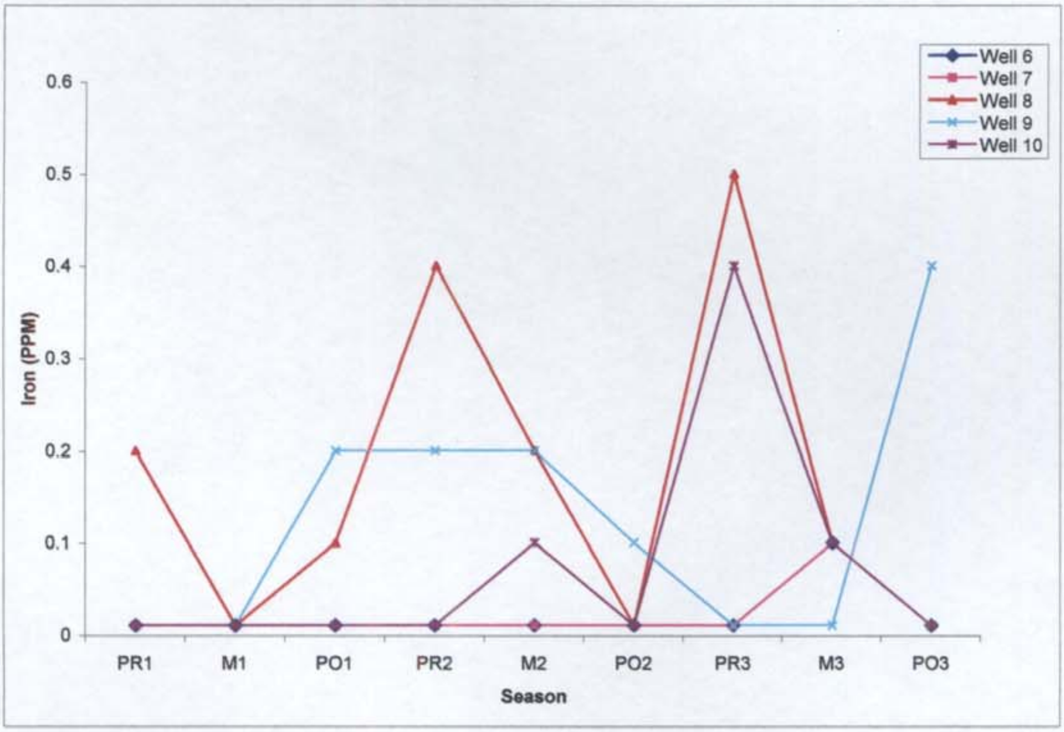
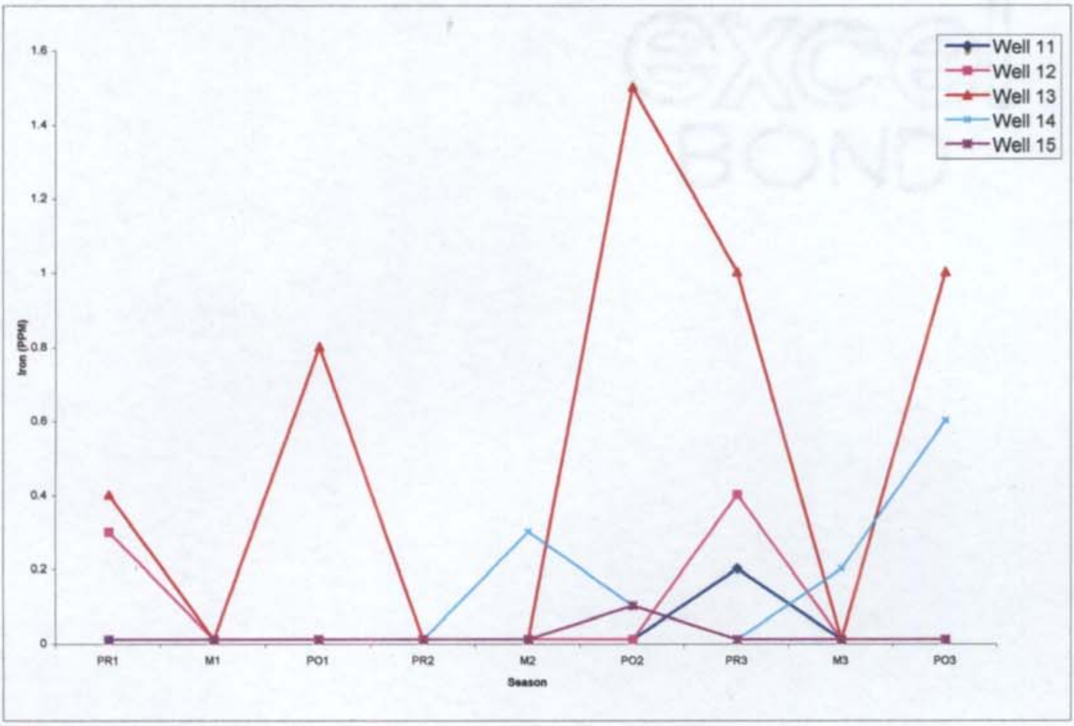


Figure 3.35 Seasonal variation in Iron at various wells

78B



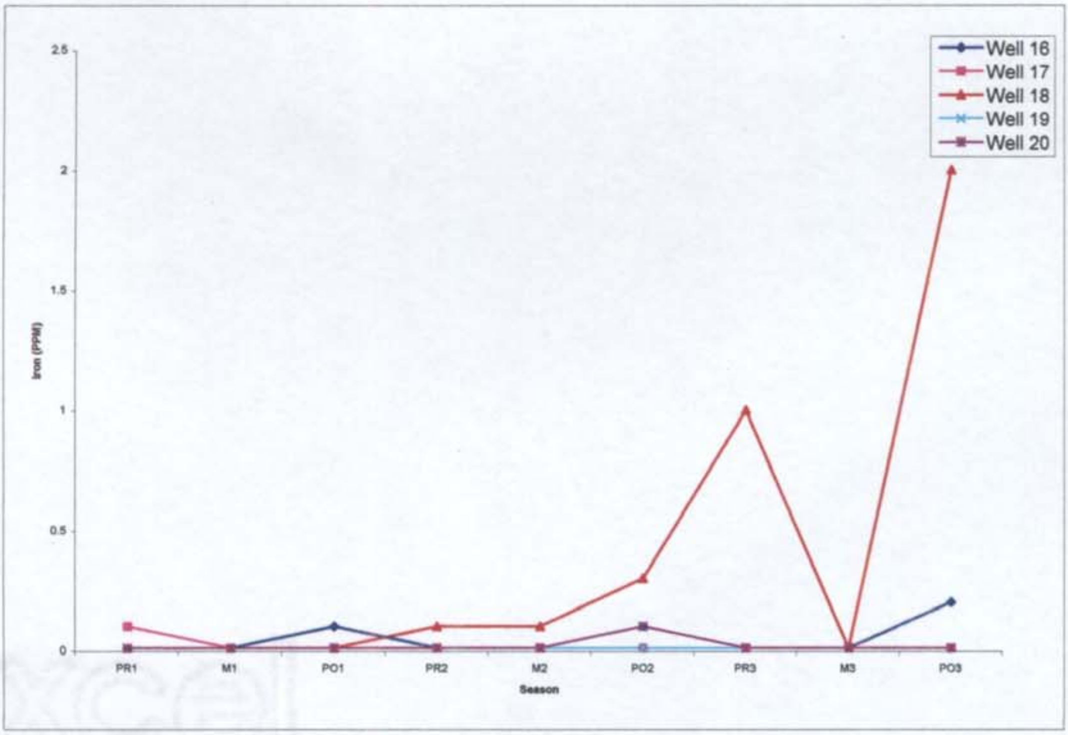


Figure 3. 36 Seasonal variation in Iron at various wells

of beverages made from the water. In the present study presence of iron was negligible in all the cases (Table 3.18). There is no significant variation of iron between neither seasons nor wells ($P>0.05$). Seasonal variation of iron is represented in graph 3.35and 3.36. No correlation was obtained between iron and other parameters during any season ($P>0.05$).

Phosphate

The quality criteria for phosphorous in water is only to check nuisance growth of algae and process of eutrophication. According to USEPA (1976) the concentration of phosphate should not exceed 50mg/L. in any tributary to river or lake and 25mg/L within these main resources.

Phosphorous in the natural fresh waters is present mostly in inorganic forms. Being an important constituent of biological systems, it may also be present in the organic forms. The phosphorus bound to the rocks is generally insoluble in water and hence the phosphorous content in natural fresh water is low and biological growth is limited due to this fact. The major sources of phosphorous are domestic sewage, detergents, and agricultural effluents with fertilizers, industrial wastewaters. High concentration of phosphate therefore is indicative of pollution but such situation did not occur in the present case (Table 3.19). The concentration of phosphate in the wells under examination is shown in graph 3.37.

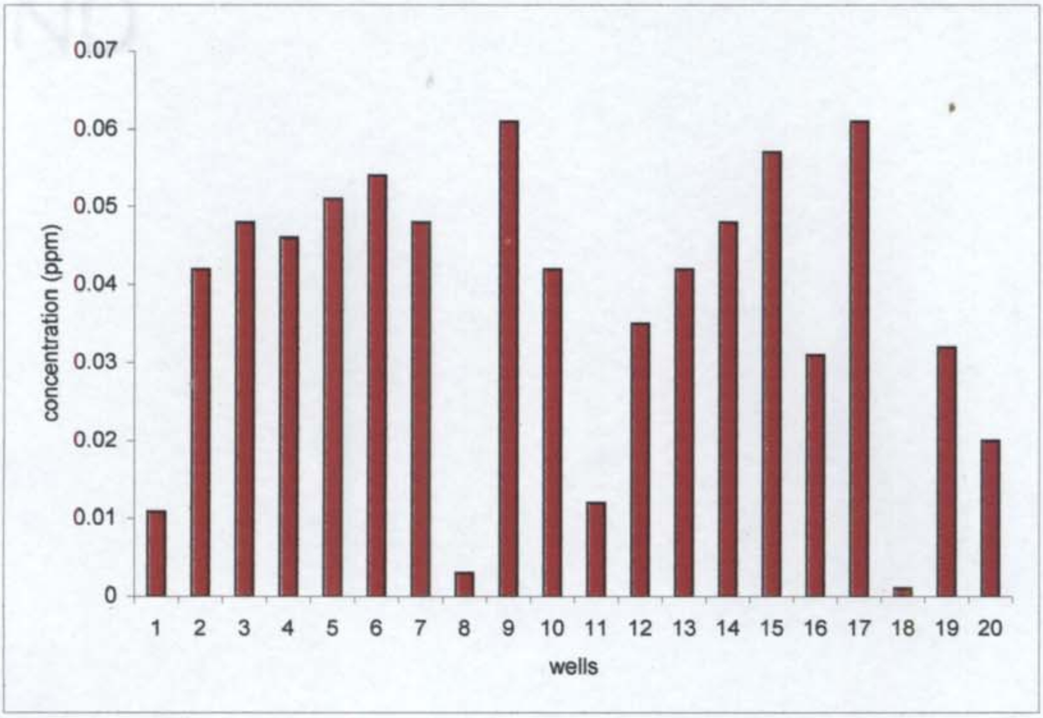


Figure 3.37. **Concentration of Phosphate in different wells**

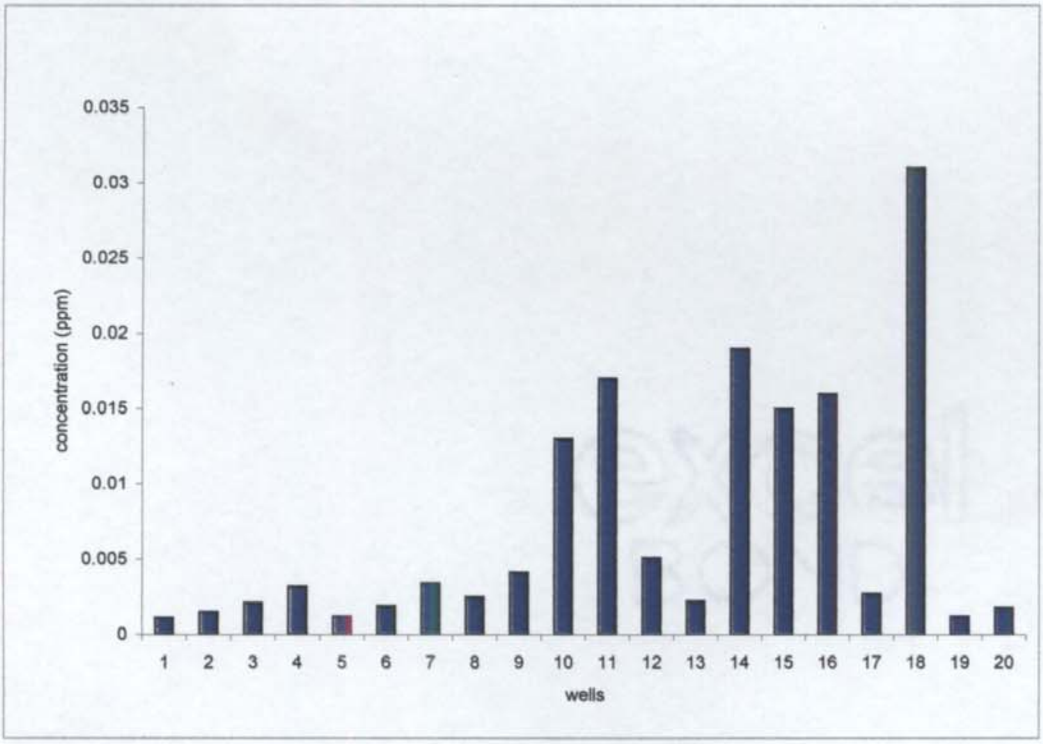


Figure 3.38 **Concentration of Flouride in different wells**

50

Fluoride

Fluorine in the surface soil exists in the form of calcium fluoride. The varying fluoride content reflects different geological and geomorphologic conditions. The distribution of fluorine in the surface soil is independent of and is unrelated to pollution due to human activities. The water supervision department has reported that the regional distribution of fluorine in ground water is completely different from that of surface soils. With the highest fluoride content in ground waters being principally in waste irrigation zones. Increasing wastewater discharges and the expansion of irrigation areas has resulted in increasing fluorine pollution. Nevertheless, in years of heavy rainfall fluorine pollution alleviated by the relative decrease of wastewater irrigation as well as dilution effect of the rain on the concentration in both wastewater and ground water.

Fluoride in water can be a blessing or a hazard depending on the concentration levels. There are plenty of evidences to show that the fluoride content up to 1.00mg/L is beneficial for the formation of bones and teeth. The relationship between fluorine content in drinking water and dental health of residents in some large cities in China was evaluated by Wang *et al.* (2004). Research on the relation between index of fluorosis (IF) and the fluorine concentration in drinking water showed the recommended concentration of fluorine in drinking water can protect from dental fluorosis. Bureau of Indian standards recommend 1.00 mg/L as the desirable limit and 1.50mg/L as the maximum permissible limit. The guideline values vary depending on the climate and total fluoride intake from other sources since the absorption of fluoride by body fluids depends on temperature. Chronic ingestion of high fluoride causes dental and skeletal fluorosis. Fluorosis is characterized by mottling of teeth enamel, abnormal calcification of spines, joints and ligaments. Dental fluorosis or mottled enamel occurs in human beings consuming water containing 1.5mg/L or more of fluorides, particularly during the first eight years of life. Mottled enamel usually takes the shape of modification of tooth enamel to produce yellow or brown stains or an unnatural opaque chalky white appearance with occasional striations and pitting. Skeletal fluorosis is reported from areas in India where the drinking water contains 2.0 to 4.0 mg/L of fluoride. As a tissue bone is metabolically active and it is continuously being destroyed and renewed by the process of formation and subsequent mineralization. Normally the rate of destruction and renewal are tightly coupled so that no net change in bone mineralization occurs. Fluoride ion in excess disturbs this equilibrium through interaction with calcium in teeth and bone.

Calcium in the bone mainly exists in the form of hydroxyapatite ($Ca_5(OH)(PO_4)_3$ which forms needle shaped crystals and composes the supporting substances in the bones. Through exchange with OH^- groups and F^- enters the bone lattice structure as well as the enamel and produces larger crystals more resistant to resorption. Fluoride thus accumulates in the body and absorbed F^- ions binds calcium from food and blood. Formation of new bones is stimulated resulting in the deformation and abnormal bone density. Together with total intake of fluoride factors like intake of calcium, vitamin C, nutritional status as a whole, age and sex are the decisive factors for development of fluorosis. Fluorosis is prevalent in areas where ground water is low in calcium, high in alkalinity, thus favouring high concentration of fluoride in ground water. Calcification of certain ligaments rendering movement of joints difficult is the early symptoms of fluorosis. The bone structure is found to be blurred and it becomes diffuse structureless and shallow with uneven contours. These changes are marked in spine and ribs. There are few early symptoms but late development includes stiffness, inability to move the spine and neurological disorders

Optimum concentration of fluoride in the range of 0.8 to 1.2 mg/L reduces dental caries to a minimum without causing noticeable dental fluorosis. In all the samples fluoride is found to be within the permissible limit (Table 3.19). The concentration fluoride in the wells under examination is shown in graph 3.38.

Heavy metals

Cadmium

Cadmium is found in very low concentrations in most rocks, as well as in coal and petroleum and often in combination with zinc. Geologic deposits of cadmium can serve as sources to groundwater and surface water, especially when in contact with soft, acidic waters. Cadmium uses include electroplating, nickel-cadmium batteries, paint and pigments and plastic stabilizers. It is introduced into the environment from mining and smelting operations and industrial operations, including electroplating, reprocessing cadmium scrap and incineration of cadmium containing plastics. The remaining cadmium emissions are from fossil fuel use, fertilizer application and sewage sludge disposal. Cadmium may enter drinking water as a result of corrosion of galvanized pipe. Landfill lichgates are also an important source of cadmium in the environment. Acute and chronic exposure to cadmium in animals and humans results in kidney dysfunction, hypertension, anemia and liver damage. The kidney is considered to be the critical target organ in humans chronically exposed to cadmium by ingestion. Cadmium was absent in all the wells under examination (Table 3. 20).

Copper

Copper, a reddish-brown metal, is often used to plumb residential and commercial structures that are connected to water distribution systems. It is ubiquitous in the environment and hence frequently present in the water. Copper contaminating drinking water as a corrosion by-product occurs as the result of the corrosion of copper pipes that remain in contact with water for a prolonged period. Above 0.05mg/L copper causes pungent taste, discolouration etc (Harikumar *et al.*, 1997). Copper is an essential nutrient, but at high doses it has been shown to cause stomach and intestinal distress, liver and kidney damage, and anemia. ISI has set desirable limit of 0.05 mg/L for copper. Copper when present in excess of 1mg/L imparts an undesirable taste to drinking water, so maximum permissible limit of 1mg/L is recommended by ISI (1983) and WHO (1984). Persons with Wilson's disease may be at higher risk of health effects due to copper contamination resulting from the corrosion of plumbing materials. Copper in the present study area is well below maximum permissible limit (Table 3.20).

Lead

Most human and animal tissues contain significant amounts of lead, which probably occurs as a contaminant (Christian, 1979.) The major fraction of lead in groundwater results from the seepage of industrial effluent. (Ernst, 1991 and Dwivedi *et al.*, 1997) and from lead containing dust fall out, which is thrown into the atmosphere by vehicles that reaches the drainage system with rain water (Ernst,1991) the ultimately percolates down in the groundwater . According to Ter Haar *et al.* (1972) approximately 75% of lead in the gasoline burned by the vehicle is emitted as a particles and the remainder of lead consumed in gasoline combustion is deposited in the engine and exhausted system. These particles, which are thrown into the atmosphere, can travel for long distances before getting into the water system. Thus lead in groundwater could be attributable to the seepage of industrial effluent and combustion of gasoline on highways (Moore et al., 1984 and Ernst, 1991.) Lead and lead compounds are toxic to all forms of life. The limiting concentration of lead in drinking water prescribed by the WHO is 0.1 mg/L (Manivasakam, 1996). It is reported that inorganic lead salts in irrigation water may be toxic to plants.

Generally 10% of the lead in drinking water is absorbed by an adult who ingests it. Lead in high doses has been recognized as a cumulative general metabolic poison. Some of the symptoms of acute poisoning are tiredness, slight abdominal discomforts, irritability, anemia and in the case of children, behavioral changes (Ramtake *et al.*, 1988). Lead at low levels can reduce the activity of the enzyme porphibilinogen synthase. Lead also has an affinity with amino acids containing sulphur. In addition, lead has a tendency to bind to mitochondrion, leading to interference in the regulation of oxygen transport and energy regulation (Drill *et al.,* 1979). Many of the studies on behavioral effects in children suggest that there is some association between adverse effects and level of lead in water.

Generally concentration of lead is too low and most of the time it is below detectable concentration in groundwater (Garrels *et al.*, 1965). Out of 20 samples analyzed lead was not present in detectable amount in any of the samples. Concentration of lead in all the samples is given in Table 3.20.

Zinc

Zinc is an essential element for both animals and man. It is necessary for the functioning of various enzyme systems. The toxicity of zinc is generally low. Zinc has no adverse physiological effects on man. In humans the oral administration of high doses usually do not cause any side effects with exception of mild gastrointestinal complaints (Ernst, 1991) Disorders of zinc metabolism are usually due to a deficiency rather than a surplus of zinc. However, high concentrations above 5mg/L of zinc in domestic waters are undesirable as they cause a stringent taste. Concentration above 30 mg/L gives water a milky appearance and causes a greasy film on boiling. It is now reported that even 5 mg/L can cause opalescence in water. (Manivasakam, 1996). In water samples collected in the study area zinc content was below the toxic detectable limit except in one sample (Table 3.20).

Chapter 4

WATER QUALITY INDEX AND DEPENDENCE OF GROUND WATER QUALITY ON RAINFALL

Water quality Index

Water is essential for the survival of any form of life. Groundwater is a replenishable resource and is considered to be the least polluted as compared to other inland water resources.

Environmental monitoring in many countries over the last few years has produced large amount of data on many aspects of pollution of natural waters. Many workers have identified the parameters causing major stresses to the system.

One of the effective ways of communicating the available knowledge of the quality of water is to use certain indices, which can be easily computed mathematically. The water quality index allows comparison of quality status of two or more water bodies from different localities and also helps to evaluate pollution control programme.

The Central Board for the prevention and control of water pollution in India has suggested the use of 52 parameters in monitoring pollution in a water body. Since the use of such a large number of parameters is a difficult task, only a few parameters, which are relevant to that particular type of aquatic system, are usually incorporated into the water quality index. WQI is defined as a rating reflecting the composite influence of different water quality parameters on the overall quality of water. WQI reflects the collective influence of various physico-chemical and biological criteria of the water. Quality analysis of water gives an idea of its physical and chemical composition represented by some numerical value. Though distortion can occur from combining various environmental variables into one single value or index score and there can be loss of information on a single variable WQI is regarded as one of the most effective way to communicate water quality. The highest score a body of water can receive is 100 (Water quality centre for environmental studies, 2001)

Water Quality Index ranges

90 - 100	Excellent
70 – 90	Good
50 – 70	Medium
25 – 50	Bad
0 – 25	Very bad

In this chapter the WQI has been calculated from the point of view of the suitability of surface and bore waters for human consumptions. According to this method WQI ranges from 0 to 100.

In the present assessment of ground water, only seven prominent parameters, which significantly alter the water quality, are selected and their quality functions are computed. The seven parameters are nitrate, DO (Dissolved oxygen), pH, chloride (Cl^-), alkalinity (alk), total hardness (HT) and total dissolved solids (TDS).

As far as bacteriological pollution is concerned there is no regular trend is variation with respect to seasons or wells. There are abrupt changes in MPN values from season to season and well to well. Based on the MPN value, purification can be effected and so this parameter is not included in the calculation of WQI. Bacteriological pollution and its control measures are separately dealt in detail in chapter 5.

Results and Discussions

The results are given in tables (Table 4.1 - 4.20). The values of WQI in water sampling areas were reported under 50- 70 range, indicating that the water is useful for human use. The quality of water in wells 4,7, 8, 9, 10, 11, 13, 14, 15,16, 17and 18 are good (Range 70-90). The wells 1, 2, 3, 12, 19 and 20 are moderately good (50 - 70). WQI of all the wells for three different seasons are calculated. The result shows that the WQI is different for each season. In most wells especially in wells 4, 7, 9, 12, 13, 14, 15, 16, 17, 18, 19 and 20 WQI was found to be comparatively low during monsoon. This is most probably because due to the onset of monsoon and first time recharge of water on account of heavy rains brings down the heaviest levels of contaminants from the atmosphere and soil which gradually seeps into the groundwater system and become part of it. The depth of the wells 2, 3, 5 and 8 are comparatively high. Therefore contamination due to seepage will be less. This may be the reason why there was not much change in the WQI during monsoon. Well no.1 since it is situated near water canal quality of water does not change with rain. Well no. 6 was a newly constructed well. Therefore the quality of water will be low but with the mixing up of rain water concentration of the contamination might have been decreased. Therefore there is rise in the WQI. Wells no. 10 and 11 do not show any variation in WQI with seasonal changes showing that there is no possibility of contamination from outside sources. The report prepared by the WHO and the World Bank emphasizes the importance of safe water supply and sanitation in the control of waterborne diseases. The value of WQI in water sampling axes was reported to be less than 100, indicating that the water is suitable for human use.

Dependence of Groundwater Quality on Rainfall

Rainfall is the chief external contributor to the groundwater storage and it influences the quality of water. Groundwater is a replenishable source and also an economical resource. The interesting advantage of groundwater over the surface water is its wide distribution, negligible evaporation loss, low risk of pollution and relatively free from harmful bacteria. The chemical composition of groundwater depends upon the soluble products of rock weathering and decomposition in addition to external polluting agents and changes in space and time. As weather forecast, quality forecast is also of vital importance for the management of groundwater resources. Rainfall is the chief external contribution to the groundwater storage and has influence on the quality. (Mariappan *et al.*, 2001) Linear relationship model has been developed using the rainfall and chemical characteristics observed since 2001 in 20 wells of Calicut town area. Mixed trend of variation is found.

In the present chapter an attempt has been made to relate quality variation with rainfall by correlation analysis.

In Kerala rainfall is received by South West monsoon during June to September followed by North East monsoon in the month of October and November. Major portion is received in the former case with a few torrential showers during April and May.

Ground water quality model

Geological factors seldom undergo changes over a period of time and space. The rainfall is the space and time dependent factor, and is the external contributor to the groundwater storage system. So it is assumed that the fluctuation in concentration of chemical constituent has direct relationship with the rainfall.

It can be stated as

$C_i = C_{i-1} + \Delta C_i$ ....(1)

C_i - Concentration of a chemical parameter at the end of the i^{th} year

C_{i-1} - Concentration of a chemical parameter at the end of the $i-1^{th}$ year (that is beginning of i^{th} year).

ΔC_i - Change during i^{th} year.

The change in concentration (ΔC_i) either dilution or denseness is related with annual rainfall (R) assuming that there is no inter basin transfer.

$\Delta C_i = A*R + B$ ...(2)

Where A and B are constants and R is the total rainfall during i^{th} year in monsoon.

The equation is applicable only to a particular area because A and B stand for soil cover complex and geological formations.

The annual quality fluctuation is the difference in quality during the pre monsoon and post monsoon. The annual quality change, parameter wise corresponding to annual rainfall in 20 wells is given in Table 4.22. Positive value represents the increase and the negative value reflects decrease in concentrations. A and B are reckoned from the observed change in concentration of chemical parameters and the corresponding annual rainfall by regression analysis. Determined values of correlation coefficient, A, B and standard error of estimate is given the table 4.21.

For well no.1 positive Coefficient of correlation varies from 0.991maximum between the rainfall and the fluctuation in chloride concentration, to 0.125, the lowest between rainfall and calcium fluctuation. Correlation coefficient between annual rainfalls and chloride, total dissolved solids and magnesium fall above 0.53 and this indicates that the above said parameters have dependency on rainfall. At the same time, no relationships are possible between rainfall and other parameters. Negative r values are given by pH, alkalinity, and nitrate and dissolved oxygen and the r values are above 0.53and show a decreasing trend with the annual rainfall.

In the case of well no.2, except pH (-0.951) and Mg (-0.0755), all the parameters show positive correlation coefficient. Highest positive value of r, 0.922 is obtained between rainfall and fluctuation in chloride. . Lowest r is shown by DO (0.182). TDS, calcium hardness and chloride show an increasing trend whereas pH & Mg show a decreasing trend. The rainfall has found to be no effect on the other chemical parameters considered.

For well no.3, positive r ranges from 0.861(TDS) to 0.3605(Mg). The rainfall has an increasing effect on TDS and Ca. Negative r is shown by pH, EC(electrical conductivity), alkalinity, chloride, nitrate, DO and CO_2(carbon dioxide). Since the r value for nitrate, HT, Mg and CaH (calcium hardness) are less than 0.53 they are independent of rainfall.

For well no.4, only electrical conductivity, total hardness and magnesium show positive r and the values are above 0.53.i.e, they are dependent on rainfall. Out of the other parameters showing negative correlation coefficient, pH, alkalinity and chloride show above 0.53 and hence they are also dependent on annual rainfall.

All the parameters except alkalinity, nitrate, DO and carbon dioxide showed positive correlation coefficient in the case of well no.5. From Table 4.21, it is clear that electrical conductivity, chloride, total solids, alkalinity and nitrate concentrations vary independently as they show very low correlation coefficient value. It is also clear that pH, total hardness, calcium hardness, Mg and Ca show an increasing tendency in concentration with annual rainfall whereas carbon dioxide and DO show a decreasing tendency.

In the case of well no.6, all show positive correlation coefficient except alkaliniy, carbon dioxide and calcium. Among those showing positive r, the values of electrical conductivity, nitrate (NO3), TDS, calcium hardness and magnesium fall above 0.53, which indicates that they are affected by annual rainfall. Highest value is shown by nitrate (0.978).

Except pH (-0.604), Cl^- (-.388), CO_2 (-0.933) and Ca (-0.222) all show positive r in the case of well no.7. Highest positive r is shown by total solids and lowest by nitrate. The correlation coefficient values of electrical conductivity, alkalinity, dissolved oxygen, TDS, total hardness, calcium hardness, Mg, pH and carbon dioxide fall above 0.53 and they show dependency on rainfall. pH and carbon dioxide show a decreasing trend while others show an increasing trend.

For well no.8, the positive r values varies between 0.992(NO_3, CO_2) and 0.611 (electrical conductivity). The values of electrical conductivity, NO_3, TDS, calcium hardness, CaH, and Ca are above 0.53 and are affected by annual rainfall. Negative r values ranges from -1.033 (DO) to -0.521 (pH). A decreasing effect in concentration is shown by alkalinity, sulphate, DO, carbon dioxide and magnesium as they show a negative r value greater than 0.53.

The parameters such as electrical conductivity, NO_3^-, DO, CO_2 and Fe have given positive r value in the case of well no.9. Of these, DO only gives a value above 0.53 and hence we can say that it shows dependency on rainfall. The negative correlation coefficient varies between-0.993 (pH) and -0.153 (TDS). pH, chloride, sulphate, calcium hardness, Mg and Ca show dependency on rainfall as their r value fall above 0.53.

For well no.10, the fluctuation of NO_3^-, DO, TDS, calcium hardness, Mg, Ca and Fe have positive correlation with rainfall. We can see from the table that

NO_3^-, DO, Mg, Ca and Fe are dependent on the rainfall as their r value is greater than 0.53. Negative r varies from –0.992(pH) to -0.031(HT) and those showing a value greater than 0.53 are pH, Cl^-, SO_4^{2-} and CO_2.

For well no.11, positive correlation coefficient varies between 0.992 (Fe) and 0.388 (SO_4). Correlation coefficient between rainfall and fluctuation in electrical conductivity, TDS and Fe fall above 0.53 and hence they show dependency on rainfall. Negative r value ranges from 0.999 (Cl) to 0.608 (CaH). pH, alkalinity, chloride, nitrate, DO, CO_2, CaH and Ca show a decreasing trend as their r values fall above 0.53.

Positive correlation coefficient is shown by EC, Cl^-, TDS, HT, Mg and Fe in the case of well no.12.The highest value is that of chloride (0.9991).The r values of EC, Cl^-, TDS and Fe are above 0.53 and are dependent on the annual rainfall. Negative r values varies between -0.792 (Ca) and -0.028 (CaH). Significant r values are shown by pH, NO_3^-, CO_2 and Ca.

In the case of well no.13, EC, alkalinity, SO_4, DO, TDS, HT, Mg and Fe has given positive r values. Highest value is that of TDS (0.994) and the lowest is that of Mg (0.260). It is clear that SO_4, DO, TDS, HT, and Fe are dependent on rainfall. Negative r values varies between -0.994 (Ca) and -0.414 (CaH). Those showing negative r values above 0.53 are pH, Cl^-, NO_3^-, CO_2 and Ca.

The positive correlation coefficients in the case of well no.14 are those of EC, Cl, SO_4, TDS, HT, CaH and Mg. Among these, the highest value is that of TDS (0.9764). All these parameters have an increasing trend with rainfall since their r values are above 0.53. Negative correlation coefficient ranges from -0.999

(Fe) to -0.278 (Ca). Among these, those having dependency on rainfall are pH, alkalinity, DO, CO_2 and Fe.

For well no.15, pH, EC, TDS, HT, CaH, Mg and Fe show positive correlation with rainfall. Highest value is that of CaH (0.912) and those showing dependency on rainfall is pH, EC, TDS, HT and CaH. Negative r values varies between -0.999 (DO) and -0.177 (Cl^-). NO_3, SO_4, DO and CO_2 are having the correlation coefficient values above 0.53 and hence show dependency on annual rainfall. All other parameters behave independently.

In the case of well no.16, positive correlation with rainfall is shown by EC, DO, TDS, HT, CaH and Mg Highest value of r 0.832 is observed between DO fluctuation& rainfall. EC, DO, CaH and Mg have given r values above 0.53.Negative r values ranges between -0.992 (Fe) and -0.485 (Cl^-). A decreasing trend with rainfall is shown by pH, alkalinity, NO_3, SO_4, CO_2, Ca and Fe.

Positive r values in the case of well no.17 are shown by NO_3, DO, TDS, HT, CaH, Mg and Ca. Highest positive r value is that of HT (0.880) and lowest is that of Ca (0.1885). The correlation between rainfall and fluctuation in HT, CaH and Mg fall above 0.53 and they are dependent on rainfall. The highest negative fluctuation is shown by alkalinity (-0.994) and those having r value above 0.53 are pH, alkalinity and Fe.

In the case of well no.18, positive correlation with rainfall is given by pH, alkalinity, DO, TDS, HT, CaH, Mg, Ca and Fe. Among these, except HT CaH and Mg all are independent of rainfall as seen from the correlation coefficient value. The highest r is that of CaH (0.992) and lowest is that of DO (0.1696). The highest negative r value is given by nitrate (-0.9921). Only nitrate and carbon dioxide have negative r values greater than 0.53.

The positive r value in the case of well no.19 ranges from 0.982 (CaH) to 0.395 (EC) and that of Cl^-, NO_3, HT, CaH and Mg fall above 0.53 which indicates that they have an increasing trend with annual rainfall. Negative r values fall between –0.977 (TDS) and -0.344 (alkalinity). pH, DO, TDS and Ca show a negative dependency with rainfall which is clear from the r values. All other behaves independently because of low correlation values.

In the case of well no.20 except pH and Mg all show positive correlation between fluctuation in concentration and rainfall. The highest r value is shown by chloride (0.992). Those of EC, Cl^-, SO_4, HT and TDS fall above 0.53 and hence they are dependent on annual rainfall. All other parameters behave independently as seen from the correlation coefficient values.

Considering all the 20 wells, the coefficient of correlation (r) between rainfall and pH fluctuation was found to be negative for all the wells except 5 and 6. i.e., pH has a decreasing trend with rainfall. Also the coefficient of correlation between rainfall and HT fluctuation was found to be positive for all the wells except 9 and 10.i.e, TDS has an increasing trend with annual rainfall.

Chapter 5

BACTERIOLOGICAL EXAMINATION OF WATER

All natural water contain a variety of organisms both plants and animals as the natural flora. In water receiving sewage domestic waste and industrial wastes a plethora of pathogenic organisms may be present. One such etiological agent is bacteria. Bacteria that can thrive only in the presence of dissolved oxygen are known as aerobic bacteria. Anaerobic bacteria require an absence of dissolved oxygen. Facultative bacteria can thrive with or without oxygen. The lower limit of DO for the existence of most aerobic bacteria is considered to be about 0.05mg/L. Methods to detect DO limit of about 0.1mg/L.

Bacteria of different varieties can withstand fluid pressures of many hundreds of bars, pH conditions from 1 to 10, temperatures from 0 to greater than 75°C and salinities much higher than that of seawater. They can migrate through porous geological materials and in favorable environments can evolve into resistant bodies that may be activated at later time. In spite of all these there are many cases where organic matter is not oxidized. The reason is lack of essential nutrients. There are various types of nutrients some are required for incorporation into the cellular mass of the bacteria *e.g.* compounds of C, N, S, P. Other nutrients are substances that function as electron donors or energy sources such as water, ammonia, glucose and H_2S. Substances that act as electron acceptors are oxygen, nitrate and sulphate. Macronutrients are those substances that are required in large amounts as direct building blocks in cell construction. Micronutrients are required in very small amounts. The micro nutrient requirements of many bacteria are similar. The micro nutrient requirements are more likely to differ from species to species.

Microorganisms are typically uni and multi cellular organisms, widely distributed in air, water and soil. They are of greatest importance from human point of view. Though these are the elements, which support life they are also potential vehicle for the spread of diseases.

Movement of microorganisms and their survival in ground water:

Soil is an effective filter that removes bacteria and other relatively larger microorganisms by straining (Bouwer, 1978). The fate of pathogenic bacteria and viruses in the subsurface is determined by their survival and their retention by the soil particles (Ward *et al.*, 1985).

- Bacteria seldom travel more than 100ft from a point source. Studies have shown that bacteria are removed by filtration. Although most microbes die out rapidly in groundwater, bacterial population may occur locally in heavily populated areas where numerous septic tanks discharge large quantities of waste (Hendricks and Morison, 1967).
- Coliforms and other microorganisms move only a few dozen centimeters with the percolating waters in unsaturated soil layers. They may, however travel greater distances under saturated flow conditions (Ward *et al.*, 1985).
- Filtration or physical straining of bacteria is the main limitation to its travel through the soil (Ward *et al.*, 1985).
- Adsorption of bacteria and hence its retention is more efficient in clayey soils (Ward *et al.*, 1985).

- Viruses found to travel as far as 400m horizontally in the groundwater from sewage infiltration basins. (Ward *et al.*, 1985).
- Survival times for bacteria in soil normally range from a few weeks to few months and sometimes longer. Survival times for entero viruses in soil may range from 1 - 6 months (Hendricks and Morrison, 1967).
- Long underground survival distances for microbes are usually associated with large sizes in the soil, as occurs in uniform grave and sand, or with periods of high rainfall. Rainfall tends to lower the salt content. This causes the subsequent mobilization (Hendricks and Morrison, 1967).

Climate, nature of the soil and nature of the microorganisms control the retention of bacteria and viruses, and thus their survival rates. Low temperature increases the survival times of microorganisms. At and below 4°C, they can survive for months or even years. At higher temperatures, inactivation or die off is fairly rapid. In the case of bacteria and probably viruses, the die off rate is approximately doubled with each 10°C rise in temperature between 5° C and 30° C. Above 30° C; temperature is probably the dominant factor determining virus survival time. Adsorbed viruses are protected to some degree against thermal effects, so their survival is prolonged at higher temperatures (Ward *et al.*, 1985). Another principal factor determining the survival of bacteria and viruses is soil moisture and drying up of soil. Survival and mobilization is greater under saturated conditions. Drying near the soil surface can cause marked inactivation (Ward *et al.*, 1985).

pH, rainfall, composition of soil, moisture holding capacity of soil, soluble organics, cations and flow rate of contaminated water also influence the movement of viruses and bacteria. During periods of high rainfall enteric bacteria survives longer time in moist soil. If the soil is sandy then survival time is less. It survives longer in cold season and at low temperature. If the soil is acidic (pH 3 to 5) then it will not survive long. Organic matter if it is present in sufficient amount supports the growth of enteric bacteria.

Adsorption of viruses to soil mainly determines its survival in soil (Ward, 1985). As the pH and temperature increases the survival of viruses' decreases. The nature of microorganisms also plays a role in its survival. While bacteria can be removed by filtration because of their large size, the much smaller viruses' are removed by adsorption to clay, organic matter and other negatively charged matter in the soil. The resistance of microorganisms to environmental factors is dependent upon the species as well as it varies rapidly outside the human gut, whereas indicator bacteria such as Escherichia coli will persist for longer periods (Ward, 1985). Although bacteria have been found to exist for longer periods in groundwater, information regarding virus survival in groundwater is almost non-existent. Viruses' have nucleic acid core with proteinaceous coating. Their physical and chemical behavior is similar to that of proteins. Viruses' are amphoteric with isoelectric points normally at pH 5 or lesser. When pH is below the isoelectric point, viruses' are positively charged. Then they are adsorbed like cation to clay and organic matter. When negatively charged as at pH>5, the viruses are less adsorbed (Bouwer, 1978).

Thus adsorption of viruses' in soil depends on decreasing pH, increasing salt content of soil water, increasing concentration of di or trivalent cations relative to monovalent cations in water. Dissolved or suspended matter often competes with viruses for adsorption sites and hence adsorption of viruses is decreased.

The microbiological examination of water enjoys a special status in pollution studies, as it is a direct measurement of deleterious effects of pollution and human health (Craun, 1991). The bacteria causing Cholera, Typhoid fever and Bacillary Dysentery may be present in sewage-polluted water.

The most likely source of contamination is from animals, man in particular. In Britain during 19th century it was common practice to obtain water from shallow wells and to dispose off sewage via earth closets and dung hills. This unhappy practice resulted in sewage contamination of water supplies and out breaks of Cholera in London in 1854 and 1866.In 1980, 1000 people in Wetherby, West Yorkshire were affected by Gastro- enteritis as a result of the Bramhan bore hole that became contaminated by a combination of a leaking stream and a polluted surface stream which passed within 8m. of the well.

It is highly essential to examine the presence of pathogenic organisms in potable water (Park, 1977). Biological monitoring of water is also essential in water used for swimming and recreation (Listorti, 1990).

The microbiological examination of water is routinely conducted to ensure the safety of potable water to monitor the water quality for recreational, industrial and agricultural uses and also to evaluate prospective water resources for drinking purposes.

Contaminated water may harbour several bacteria capable of causing diseases such as typhoid fever, dysentery, diarrhea and cholera and hepatitis.

These pathogenic bacteria may be contaminated by domestic sewage and other pollutants. Coliform bacteria are discharged from the human intestine. These are considered as indicator type of bacteria that indicates the presence of pathogenic organisms in water.

The detection and estimation of bacteria is a tedious work because of the presence of very small number and complicated techniques hence another indicator type of bacteria are routinely monitored to indicate the presence of pathogenic organisms in water. The organisms known as coliform bacteria are discharged from the human intestine and their presence indicate the possibility of the presence of pathogenic organisms. The coliform group comprises of the facultative and aerobic gram-negative, non-spore forming, rod shaped bacteria that ferment lactone with gas formation within 48 hours at 37°C. The coliform bacteria include the general Escherichia, Citrobacter, Enterobacta and Klebsiella. The Escherichia Coli are entirely of human origin but their exclusive estimation is difficult and hence the entire coliforms are used as indicator. The routine tests to conform the water quality to drinking water standards the actual number of coliforms is not reported but they are reported as an approximate count that is Most Probable Number (MPN).

In the present study the method used was the Multiple Tube Dilution (MTD) Technique or the fermentation Technique. Results were expressed in terms of MPN. MPN tables have been provided to obtain the approximate number of coliforms per ml of the sample.

The wells under investigation were not subjected to any type of disinfection programme during the first year of the study period. Since 19 of them were open wells there is every possibility of bacteriological contamination. This is understood from the MPN index values of the samples of pre monsoon and monsoon seasons of year one. When the water was treated using aquatic organisms the quality of water improved (see Table 5.1- 5.6). Experimental details of treatment and discussion are given in chapter 6.

Chapter 6

WATER TREATMENT

The primary objective of any water treatment methods is to render the water safe for human consumption and other uses, eliminating from the raw water, potentially dangerous microorganisms and chemicals. In view of the alarming number of cases of water borne infections in developing countries, what assumes primary importance during treatment is the effective removal and inactivation of harmful infectious agents.

Water treatment plays an important role in the wide subject of pollution problems solving and represents today as one of the most important fields of study. In fact a ration of hydrologic resource management is necessary because of increased world's demand of water, particularly in these last years owing to lack of these resources.

Traditional method for water treatment

Common methods of treating water include sedimentation, either plain or with coagulation (ii) filtration through sand (iii) miscellaneous methods. These include disinfection, aeration, softening, removal of iron, manganese and other minerals, prevention of taste and odour etc and combination to suit requirements. Some of the methods are discussed in detail. In case of ground water and surface storage, which are well protected where the water has turbidity below 10 JTU and is free from odour and colour, plain disinfection by chlorination alone is sufficient before distribution.

The various unit operations of water treatment adopted to treat water are briefly described below:

Aeration

In water treatment the term 'aeration' is applied to those processes in which water is brought in intimate contact with air. Aeration is practiced with three purposes. To add oxygen to water for imparting freshness, expulsions of carbon dioxide, hydrogen sulphide and other volatile substances causing taste and odour and to precipitate impurities like iron and manganese. Aeration process is governed by the principle that gases are dissolved in or liberated from water until the concentration of the gas in the water has reached its saturation value. Aeration of water is affected by employing various types of aerators.

Types of aerators

There are two main types of aerators based on the mechanism of aeration. They are those forming drops or thin sheet of water, exposed to atmosphere and those forming bubbles of air, which rise in water. Spray type, waterfall or multiple trays and cascade type are the common types coming under the first category while diffusion aerators fall under the second category.

Spray aerators

Spray aerators consist of fixed nozzles on pipe distribution grid through which water is posed into the air as in a fountain. The design of the nozzles is extremely important in achieving optimum dispersion of water. Usually nozzles of diameters varying from 10 to 40 mm spaced in the pipe at intervals of 0.5 to 1 m are used.

Cascade aerators

The general principle of cascade aerators is to spread the water as much as possible and let it flow over obstructions to produce turbulence and to change water surfaces in contact with the atmosphere.

Waterfall or multiple tray aerators

Multiple tray aerators consists of a series of trays equipped with slat perforated or wire mesh bottoms over which water is distributed and caused to fall to a collection of basins at the base. This type of aerators produces good turbulence and exposes a large water surface area to the atmosphere.

Diffused air aerators

This type consists of basin in which perforated pipes, porous tubes and plates are used for release of fine bubbles of compressed air, which then rise through the water being aerated. This type provides a longer aeration time than the waterfall type.

Coagulation and Flocculation

Coagulation and Flocculation followed by filtration is the most widely used process to remove turbidity from water. Coagulation is the effect produced by the addition of chemicals called coagulants to a colloidal dispersion resulting in particle destabilization. This is achieved by the addition of coagulants and rapid and intense mixing. The coagulants when thoroughly mixed with water form a gelatinous precipitate called floc. The very fine mud particles and colloidal matters present in water get attracted and absorbed in these flocs forming the bigger size flocculated particle. This formation of settable particle from destablised colloidal sized particles is termed as flocculation. It is a common practice to provide an initial rapid or flash mix for dispersal of the coagulant or other chemical into the water followed by slow mixing were growth of the floc takes place. For coagulation the most commonly used chemicals are alum and iron salts like ferrous sulphate.

Action of coagulants

Alum $Al_2(SO_4)_3\ 18H_2O$ when added to raw water reacts with bicarbonate alkalinities to form a gelatinous precipitate (floc) of aluminium hydroxide. This floc attracts other fine particles and suspended matter and thus grows in size and finally settles down to the bottom of the tank. The chemical equation is

$$Al_2SO_4\ 18\ H_2O + 3Ca(HCO_3)_3 \rightarrow 3CaSO_4 + 2Al(OH)_3 + 6\ CO_2 + 18\ H_2O$$

The amount of alum required for coagulation depends on the turbidity and colour of raw water. The effective pH ranged for the use of alum is 6.5 to 8.5. Ferrous sulphate is gently added to raw water in conjunction with lime. The reaction taking place when ferrous sulphate is added to water treated with lime is

$$FeSO_4\ 7\ H_2O + Ca(OH)_2 \rightarrow CaSO_4 + Fe(OH)_2 + 7\ H_2O$$

The ferrous hydroxide formed in either case further gets oxidised forming ferric hydroxide as shown below:

$4Fe(OH)_2 + O_2 + 2H_2O \rightarrow 4Fe(OH)_3$.

The ferric hydroxide forms the floc and thus helps in sedimentation. The effective pH range is 8.5 and above.

Mixing and sedimentation

Most of the suspended impurities present in water do have a specific gravity greater than that of water. In still water these impurities will therefore tend to settle down under gravity. This is the principle behind sedimentation. Sedimentation of water can be plain or aided by coagulants. When the impurities are separated from water by the action of natural forces alone the operation is called plain sedimentation and sedimentation following chemical coagulation and flocculation is called chemically aided sedimentation. When water contains very fine suspended mud particles and colloidal matter they will not settle down by plain sedimentation but can be easily removed by increasing their size by changing them into flocculated articles by the addition of coagulants and allowing it to settled in chemically aided sedimentation tanks. The separation of settleable suspended solids from water is carried out in sedimentation tanks. For efficient coagulation the chemicals used should be uniformly distributed through out the water to be treated. The violent agitation required for this is achieved by means of mixing devices such as centrifugal pumps, compressed air, mixing basins etc.

Sedimentation

Removal of suspended particles from water in sedimentation tanks is affected by providing conditions favourble for the settling of particles. The settlement of a particle in water is affected mainly by the factors:

The velocity of the flow, which carries the particle horizontally, the velocity of water, the size, shape and specific gravity of the particle.

Water Distillation (Water Distillers)

Water Distillation involves heating the water to boiling point and condensing the steam. Pollutants with a boiling point near that of water are hard to remove, but generally the distilled water is of very high quality. The major drawback to this method is that it requires a large amount of energy. Some people will also complain that the distilled water tastes flat (this is due to less dissolved oxygen).

Reverse Osmosis (Hyper-filtration)

In water filter terms, reverse osmosis (or hyper-filtration) is the process of filtering water under pressure through a semi-permeable membrane, allowing water to pass through but rejecting other particles such as bacteria, toxins, salts, and anything bigger than around 150 Daltons.

Filtration

Sedimentation with or without chemical coagulation is usually followed by rapid filtrations. Filtration in water treatment is conducted to remove the very fine suspended particles of silt, clay, microorganisms including algae, bacteria, viruses etc. To remove these impurities filtration of water through beds of fine granular material such as sand, gravel etc is practiced. Filtration also helps in removing colour, odour and turbidity.

There are a number of methods of water filtration each with varying degrees of effectiveness and varying costs. The general purpose of filtering water is to improve the water's hygiene and aesthetic qualities. Some of the available water filters are described below:

Activated Carbon (AC) Water Filters

Activated Carbon Filtration is an established technology that works through absorption of the problematic compounds, primarily to remove taste and odour but systems will also remove some harmful contaminants. AC is a highly porous material with a very large surface area. Chemical pollutants are attracted to and held by AC's surface. These water filters are best suited for the removal of organic compounds.

Ultraviolet (UV) Water Filters

UV Filters are able to kill the majority of bacteria and viruses in the water which passes through them, However, they won't remove chemical pollutants from the water. Since the treatment is ineffective outside the treatment area, water should be used immediately after it is treated.

Sand Filters

Sand based water filters have been used for over 100 years to treat wastewater; they are generally used on a larger scale to treat a water supply for a whole community. Most units require a constant flow of water to work correctly and so wouldn't be suitable for well water treatment.

In water treatment for domestic purposes two types of filters are used-rapid sand gravity filter and slow sand gravity filter. The filters purify water through the four different actions:

- Mechanical straining by the voids between sand particles
- Flocculation and sedimentation occurring in the void spaces in sand layers.
- Biological metabolism by the micro organisms in the sand voids and
- Electrolytic action between the sand grains of the filter media and impurities in the water.

Rapid sand gravity filter is a type of filter commonly used for large municipal supplies. Sand, which is cheap, inert, durable and widely available, makes a highly desirable filter medium for the treatment or pre treatment of potable water and is used in many rural settings because they are relatively simple to built and operate. Such filters consist of 60 to 70 cm deep column of fine sand to permit a filtration rate of not more than 200 L/m^2/hour of water.

Slow sand filter are generally satisfactory in the retention of bacteria and viruses and they can effectively removes cysts, ova and cercariae from water. Slow sand filter is a very desirable means of treatment of water in rural settings for the removal of coliforms, giardia, cysts, cyclops etc.

Rice hull ash filters

Rice hull, which is readily available in many parts of the developing world, are of low nutritional and agricultural value. The original structure and porosity of the hull is retained even after their incineration and such ash containing almost 90% silica has been found to be a suitable media for the filtration of drinking water.

Charcoal based filtration/adsorption media

Charcoal act as a potential filtration – adsorption media for domestic water, which removes organic impurities and pathogens.

The Unicef filter

This upward flow filter consists of two tanks placed one on the top of the other. The upper tank is used for raw water storage. The lower tank, which is larger, contains a layer of crushed charcoal sandwiched between two layers of fine sand. Raw water enters the base of the lower tank pushes upward through the filter and accumulates above the filter for collection via a delivery tube.

Disinfection

Treatment of water by methods such as storage, coagulation, sedimentation and filtration, would render the water chemically and aesthetically acceptable with some reduction in bacterial content. However this does not provide safe water and it is necessary to disinfect the water to destroy all the decease-producing organisms.

Disinfection not only removes the existing bacteria from water but also ensures their immediate filling even afterwards in the distribution system. The chemical, which is used as disinfectant, must therefore be able to view this residual sterilizing effect for a long period thus providing protection against recontamination. In addition to this it should be harmless, unobjectionable to tongue, economical and measurable by simple tests. Chlorine has been found to be a disinfectant satisfying these requirements.

Minor methods for disinfection

Minor methods of disinfection are:

- Boiling of water
- Treatment with excess lime
- Treatment with ozone
- Treatment with iodine and bromine
- Treatment with ultra violet rays
- Treatment with potassium permanganate

These methods are applied only for small water supplies.

Defluoridation of water

Excessive fluorides in drinking water may cause mottling of teeth or dental fluorosis, a condition resulting in the decolouration of the enamel with chipping of the teeth in severe cases. The different methods used for defluoridation are fluoride exchangers like tricalcium phosphate, anion exchangers, activated carbon, aluminium salts etc.

Removal of iron and manganese

Iron and manganese in water in reduced form is converted to soluble ferric and manganic compounds by oxidation and these are removed by filtration alone or by sedimentation and filtration. Manganese removal requires a pH adjustment up to 9.4 to 9.6. Chlorine dioxide and potassium permanganate, which are strong oxidants, are employed chiefly for manganese baring water.

Ion exchange

If the iron is present in the reduced state and in a soluble form zeolite is used for its removal. The process consists of percolation of water through the bed of zeolite, which takes of the iron and manganese by a process of iron exchange. The base exchanger may be of the siliceous or synthetic resin type.

Water softening

The reduction or removal of hardness from water is known as iron softening. If bicarbonates of calcium and magnesium are present in water such hardness is called temporary hardness or carbonate hardness and this can be easily removed by boiling or by the addition of lime. If sulphates, chlorates and nitrates of calcium and magnesium are present in water they cannot be removed by simple boiling and requires special treatment such as lime soda process, zeolite process and demineralization process. In lime soda process lime and soda ash are added to the hard water, which reacts with calcium and magnesium salts so as to form insoluble precipitates of calcium carbonate and magnesium hydroxide. In zeolite process hard water is passed through a bed of zeolite sand (complex silicates of aluminium and sodium) whereby it exchanges its calcium and magnesium for the sodium in the zeolite until sodium becomes exhausted. In demineralization removal of minerals present in water can be carried out by first passing the water through a bed of cation exchange resins and then through a bed of anion exchange resins.

Commercial devices

The popularity of the use of commercial devices for drinking water treatment is rapidly increasing in many developing countries. Two commercial water treatment devices in India are tap attachable water filter, candle filter and ultra violet water filter.

In the **tap attachable water filters** water passes through either cotton wool held on a coarse sintered silica crucible or sponge type wool placed over a micro porous bed held on a porous Buchner type funnel and is capable of filtering out fine particulates and clusters of bacteria.

Candle filters are more popular and comprise a top chamber with one or more micro porous ceramic filter candles and a bottom chamber with tap, this filter traps microorganisms, dirt and other suspended impurities.

Ultraviolet water purifier

The ultra violet water purifier consists of a pre-filter to remove the larger particulate matter. Then the water is passed through an activated carbon chamber, which removes the unobjectionable odour, colour, and biological contaminants. Finally a chamber of ultra violet rays removes the remaining bacteria, viruses and protozoa. Micro filtration and ultra filtration are not effective in removing natural organic material unless coagulant and powdered activated carbons (PAC) are used. This process generates a PAC chemical waste stream with ancillary disposal problem.

Biological treatment

In the field of water purification, the pace of technological advancement is speeding up and application of capital intensive and energy intensive technologies are spreading. The comparative advantage of these developments lies clearly with the developing countries. These events burden the social and economic structure of developing countries. The third world faces a formidable challenge in farming, implementing and managing these types of high technologies. Hence, the available technology for water treatment that is suitable for developed countries is often inappropriate for third world countries particularly for villages and small communities. Urban dwellers in the developing countries are also becoming increasingly aware of the potential dangers of consuming water which is either improperly treated in centralized facilities or becomes contaminated during distribution or storage. Hence, here exists a renewed interest in the development and testing of those simple and inexpensive devices or systems of water purification, which is promising for application in small communities or individual households in developing countries. The development of these simple technologies needs an integrated outlook and multidisciplinary approach where the fields like biology and chemistry should intervene with engineering aspects. These type of interventions would help to explore the possibility for the improvement and standardisation of traditional technologies and development of expensive simple devices / methods for water purification. The existing water treatment methods mainly involve chemical methods where health problems are a matter of concern. The emergence of biological system for wastewater treatment has received much attention since they represent an alternative cost effective and environmental approach for the removal of pollutants. Thus, biological water treatment provides classic example of the development of successful process in a vital area, biotechnology resulting from the coordinated application of engineering biology.

Biological treatment systems are living systems, which rely in individual or mixed biological cultures either by directly consuming the waste materials or by breaking down the organics/ inorganics and removing it from solutions. Nature has evolved number of systems to compensate pollution generated as a result of normal events. The functional system in the environment offer a variety of ways in which contaminants can be altered and transported. The best way of fighting pollution is by bio-remediation using aquatic organisms. These techniques have been intensified and accelerated to the range of biological treatment systems currently in use for the large-scale purification of industrial and domestic waters.

Aquatic organisms have been cultured by human beings for food since several thousands of years. Culture pond waters have typically been fertilised with organic wastes. Phytoplankton and zooplankton population in the enriched waters are grazed upon by larger organisms, being grown for food. But the deliberate mass cultivation of selected animals and plant species for the improvement of water quality is a recent concept. Controlled culture of aquatic organisms is a promising means of water purification. Omnivorous and herbivorous organisms with filter feeding mechanism are suitable for improving the quality of water.

Filter feeding organisms through consumption can remove much of the residual and suspended organic matter from water including bacteria and protozoa. There are a large number of vertebrates and invertebrates, which could possibly be employed to remove the pollutants and improve the quality of water. Biological purification of water using aquatic organisms is a low-cost method, which needs very little investment, energy requirement and maintenance compared to the existing water treatment processes. Some of the biological species/ systems for removal of pollutants from water are described below.

Paramecium, popularly called slipper animalcule, occurs in freshwater ponds and ditches, especially in those areas where leaves undergo decomposition. It is about 0.3 mm in length. Paramecium chiefly feed on bacteria, and other organisms that are swept into the cyostome by ciliary action.

Daphnia are filter feeding crustaceans about 1-3mm in lengths, found in ponds and lakes throughout the temperature. The physiological structures, which enable them to improve the quality of water, are the five pairs of thoracic legs, which are endowed with very fine hair like projections. These appendages permit Daphnia to filter suspended materials from water. Rapid movements of the legs create a current of water that flows in a groove towards the mouth. Algae, bacteria, protozoa and detritus get concentrated as it moves towards the mouth region. Daphnia can be cultured on a mass scale and released into the water bodies. They grow well and multiply in suitable conditions. In the aquatic food chain, they occupy the position of secondary consumers, since they are fed on bacteria.

Tilapia is a fast growing hardy fish. It is prolific breeder and shows parental care. The fry of Tilapia feeds on zooplankton and phytoplankton, but the adults are chiefly herbivorous.

Nuria danricus inhabits shallow waters of ponds and pools. In fishes the gills and gill rackers effectively filter the biological contents and organic pollutants.

Aquatic plants

Pollution of water with heavy metals is a major environmental problem (Srivastava and Purnima, 1998). Metals cannot easily degrade and the clean up usually requires their removal (Lasat, 2002). However, this energy intensive approach can be prohibitively expensive. Phytoremediation offers a cost effective, nonintrusive and safe alternative to conventional cleanup techniques. Utilizing the ability of certain tree, shrub and grass species to remove, degrade or immobilise harmful chemicals can reduce risk from contaminated soil, sludges, sediments and groundwater through contaminant removal, degradation or containment (Zavoda *et al.*, 2001). Removal of heavy metals using plants has been reported (Rugh *et al.*, 1998; Lytle *et al.*, 1998; Srivastava and Purnima, 1998; Lasat, 2002; Kaiser *et al.*, 1987 and Dymond, 1948).

Metal contamination is a dangerous cause of water pollution. For example Cu^{2+}ions are essential nutrient, but when people are exposed to copper level of above 1.3mg/L for a short period of time stomach and intestinal problems occur. Long-term exposure to Cu^{2+} leads to kidney and liver damage. The heavy metal ions Cu^{2+}, Zn^{2+} , Mn^{2+}, Fe^{2+}, $Ni^{2+}$and Co^{2+} are essential micronutrients for plants with Fe^{2+} being required in the highest concentrations (Ebbs *et al.*,1997). However present in excess all the metals are toxic (Hinchman *et al.*, 1998).

A variety of separation process for metal ions has been developed up to date. For example in water softening for the removal of Mg^{2+} and Ca^{2+} the first studied traditional process is the lime soda method, which causes a precipitation of hardness. (Frateur, 1999). But this method has two important drawbacks. (i) They produce big amount of sludge (Zacheus, 2001; Van der Wende, 1989 and Lechevallier, 1987) containing residual of reagents used which resulted in pollution problems and (ii) treated water may contain residual coagulants if the process is not correctly controlled or operated (Percival, 1999).

Deepak Saigal and Saxena (2003) tried with Eichornia, Hydrilla and Vallisnaria to reduce salinity. The result of the study reveals that Hydrilla efficiently reduced the salinity by bringing down Na^+, K^+, Ca^{2+} Mg^{2+} and SO_4^{2-}.

Vallisnaria too was effective by bringing down Ca $^{2+}$, Mg2^{+} and Cl^{-} only. The role of Eichornia in bringing down the salinity of water was very efficient which was through reducing the Na^{+}, K^{+}, and Cl^{-} and SO$_4^{2-}$ levels. Qian *et al.* (1999) used 12 different plants (fuzzy water clover (*Marsilea drummondii*), iris-leaved rush (*Juncus xiphiloides E.Mey*). mare tail (*Hippuris Vulgaris vulgaris L.*), monkey flower (*Mimulus guttatus Fisch*), parrot feather (*Myriophyllum brasiliene Camb.*), sedge (*Cyperus pseudovegetus*), smart weed (*Polygonum hydropiperoides L.*). smooth cordgrass (*Spartina altemiflora Loisel*), striped rush (*Baumia rubiginosa*), umbrella plant (*Cyperus altemifoius L.*), water lettuce (*Pistia stratiotes L.),* water zinnia*(Wedelia trilobata Hitchc.*) grown hydroponically in greenhouse for treating copper contaminated water and found to be effective. Duckweed was found to be effective for the treatment of copper contaminated water with different concentrations (Zayed *et al.*, 1998). Zhu *et al.* (1999) carried out experiment using water hyacinth (*Eichhornia crassipes*) grown hydroponically for treating copper contaminated water with initial concentration of 10mg /L

Samecka Cymerman and Kempers (1996) used undulate that has an initial copper concentration in its tissues of 2.33 mg/kg (dry weight) to remove copper from sewage collected from pesticide producing factory having copper concentration of 31 µg/L.

For the treatment of iron-contaminated water, duckweed and water velvet also were found to be useful (Jain *et al.*, 1988, 1989, 1990). They also used Parrot feather (*Myriophylhum aquaticum*), creeping primrose (*Ludwigina palustris*) and water mint (*Mentha aquatic*) to remove heavy metals from contaminated water. Sridevi *et al.* (2003) successfully used Eichhornia crassipes for the removal of

Zn^{2+} and Ni^{2+}. They found that higher concentration of metals curtails the growth and development of plants.

Legenandra toxicariae is a water plant, usually found in fresh water ponds and wells in Kerala. It is used to remove/reduce hardness of the water. When it is introduced into the well along with fish nuria the excreta of the fish becomes nutrient for the plant and the decayed leaves and the microorganisms and other sediments which get attached to the root of the plant becomes food for the fish. (The plants float in the water). The fish noria also has the capacity to remove pollutants from the water.

Experimental Details

Test organisms selected

1. ***Legenandra toxicariae*** – water plant found in fresh water
2. ***Nuria danricus*** – inhabits in shallow water of ponds, pools etc.

These were collected from the nearby canals and ponds.

Experiments were conducted using these two organisms during the beginning of the second year. Analysis of biological characteristics of the experimental water samples was carried out at 3 stages.

1. Pre experimental stage (first year)
2. Experimental stage (second year)
3. Post experimental stage (third Year)

Coliform and MPN were determined in all the 20 samples. Details are given in tables 5.1 – 5. 6.

Results and Discussions

Appreciable decrease in the MPN of Coliforms was observed in experimental sets with test organisms. In the present study for water treatment *Legenandra toxicariae* is used along with the fish Nuria. All the wells were treated with Nuria and *Legenandra toxicariae* during the post monsoon season of the first year of study i.e. in February. The physical conditions of the water plants were fleshy and green in all the wells except in well No.10. In well No.10 it was found that the plant remained only for a short period. After few months it dried off; it may be due to the presence of high alkalinity and total dissolved solids present in that particular well. (Table 3.5, 3.2.). In other wells when the plant was growing the water became more clear. In well No.6 the rate of growth of the plant was very fast may be due to the presence of nutrients for the well was a newly constructed one. It was found that in the presence of Legenandra *toxicariae,* MPN count and the number of lactone fermenting colonies were almost nil in all the wells. But during monsoon in some of the wells even in the presence of the plant, MPN count was found to be 1100.This may be because of the entry of the contaminated rainwater. In the post monsoon season since the water receded in most of the wells, number of colonies were less compared to monsoon period. In wells where the total solids were comparatively high the plant did not survive for the second year. This may be because they get accumulated in various parts of the plants, which may adversely affect the growth of the plant and metabolism (Barman and Lal, 1994).

However it can be concluded that studies on the biological water treatment technique are relevant for the improvement of the quality status of water, especially of wells and ponds, which are the main drinking water sources.

Chapter 7

SOIL ANALYSIS

Life on earth depends directly on the living soil and the aquatic ecosystem of rivers. Without fertile soil and the microbial fauna that inhabit it food would not grow, dead things would not decay and nutrients would not be recycled. Dumping of industrial and municipal wastes causes toxic substances to be leached and seep into the soil.

Soil by definition is a natural body of mineral and organic constituents differentiated into horizons (the layers in the soil body are separated from each other by a curved line and are therefore called horizons) which differ among themselves as well as from the underlying material in morphology, physical making, chemical composition and biological characteristics. The soil body is made up of four components, mineral, organic matter, water and gas. Under natural conditions the mineral and organic components remain fairly constant in any individual soil type. The water and gas components vary from day to day even from hour to hour.

Soil acidity

It is most prevalent in the soils of the humid regions. It is caused by leaching of bases from the profile to the ground waters. In cultivated areas large quantities are removed by harvested crops. Acidity is also accentuated by acid carrying fertilizer, salts such as $(NH_4)_2SO_4$, NH_4NO_3 and by the acids formed by spray materials such as sulphur. Both inorganic acids (HNO_3, H_2SO_4, H_2CO_3) and organic acids (acetic acid, oxalic acid and citric acid) supply the H^+ ions to the exchange complex of the soil. Nitric acid is supplied by the nitrification process. Oxidation of sulphur compounds produce sulphuric acid. They are also released in the decay of organic matter. H_2CO_3 is produced by dissolving CO_2 in rainwater. They are also excreted by roots. Oxalic acid and citric acids are produced by various microorganisms especially fungi and are also found in plants. Acetic acid is associated with fermentation. A lot of other organic acids also increase soil acidity. These include malic, propionic, butyric, benzoic, and carbolic acids. pH is the most important single property identifying the chemical character of the soil. The main value of pH measurement is not that it shows a soil to be acidic or alkaline but the information it gives about associated soil properties such as phosphorus availability, base status etc. Most of the agricultural soils have pH values lying between 4 and 8. pH controls the sorption of and distribution of the various cations by soil colloids. The solubility of many soil constituents is sensitive to pH since the various minerals of the soil dissolve at different pH levels.

Soil Nitrogen

There are nearly 12 pounds of nitrogen above every square foot of the surface of the earth. Yet nitrogen is one of the most critical elements for plant growth, the reason is that plants cannot utilize nitrogen as a gas, it must first be changed into some stable form. The only storehouse of any kind of nitrogen is soil organic matter. Quantities of nitrogen in soil vary with a number of factors including properties of the soil, vegetation, climate and management practices. It is present in both organic and inorganic forms. In most of the surface soils the majority (95%) of the nitrogen is present in organic form. Practically all the nitrogen is combined in humus (when all the plants animals and microorganisms have eaten and digested each other until they can get nothing more out of each other, what is left is known as humus. Humus is not a definite substance it is in a continued state of flux, disappearing by decomposition and oxidation and being reformed from the residues and excrements of organisms. Humus is ordinarily dark coloured and gives soils their characteristic brown, grey and black colour) and plant residues and in that form it is unavailable. It does not become available until it has been converted by bacterial action into nitrate. Once it is converted to nitrate it is immediately taken up by plant, which happens to be growing in the soil. In their transformation into nitrate, organic nitrogenous compounds are first broken down by organisms to nitrites, which are immediately oxidized by other microorganisms to nitrates. The quickest of these stages is the last nitrification, and very little ammonia and no nitrite are normally found in soils. The making of available soil nitrogen is an entirely biological process and is carried out by animals, worms, insects and microorganisms. Therefore they can only control indirectly and to a limited extent by adding the soil substances of which lime is common. Nitrogen makes plants darker green and more succulent. It increases the proportion of water and decreases the percentage of calcium in plant tissues.

Soil Phosphorus

Phosphorus is present in soils as (1) completely insoluble inorganic materials of the apatite type (complex calcium phosphates) (2) very insoluble iron and aluminium phosphate (3) slightly soluble dicalcium phosphate ($CaHPO_4$) which is probably available to plants but is unstable and changes over to less soluble forms. (4) Exchangeable phosphate. Phosphorus availability is low in strongly acid soils because of the formation of iron and aluminum phosphates from which phosphorus is very slowly available. In alkaline soils tricalcium phosphate $Ca_3 (PO_4)_2$ forms but it readily reduce to the available phosphorus.

Soil Potassium

There are three categories of potassium status in soil (1) immediately available, which are water soluble and exchangeable (2) moderately available and which is known as fixed potassium (3) Slowly available which is the main reserve of potassium. Slowly available form of potassium is lattice bound and is released by weathering. The fixation and release of potassium by soils can be affected by the temperature and moisture regimes. Areas receiving low rainfall had low available potassium and that low available potassium was also associated with areas having excessive rainfall. Plants appear to derive most of their potassium from the exchangeable potassium adsorbed on the clay humus complex but not all the exchangeable potassium is available. The amount of exchangeable potassium does however give a fairly reliable indication of a soil's probable response to potassium fertilizers. Some potassium containing soil minerals such as muscovite weather readily and may provide steady sources of plant available potassium. Many plant residues also contain potassium in a soluble and therefore immediately available form. Applying a surface mulch of straw or similar material is a very effective way of increasing the available potassium content of the soil. The extra potassium can only have come by being washed out of the mulch. Humus is not a source of potassium. Potassium levels can affect a plant's water utilization. High concentration of potassium in a soil contribute to excessive osmotic pressure in the plant and so increase its absorptive capacity of water. On the other hand high potassium in a soil solution affects the osmotic pressure of that solution and makes the water less available. Increasing soil moisture under aerobic conditions increases potassium uptake by plants, but high moisture does not assist in potassium uptake, which will be poor.

Soil soluble salts

The main source of the soluble salts, which are present to some extent in all soils, is the primary minerals. The soluble salts are in equilibrium with the exchangeable bases in soils, but the equilibrium depends on the water content of the soil. Of the soluble anions sulphate and chloride are usually the most important and carbonate and hydrogen carbonate usually occur in a small amounts unless the pH is higher. Exchangeable cations in equilibrium with carbonic acid in the soil give rise to soluble carbonates and hydrogen carbonates. Nitrates, phosphates and silicates occur in varying amount, often negligible but sometimes predominant. The cations involved are usually calcium, magnesium, potassium and sodium. When a soil has excess soluble salts it is said to be saline, if the sodium content increases the soil becomes a saline alkali soil the pH remaining below 5-8. If salts are leached from a saline alkali soil it reverts to a non-saline alkali soil whereas leaching a saline soil converts it to a normal soil. If the total soluble salt content of a soil is less than 0.15% there is little point in measuring individual ions except for some specific purpose.

Experimental methods

Soil analysis is essential for getting the maximum yield as it provides the knowledge of soil component nutrients and their deficiency in a particular part of soil. Soil analysis method is scientific, accurate and rapid. Soil fertility is one of the factors, which determine the magnitude of crop yields.

Experiments were conducted to analyse the soil samples (20) in the study area to estimate mainly N, P, K and heavy trace metals.

Soil sampling

The sampling involves a number of stages prior to the analysis of the mineral. Bulk materials of sediments are non homogenous, they may contain particles of different composition which are not uniformly distributed within the material. So a number of increments are taken in random manner from different places in bulk material. The combination of these increments forms the gross sample. The gross sample is often too large for direct analysis ands is divided onto sub sample.

The incremental sample of about 50g is taken from specified sampling points on the site (four different places around the well). The sampling points included surface soil and two samples from 0.5and 1.0 m depth. Twenty individual samples were carefully labeled and stored in separate containers to avoid cross contamination. The respective dried samples were passed through a sieve. It is then thoroughly mixed and used as analytic sample. The samples were transported to soil testing laboratory under the agricultural department. These soil samples are analysed in the laboratory for their pH, organic carbon, available nitrogen phosphorus and potash, total soluble salts. The samples were also analysed for heavy metals like copper, cadmium, mercury, lead and zinc by AAS in IISR, Calicut (details are given in Chapter 2)

Results and discussion

Results are presented in Table 7.1 a.d 7.2. Samples 7, 8, 11 and 19 were found to be neutral. All the other samples were acidic. pH of samples 5, 9, 15, and 17 were below 5. Therefore lime should be added to make them neutral. For all samples TSSEC was found to be normal. The organic carbon percentage, which is a measure of nitrogen, was low for samples 3, 6, 13, and 15. So nutrients should be added in the form of fertilizers. In all the other samples organic carbon percentage is found to be medium. In the case of samples 1, 3, 4, 13, 14 and 19 value of phosphorus value is low and for samples 6, 8, 9, 10, 11, 15, 16, 17 and 18 the value is high. In all the other samples it is found to be medium. Amount of potassium present in samples 2, 3, 4, 6, 12, 13, 14, 16, and 17 were medium. It was found to be high for samples 7, 9, 10, 18, 19 and 20 and low in samples 1, 5, 8, 11 and 15.

Heavy metals like copper, cadmium, mercury, lead and zinc were found to be absent in all the samples (Table 7.2) indicating its suitability for cultivation as well as living.

SUMMARY AND CONCLUSIONS

The present investigation deals with systematic monitoring of important parameters in different waters collected from sites of residential, industrial and agricultural origin in Calicut city for three consecutive years (2000-2003). WQI of different samples have been calculated. To get a comprehensive picture of metallic burden in the environment of Calicut, a few samples of soil are also analysed. New methods of water treatment for biological pollution are also presented.

Statistical techniques used in this study are

- **Correlation Analysis**: To study the correlation among parameters as well as parameters and rain water for 3 consecutive years multiple correlation analysis is carried out.
- **Analysis of Variance (ANOVA)**: To interpret the variation of various parameters with respect to seasons and spaces (different wells in the city).
- **WQI** values of 20 well water during 3 different seasons and average values for each year have been calculated using statistical programme.

A systematic hydrochemical study of the ground water of Calicut district has been carried out to examine the suitability of water for drinking purpose. Water samples representing the shallow ground water of this region were collected during pre monsoon, monsoon and post monsoon seasons for three consecutive years. The physicochemical parameters like temperature, total dissolved solids, pH , electrical conductivity, alkalinity, total hardness, calcium hardness, dissolved oxygen, oxygen absorbed, carbon dioxide, nitrate, chloride, sulphate, sodium, potassium, calcium, magnesium, iron and heavy metals like lead, mercury, cadmium, copper and zinc were analysed with reference to BIS and WHO standards. The results are discussed with the aid of graphs.

The overall results meet the standards and guidelines recommended for drinking water. There are no major problems in the wells except for a few parameters. This may be due to local sources of contamination or poor maintenance. Though some of the wells are situated in industrial area the water is not affected by industrial pollution. Wells in the agricultural area are also not contaminated by fertilizers. Though problem of salinity intrusion was reported in the near by places (James, 1996) the amount of chloride present in the wells under investigation was low and within the permissible limit salinity could not be calculated.

The seasonal and temporal variations in the water quality indices were investigated. The results are used for the systematic calculation of correlation coefficient between water quality variables and regression analysis, which provides an indirect means of rapid monitoring of water quality.

There is significant variation in temperature between seasons but variation between wells is insignificant. Considering all the seasons and all the wells, temperature and dissolved oxygen are correlated. There is no significant correlation between temperature and any other parameters.

When all the wells are considered there is significant correlation between TDS and alkalinity, calcium, calcium hardness, chloride, total hardness, potassium, magnesium, pH, DO and sulphate. Same correlation was found during all the three seasons.

Some samples have the problems of acidity. This may be due to acidity of the soil and usage of fertilizers like ammonium sulphate, ammonium nitrate etc. No regular variation of pH was observed in any wells. Significant variation in pH is observed between wells and between seasons. pH has high positive correlation with alkalinity, calcium, calcium hardness, sulphate, chloride, magnesium, total hardness and total dissolved solids in all the seasons.

The value of electrical conductivity in the study area is from 0.1-1.9 millimhos. There is no significant variation in electrical conductivity between seasons and between wells. When all the wells and all the season are considered there is positive correlation between electrical conductivity and alkalinity, calcium, calcium hardness, chloride, sulphate, total dissolved solids and total hardness. During pre monsoon and post monsoon seasons also positive correlation between electrical conductivity and these parameters were significant.

Since in all the samples phenolphthalein alkalinity is zero, the alkalinity is only bicarbonate alkalinity, hydroxide and carbonate alkalinity are zero. There is significant variation in alkalinity in different seasons and in different wells. High positive correlation is observed between alkalinity and calcium, calcium hardness, pH, sulphate, magnesium, potassium, electrical conductivity, total dissolved solids, total hardness and chloride when all the wells and all the seasons were considered. This high positive correlation is significant during all seasons also.

The total hardness in the study area varied from 8-272 mg/L. None of the wells belong to very hard category or extremely hard category. There is significant variation in total hardness between seasons and between wells. But there is no significant variation in calcium hardness at various wells. Positive correlation is found between total hardness and alkalinity, calcium, calcium hardness, chloride, sulphate, potassium, magnesium, pH, electrical conductivity and total dissolved solids. Same correlation was found in the case of calcium hardness also.

The values of DO in the study area are found to be between 3.26 and 12. Significant variations of dissolved oxygen were observed between seasons. Variations of DO between wells were insignificant. Correlation between DO and temperature were highly significant.

Significant variations of absorbed CO_2 are observed when all the wells are considered; but variation of absorbed CO_2 is insignificant with respect to all the seasons. There is no correlation between CO_2 and other parameters.

Ammonia and nitrite were not present in any of the samples.

The nitrate content in the wells varied from 0 ppm to 6 ppm. There is significant variation in nitrate between seasons and between wells. No correlation is found between nitrate and other parameters.

Significant variations in chloride are found between the wells. Variation in chloride between the seasons was also significant. High positive correlation is found between chloride and alkalinity, calcium, calcium hardness, total hardness, sulphate, total dissolved solids, potassium, magnesium and electrical conductivity.

The sulphate ion concentration in the entire study area varied from 0-150mg/L. There is significant variation in sulphate between seasons and between wells. Positive correlation found between sulphate and alkalinity, calcium, total hardness, potassium, magnesium and total dissolved solids.

In the present study it was found that during pre monsoon concentration of sodium was comparatively high and variation in sodium between seasons is insignificant. There is significant correlation between sodium and chloride, total dissolved solids, hardness total, electrical conductivity and alkalinity especially during pre monsoon.

In all the well water samples presence of potassium was negligible. Variation in potassium between seasons and between wells is significant. There is significant correlation between potassium and sulphate, pH, total dissolved solids, hardness total and alkalinity.

The concentration of calcium in water samples ranges between 0.48 and 75.7ppm. Thus the calcium concentration is low in the groundwater of that area. There is significant variation in calcium between wells and between seasons. Positive correlation is observed between calcium and alkalinity, calcium hardness, electrical conductivity, total dissolved solids, chloride, magnesium and sulphate when all the wells of all the seasons are considered.

The concentration of magnesium was found to vary from 0.2 to 47.5ppm. The variation of magnesium between wells and between seasons is significant. There is significant correlation between magnesium and total hardness, total solids, alkalinity, sulphates, calcium, pH and calcium hardness.

Presence of iron was negligible in all the cases. There is no significant variation of iron between neither seasons nor wells. No correlation was obtained between iron and other parameters during any season.

In all the samples fluoride and phosphate were found to be within the permissible limit.

In water samples collected in the study area copper, lead, cadmium, zinc and mercury were below the toxic detectable limit but in one sample concentration of zinc were found to be slightly high.

WQI depends varies from well to well. Therefore WQI of all the wells for three different seasons were calculated. The values of WQI in water sampling areas were reported under 50 - 70 range, indicating that the water is useful for human use. WQI of all the wells for three different seasons are calculated. The result shows that the WQI is different for each season.

An attempt has been made to relate quality variation with rainfall by correlation analysis. Considering all the 20 wells, the coefficient of correlation (r) between rainfall and pH fluctuation was found to be negative for all the wells except 5 and 6. i.e., pH has a decreasing trend with rainfall. Also the coefficient of correlation between rainfall & HT fluctuation was found to be positive for all the wells except 9 and 10 i.e., TDS has an increasing trend with annual rainfall.

Nature has evolved a number of systems to compensate pollution generated as a result of natural events. The functional system is the environment offer a variety of ways in which contaminants can be altered and transported. The best way of fighting pollution is by bioremediation using aquatic organisms.

In the present study for treatment *Legenandra toxicariae* is used along with the fish Nuria. The physical conditions of the water plants were fleshy and green in all the wells except in well No.10. In wells No.10 it was found that the plant remained only for a short period. After few months it dried off; it may be due to the presence of high alkalinity and total dissolved solids present in that particular well. In other wells, when the plant was growing the water became more clear. In well No.6 the rate of growth of the plant was very fast may be due to the presence of nutrients for the well was a newly constructed one. It was found that there was in the presence of Legenandra *toxicariae* MPN count and the number of lactone fermenting colonies were almost nil in all the wells. But during monsoon even in the presence of the plant MPN counts is found to be 1100 in some of the wells. This is may be because of the entry of the contaminated rainwater. In the post monsoon season since the water receded in most of the wells, number of colonies were less compared to monsoon period. In wells where the total solids were comparatively high the plant did not survive for the second year. This may be because they get accumulated in various parts of the plants, which may adversely affect the plant growth and metabolism.

From the analysis of soil samples, it was found that except five samples all the samples were acidic. For all samples TSSEC was found to be normal. The organic carbon percentage, which is a measure of nitrogen, was low for six samples. So nutrients should be added in the form of fertilizers. For nine samples addition of nutrients should be avoided, since the percentage of carbon was found to be high. In the case of 7samples phosphorus value was medium. In other cases it was either high or low. Only 8 samples had medium amount of potassium. The trace metals (Zn, Cd, Cu, Hg and Pb) were found to be almost nil in all the samples.

In conclusion it can be said that the present studies are able to provide the following inference.

1. The metallic concentrations and various parameters of different waters of Calicut district are found to be well within the permissible levels irrespective of whether the sites are of industrial, agricultural or residential origin and hence our study area can be designated as unpolluted. It is heartening to note that even a populated city like Calicut with several hospitals, small scale industries, slum areas, education institutions etc is free from contamination of toxic trace metals in water or soil in the selected area of study.
2. The study provides a good understanding of the correlation of various parameters and a fairly good idea of comparison of Water Quality Index Values of 3 consecutive years (2000-2003).
3. The only source of pollution in the study area is that of bacteriological origin and useful methods are suggested for effective removal of this pollution based on a series of experiments.
4. The trace metals contamination (Zn, Cd, Cu, Hg and Pb)is found to be almost nil in the study area soil samples indicating the suitability for cultivation as well as living.
5. Modern statistical tools have been utilized effectively in the interpretation of data.

Systematic study of the extent and nature of environmental pollution by metals, bacteria and certain physico- chemical parameters in the City and remedial measures for protection are urgent task as noticed from the data which indicate that parameters like CaH, EC, Mg, Ca, Na, Cl^- are gradually increasing with time.

The author is conscious of the limitations in the approaches made and the vastness of the area still remains to be covered. More work is in progress in a similar line under the KSCSTE Project.

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Table 2.1 Locations

Well No.

1. Near paddy field, near a canal, near Providence College, used by 600 hostellers
2. Houses and coconut trees are nearby, underneath rock, used by 10 families in Vengerri
3. No houses close by, very deep (19.69 meter) in Vengerri
4. No houses nearby in Malaparmba
5. One or two houses around in Malaparmba
6. Newly constructed, coconut trees inVellayil
7. Houses nearby, coconut trees in Eranhipalam
8. Houses nearby coconut trees in Eranhipalam
9. Near industrial estate in West Hill
10. Many houses close by, marshy area in Nadakkav
11. Gutter nearby coconut in Nadakkav
12. School well Providence School
13. Inside a building, used by 100 hostellers, septic tank near by in Vellayil
14. Gutter neat by, coconut trees near a private school
15. Houses and gutter near by in Vellayil
16. Between many buildings in Calicut city
17. School well in Calicut city
18. Bore well in Malaparmba
19. In coconut grove, away from city
20. In coconut grove, away from city

Table 3. BIS AND WHO GUIDELINE FOR DRINKING WATER

Substance/Test	Unit	Desirable Limit BIS	Permissible Limit	WHO Guideline
Essential Characteristics				
Colour	Hazen units	5	25	15
Odour		Unobjectionable	Un objectionable	Un objectionable
Taste		Agreeable	Agreeable	Agreeable
Turbidity	NTU	5	10	5
pH Value		6.5 to 8.5	No Relaxation	6.5 to 8.5
Total Hardness	As $CaCo_3$,mg/lit	300	600	
Alkalinity	mg/lit	200	600	
Chlorides	As Cl^-, mg/lit	250	1000	250
Dissolved solids	mg/lit	500	2000	
Sulfate	As SO_4, mg/lit	200	400	
Nitrate	As NO_3, mg/lit	45	100	50
Fluoride	As F^-, mg/lit	1	1.5	1.5
Phosphate	As PO_4, mg/lit	50		
Dissolved Oxygen	mg/lit	4		
Sodium	As Na, mg/lit	200		200
Iron	As Fe, mg/lit	0.3	1	0.3
Calcium	As Ca, mg/lit	75	200	
Magnesium	As Mg,mg/lit	30		
Cadmium	As Cd, mg/lit	0.01	No relaxation	0.003
Lead	As Pb, mg/lit	0.05	No relaxation	0.1
Zinc	As Zn, mg/lit	5	15	3.0
Copper	As Cu, mg/lit	0.05	1.5	1.2
Bacterial Contaminant				
Bacteriological Coliforms	MPN/100ml	10	No relaxation	
E.Coli	MPN/100ml	0	No relaxation	0
Total Coliform	MPN/100ml	50	No relaxation	0

Table 3.1 **Temperature (°C)**

Wells	PR1	M1	PO1	PR2	M2	PO2	PR3	M3	PO3
Well 1	29.5	25.5	27	29.5	24.5	26.5	31	25	26
Well 2	29	26	27	29	24	27	31.5	25	27
Well 3	28.5	25.5	28	29.5	24.5	27.5	30	25.5	27
Well 4	29	25	27.5	30	25	27	31.5	24.5	27
Well 5	29.5	25	27	30.5	25.5	27.5	30.5	24	27.5
Well 6	29.5	26	27	29.5	24.5	27	30.5	24.5	27.5
Well 7	28.5	26.5	27.5	29.5	24.5	27	31.5	24	27
Well 8	28.5	25.5	27.5	29.5	24.5	27.5	31	24.5	27.5
Well 9	29	26	27.5	29	24	27.5	31.5	25.5	26.5
Well 10	30	25.5	27	30.5	24.5	27	31.5	25	26.5
Well 11	28.5	26	27	31	25	27	31	25	26
Well 12	29.5	26	27.5	31	24.5	27.5	31.5	25	26.5
Well 13	29	25.5	26.5	31.5	25	27	31	25.5	27
Well 14	29.5	25.5	27.5	31	25	27	31.5	24	27.5
Well 15	29	26	27	31.531	24.5	27	31.5	24.5	26.5
Well 16	29	25.5	27	30.5	24	27.5	31	25.5	26
Well 17	29.5	26	26.5	30.5	24	26.5	31	25	26
Well 18	30	25.5	27	30.5	24	26.5	31	24	26.5
Well 19	30	26	27	31	24.5	26.5	31	24	27
Well 20	30	25.5	27.5	31	24.5	27	31.5	25	27

PR -Pre monsoon, **M**-Monsoon, **PO**- Post monsoon

1, 2 and **3** stands for year 1, year 2 and year 3 respectively

Table 3.2 **Total dissolved Solids (ppm)**

Wells	PR1	M1	PO1	PR2	M2	PO2	PR3	M3	PO3
Well 1	91	161	128	59	34	40	47	62	30
Well 2	147	197	89	70	55	68	141	202	61
Well 3	117	177	90	55	70	72	124	128	76
Well 4	95	158	79	69	27	34	58	46	22
Well 5	113	127	70	44	23	29	66	102	18
Well 6	227	302	371	315	252	275	335	484	268
Well 7	88	141	129	85	83	100	170	254	106
Well 8	109	320	218	120	194	107	136	258	126
Well 9	391	302	298	206	136	151	175	228	124
Well 10	615	400	461	416	120	367	472	284	348
Well 11	162	155	179	194	302	292	220	310	250
Well 12	143	147	210	138	135	192	180	142	101
Well 13	262	406	205	256	215	257	341	320	230
Well 14	250	217	348	212	196	270	249	242	230
Well 15	377	425	503	393	364	385	452	328	334
Well 16	259	340	356	451	371	386	317	314	283
Well 17	200	374	253	297	198	220	207	214	176
Well 18	174	236	162	172	128	100	120	120	68
Well 19	122	155	76	53	22	28	34	28	18
Well 20	134	120	56	39	22	22	52	42	13

PR -Pre monsoon, **M**-Monsoon, **PO**- Post monsoon

1,**2** and **3** stands for year 1, year 2 and year 3 respectively

Table 3.3 **pH**

WELLS	PR1	M1	PO1	PR2	M2	PO2	PR3	M3	PO3
WELL 1	6.6	6.8	6.6	6.8	6.2	6.9	5.6	6	6
WELL 2	6	6.6	6	6.1	5.4	6	5.6	5.2	6
WELL 3	6.2	6.8	6	6.8	6	6.2	6	6	6.6
WELL 4	6.8	6.8	6.8	6.9	6.6	7	6.4	6.2	6.2
WELL 5	6.8	6.8	6.6	6.8	5.8	6.8	6	5.4	7.6
WELL 6	7.4	7	7.6	7.4	7.4	7.6	7.4	7.6	5.4
WELL 7	6	6	6	5.6	5.4	6	5	5.4	7.4
WELL 8	6.8	7.6	6.4	6.4	7.4	7.6	6.2	6.8	7.6
WELL 9	7	7	6.8	7.4	7.1	7.4	7	7.6	8
WELL 10	7.6	6.8	7.6	7.5	7.4	7.5	7.6	7.4	7.6
WELL 11	6.8	7	6.8	8	7.3	7.4	6.4	6.6	7
WELL 12	6.8	6.8	7.4	7.5	7.4	7.3	6.6	7.4	7.6
WELL 13	6.8	6.8	7.4	6.9	6.8	7.6	6.6	7	7.6
WELL 14	7	6.8	7.4	7.8	6.4	7.5	6.8	6.8	7.8
WELL 15	7.6	6.8	6.8	7.4	7	7.3	7.4	6.8	7.8
WELL 16	7.6	7.6	6.8	7.4	6.8	7.4	7	8.2	7.8
WELL 17	7.6	7.6	7	7.4	7.4	7.5	7	7	7.8
WELL 18	7.4	7	7.6	7.1	7.3	7.4	7.2	7	7.2
WELL 19	6.2	7	6.2	6.5	5.4	6.2	5.8	6	6.8
WELL 20	6.6	7	6.6	6	6.4	6.9	5.8	6.4	6.4

PR -Pre monsoon, **M**-Monsoon, **PO**- Post monsoon

1,**2** and **3** stands for year 1, year 2 and year 3 respectively

Table3.4 **Electrical Conductivity (micro mhos/cm)**

WELLS	PR1	M1	PO1	PR2	M2	PO2	PR3	M3	PO3
Well I	0.01	0.06	0.1	0.06	0.07	0.05	0.044	0.126	0.054
Well 2	0.02	0.05	0.1	0.11	0.08	0.11	0.121	0.123	0.108
Well 3	0.02	0.09	0.1	0.12	0.11	0.15	0.121	0.118	0.138
Well 4	0.02	0.04	0.1	0.06	0.05	0.05	0.06	0.09	0.041
Well 5	0.02	0.03	0.1	0.04	0.05	0.05	0.071	0.087	0.032
Well 6	0.09	0.31	0.4	0.46	0.48	0.38	0.39	0.086	0.477
Well 7	0.03	0.13	0.2	0.3	0.18	0.2	0.322	0.088	0.207
Well 8	0.03	0.27	0.2	0.2	0.38	0.2	0.312	0.086	0.231
Well 9	0.15	0.2	0.3	0.36	0.28	0.25	0.201	0.029	0.222
Well 10	0.25	0.48	0.6	0.85	0.32	0.69	0.322	0.021	0.621
Well 11	0.1	0.48	0.5	0.51	0.58	0.46	0.501	0.539	0.465
Well 12	0.04	0.21	0.2	0.22	0.25	0.22	0.291	0.205	0.202
Well 13	0.11	0.37	0.4	0.42	0.4	0.45	0.493	0.268	0.413
Well 14	0.11	0.29	0.4	0.36	0.4	0.42	0.378	0.203	0.426
Well 15	0.15	0.47	0.6	0.57	0.68	0.7	0.613	0.006	0.608
Well 16	0.11	0.42	0.5	0.66	0.74	0.53	0.621	0.01	0.525
Well 17	0.1	0.3	0.4	0.45	0.35	0.38	0.304	0.157	0.333
Well 18	0.11	0.1	0.1	0.3	0.25	0.16	0.121	.009.	0.131
Well 19	0.02	0.05	0.1	0.05	0.05	0.03	0.04	0.02	0.035
Well 20	0.02	0.05	0.1	0.04	0.05	0.02	0.031	0.0301	0.024

PR -Pre monsoon, **M**-Monsoon, **PO** -Post monsoon

1,2 and **3** stands for year 1, year 2 and year 3 respectively

Table 3.5 **Alkalinity (ppm)**

WELLS	PR1	M1	PO1	PR2	M2	PO2	PR3	M3	PO3
Well I	10	12	10	6	14	8	7	10	12
Well 2	8	6	10	4	8	2	8	8	8
Well 3	12	12	6	8	18	8	10	10	14
Well 4	20	10	18	14	16	14	20	14	14
Well 5	10	6	8	8	8	10	10	10	10
Well 6	80	102	140	134	190	168	130	150	186
Well 7	4	6	6	16	8	4	8	6	6
Well 8	48	118	54	50	188	50	32	174	100
Well 9	120	110	20	72	104	50	34	128	46
Well 10	156	132	138	130	104	144	168	142	144
Well 11	50	130	112	104	138	130	54	150	130
Well 12	42	64	48	60	68	64	48	82	54
Well 13	46	146	96	80	146	118	44	200	84
Well 14	90	82	108	76	96	92	56	110	124
Well 15	150	164	172	152	238	212	166	246	220
Well 16	164	162	196	182	190	184	68	204	190
Well 17	138	120	140	134	148	138	130	168	132
Well 18	58	56	68	100	130	68	84	90	62
Well 19	8	16	8	80	8	6	16	8	12
Well 20	10	16	10	80	10	10	8	28	12

PR -Pre monsoon, **M**-Monsoon, **PO** -Post monsoon

1,2 and **3** stands for year 1, year 2 and year 3 respectively

Table 3.6 **Hardness Total (ppm)**

Well	PR1	M1	PO1	PR2	M2	PO2	PR3	M3	PO3
Well I	14	16	50	8	10	10	8	18	6
Well 2	18	16	40	14	24	18	14	14	20
Well 3	18	18	44	12	14	14	14	16	23
Well 4	24	18	44	16	18	16	18	14	14
Well 5	14	16	34	10	8	10	10	8	14
Well 6	138	356	208	170	180	160	168	188	176
Well 7	22	20	58	22	18	24	20	26	10
Well 8	90	164	140	62	180	64	36	156	116
Well 9	188	130	170	100	58	60	50	138	62
Well 10	240	192	250	224	126	190	204	148	198
Well 11	74	182	204	80	170	128	74	174	136
Well 12	68	96	124	80	100	82	68	94	86
Well 13	118	206	180	120	174	160	124	206	152
Well 14	116	104	194	76	100	98	98	116	118
Well 15	184	210	230	170	240	234	194	230	212
Well 16	190	206	272	222	252	216	212	214	224
Well 17	162	144	198	138	148	136	144	144	132
Well 18	46	44	104	74	102	68	72	52	56
Well 19	12	26	46	8	10	14	10	14	18
Well 20	16	24	40	12	10	10	8	8	8

PR -Pre monsoon, **M**-Monsoon, **PO**- Post monsoon

1,2 and **3** stands for year 1, year 2 and year 3 respectively

Table 3.7 **Ca Hardness (ppm)**

Wells	PR1	M1	PO1	PR2	M2	PO2	PR3	M3	PO3
Well I	6	21.01	6.006	11.01	11.01	7.007	10.01	11.01	8
Well 2	10.01	9	12.01	9	14	10.01	11.01	8	12
Well 3	9.01	11.11	10.01	11.01	11.01	5.005	18.02	12	13
Well 4	17.01	13.01	12.01	17.02	16.02	23.02	12.02	12.01	14
Well 5	7	5.008	10.1	10.01	12.01	10.01	18.01	6.006	8
Well 6	117.1	135	150	151.2	167.16	140	142	153.1	129
Well 7	11.01	11.01	14.01	18.02	19.02	19.01	19	15	16
Well 8	8	42	128	49	62	181	69	34	92
Well 9	121	60	35	89	55	58	40	95	53
Well 10	176	144	154	190	84	152	194	121	161
Well 11	50	138	116	107	160	119	77	146	108
Well 12	46	74	65	75	99	75	57	77	69
Well 13	77	163	126	140	138	105	98	174	110
Well 14	78	76	84	63	88	94	99	95	97
Well 15	145	173	173	162	220	210	192	192	171
Well 16	163	184	191	224	235	214	208	187	189
Well 17	124	104	115	123	130	163	135	112	102
Well 18	26	23	32	42	53	48	32	20	20
Well 19	5	7	10	6	10	10		4	6
Well 20	8	7	6	5	5	7	10	13	11

PR -Pre monsoon, **M**-Monsoon, **PO**- Post monsoon

1, 2 and **3** stands for year 1, year 2 and year 3 respectively

Table 3.8 **Dissolved oxygen (ppm)**

Wells	PR1	M1	PO1	PR2	M2	PO2	PR3	M3	PO3
Well 1	6.56	6.2	5.92	5.92	6.4	4.48	6.72	6.2	6.8
Well 2	6.24	6.4	4.8	4.8	5.92	6.88	5.92	6.56	8.96
Well 3	6.72	6.1	5	5	6.24	6.56	5.92	7.5	7.84
Well 4	5.12	5.8	3.26	3.3	6.24	5.76	4.96	7.2	5.6
Well 5	3.84	3.9	5.7	5.88	5.92	7.68	7.36	6.88	8
Well 6	6.56	6.4	7.36	7.36	4.32	5.8	6.72	6.24	6.88
Well 7	4.16	4.3	4.16	4.16	6.4	5.12	7.2	6.56	6.88
Well 8	4.32	4.5	4.16	4.16	6.4	6.1	6.4	7.68	7.04
Well 9	3.84	5	6.08	4.16	7.2	7.04	6.56	7.68	5.76
Well 10	4.2	4.9	5.28	5.28	5.6	7.04	6.24	6.56	5.6
Well 11	4	5.3	4.96	6.08	6.4	6.8	4.38	7.56	6.08
Well 12	5.28	5.3	6.4	6.4	7.2	6.2	6.08	8	7.04
Well 13	5.28	5.2	4.48	4.48	7.2	5.76	3.84	7.36	7.2
Well 14	5.12	4.2	5.28	5.28	5.76	5.44	4.96	6.88	6.4
Well 15	4.16	3.6	4.48	4.48	6.4	5.12	4.8	4.4	7.2
Well 16	3.52	4.8	4.8	4.64	5.94	5.6	5.6	7.84	6.4
Well 17	4.4	4.7	5.12	5.44	7.2	6.88	5.76	8.64	6.4
Well 18	4.64	7.3	3.8	3.84	6.4	6.56	6.56	6.56	6.56
Well 19	7.2	7.2	4.8	4.6	6.4	5.92	6.4	6.88	8
Well 20	7.36	7	5.44	5.44	7.68	6.1	6.56	8.33	7

PR -Pre monsoon, **M**-Monsoon, **PO**- Post monsoon

1,**2** and **3** stands for year 1, year 2 and year 3 respectively

Table 3.9 **Oxygen absorbed (ppm)**

Wells	PR1	M1	PO1	PR2	M2	PO2	PR3	M3	PO3
Well 1	0.1	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.3
Well 2	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1
Well 3	0.2	0.1	0.2	0.1	0.1	0.1	0.1	0.2	0.4
Well 4	0.1	0.1	0.3	0.1	0.1	0.2	0.2	0.1	0.2
Well 5	0.1	0.2	0.1	0.1	0.1	0.2	0.1	0.1	0.1
Well 6	0.3	0.3	0.3	0.1	0.5	0.3	0.1	0.7	0.5
Well 7	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Well 8	0.3	0.3	0.1	0.1	0.2	0.2	0.2	0.1	0.4
Well 9	0.4	0.3	0.8	0.1	2.3	0.4	0.7	0.1	0.3
Well 10	0.5	0.5	0.3	0.4	0.6	1.2	0.7	0.3	0.4
Well 11	0.2	0.1	0.3	0.1	0.1	0.3	0.1	0.3	0.1
Well 12	0.2	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1
Well 13	0.2	0.1	0.3	0.3	0.1	0.1	0.1	0.1	0.1
Well 14	0.3	0.3	0.4	1.2	0.5	0.5	0.2	0.1	0.1
Well 15	0.2	0.4	0.3	0.7	0.2	0.4	0.3	0.1	0.1
Well 16	0.1	0.1	0.2	0.7	0.1	0.1	0.1	0.1	0.2
Well 17	0.2	0.1	0.2	0.5	0.1	0.2	0.1	0.1	0.1
Well 18	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1
Well 19	0.1	0.1	0.2	0.6	0.1	0.2	0.1	0.1	0.1
Well 20	0.1	0.1	0.1	0.3	0.1	0.3	0.2	0.1	0.1

PR -Pre monsoon, **M**-Monsoon, **PO**- Post monsoon

1,2 and 3 stands for year 1, year 2 and year 3 respectively

Table 3.10 **Dissolved Carbon dioxide (ppm)**

Wells	PR1	M1	PO1	PR2	M2	PO2	PR3	M3	PO3
Well I	45	22	22	45	30	36	43	43	35
Well 2	35	50	20	40	66	72	32	35	21
Well 3	62	44	35		66	38	54	40	65
Well 4	49	48	23	25	24	15	37	19	22
Well 5	46	43	29	29	59		56	41	64
Well 6	56	50	22	22	37	28	39	28	71
Well 7	103	52	77	56	69	59	41	41	34
Well 8	38	56	49	45	40	42	40	24	58
Well 9	35	58	67	43	32	52	40	42	32
Well 10	40	40	26	26	14	18	21	18	86
Well 11	53	49	43	43	50	61	33	38	20
Well 12	18	44	14	14	10	15	19	15	71
Well 13	60	42	76	66	37	78	43	44	79
Well 14	41	51	54	50	59	73	39	56	77
Well 15	45	60	62	59	57	69	42	46	54
Well 16	43	51	70	42	38	33	49	41	56
Well 17	46	40	45	24	33	42	40	14	45
Well 18	37	48	50	21	25	13	20	14	33
Well 19	30	42	45	52	50	29	45	36	29
Well 20	30	32	35	45	48	34	43	16	31

PR -Pre monsoon, **M**-Monsoon, **PO**- Post monsoon

1, 2 and 3 stands for year 1, year 2 and year 3 respectively

Table 3.11 **Nitrate (ppm)**

Wells	**PR1**	**M1**	**PO1**	**PR2**	**M2**	**PO2**	**PR3**	**M3**	**PO3**
Well I	0.3	0	0	0	0	0	0.1	0	0.2
Well 2	1	3	1	4	0.5	2	2	6	2.8
Well 3	0.5	3	6	0	0	1.5	0.8	1.6	0.6
Well 4	0.2	0	0.1	0.5	0	0	0	1	0.6
Well 5	0.5	1	1	1	0	0	0.2	0.6	0.6
Well 6	2	2	0.5	1	0	0	0	0	0
Well 7	1	4	2	2	0	2	1.5	6	2
Well 8	0	0	0	0	0	0	0.2	6	0
Well 9	0.7	0	1	1.5	0	0	0.8	3	0.2
Well 10	0	0	0	0	0	0	0	0.5	0
Well 11	0.4	6	0	0	0.5	0	0.3	3	0.6
Well 12	0	3	0	0.5	0.5	0	0.2	2	0.4
Well 13	0	0	0	0	0	0	0	2	0
Well 14	3	0	0	0	0.5	0.3	0.4	0	0
Well 15	5	2	4	3	3	4	1.5	0	2.4
Well 16	0.3	0	0	0.5	0	0	0	0	0.2
Well 17	2	2	0	0	2	0	0	0	0.2
Well 18	0	0	0	0	0	0	0	0	0
Well 19	0.4	1	0	0	1	1	0	1	0.2
Well 20	0	1	0	0	0	0	0	0	0

PR -Pre monsoon, **M**-Monsoon, **PO**- Post monsoon

1,**2** and **3** stands for year 1,year 2 and year 3 respectively

Table 3.12 **Chloride (ppm)**

Wells	PR1	M1	PO1	PR2	M2	PO2	PR3	M3	PO3
Well I	10	12	14	12	16	16	14	26	14
Well 2	16	12	30	18	18	22	14	30	18
Well 3	22	22	18	26	30	26	28	30	32
Well 4	8	6	6	10	10	10	8	10	8
Well 5	8	8	8	8	14	10	8	12	8
Well 6	30	32	40	38	38	24	48	62	44
Well 7	30	28	34	38	34	40	38	40	42
Well 8	16	10	16	16	18	16	16	10	10
Well 9	78	50	38	26	16	30	24	36	24
Well 10	150	74	96	136	36	102	112	60	102
Well 11	36	54	34	56	66	56	38	64	56
Well 12	16	12	14	16	16	38	16	18	18
Well 13	54	32	50	50	38	32	50	36	54
Well 14	58	40	62	38	54	54	64	50	50
Well 15	44	36	44	36	38	58	62	44	50
Well 16	32	32	40	60	74	38	36	20	48
Well 17	30	22	28	30	24	28	28	26	26
Well 18	6	6	28	6	10	12	8	12	28
Well 19	8	8	10	8	10	12	8	4	6
Well 20	6	6	6	8	12	8	8	6	4

PR -Pre monsoon, **M**-Monsoon, **PO**- Post monsoon

1,2 and 3 stands for year 1, year 2 and year 3 respectively

Table 3.13 **Sulphate (ppm)**

Wells	PR1	M1	PO1	PR2	M2	PO2	PR3	M3	PO3
Well I	0	0	0	0	0	0	0	0	0
Well 2	0	0	0	0	0	0	0	0	0
Well 3	0	0	0	0	0	0	0	0	0
Well 4	0	0	0	0	0	0	0	0	0
Well 5	0	0	0	0	0	0	0	0	0
Well 6	30	10	30	30	40	50	30	30	40
Well 7	0	0	0	0	0	0	0	0	0
Well 8	15	25	5	20	10	20	10	20	20
Well 9	40	15	20	40	15	30	50	25	40
Well 10	40	30	40	50	20	30	50.5	40	80
Well 11	30	20	20	25	20	40	50	20	40
Well 12	15	15	0	5	10	15	5	10	10
Well 13	40	25	30	50	30	60	150	50	80
Well 14	30	20	15	40	25	40	75	40	40
Well 15	20	20	10	20	20	25	25	5	30
Well 16	20	25	15	30	60	40	25	0.5	40
Well 17	20	0	10	10	15	20	10	1	10
Well 18	5	5	0	0	0	0	0	0	0
Well 19	0	0	0	0	0	0	0	0	0
Well 20	0	0	0	0	0	0	0	0	0

PR -Pre monsoon, **M**-Monsoon, **PO**- Post monsoon

1,2 and **3** stands for year 1, year 2 and year 3 respectively

Table 3.14 **Sodium (ppm)**

Wells	PR1	M1	PO1	PR2	M2	PO2	PR3	M3	PO3
Well I	0.248	0.2857	0.261	0.231	0.271	0.248	0.357	0.371	0.257
Well 2	0.301	0.345	0.4229	0.309	0.452	0.429	0.439	0.348	0.319
Well 3	0.342	0.399	0.399	0.391	0.416	0.386	0.412	0.472	0.396
Well 4	0.111	0.166	0.166	0.16	0.166	0.1562	0.182	0.194	0.162
Well 5	0.123	0.189	0.188	0.193	0.173	0.179	0.183	0.183	0.183
Well 6	0.578	0.627	0.621	0.621	0.647	0.578	0.501	0.633	0.601
Well 7	0.43	0.497	0.489	0.468	0.476	0.477	0.476	0.498	0.487
Well 8	0.426	0.462	0.562	0.451	0.463	0.443	0.151	0.522	0.452
Well 9	0.359	0.414	0.414	0.409	0.414	0.401	0.304	0.414	0.404
Well 10	0.801	0.861	0.869	0.869	0.872	0.852	0.767	0.876	0.866
Well 11	0.571	0.555	0.567	0.538	0.542	0.542	0.535	0.565	0.545
Well 12	0.221	0.281	0.296	0.341	0.226	0.265	0.265	0.367	0.276
Well 13	0.541	0.281	0.535	0.512	0.523	0.529	0.521	0.672	0.533
Well 14	0.533	0.569	0.565	0.578	0.556	0.556	0.555	0.661	0.566
Well 15	0.601	0.628	0.634	0.638	0.609	0.609	0.659	0.649	0.619
Well 16	0.464	0.519	0.5127	0.524	0.487	0.512	0.397	0.517	0.497
Well 17	0.395	0.419	0.511	0.415	0.406	0.401	0.411	0.521	0.411
Well 18	0.233	0.258	0.263	0.263	0.254	0.262	0.283	0.353	0.253
Well 19	0.145	0.166	0.168	0.172	0.156	0.152	0.157	0.271	0.162
Well 20	0.145	0.174	0.172	0.158	0.174	0.171	0.165	0.121	0.168

PR -Pre monsoon, **M**-Monsoon, **PO**- Post monsoon

1, 2 and **3** stands for year 1, year 2 and year 3 respectively

Table 3.15 **Potassium (ppm)**

Wells	PR1	M1	PO1	PR2	M2	PO2	PR3	M3	PO3
Well I	0.011	0.014	0.014	0.011	0.037	0.018	0.023	0.023	0.013
Well 2	0.021	0.029	0.031	0.023	0.032	0.031	0.037	0.038	0.028
Well 3	0.011	0.016	0.014	0.012	0.017	0.012	0.021	0.017	0.015
Well 4	0.002	0.004	0.004	0.003	0.004	0.002	0.028	0.007	0.003
Well 5	0.002	0.004	0.007	0.002	0.003	0.003	0.013	0.006	0.003
Well 6	0.038	0.049	0.049	0.057	0.057	0.037	0.042	0.056	0.047
Well 7	0.019	0.034	0.029	0.029	0.032	0.023	0.014	0.028	0.024
Well 8	0.102	0.117	0.197	0.101	0.117	0.101	0.117	0.188	0.107
Well 9	0.142	0.163	0.162	0.155	0.163	0.151	0.167	0.162	0.153
Well 10	0.131	0.141	0.146	0.142	0.141	0.143	0.142	0.139	0.139
Well 11	0.122	0.128	0.143	0.142	0.134	0.114	0.114	0.138	0.124
Well 12	0.02	0.033	0.027	0.021	0.021	0.012	0.018	0.034	0.023
Well 13	0.059	0.033	0.064	0.059	0.052	0.065	0.051	0.087	0.061
Well 14	0.011	0.017	0.017	0.014	0.011	0.018	0.004	0.017	0.013
Well 15	0.12	0.141	0.142	0.143	0.104	0.134	0.123	0.133	0.13
Well 16	0.056	0.085	0.085	0.076	0.065	0.065	0.065	0.075	0.075
Well 17	0.078	0.088	0.092	0.089	0.073	0.072	0.073	0.092	0.082
Well 18	0.018	0.031	0.024	0.038	0.021	0.019	0.033	0.037	0.028
Well 19	0.012	0.012	0.016	0.019	0.015	0.009	0.023	0.018	0.013
Well 20	0.001	0.002	0.002	0.018	0.019	0.018	0.011	0.004	0.002

PR -Pre monsoon, **M**-Monsoon, **PO**- Post monsoon

1, 2 and **3** stands for year 1, year 2 and year 3 respectively

Table 3.16 **Calcium (ppm)**

Wells	PR1	M1	PO1	PR2	M2	PO2	PR3	M3	PO3
Well I	2.4	8.4	2.4	4.4	4.4	2.8	4	4.4	3.2
Well 2	2.4	3.6	4.8	3.6	13.6	4.004	4.4	3.2	4.8
Well 3	3.6	4.4	4.004	4.4	5.6	2.002	7.2	4.8	5.2
Well 4	6.8	5.2	0.97	6.8	6.4	9.2	4.8	4.8	5.6
Well 5	2.8	2	0.8	4	4.8	4	7.2	2.4	3.2
Well 6	46.8	54.05	12.8	56	56.8	61.24	56.8	61.24	51.6
Well 7	4.4	5.2	0.98	7.24	7.6	7.6	7.6	6	6.41
Well 8	16.8	51.2	4.1	27.6	13.6	38.04	13.6	54.4	36.84
Well 9	48.4	40	2.7	35.6	22.02	23.2	77.6	38.04	21.2
Well 10	70.4	57.6	15.9	76.1	33.6	60.8	77.6	48.4	64.4
Well 11	20	55.25	10.3	42.8	64.1	68	30.8	58.5	43.2
Well 12	28.4	29.6	5.5	30	39.6	30	22.8	30.8	27.6
Well 13	30.8	66.8	10.76	56.04	55.3	42	39.24	96.7	44
Well 14	31.2	30.4	7.1	25.2	35.2	37.6	39.6	38.04	38.8
Well 15	58.4	69.26	14.8	64.87	88	84	76.48	76.9	68.5
Well 16	65.2	73.6	16.5	89.6	94.08	85.6	83.3	74.88	75.7
Well 17	49.6	41.6	9.5	49.48	52	65.3	54	44.84	40.8
Well 18	10.4	9.2	2.6	16.8	21.2	19.2	12.8	8.08	8
Well 19	2	2	0.56	4.04	2.4	4	4	1.6	2.4
Well 20	3.2	2.8	0.48	2	2.002	2.8	4.004	5.2	4.4

PR -Pre monsoon, **M**-Monsoon, **PO**- Post monsoon

1, 2 and **3** stands for year 1, year 2 and year 3 respectively

Table 3.17 **Magnesium (ppm)**

Wells	PR1	M1	PO1	PR2	M2	PO2	PR3	M3	PO3
Well I	0.48	20.17	1.07	2.18	2.45	1.44	2.9	2.4	1.68
Well 2	2.67	1.68	10.01	0.2	7.71	2.31	2.26	1.6	2.3
Well 3	0.73	2.3	1.95	1.2	2.85	0.73	2.31	2.6	2.45
Well 4	0.73	2.38	2.48	0.72	3.38	5.13	2.41	2.6	2.86
Well 5	1.2	0.88	2.02	0	2.55	1.98	4.06	1.3	1.58
Well 6	3.16	15.05	32.14	18	36	29.78	30.37	32.96	27.4
Well 7	2.18	2.48	2.46	1.94	4.11	3.9	4.05	3.15	3.14
Well 8	1.46	36.34	10.31	2.67	36.8	15.1	7.33	28.48	19.7
Well 9	9.2	10.68	6.89	3.14	11.68	12.24	8.32	20.06	11.16
Well 10	14.33	42.69	39.8	9.2	19.9	32.4	42.01	25.9	34.4
Well 11	10.45	40.33	25.7	4.6	34.56	25.8	16.71	31.8	23.1
Well 12	3.64	21.36	13.9	3.8	21.5	16.1	12.16	16.9	14.88
Well 13	6.8	36.25	26.9	4.6	29.9	22.5	20.55	37.6	23.15
Well 14	4.6	16.56	17.63	5.6	18.8	20.3	21.3	20.4	20.68
Well 15	6.1	37.9	37.2	4.6	47.57	45.4	41.6	41.6	36.6
Well 16	2.1	39.72	41.25	1.2	50.9	46.7	45.51	40.5	40.88
Well 17	5.1	28.4	24.03	5.4	27.9	35.9	29.31	98.6	21.8
Well 18	6.07	4.4	6.45	10.6	10.14	10.46	6.25	3.08	3.72
Well 19	1.5	1.38	0.48	1.14	2.1	2.01		0.73	1.16
Well 20	0.2	1.49	1.22	0.49	1.01	1.3	2.24	2.9	2.45

PR -Pre monsoon, **M**-Monsoon, **PO-** Post monsoon

1, 2 and **3** stands for year 1, year 2 and year 3 respectively

Table 3.18 **Iron (ppm)**

Wells	PR1	M1	PO1	PR2	M2	PO2	PR3	M3	PO3
Well I	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.6	0.01
Well 2	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.1	0.01
Well 3	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.1	0.01
Well 4	0.01	0.01	0.01	0.01	0.01	0.1	0.5	0.2	0.01
Well 5	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.1	0.01
Well 6	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.1	0.01
Well 7	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.1	0.01
Well 8	0.2	0.01	0.1	0.4	0.2	0.01	0.5	0.1	0.01
Well 9	0.01	0.01	0.2	0.2	0.2	0.1	0.01	0.01	0.4
Well 10	0.01	0.01	0.01	0.01	0.1	0.01	0.4	0.1	0.01
Well 11	0.01	0.01	0.01	0.01	0.01	0.01	0.2	0.01	0.01
Well 12	0.3	0.01	0.01	0.01	0.01	0.01	0.4	0.01	0.01
Well 13	0.4	0.01	0.8	0.01	0.01	1.5	1	0.01	1
Well 14	0.01	0.01	0.01	0.01	0.3	0.1	0.01	0.2	0.6
Well 15	0.01	0.01	0.01	0.01	0.01	0.1	0.01	0.01	0.01
Well 16	0.01	0.01	0.1	0.01	0.01	0.1	0.01	0.01	0.2
Well 17	0.1	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Well 18	0.01	0.01	0.01	0.1	0.1	0.3	1	0.01	2
Well 19	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Well 20	0.01	0.01	0.01	0.01	0.01	0.1	0.01	0.01	0.01

PR -Pre monsoon, **M**-Monsoon, **PO**- Post monsoon

1, 2 and 3 stands for year 1, year 2 and year 3 respectively

Table 3. 19

Wells	Fluoride (ppm)	Phosphate (ppm)
1	0.0011	0.0109
2	0.0015	0.042
3	0.0021	0.048
4	0.0032	0.046
5	0.0012	0.051
6	0.0019	0.054
7	0.0034	0.048
8	0.0025	0.003
9	0.0041	0.061
10	0.013	0.042
11	0.017	0.012
12	0.0051	0.035
13	0.0022	0.042
14	0.019	0.048
15	0.015	0.057
16	0.016	0.031
17	0.0027	0.061
18	0.031	0.001
19	0.0012	0.032
20	0.0018	0.02

Table 3. 20 Analysis of heavy metals in water samples

Well	Copper (ppm)	Cadmium (ppm)	Zinc (ppm)	Mecury (ppm)	Lead (ppm)
Well water 1	0.001	-0.001	0.007	0.001	0.001
Well Water 2	0	-0.002	0.007	0.01	-0.002
Well water 3	0.001	-0.004	0.073	0.016	0.001
Well water 4	0.004	-0.003	0.01	0.038	0.004
Well water 5	0.001	-0.004	0.021	0.078	-0.001
Well water 6	0.004	-0.002	0.007	0.092	-0.002
Well water 7	-0.001	-0.001	0.006	0.094	0.001
Well water 8	0	-0.001	0.007	0.05	0.002
Well water 9	0.005	-0.001	0.057	0.049	0.005
Well water 10	0.001	-0.001	0.042	0.028	-0.002
Well water 11	0	-0.004	0.008	0.018	-0.003
Well water 12	0.001	-0.002	0.016	0.014	0.001
Well water 13	0	-0.002	0.096	0.008	-0.001
Well water 14	0	-0.002	0.092	0.002	-0.002
Well water 15	0.001	-0.002	0.017	0.001	0.001
Well water 16	0.001	-0.003	0.002	0.001	0.002
Well water 17	0.001	-0.002	0.014	0.007	0.001
Well water 18	0	-0.004	1.619	0.004	-0.003
Well water 19	0.001	-0.002	0.105	0.001	-0.004
Well water 20	0	-0.002	0.042	0.001	-0.004

Table 3.21 Correlation Coefficients of all wells

[** - P< 0.01 (highly significant at 1% level); * - P< 0.05 (significant at 5% level)]

All season

	ALK	Ca	CaH	Cl	CO_2	DO
ALK	1.0000	0.8014**	0.8644**	0.5201**	0.0589	-0.0263
Ca	0.8014**	1.0000	0.8981**	0.5782**	0.0369	-0.0466
CaH	0.8644**	0.8981**	1.0000	0.6309**	0.0698	-0.0935
Cl^-	0.5201**	0.5782**	0.6309**	1.0000	0.2016**	-0.1622*
CO_2	0.0589	0.0369	0.0698	0.2016**	1.0000	-0.1613*
DO	-0.0263	-0.0466	-0.0935	-0.1622*	-0.1613*	1.0000
EC	0.1839*	0.2187**	0.2391**	0.1953**	-0.0365	-0.0592
Fe	-0.0490	-0.0452	-0.0691	-0.0461	-0.0323	-0.0037
HT	0.8593**	0.8070**	0.9429**	0.6661	0.0704	-0.1621*
K	0.5962**	0.5581**	0.6138**	0.5153**	0.1184	-0.1316
Mg	0.6591**	0.6882**	0.6850**	0.3941**	0.0664	0.2071**
Na	-0.0651	-0.0910	-0.0628	-0.0327	0.0321	-0.0193
NO_3	0.0664	0.0367	0.0318	-0.0150	0.0023	-0.0267
OABS	0.0619	0.0515	0.0456	0.0864	-0.1319	-0.0290
pH	0.5776**	0.6059**	0.6258**	0.3543**	-0.1072	-0.0701
SO_4	0.4593**	0.5895**	0.5727**	0.6373**	0.1629*	-0.1546*
TEMP	-0.1850*	-0.0477	-0.0549	0.0741	0.0566	-0.3048**
TDS	0.7596**	0.7208**	0.8296**	0.7293**	0.0593	-0.2306**

	EC	Fe	HT	K	Mg	Na
ALK	0.1839*	-0.0490	0.8593**	0.5962**	0.6591**	-0.0651
Ca	0.2187**	-0.0452	0.8070**	0.5581**	0.6882**	-0.0910
CaH	0.2391**	-0.0691	0.9429**	0.6138**	0.6850**	-0.0628
Cl^-	0.1953**	-0.0461	0.6661**	0.5153**	0.3941**	-0.0327
CO_2	-0.0365	-0.0323	0.0704	0.1184	0.0664	0.0321

(ALK–alkalinity, CaH– Calcium hardness, EC– electrical conductivity, HT– total hardness, OABS– Oxygen absorbed, Temp – temperature, TDS – total dissolved solids, DO – dissolved oxygen)

	EC	Fe	HT	K	Mg	Na
DO	-0.0592	-0.0037	-0.1621*	-0.1316	0.2071**	-0.0193
EC	1.0000	0.8124**	0.2272**	0.1742*	0.1738*	-0.0217
Fe	0.8124**	1.0000	-0.0506	-0.0275	0.0007	-0.0056
HT	0.2272**	-0.0506	1.0000	0.6625**	0.6234**	-0.0114
K	0.1742*	-0.0275	0.6625**	1.0000	0.4144**	0.1203
Mg	0.1738*	0.0007	0.6234**	0.4144**	1.0000	-0.0577
Na	-0.0217	-0.0056	-0.0114	0.1203	-0.0577	1.0000
NO_3	0.2398**	0.1432	0.0120	0.1076	-0.0799	-0.0126
OABS	0.8590**	0.7688**	0.0480	0.1484*	0.0293	-0.0220
pH	0.0936	-0.0210	0.6363**	0.4239**	0.4307**	-0.0985
SO_4	0.2263**	0.1109	0.5867**	0.4428**	0.4354**	-0.0632
TEMP	-0.0522	-0.0322	-0.0850	-0.0345	-0.1866*	-0.0384
TDS	0.1854*	-0.0903	0.8818**	0.6143**	0.4785**	-0.0118

	NO_3	**OABS**	**pH**	**SO_4**	**TEMP**	**TDS**
ALK	0.0664	0.0619	0.5776**	0.4593**	-0.1850*	0.7596**
Ca	0.0367	0.0515	0.6059**	0.5895**	-0.0477	0.7208**
CaH	0.0318	0.0456	0.6258**	0.5727**	-0.0549	0.8296**
Cl^-	0.0150	0.0864	0.3543**	0.6373**	0.0741	0.7293**
CO_2	0.0023	-0.1319	-0.1072	0.1629*	0.0566	0.0593
DO	-0.0267	-0.0290	-0.0701	-0.1546*	-0.3048**	-0.2306**
EC	0.2398**	0.8590**	0.0936	0.2263**	-0.0522	0.1854*
Fe	0.1432	0.7688**	-0.0210	0.1109	-0.0322	-0.0903
HT	0.0120	0.0480	0.6363**	0.5867**	-0.0850	0.8818**
K	0.1076	0.1484*	0.4239**	0.4428**	-0.0345	0.6143**
Mg	-0.0799	0.0293	0.4307**	0.4354**	-0.1866*	0.4785**
Na	-0.0126	-0.0220	-0.0985	-0.0632	-0.0384	-0.0118
NO_3	1.0000	0.2015**	-0.1851*	-0.1282	-0.0642	0.1424
OABS	0.2015**	1.0000	0.0266	0.0700	-0.0752	0.0393
pH	-0.1851*	0.0266	1.0000	0.4634**	-0.0083	0.5378**
SO_4	-0.1282	0.0700	0.4634**	1.0000	0.1431	0.5890**
TEMP	-0.0642	-0.0752	-0.0083	0.1431	1.0000	0.0177
TDS	0.1424	0.0393	0.5378**	0.5890**	0.0177	1.0000

Pre-monsoon

	ALK	Ca	CaH	Cl^-	CO_2	DO
ALK	1.0000	0.7844**	0.7444**	0.5460**	-0.0994	-0.2042
Ca	0.7844**	1.0000	0.9804**	0.7343**	-0.0682	-0.2104
CaH	0.7444**	0.9804**	1.0000	0.7040**	-0.0514	-0.1726
Cl^-	0.5460**	0.7343**	0.7040**	1.0000	0.0525	-0.1838
CO_2	-0.0994	-0.0682	-0.0514	0.0525	1.0000	-0.3225*
DO	-0.2042	-0.2104	-0.1726	-0.1838	-0.3225*	1.0000
EC	0.5295**	0.7340**	0.7160**	0.5731**	0.0240	-0.1042
Fe	0.0467	-0.0106	-0.068	-0.0234	-0.0873	-0.0484
HT	0.7610**	0.9653**	0.9641**	0.7442**	-0.0760	-0.2489
K	0.5864**	0.6354**	0.6034**	0.5604**	0.0532	-0.2508
Mg	0.3030*	0.5738**	0.6010**	0.4551**	-0.0798	0.0405
Na	0.6025**	0.7640**	0.7218**	0.8247**	0.1338	-0.1579
NO_3	0.2278	0.1576	0.1517	0.0038	0.0103	-0.1015
OABS	0.6122**	0.5309**	0.5162**	0.5048**	-0.0118	-0.2074
pH	0.6338**	0.7014**	0.6951**	0.4226**	-0.2652*	-0.2562*
SO_4	0.3475**	0.5742**	0.4931**	0.6166**	0.0028	-0.2360
TEMP	0.1554	0.1475	0.1385	0.0688	-0.1639	0.2770*
TDS	0.7345**	0.9063**	0.8806**	0.8372**	-0.0691	-0.2039

	EC	Fe	HT	K	Mg	Na
ALK	0.5295**	0.0467	0.7610**	0.5864**	0.3030*	0.6025**
Ca	0.7340**	-0.0106	0.9653**	0.6354**	0.5738**	0.7640**
CaH	0.7160**	-0.0682	0.9641**	0.6034**	0.6010**	0.7218**
Cl^-	0.5731**	-0.0234	0.7442**	0.5604**	0.4551**	0.8247**
CO_2	0.0240	-0.0873	-0.0760	0.0532	-0.0798	0.1338
DO	-0.1042	-0.0484	-0.2489	-0.2508	0.0405	-0.1579
EC	1.0000	0.0637	0.6569**	0.5404**	0.5533**	0.6708**
Fe	0.0637	1.0000	0.0358	0.1020	0.1445	0.0310
HT	0.6569**	0.0358	1.0000	0.6279**	0.5901**	0.7400**
K	0.5404**	0.1020	0.6279**	1.0000	0.3550*	0.6221**
Mg	0.5533**	0.1445	0.5901**	0.3550**	1.0000	0.4581**

	EC	Fe	HT	K	Mg	Na
Na	0.6708**	0.0310	0.7400**	0.6221**	0.4581**	1.0000
NO_3	0.1054	-0.1966	0.1367	0.1474	-0.1153	0.1432
OABS	0.3409**	-0.0643	0.5020**	0.5091**	0.1442	0.4058**
pH	0.4153**	0.0052	0.7060**	0.4663**	0.3163*	0.4315**
SO_4	0.5812**	0.3460**	0.5733**	0.4498**	0.4545**	0.6062**
TEMP	0.4290**	0.1699	0.0384	0.0551	0.3527**	0.0556
TDS	0.6777**	0.0390	0.9202**	0.6256**	0.5857**	0.7799**

	NO_3	OABS	pH	SO_4	TEMP	TDS
ALK	0.2278	0.6122**	0.6338**	0.3475**	0.1554	0.7345**
Ca	0.1576	0.5309**	0.7014**	0.5742**	0.1475	0.9063**
CaH	0.1517	0.5162**	0.6951**	0.4931**	0.1385	0.8806**
Cl^-	0.0038	0.5048**	0.4226**	0.6166**	0.0688	0.8372**
CO_2	0.0103	-0.0118	-0.2652*	0.0028	-0.1639	-0.0691
DO	-0.1015	-0.2074	0.2562*	-0.2360	0.2770*	-0.2039
EC	0.1054	0.3409**	0.4153**	0.5812**	0.4290**	0.6777**
Fe	-0.1966	-0.0643	0.0052	0.3460*	0.1699	0.0390
HT	0.1367	0.5020**	0.7060**	0.5733**	0.0384	0.9202**
K	0.1474	0.5091**	0.4663**	0.4498**	0.0551	0.6256**
Mg	0.1153	0.1442	0.3163*	0.4545**	0.3527**	0.5857**
Na	0.1432	0.4058**	0.4315**	0.6062**	0.0556	0.7799**
NO_3	1.0000	0.2493	0.0968	-0.0960	-0.1119	0.1585
OABS	0.2493	1.0000	0.3653**	0.2578*	0.2134	0.5699**
pH	0.0968	0.3653**	1.0000	0.3777**	-0.0518	0.6085**
SO_4	-0.0960	0.2578*	0.3777**	1.0000	0.1648	0.6146**
TEMP	-0.1119	0.2134	-0.0518	0.1648	1.0000	0.1215
TDS	0.1585	0.5699**	0.6085**	0.6146**	0.1215	1.0000

Monsoon

	ALK	Ca	CaH	Cl^-	CO_2	DO
ALK	1.0000	0.8929**	0.8883**	0.5575**	-0.0137	-0.0045
Ca	0.8929**	1.0000	0.9791**	0.6123**	0.0000	-0.1238
CaH	0.8883**	0.9791**	1.0000	0.5706**	0.0065	-0.1035
Cl^-	0.5575**	0.6123**	0.5706**	1.0000	0.2411	-0.2098
CO_2	-0.0137	0.0000	0.0065	0.2411	1.0000	-0.2592*
DO	-0.0045	-0.1238	-0.1035	-0.2098	-0.2592*	1.0000
EC	-0.0298	0.0436	0.0172	-0.0089	-0.1870	-0.1091
Fe	-0.1438	-0.1252	-0.1389	-0.1383	-0.2164	-0.0231
HT	0.9088**	0.9818**	0.9612**	0.6356**	-0.0359	-0.1516
K	0.6588**	0.6666**	0.6452**	0.5171**	-0.0211	-0.0798
Mg	0.7017**	0.6562**	0.6693**	0.3605**	-0.0231	0.3356**
Na	-0.1452	-0.1277	-0.1247	0.0204	0.0331	0.1369
NO_3	-0.0180	0.0423	0.0395	-0.0029	-0.0149	-0.0076
OABS	-0.0730	-0.0703	-0.0930	-0.0776	-0.2339	-0.0669
pH	0.5134**	0.5684**	0.5586**	0.1426	-0.3384**	-0.0053
SO_4	0.6278**	0.7343**	0.6932**	0.6548**	-0.0045	-0.1665
TEMP	-0.1607	-0.0132	-0.0228	0.0342	0.1098	-0.3668**
TDS	0.7276**	0.7631**	0.7319**	0.5941**	-0.0497	-0.3169*

	EC	Fe	HT	K	Mg	Na
ALK	-0.0298	-0.1438	0.9088**	0.6588**	0.7017**	-0.1452
Ca	0.0436	-0.1252	0.9818**	0.6666**	0.6562**	-0.1277
CaH	0.0172	-0.1389	0.9612**	0.6452**	0.6693**	-0.1247
Cl^-	-0.0089	-0.1383	0.6356**	0.5171**	0.3605**	0.0204
CO_2	-0.1870	-0.2164	-0.0359	-0.0211	0.0231	0.0331
DO	-0.1091	-0.0231	-0.1516	-0.0798	0.3356**	0.1369
EC	1.0000	0.9689**	0.0068	0.0063	0.0063	-0.0311
Fe	0.9689**	1.0000	-0.1549	-0.0865	-0.0553	-0.0070
HT	0.0068	-0.1549	1.0000	0.7056**	0.6299**	-0.1329
K	0.0063	-0.0865	0.7056**	1.0000	0.4291**	-0.1023
Mg	0.0063	-0.0553	0.6299**	0.4291**	1.0000	-0.0839

	E C	Fe	HT	K	Mg	Na
Na	-0.0311	-0.0070	-0.1329	-0.1023	-0.0839	1.0000
NO_3	0.3446**	0.3411**	-0.0410	0.1316	-0.1122	0.0227
OABS	0.9146**	0.9341**	-0.0985	0.0640	-0.0415	-0.0177
pH	-0.0829	-0.1522	0.6138**	0.4372**	0.3945**	-0.1447
SO_4	0.0977	-0.0399	0.7190**	0.4603**	0.4109**	-0.1034
TEMP	-0.0116	-0.0311	0.0298	0.0565	-0.2164	0.0787
TDS	-0.0867	-0.2182	0.8054**	0.5618**	0.3457**	-0.0811

	NO_3	OABS	pH	SO_4	TEMP	TDS
ALK	-0.0180	-0.0730	0.5134**	0.6278**	-0.1607	0.7276**
Ca	-0.0423	-0.0703	0.5684**	0.7343**	-0.0132	0.7631**
CaH	-0.0395	-0.0930	0.5586**	0.6932**	-0.0228	0.7319**
Cl^-	-0.0029	-0.0776	0.1426	0.6548**	0.0342	0.5941**
CO_2	-0.0149	-0.2339	-0.3384**	-0.0045	0.1098	-0.0497
DO	-0.0076	-0.0669	-0.0053	-0.1665	-0.3668**	-0.3169*
EC	0.3446**	0.9146**	-0.0829	0.0977	-0.0116	-0.0867
Fe	0.3411**	0.9341**	-0.1522	-0.0399	-0.0311	-0.2182
HT	-0.0410	-0.0985	0.6138**	0.7190**	0.0298	0.8054**
K	0.1316	0.0640	0.4372**	0.4603**	0.0565	0.5618**
Mg	-0.1122	-0.0415	0.3945**	0.4109**	-0.2164	0.3457**
Na	0.0227	-0.0177	-0.1447	-0.1034	0.0787	-0.0811
NO_3	1.0000	0.2623*	-0.2300	-0.0437	0.2622*	0.1879
OABS	0.2623*	1.0000	-0.0641	0.0343	-0.0559	-0.1566
pH	-0.2300	-0.0641	1.0000	0.3800**	0.1400	0.5252**
SO_4	-0.0437	0.0343	0.3800**	1.0000	-0.0802	0.5925**
TEMP	0.2622*	-0.0559	0.1400	-0.0802	1.0000	0.2661*
TDS	0.1879	-0.1566	0.5252**	0.5925**	0.2661*	1.0000

Post-monsoon

	ALK	Ca	CaH	Cl^-	CO_2	DO
ALK	1.0000	0.7348**	0.9634**	0.6123**	0.2919*	-0.0805
Ca	0.7348**	1.0000	0.7390**	0.4457**	0.2118	0.1177
CaH	0.9634**	0.7390**	1.0000	0.6605**	0.2511	-0.0869
Cl^-	0.6123**	0.4457**	0.6605**	1.0000	0.3193*	-0.0791
CO_2	0.2919*	0.2118	0.2511	0.3193*	1.0000	0.0407
DO	-0.0805	0.1177	-0.0869	-0.0791	0.0407	1.0000
EC	0.9084**	0.6716**	0.9299**	0.8240**	0.3989**	-0.1203
Fe	0.0861	0.0935	0.0515	0.0723	0.3205*	0.0079
HT	0.9068**	0.5322**	0.9181**	0.6804**	0.2669*	-0.2201
K	0.5519**	0.3832**	0.5896**	0.5125**	0.2993*	-0.1369
Mg	0.8205**	0.9048**	0.8314**	0.5499**	0.3222*	0.0437
Na	-0.0364	-0.0963	-0.0441	-0.0908	0.0420	-0.1866
NO_3	-0.0556	-0.0823	-0.0473	-0.0023	0.1123	-0.0705
OABS	0.2498	0.1982	0.2834*	0.4965**	0.0108	0.0015
pH	0.6973**	0.6634**	0.6733**	0.4644**	0.1605	-0.0058
SO_4	0.6540**	0.6429**	0.6994**	0.6567**	0.4117**	0.0246
TEMP	-0.2596*	-0.2777*	-0.2270	-0.1576	-0.1005	-0.0302
TDS	0.8513**	0.4964**	0.8841**	0.7658**	0.2844*	-0.2352

	EC	Fe	HT	K	Mg	Na
ALK	0.9084**	0.0861	0.9068**	0.5519**	0.8205**	-0.0364
Ca	0.6716**	0.0935	0.5322**	0.3832**	0.9048**	-0.0963
CaH	0.9299**	0.0515	0.9181**	0.5896**	0.8314**	-0.0441
Cl^-	0.8240**	0.0723	0.6804**	0.5125**	0.5499**	-0.0908
CO_2	0.3989**	0.3205*	0.2669*	0.2993*	0.3222*	0.0420
DO	-0.1203	0.0079	-0.2201	-0.1369	0.0437	-0.1866
EC	1.0000	0.0880	0.9114**	0.6663**	0.7913**	-0.0454
Fe	0.0880	1.0000	0.0875	0.0088	0.0680	-0.0136
HT	0.9114**	0.0875	1.0000	0.6538**	0.6664**	0.0651
K	0.6663**	0.0088	0.6538**	1.0000	0.4672**	0.3431**

	E C	Fe	HT	K	Mg	Na
Mg	0.7913**	0.0680	0.6664**	0.4672**	1.0000	-0.0820
Na	-0.0454	-0.0136	0.0651	0.3431**	-0.0820	1.0000
NO$_3$	0.0337	-0.1663	-0.0549	0.0165	-0.0632	-0.0702
OABS	0.4176**	-0.1265	0.3432**	0.4128**	0.2712*	-0.0911
pH	0.6049**	0.2423	0.6037**	0.3944**	0.6533**	0.1221
SO$_4$	0.7385**	0.3001*	0.6345**	0.5015**	0.7207**	-0.0721
TEMP	-0.1897	-0.1282	-0.1210	-0.1572	-0.2610*	0.1444
TDS	0.9367**	0.0452	0.9532**	0.6573**	0.6310**	0.0387

	NO$_3$	OABS	pH	SO$_4$	TEMP	TDS
ALK	-0.0556	0.2498	0.6973**	0.6540**	-0.2596*	0.8513**
Ca	-0.0823	0.1982	0.6634**	0.6429**	-0.2777*	0.4964*
CaH	-0.0473	0.2834*	0.6733**	0.6994**	-0.2270	0.8841**
Cl^-	-0.0023	0.4965**	0.4644**	0.6567**	-0.1576	0.7658**
CO$_2$	0.1123	0.0108	0.1605	0.4117**	-0.1005	0.2844*
DO	-0.0705	0.0015	-0.0058	0.0246	-0.0302	-0.2352
EC	0.0337	0.4176**	0.6049**	0.7385**	-0.1897	0.9367**
Fe	-0.1663	-0.1265	0.2423	0.3001*	-0.1282	0.0452
HT	-0.0549	0.3432**	0.6037**	0.6345**	-0.1210	0.9532**
K	0.0165	0.4128**	0.3944**	0.5015**	-0.1572	0.6573**
Mg	-0.0632	0.2712*	0.6533**	0.7207**	-0.2610*	0.6310**
Na	-0.0702	-0.0911	-0.1221	-0.0721	0.1444	0.0387
NO$_3$	1.0000	-0.0659	-0.4319**	-0.2336	0.1978	0.0236
OABS	-0.0659	1.0000	0.2240	0.2768*	0.0929	0.4009**
pH	-0.4319**	0.2240	1.0000	0.6984**	-0.2482	0.5467**
SO$_4$	-0.2336	0.2768*	0.6984**	1.0000	-0.1770	0.6424**
TEMP	0.1978	0.0929	-0.2482	-0.1770	1.0000	-0.0670
TDS	0.0236	0.4009**	0.5467**	0.6424**	-0.0670	1.0000

Table 4.1 Calculation of Water Quality Index of Well 1

Parameter	Unit wt (wi)	Standards (Si)	Observed value (Vi)	Quality standards (qi)	qiwi
Nitrate	0.05	20	0.7367	3.6835	0.1842
DO	0.2	5	6.1111	88.426	17.6852
pH	0.004	7	6.3889	-40.74	-0.163
Chloride	0.004	250	12.6667	5.0667	0.0203
Alkalinity	0.0083	120	9.4444	7.8703	0.0653
TH	0.0033	300	15.7778	5.2593	0.0174
TDS	0.002	500	66.2222	13.2444	0.0265
water quality index =		**65.6696**			
Pre monsoon					
Nitrate	0.05	20	0.1367	0.6835	0.0342
DO	0.2	5	6.4	85.4167	17.0833
pH	0.004	7	6.3331	-44.4467	-0.1778
Chloride	0.004	250	12	4.8	0.0192
Alkalinity	0.0083	120	7.6667	6.3889	0.053
TH	0.0033	300	10	3.3333	0.011
TDS	0.002	500	65.6667	13.13333	0.0263
water quality index =		**62.7733**			
Monsoon					
Nitrate	0.05	20	2.0067	10.0335	0.5017
DO	0.2	5	6.2	87.5	17.5
pH	0.004	7	6.3333	-44.4467	-0.1778
Chloride	0.004	250	11.3333	4.5333	0.0181
Alkalinity	0.0083	120	10.6667	8.8889	0.0738
TH	0.0033	300	10.6667	3.5556	0.0117
TDS	0.002	500	67	13.4	0.0268
water quality index =		**66.1058**			
Post- monsoon					
Nitrate	0.05	20	0.0667	0.3335	0.0167
DO	0.2	5	5.7333	92.3615	18.4723
pH	0.004	7	6.5	-33.3333	-0.1333
Chloride	0.004	250	14.6667	5.8667	0.0235
Alkalinity	0.0083	120	10	8.3333	0.0692
TH	0.0033	300	26.6667	8.8889	0.0293
TDS	0.002	500	66	13.2	0.0264
water quality index =		**68.1296**			

Table 4.2 Calculation of Water Quality Index of Well 2

Parameter	Unit wt (wi)	Standards (Si)	Observed value (Vi)	Quality standards (qi)	qiwi
Nitrate	0.05	20	2.4778	12.389	0.6195
DO	0.2	5	6.2756	86.7125	17.3425
pH	0.004	7	5.8778	-74.8133	-0.2993
Chloride	0.004	250	20	8	0.032
Alkalinity	0.0083	120	16.6667	13.8889	0.1153
TH	0.0033	300	18.6667	6.2222	0.0205
TDS	0.002	500	114.444	22.8889	0.0458
water quality index =		**65.8184**			
Premonsoon					
Nitrate	0.05	20	2.333	11.6665	0.5833
DO	0.2	5	5.6533	93.1948	18.639
pH	0.004	7	5.9	-73.3333	-0.2933
Chloride	0.004	250	16.6667	6.6667	0.0267
Alkalinity	0.0083	120	6.6667	5.5556	0.0461
TH	0.0033	300	15.3333	5.1111	0.0169
TDS	0.002	500	119.3333	23.8667	0.0477
water quality index =		**70.2**			
Monsoon					
Nitrate	0.05	20	3.1667	15.8335	0.7917
DO	0.2	5	6.2933	86.5281	17.3056
pH	0.004	7	5.7333	-84.4467	-0.3378
Chloride	0.004	250	20	8	0.032
Alkalinity	0.0083	120	36.6667	30.5556	0.2536
TH	0.0033	300	14.6667	4.8889	0.0161
TDS	0.002	500	151.333	30.2667	0.0605
water quality index =		**66.7223**			
Post monsoon					
Nitrate	0.05	20	1.9333	9.6665	0.4833
DO	0.2	5	6.88	80.4167	16.0833
pH	0.004	7	6	-66.6667	-0.2667
Chloride	0.004	250	23.3333	9.3333	0.0373
Alkalinity	0.0083	120	6.6667	5.5556	0.0461
TH	0.0033	300	26	8.6667	0.0286
TDS	0.002	500	72.6667	14.5333	0.0291
water quality index =		**60.5342**			

Table 4.3 Calculation of Water Quality Index of Well 3

Parameter	Unit wt (wi)	Standards (Si)	Observed value (Vi)	Quality standards (qi)	qiwi
Nitrate	0.05	20	1.5578	7.789	0.3895
DO	0.2	5	6.3133	86.3198	17.264
pH	0.004	7	6.2889	-47.4067	-0.1896
Chloride	0.004	250	26	10.4	0.0416
Alkalinity	0.0083	120	10.8889	9.0741	0.0753
TH	0.0033	300	19.1111	6.3704	0.021
TDS	0.002	500	104.3333	20.8667	0.0417
water quality index =		**64.9612**			
Pre-monsoon					
Nitrate	0.05	20	0.4367	2.1835	0.1092
DO	0.2	5	5.88	90.8333	18.1667
pH	0.004	7	6.333	-44.4467	-0.1778
Chloride	0.004	250	25.3333	10.1333	0.0405
Alkalinity	0.0083	120	10	8.3333	0.0692
TH	0.0033	300	14.6667	4.88889	0.0161
TDS	0.002	500	108.6667	21.7333	0.0435
water quality index =		**67.2583**			
Monsoon					
Nitrate	0.05	20	1.5367	7.6835	0.3842
DO	0.2	5	6.6133	83.1948	16.639
pH	0.004	7	6.2667	-48.8867	-0.1955
Chloride	0.004	250	27.3333	10.9333	0.0437
Alkalinity	0.0083	120	13.3333	11.1111	0.0922
TH	0.0033	300	16	5.3333	0.0176
TDS	0.002	500	125	25	0.05
water quality index =		**62.7067**			
Post monsoon					
Nitrate	0.05	20	2.7	13.5	0.675
DO	0.2	5	6.4467	84.9302	16.986
pH	0.004	7	6.2667	-48.8867	-0.1955
Chloride	0.004	250	25.3333	10.1333	0.0405
Alkalinity	0.0083	120	9.3333	7.7777	0.0646
TH	0.0033	300	26.6667	8.8889	0.0293
TDS	0.002	500	79.3333	15.8667	0.0317
water quality index =		**64.9177**			

Table4. 4 Calculation of Water Quality Index of Well 4

Parameter	Unit wt (wi)	Standards (Si)	Observed value (Vi)	Quality standards (qi)	qiwi
Nitrate	0.05	20	0.37	1.85	0.0925
DO	0.2	5	5.2822	97.0604	19.4121
pH	0.004	7	6.6778	-21.48	-0.0859
Chloride	0.004	250	8.444	3.3778	0.0135
Alkalinity	0.0083	120	15.5556	12.963	0.1076
TH	0.0033	300	20.2222	6.7407	0.0222
TDS	0.002	500	66.4444	13.2889	0.0266
water quality index =		**72.1229**			
Pre monsoon					
Nitrate	0.05	20	0.233	1.1665	0.0583
DO	0.2	5	4.46	105.625	21.125
pH	0.004	7	6.7	-20	-0.08
Chloride	0.004	250	8.6667	3.4667	0.0139
Alkalinity	0.0083	120	18	15	0.1245
TH	0.0033	300	19.3333	6.4444	0.0213
TDS	0.002	500	84	16.8	0.0336
water quality index =		**78.4115**			
Monsoon					
Nitrate	0.05	20	0.34	1.7	0.085
DO	0.2	5	6.5133	84.2365	16.8473
pH	0.004	7	6.5333	-31.1133	-0.1245
Chloride	0.004	250	8.6667	3.4667	0.0139
Alkalinity	0.0083	120	13.3333	11.1111	0.0922
TH	0.0033	300	16.6667	5.5556	0.0183
TDS	0.002	500	70.3333	14.0667	0.0281
water quality index =		**62.4462**			
Post monsoon					
Nitrate	0.05	20	0.5367	2.6835	0.1342
DO	0.2	5	4.8733	101.3198	20.264
pH	0.004	7	6.8	-13.3333	-0.0533
Chloride	0.004	250	8	3.2	0.0128
Alkalinity	0.0083	120	15.3333	12.7778	0.1061
TH	0.0033	300	24.6667	8.2222	0.0271
TDS	0.002	500	45	9	0.018
water quality index =		**75.511**			

Table 4. 5 Calculation of Water Quality Index of Well 5

Parameter	Unit wt (wi)	Standards (Si)	Observed value (Vi)	Quality standards (qi)	qiwi
Nitrate	0.05	20	0.5456	2.728	0.1364
DO	0.2	5	6.5733	83.6115	16.7223
pH	0.004	7	6.3556	-42.96	-0.1718
Chloride	0.004	250	9.333	3.7333	0.0149
Alkalinity	0.0083	120	22.2222	18.5185	0.1537
TH	0.0033	300	13.7778	4.5926	0.0152
TDS	0.002	500	65.7778	13.1556	0.0263
water quality index =		**62.2126**			
Pre monsoon					
Nitrate	0.05	20	0.5667	2.8335	0.1417
DO	0.2	5	5.6933	92.7781	18.5556
pH	0.004	7	6.5333	-31.1133	-0.1245
Chloride	0.004	250	8	3.2	0.0128
Alkalinity	0.0083	120	9.3333	7.7777	0.0646
TH	0.0033	300	11.3333	3.7778	0.0125
TDS	0.002	500	74.3333	14.8667	0.0297
water quality index =		**68.8233**			
Monsoon					
Nitrate	0.05	20	0.5367	2.6835	0.1342
DO	0.2	5	5.5667	94.0969	18.8194
pH	0.004	7	6	-66.6667	-0.2667
Chloride	0.004	250	11.3333	4.5333	0.0181
Alkalinity	0.0083	120	48	40	0.332
Total Hardi	0.0033	300	10.6667	3.5556	0.0117
Total Solids	0.002	500	84	16.8	0.0336
water quality index =		**70.259**			
Post monsoon					
Nitrate	0.05	20	0.5333	2.6665	0.1333
DO	0.2	5	8.46	63.9583	12.7917
pH	0.004	7	6.5333	-31.1133	-0.1245
Chloride	0.004	250	8.6667	3.4667	0.0139
Alkalinity	0.0083	120	9.3333	7.7777	0.0646
TH	0.0033	300	19.3333	6.4444	0.0213
TDS	0.002	500	39	7.8	0.0156
water quality index =		**47.5546**			

Table 4. 6 Calculation of Water Quality Index of Well 6

Parameter	Unit wt (wi)	Standards (Si)	Observed value (Vi)	Quality standards (qi)	qiwi
Nitrate	0.05	20	0.6811	3.4055	0.1703
DO	0.2	5	6.4044	85.3708	17.0742
pH	0.004	7	7.4444	29.6267	0.1185
Chloride	0.004	250	39.5556	15.8222	0.1633
Alkalinity	0.0083	120	153.1111	127.5926	1.059
TH	0.0033	300	172.4444	57.4815	0.1897
TDS	0.002	500	314.3333	62.8667	0.1257
water quality index =		**62.2219**			
Pre monsoon					
Nitrate	0.05	20	1.0033	5.0165	0.2508
DO	0.2	5	6.88	80.4167	16.0833
pH	0.004	7	7.4	26.6667	0.1067
Chloride	0.004	250	38.6667	15.4667	0.0619
Alkalinity	0.0083	120	114.6667	95.5556	0.7931
TH	0.0033	300	158.6667	52.8889	0.1745
TDS	0.002	500	292.3333	58.4667	0.1169
water quality index =		**64.7543**			
Monsoon					
Nitrate	0.05	20	0.87	4.35	0.2175
DO	0.2	5	50.6533	93.1948	18.639
pH	0.004	7	7.3333	22.22	0.0889
Chloride	0.004	250	44	17.6	0.0704
Alkalinity	0.0083	120	182	151.6667	1.2588
TH	0.0033	300	174.6667	58.2222	0.1921
TDS	0.002	500	346	69.2	0.1384
water quality index =		**75.8656**			
post monsoon					
Nitrate	0.05	20	0.17	0.85	0.0425
DO	0.2	5	6.68	82.5	16.5
pH	0.004	7	7.6	40	0.16
Chloride	0.004	250	36	14.4	0.0576
Alkalinity	0.0083	120	162.6667	135.5556	1.1251
TH	0.0033	300	184	61.3333	0.2024
TDS	0.002	500	304.6667	60.9333	0.1219
water quality index =		**67.0452**			

Table 4. 7 Calculation of Water Quality Index of Well 7

Parameter	Unit wt (wi)	Standards (Si)	Observed value (Vi)	Quality standards (qi)	qiwi
Nitrate	0.05	20	2.2778	11.389	0.5695
DO	0.2	5	5.4378	95.4396	19.0879
pH	0.004	7	5.6444	-90.3733	-0.3615
Chloride	0.004	250	36	14.4	0.0576
Alkalinity	0.0083	120	16.6667	13.8889	0.1153
Total Hardı	0.0033	300	24.4444	8.1481	0.0269
Total Solids	0.002	500	128.4444	25.6889	0.0514
water quality index =		**71.9699**			
Pre monsoon					
Nitrate	0.05	20	1.5	7.5	0.375
DO	0.2	5	5.1733	98.1948	19.639
pH	0.004	7	5.5333	-97.78	-0.3911
Chloride	0.004	250	35.3333	14.1333	0.0565
Alkalinity	0.0083	120	18	15	0.1245
TH	0.0033	300	21.333	7.1111	0.0235
TDS	0.002	500	114.3333	22.8667	0.0457
water quality index =		**73.1704**			
Monsoon					
Nitrate	0.05	20	3.3333	16.6665	0.8333
DO	0.2	5	5.7533	92.1531	18.4306
pH	0.004	7	5.6	-93.3333	-0.3733
Chloride	0.004	250	34	13.6	0.0544
Alkalinity	0.0083	120	26.6667	22.2222	0.1844
TH	0.0033	300	21.3333	7.1111	0.0235
TDS	0.002	500	159.3333	31.8667	0.0637
water quality index =		**70.7535**			
Post monsoon					
Nitrate	0.05	20	2	10	0.5
DO	0.2	5	5.3867	95.9719	19.1944
pH	0.004	7	5.8	-80	-0.32
Chloride	0.004	250	38.6667	15.4667	0.0619
Alkalinity	0.0083	120	5.3333	4.4444	0.0369
TH	0.0033	300	30.6667	10.2222	0.0337
TDS	0.002	500	111.6667	22.3333	0.0447
water quality index =		**71.9865**			

Table 4.8 Calculation of Water Quality Index of Well 8

Parameter	Unit wt (wi)	Standards (Si)	Observed value (Vi)	Quality standards (qi)	qiwi
Nitrate	0.05	20	0.69	3.45	0.1725
DO	0.2	5	5.64	93.3333	18.6667
pH	0.004	7	6.9556	-2.96	-0.0118
Chloride	0.004	250	14.222	5.6889	0.0228
Alkalinity	0.0083	120	105.5556	87.963	0.7301
TH	0.0033	300	112	37.3333	0.1232
TDS	0.002	500	176.4444	35.2889	0.0706
water quality index=		72.8054			
Pre monsoon					
Nitrate	0.05	20	0.0667	0.3335	0.0167
DO	0.2	5	4.96	100.4167	20.0833
pH	0.004	7	6.4667	-35.5533	-0.1422
Chloride	0.004	250	16	6.4	0.0256
Alkalinity	0.0083	120	88.6667	73.8889	0.6133
TH	0.0033	300	62.6667	20.8889	0.0689
TDS	0.002	500	121.6667	24.3333	0.0487
water quality index =		76.2676			
Monsoon					
Nitrate	0.05	20	2.0033	10.0165	0.5008
DO	0.2	5	6.1933	87.5698	17.514
pH	0.004	7	7.2667	17.78	0.0711
Chloride	0.004	250	12.6667	5.0667	0.0203
Alkalinity	0.0083	120	160	133.3333	1.1067
TH	0.0033	300	166.6667	55.5556	0.1833
TDS	0.002	500	257.3333	51.4667	0.1029
water quality index =		71.7935			
Post monsoon					
Nitrate	0.05	20	0	0	0
DO	0.2	5	5.7667	92.0135	18.4027
pH	0.004	7	7.1333	8.8867	0.0355
Chloride	0.004	250	14	5.6	0.0224
Alkalinity	0.0083	120	68	56.6667	0.4703
TH	0.0033	300	106.6667	35.5556	0.1173
TDS	0.002	500	150.3333	30.0667	0.0601
water quality index =		70.3551			

Table 4. 9 Calculation of Water Quality Index of Well 9

Parameter	Unit wt (wi)	Standards (Si)	Observed value (Vi)	Quality standards (qi)	qiwi
Nitrate	0.05	20	0.8022	4.011	0.2006
DO	0.2	5	5.8667	90.9719	18.1944
pH	0.004	7	7.2111	14.0733	0.0563
Chloride	0.004	250	38	15.2	0.0608
Alkalinity	0.0083	120	73.1111	60.9259	0.5057
TH	0.0033	300	109.5556	36.5185	0.1205
TDS	0.002	500	223.2222	44.6444	0.0893
water quality index =		**70.7935**			
Pre monsoon					
Nitrate	0.05	20	1	5	0.25
DO	0.2	5	4.8533	101.5281	20.3056
pH	0.004	7	7.1333	8.8867	0.0355
Chloride	0.004	250	42.6667	17.0667	0.0683
Alkalinity	0.0083	120	65	54.1667	0.4496
TH	0.0033	300	112.6667	37.5556	0.1239
TDS	0.002	500	257.3333	51.4667	0.1029
water quality index =		**78.5563**			
Monsoon					
Nitrate	0.05	20	1.0067	5.0335	0.2517
DO	0.2	5	6.46	84.7917	16.9583
pH	0.004	7	7.2333	15.5533	0.0622
Chloride	0.004	250	40.6667	16.2667	0.0651
Alkalinity	0.0083	120	115.6667	96.3889	0.8
TH	0.0033	300	118.6667	39.5556	0.1305
TDS	0.002	500	221.3333	44.2667	0.0885
water quality index =		**67.5861**			
Post monsoon					
Nitrate	0.05	20	0.4	2	0.1
DO	0.2	5	6.2867	86.5969	17.3194
pH	0.004	7	7.2667	17.78	0.0711
Chloride	0.004	250	30.6667	12.2667	0.0491
Alkalinity	0.0083	120	38.6667	32.21222	0.2674
TH	0.0033	300	97.3333	32.4444	0.1071
TDS	0.002	500	191	38.2	0.0764
water quality index =		**66.2389**			

Table 4. 10 Calculation of Water Quality Index of Well 10

Parameter	Unit wt (wi)	Standards (Si)	Observed value (Vi)	Quality standards (qi)	qiwi
Nitrate	0.05	20	0.0578	0.289	0.0145
DO	0.2	5	5.6333	93.4031	18.6806
pH	0.004	7	7.5111	34.0733	0.1363
Chloride	0.004	250	96.4444	38.5778	0.1543
Alkalinity	0.0083	120	135.5556	112.963	0.9376
Th	0.0033	300	196.8889	65.6296	0.2166
TDS	0.002	500	392.5556	78.5111	0.157
water quality index =		**74.7307**			
Pre monsoon					
Nitrate	0.05	20	0	0	0
DO	0.2	5	5.24	97.5	19.5
pH	0.004	7	7.5667	37.78	0.1511
Chloride	0.004	250	132.6667	53.0667	0.2123
Alkalinity	0.0083	120	138.6667	115.5556	0.9591
TH	0.0033	300	222.6667	74.2222	0.2449
TDS	0.002	500	501	100.2	0.2004
water quality index =		**78.3057**			
Monsoon					
Nitrate	0.05	20	0.17	0.85	0.0425
DO	0.2	5	5.6867	92.8469	18.5694
pH	0.004	7	7.2667	17.78	0.0711
Chloride	0.004	250	56.6667	22.6667	0.0907
Alkalinity	0.0083	120	126	105	0.8715
TH	0.0033	300	155.3333	51.7778	0.1709
TDS	0.002	500	284.6667	56.9333	0.1139
Water quality Index		**73.3796**			
Post monsoon					
Nitrate	0.05	20	0.0033	0.0165	0.0008
DO	0.2	5	5.9733	89.8615	17.9723
pH	0.004	7	7.7	46.6667	0.1867
Chloride	0.004	250	100	40	0.16
Alkalinity	0.0083	120	142	118.3333	0.9822
TH	0.0033	300	212.6667	70.8889	0.2339
TDs	0.002	500	392	78.4	0.1568
water quality index =		**72.5062**			

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Table 4 .11 Calculation of Water Quality Index of Well 11

Parameter	Unit wt (wi)	Standards (Si)	Observed value (Vi)	Quality standards (qi)	qiwi
Nitrate	0.05	20	1.2022	6.011	0.3006
DO	0.2	5	5.7222	92.4771	18.4954
pH	0.004	7	7.0778	5.1867	0.0207
Chloride	0.004	250	51.1111	20.4444	0.0818
Alkalinity	0.0083	120	110.6667	92.2223	0.7654
TH	0.0033	300	135.7778	45.2593	0.1494
TDS	0.002	500	273.7778	54.7556	0.1095
water quality index =		**73.3535**			
Pre monsoon					
Nitrate	0.05	20	0.2333	1.1665	0.0583
DO	0.2	5	4.8	102.0833	20.4167
pH	0.004	7	7.0667	4.4467	0.0178
Chloride	0.004	250	43.3333	17.3333	0.0693
Alkalinity	0.0083	120	68.6667	57.2223	0.4749
TH	0.0033	300	76	25.3333	0.0836
TDS	0.002	500	192	38.4	0.0768
water quality index =		**78.0466**			
Monsoon					
Nitrate	0.05	20	3.1667	15.8335	0.7917
DO	0.2	5	6.42	85.2083	17.0417
pH	0.004	7	6.9	-6.6667	-0.0267
Chloride	0.004	250	61.3333	24.5333	0.0981
Alkalinity	0.0083	120	139.3333	116.1111	0.9637
TH	0.0033	300	175.3333	58.4444	0.1929
TDS	0.002	500	322.3333	64.4667	0.1289
water quality index =		**70.6566**			
Post monsoon					
Nitrite	0.05	20	0.2067	1.0335	0.0517
DO	0.2	5	5.9467	90.1385	18.0277
pH	0.004	7	7.2667	17.78	0.0711
Chloride	0.004	250	48.6667	19.4667	0.0779
Alkalinity	0.0083	120	124	103.3333	0.8577
Total Hardı	0.0033	300	156	52	0.1716
Total Solids	0.002	500	307	61.4	0.1228
water quality index =		**71.3565**			

Table 4. 12 Calculation of Water Quality Index of Well 12

Parameter	Unit wt (wi)	Standards (Si)	Observed value (Vi)	Quality standards (qi)	qiwi
Nitrate	0.05	20	0.7344	3.672	0.1836
DO	0.2	5	6.4311	85.0927	17.0185
pH	0.004	7	7.2222	14.8133	0.0593
Chloride	0.004	250	21.1111	8.4444	0.0338
Alkalinity	0.0083	120	55.5556	46.2963	0.3843
TH	0.0033	300	85.1111	28.3704	0.0936
TDS	0.002	500	184.2222	36.8444	0.0737
water quality index =		**65.7097**			
Pre monsoon					
Nitrate	0.05	20	0.2333	1.1665	0.0583
DO	0.2	5	5.92	90.4167	18.0833
pH	0.004	7	6.9667	-2.22	-0.0089
Chloride	0.004	250	16	6.4	0.0256
Alkalinity	0.0083	120	50	41.6667	0.3458
TH	0.0033	300	71.3333	23.7778	0.0785
TDS	0.002	500	153.6667	30.7333	0.0615
water quality index =		**68.6456**			
Monsoon					
Nitrate	0.05	20	1.8333	9.1665	0.4583
DO	0.2	5	6.8333	80.9031	16.1806
pH	0.004	7	7.2667	17.78	0.0711
Chloride	0.004	250	15.3333	6.1333	0.0245
Alkalinity	0.0083	120	61.3333	51.1111	0.4242
TH	0.0033	300	96.6667	32.2222	0.1063
TDS	0.002	500	231.3333	46.2667	0.0925
water quality index =		**63.909**			
Post monsoon					
Nitrate	0.05	20	0.1367	0.6835	0.0342
DO	0.2	5	6.54	83.9583	16.7917
pH	0.004	7	7.4333	28.8867	0.1155
Chloride	0.004	250	32	12.8	0.0512
Alkalinity	0.0083	120	55.3333	46.1111	0.3827
Th	0.0033	300	87.3333	29.1111	0.0961
TDS	0.002	500	167.6667	33.5333	0.0671
water quality index =		**64.5745**			

Table 4. 13 Calculation of Water Quality Index of Well 13

Parameter	Unit wt (wi)	Standards (Si)	Observed value (Vi)	Quality standards (qi)	qiwi
Nitrate	0.05	20	0.5567	2.7835	0.1392
DO	0.2	5	5.6556	93.1708	18.6342
pH	0.004	7	7.0778	5.1867	0.0207
Chloride	0.004	250	41.7778	16.7111	0.0668
Alkalinity	0.0083	120	97.5556	81.2963	0.6748
TH	0.0033	300	147.7778	49.2593	0.1626
TDS	0.002	500	291.4444	58.2889	0.1166
water quality index =		**72.9559**			
Pre monsoon					
Nitrate	0.05	20	0	0	0
DO	0.2	5	4.5333	104.8615	20.9723
pH	0.004	7	6.7667	-15.5533	-0.0622
Chloride	0.004	250	51.3333	20.5333	0.0821
Alkalinity	0.0083	120	56.6667	47.2222	0.3919
TH	0.0033	300	120.6667	40.2222	0.1327
TDS	0.002	500	286.3333	57.2667	0.1145
water quality index =		**79.6444**			
Monsoon					
Nitrate	0.05	20	1.6667	8.3335	0.4167
DO	0.2	5	6.62	83.125	16.625
pH	0.004	7	6.9333	-4.4467	-0.0178
Chloride	0.004	250	28.6667	11.4667	0.0459
Alkalinity	0.0083	120	136.6667	113.8889	0.9453
TH	0.0033	300	158.6667	52.8889	0.1745
TDS	0.002	500	317.3333	63.4667	0.1269
water quality index =		**67.4392**			
Post monsoon					
Nitrate	0.05	20	0.0033	0.0165	0.0008
DO	0.2	5	5.8133	91.5281	18.3056
pH	0.004	7	7.5333	35.5533	0.1422
Chloride	0.004	250	45.3333	18.1333	0.0725
Alkalinity	0.0083	120	99.3333	82.7777	0.6871
Th	0.0033	300	164	54.6667	0.1804
TDS	0.002	500	270.6667	54.1333	0.1083
water quality index =		**71.7854**			

Table4. 14 Calculation of Water Quality Index of Well 14

Parameter	Unit wt (wi)	Standards (Si)	Observed value (Vi)	Quality standards (qi)	qiwi
Nitrate	0.05	20	0.4356	2.178	0.1089
DO	0.2	5	5.48	95	19
pH	0.004	7	7.1444	9.6267	0.0385
Chloride	0.004	250	51.1111	20.4444	0.0818
Alkalinity	0.0083	120	92.6667	77.2223	0.6409
TH	0.0033	300	113.3333	37.7778	0.1247
TDS	0.002	500	244.2222	48.8444	0.0977
water quality index =		**73.9782**			
Pre monsoon					
Nitrate	0.05	20	1.1333	5.6665	0.2833
DO	0.2	5	5.12	98.75	19.75
pH	0.004	7	7.2	13.333	0.0533
Chloride	0.004	250	53.3333	21.3333	0.0853
Alkalinity	0.0083	120	74	61.6667	0.5118
TH	0.0033	300	96.6667	32.2222	0.1063
TDS	0.002	500	237	47.4	0.0948
water quality index =		**76.896**			
Monsoon					
Nitrate	0.05	20	0.17	0.85	0.0425
DO	0.2	5	5.6133	93.6115	18.7223
pH	0.004	7	6.6667	-22.22	-0.0889
Chloride	0.004	250	44.6667	17.8667	0.00715
Alkalinity	0.0083	120	96	80	0.664
TH	0.0033	300	106.6667	35.5556	0.1173
TDS	0.002	500	213	42.6	0.0852
water quality index =		**72.2161**			
Post monsoon					
Nitrate	0.05	20	0.0033	0.0165	0.0008
DO	0.2	5	5.7067	92.6385	18.5277
pH	0.004	7	7.5667	37.78	0.1511
Chloride	0.004	250	55.3333	22.1333	0.0885
Alkalinity	0.0083	120	108	90	0.747
TDS	0.0033	300	136.6667	45.5556	0.1503
Total Solids	0.002	500	282.6667	56.5333	0.1131
water quality index =		**72.8225**			

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Table4. 15 Calculation of Water Quality Index of Well 15

Parameter	Unit wt (wi)	Standards (Si)	Observed value (Vi)	Quality standards (qi)	qiwi
Nitrate	0.05	20	2.7667	13.8335	0.6917
DO	0.2	5	15.1822	-6.0646	-1.2129
pH	0.004	7	7.2111	14.0733	0.0563
Chloride	0.004	250	45.7778	18.3111	0.0732
Alkalinity	0.0083	120	192	160	1.328
TH	0.0033	300	211.5556	70.5185	0.2327
TDS	0.002	500	395.6667	79.1333	0.1583
water quality index =		**81.5569**			
Pre monsoon					
Nitrate	0.05	20	3.1667	15.8335	0.7917
DO	0.2	5	4.48	105.4167	21.0833
pH	0.004	7	7.4667	31.1133	0.1245
Chloride	0.004	250	47.3333	18.9333	0.0757
Alkalinity	0.0083	120	156.6667	130.5556	1.0836
TH	0.0033	300	182.6667	60.8889	0.2009
TDS	0.002	500	407.3333	81.4667	0.1629
water quality index =		**86.6078**			
Monsoon					
Nitrate	0.05	20	1.6667	8.3335	0.4167
DO	0.2	5	5.4667	95.1385	19.0277
pH	0.004	7	6.8667	-8.8867	-0.0355
Chloride	0.004	250	39.3333	15.7333	0.0629
Alkalinity	0.0083	120	216	180	1.494
TH	0.0033	300	226.6667	75.5556	0.2493
TDS	0.002	500	372.3333	74.4667	0.1489
water quality index =		**78.6599**			
Post monsoon					
Nitrate	0.05	20	3.4667	17.3335	0.8667
DO	0.2	5	5.6	93.75	18.75
pH	0.004	7	7.3	20	0.08
Chloride	0.004	250	50.6667	20.2667	0.0811
Alkalinity	0.0083	120	203.3333	169.4444	1.4064
TH	0.0033	300	225.3333	75.1111	0.2479
TDS	0.002	500	407.3333	81.4667	0.1629
water quality index =		**79.51**			

Table 4. 16 Calculation of Water Quality Index of Well 16

Parameter	Unit wt (wi)	Standards (Si)	Observed value (Vi)	Quality standards (qi)	qiwi
Nitrate	0.05	20	0.1167	0.5835	0.0292
DO	0.2	5	5.46	95.2083	19.0417
pH	0.004	7	7.3111	20.74	0.083
Chloride	0.004	250	42.2222	16.8889	0.0676
Alkalinity	0.0083	120	164.4444	137.037	1.1374
TH	0.0033	300	223.1111	74.3704	0.2454
TDS	0.002	500	341.8889	68.3778	0.1368
water quality index =		**76.3658**			
Pre monsoon					
Nitrate	0.05	20	0.27	1.35	0.0675
DO	0.2	5	4.5867	104.3052	20.861
pH	0.004	7	7.3333	22.22	0.0889
Chloride	0.004	250	42.6667	17.0667	0.0683
Alkalinity	0.0083	120	118	98.3333	0.8162
TH	0.0033	300	208	69.3333	0.2288
TDS	0.002	500	342.3333	68.4667	0.1369
water quality index =		**81.9867**			
Monsoon					
Nitrate	0.05	20	0.0067	0.0335	0.0017
DO	0.2	5	6.1933	87.5698	17.514
pH	0.004	7	7.2667	17.78	0.0711
Chloride	0.004	250	42	16.8	0.0672
Alkalinity	0.0083	120	185.3333	154.4444	1.2819
TH	0.0033	300	224	74.6667	0.2464
TDS	0.002	500	341.6667	68.3333	0.1367
water quality index =		**71.13**			
Post monsoon					
Nitrate	0.05	20	0.0733	0.3665	0.0183
DO	0.2	5	5.6	93.75	18.75
pH	0.004	7	7.8333	55.5533	0.2222
Chloride	0.004	250	42	16.8	0.0672
Alkalinity	0.0083	120	190	158.3333	1.3142
TH	0.0033	300	237.3333	79.1111	0.2611
TDS	0.002	500	341.6667	68.3333	0.1367
water quality index =		**76.4714**			

Table 4. 17 Calculation of Water Quality Index of Well 17

Parameter	Unit wt (wi)	Standards (Si)	Observed value (Vi)	Quality standards (qi)	qiwi
Nitrate	0.05	20	1.8011	9.0055	0.4503
DO	0.2	5	6.06	88.9583	17.7917
pH	0.004	7	7.3667	24.4467	0.0978
Chloride	0.004	250	26.8889	10.7556	0.043
Alkalinity	0.0083	120	127.7778	106.4815	0.8838
TH	0.0033	300	148.4444	49.4815	0.1633
TDS	0.002	500	237.6667	47.5333	0.0951
water quality index =		**71.8884**			
Pre monsoon					
Nitrate	0.05	20	4	20	1
DO	0.2	5	5.2	97.9167	19.5833
pH	0.004	7	7.3333	22.22	0.0889
Chloride	0.004	250	29.333	11.7333	0.0469
Alkalinity	0.0083	120	101.3333	84.4444	0.7009
TH	0.0033	300	144.6667	48.2222	0.1591
TDS	0.002	500	234.6667	46.9333	0.0939
water quality index =		**79.7976**			
Monsoon					
Nitrate	0.05	20	1.3333	6.6665	0.3333
DO	0.2	5	6.8467	80.7635	16.1527
pH	0.004	7	7.3333	22.22	0.0889
Chloride	0.004	250	24	9.6	0.0384
Alkalinity	0.0083	120	145.3333	121.1111	1.0052
TH	0.0033	300	145.3333	48.4444	0.1599
TDS	0.002	500	262	52.4	0.1048
water quality index =		**65.8439**			
Post monsoon					
Nitrate	0.05	20	0.07	0.35	0.0175
DO	0.2	5	6.1333	88.1948	17.639
pH	0.004	7	7.4333	28.8867	0.1155
Chloride	0.004	250	27.3333	10.9333	0.0437
Alkalinity	0.0083	120	136.6667	113.8889	0.9453
TH	0.0033	300	155.3333	51.7778	0.1709
TDS	0.002	500	216.3333	43.2667	0.0865
water quality index =		**70.0236**			

Table 4. 18 Calculation of Water Quality Index of Well 18

Parameter	Unit wt (wi)	Standards (Si)	Observed value (Vi)	Quality standards (qi)	qiwi
Nitrate	0.05	20	0.0011	0.0055	0.0003
DO	0.2	5	5.8	91.6667	18.3333
pH	0.004	7	7.311	20.74	0.083
Chloride	0.004	250	12.8889	5.1556	0.0206
Alkalinity	0.0083	120	79.5556	66.2963	0.5503
TH	0.0033	300	68	22.6667	0.0748
TDS	0.002	500	142.2222	28.4444	0.0569
water quality index =		**70.3945**			
Pre monsoon					
Nitrate	0.05	20	0	0	0
DO	0.2	5	5.0133	99.8615	19.9723
pH	0.004	7	7.2333	15.5533	0.0622
Chloride	0.004	250	6.6667	2.6667	0.0107
Alkalinity	0.0083	120	80.6667	67.2223	0.5579
TH	0.0033	300	64	21.3333	0.0704
TDS	0.002	500	155.3333	31.0667	0.0621
water quality index =		**76.3463**			
Monsoon					
Nitrate	0.05	20	0	0	0
DO	0.2	5	6.7467	81.8052	16.361
pH	0.004	7	7.3	20	0.08
Chloride	0.004	250	9.3333	3.7333	0.0149
Alkalinity	0.0083	120	92	76.667	0.6363
TH	0.0033	300	66	22	0.0726
TDS	0.002	500	161.3333	32.2667	0.0645
water quality index =		**63.4368**			
Post monsoon					
Nitrate	0.05	20	0.0033	0.0165	0.0008
DO	0.2	5	5.64	93.3333	18.6667
pH	0.004	7	7.4	26.6667	0.1067
Chloride	0.004	250	22.6667	9.0667	0.0363
Alkalinity	0.0083	120	66	55	0.4565
TH	0.0033	300	74	24.6667	0.0814
TDS	0.002	500	110	22	0.044
water quality index =		**71.4003**			

Table 4. 19 Calculation of Water Quality Index of Well 19

Parameter	Unit wt (wi)	Standards (Si)	Observed value (Vi)	Quality standards (qi)	qiwi
Nitrate	0.05	20	0.5133	2.5665	0.1283
DO	0.2	5	6.2711	86.7594	17.3519
pH	0.004	7	6.2333	-51.1133	-0.2045
Chloride	0.004	250	8.2222	3.2889	0.0132
Alkalinity	0.0083	120	18	15	0.1245
Th	0.0033	300	17.5556	5.8519	0.0193
TDS	0.002	500	59.5556	11.9111	0.0238
water quality index =		64.273			
Pre monsoon					
Nitrate	0.05	20	0.4667	2.3335	0.1167
DO	0.2	5	5.7467	92.2219	18.4444
pH	0.004	7	6.1667	-55.5533	-0.2222
Chloride	0.004	250	8	3.2	0.0128
Alkalinity	0.0083	120	34.6667	28.8889	0.2398
TH	0.0033	300	10	3.3333	0.011
TDS	0.002	500	69.6667	13.9333	0.0279
water quality index =		68.5945			
Monsoon					
Nitrate	0.05	20	0.67	3.35	0.1675
DO	0.2	5	6.8267	80.9719	16.1944
pH	0.004	7	6.1333	-57.78	-0.2311
Chloride	0.004	250	7.3333	2.9333	0.0117
Alkalinity	0.0083	120	10.6667	8.8889	0.0738
TH	0.0033	300	16.6667	5.5556	0.0183
TDS	0.002	500	68.3333	13.6667	0.0273
water quality index =		59.8746			
post monsoon					
Nitrate	0.05	20	0.4033	2.0165	0.1008
DO	0.2	5	6.24	87.0833	17.4167
pH	0.004	7	6.4	-40	-0.16
Chloride	0.004	250	9.3333	3.7333	0.0149
Alkalinity	0.0083	120	8.6667	7.2223	0.0599
TH	0.0033	300	26	8.6667	0.0286
TDS	0.002	500	40.6667	8.1333	0.0163
water quality index =		64.3492			

Table 4. 20 Calculation of Water Quality Index of Well 20

Parameter	Unit wt (wi)	Standards (Si)	Observed value (Vi)	Quality standards (qi)	qiwi
Nitrate	0.05	20	0.1111	0.5555	0.0278
DO	0.2	5	6.6122	83.2063	16.6413
pH	0.004	7	6.4556	-36.2933	-0.1452
Chloride	0.004	250	7.1111	2.8444	0.0114
Alkalinity	0.0083	120	20.4444	17.037	0.1414
TH	0.0033	300	15.1111	5.037	0.0166
TDS	0.002	500	59.1111	11.8222	0.0236
water quality index =		**61.5497**			
Pre monsoon					
Nitrate	0.05	20	0	0	0
DO	0.2	5	6.42	85.2083	17.0417
pH	0.004	7	6.1333	-57.78	-0.2311
Chloride	0.004	250	7.3333	2.9333	0.0117
Alkalinity	0.0083	120	32.6667	27.2222	0.2259
Total Hard	0.0033	300	12	4	0.0132
Total Solids	0.002	500	75.6667	15.1333	0.0303
water quality index =		**62.9296**			
Monsoon					
Nitrate	0.05	20	0.3333	1.6665	0.0833
DO	0.2	5	7.67	72.1875	14.4375
pH	0.004	7	6.6	-26.6667	-0.1067
Chloride	0.004	250	8	3.2	0.0128
Alkalinity	0.0083	120	18	15	0.1245
TH	0.0033	300	14	4.6667	0.0154
TDS	0.002	500	61.3333	12.2667	0.0245
water quality index =		**53.7238**			
post monsoon					
Nitrate	0.05	20	0	0	0
DO	0.2	5	5.7467	92.2219	18.4444
pH	0.004	7	6.6333	-24.4467	-0.0978
Chloride	0.004	250	6	2.4	0.0096
Alkalinity	0.0083	120	10.6667	8.8889	0.0738
TH	0.0033	300	19.3333	6.4444	0.0213
TDS	0.002	500	40.3333	8.0667	0.0161
water quality index =		**67.9947**			

Table 4. 21 Relation between rainfall and fluctuation in quality

Well 1	A	B	r	Standard Deviation
pH	1.560276	-0.000613276	-0.99315	0.169967
EC	-0.1280707	6.95419E-05	0.44303	0.0432
Alk	18.6219399	-0.007168019	-0.96018	2.0548
Cl	-12.4376108	0.006622102	0.99112	1.8856
NO3	1.03695939	-0.000487132	-0.794704	0.18798
SO4	0	0	0	0
DO	3.926095	-0.020651128	-0.89865	0.63252
TDS	-123.68483	0.054578	0.579103	25.4401
HT	-24.70671418	0.0182069	0.351254	14.2673
CO2	-30.07422079	0.008687241	0.180126	13.27487
CaH	-3.72979365	0.000760485	0.1278	1.63667
Mg	-8.12438359	0.003569376	0.71139	1.38104
Ca	-1.47505936	0.000297069	0.12518	0.65319
Fe	0	0	0	0
Well 2	**A**	**B**	**r**	**Standard Deviation**
pH	1.7953468	-0.00074606	-0.950599	0.21602
EC	-0.11421995	6.34656E-05	0.490835	0.03559
Alk	-3.7622143	0.002019315	0.362539	1.63299
Cl	-29.282233	0.016406	0.9218038	4.89898
NO3	-14.3323633	0.008044665	0.415316	1.40554
S04	0	0	0	
DO	4.3106638	0.003139411	0.181539	1.93852
TDS	-216.099369	0.07456112	0.625007	32.83629
HT	-23.9561205	0.0152362	0.520617	8.05536
CO2	-55.271124	0.0222691	0.43175	1.4197
CaH	-1.0309301	0.001041893	0.611387	0.46906
Mg	1.1203878	-0.000427032	-0.07547	1.55737
Ca	-473.102074	0.2676914	0.387656	0.18667
Fe	0	0	0	0

Well 3	**A**	**B**	**r**	**Standard Deviation**
pH	2.81809347	-0.001210802	-0.66803	0.49888
EC	2.3199226	-0.000916765	-0.9791	0.027157
Alk	28.893175	0.0130082	-0.87125	4.10961
Cl	24.854822	-0.0109376	-0.9218	3.26598
NO3	5.60896	-0.000197396	-0.1766025	2.3959
SO4	0	0	0	0
DO	9.81408	-4.0694479	-0.6724	1.66584
TDS	131.54004	0.0449774	0.8607	14.3836
HT	-21.293064	0.01465105	0.395438	10.4986
CO2	97.131.51289	-0.0446509	-0.75136	16.35713
CaH	-15.964022	0.005554636	0.4936248	3.0973
Mg	-2.23275219	0.001178948	0.36049	0.8684
Ca	-8.40548682	0.00325976	0.52586	1.70622
Fe	0	0	0	0
Well 4	**A**	**B**	**r**	**Standard Deviation**
pH	0.7213705	-0.000273442	-0.9218	0.08164
EC	-0.22947665	0.000108465	0.66791	3.3993
Alk	29.205552	-0.0122655	-0.993157	0.04469
Cl	4.038353	-2.070506	-0.604477	0.9428
NO3	1.4772987	-5.1661918	-0.25084	0.56688
SO4	0	0	0	1.4373
DO	1.933458	-0.000551601	-0.105633	
TDS	68.121412	-0.0359038	-0.29261	20.60744
HT	-57.161647	0.0275017	0.72102	10.49867
CO2	1.3341805	-0.008068201	-0.33228	6.6833
CaH	11.3908812	-0.004574113	-0.27699	4.54532
Mg	-5.658202	0.003374495	0.53928	1.72232
Ca	12.306576	-0.005801462	-0.44818	3.5629
Fe	0	0	0	0.25486

Well 5	A	B	r	Standard Deviation
pH	1.242741	-0.00054688	0.9218	0.163299
EC	-0.00970102	0.000231917	0.222	0.02872
Alk	1.687648	-0.000742672	-0.12518	1.63299
Cl	-0.8560098	0.00053455	0.1568	0.94281
NO3	1.84357	-0.000825958	-0.332009	0.68475
SO4	0	0	0	
DO	13.5912	-0.4763529	-0.989649	1.24003
TDS	-96.8825	0.0270855	0.51337	14.522
HT	159.5734	0.0592278	0.5674	6.599663
CO2	81.34703116	-0.0386479	-0.9815506	10.4243
CaH	-48.0314	0.020111	0.99527	5.561896
Mg	-13.42112	0.005881273	0.88345	1.83238
Ca	-12.73976	4.7261761	0.796622	1.63299
Fe	0	0	0	

Well 6	A	B	r	Standard Deviation
pH	0.2	0	0	0
EC	-0.3550489	0.000226214	0.582947	0.1068
Alk	80.83316	-0.0144486	-0.279359	14.2361
Cl	-20.514948	-0.00785437	0.219635	9.8432
NO3	4.204117	-0.002216797	0.97845	0.62361
SO4	-18.43824	0.003713361	0.12518	8.164965
DO	-8.774454	0.001616993	0.0585	0.99652
TDS	-524.7807718	0.23636642	0.693945	93.7526
HT	-105.43542	0.057546539	0.4973	31.84685
CO2	61.309755	-0.0202325	-0.75629	7.36357
CaH	-107.9133744	0.04877957	0.6332	21.20382
Mg	-33.1266569	0.01637035	0.74646	6.03686
Ca	52.100317	-0.029337278	-0.587308	13.74929
Fe	0	0	0	0

Well 5	A	B	r	Standard Deviation
pH	1.242741	-0.00054688	0.9218	0.163299
EC	-0.00970102	0.000231917	0.222	0.02872
Alk	1.687648	-0.000742672	-0.12518	1.63299
Cl	-0.8560098	0.00053455	0.1568	0.94281
NO3	1.84357	-0.000825958	-0.332009	0.68475
SO4	0	0	0	
DO	13.5912	-0.4763529	-0.989649	1.24003
TDS	-96.8825	0.0270855	0.51337	14.522
HT	159.5734	0.0592278	0.5674	6.599663
CO2	81.34703116	-0.0386479	-0.9815506	10.4243
CaH	-48.0314	0.020111	0.99527	5.561896
Mg	-13.42112	0.005881273	0.88345	1.83238
Ca	-12.73976	4.7261761	0.796622	1.63299
Fe	0	0	0	
Well 6	**A**	**B**	**r**	**Standard Deviation**
pH	0.2	0	0	0
EC	-0.3550489	0.000226214	0.582947	0.1068
Alk	80.83316	-0.0144486	-0.279359	14.2361
Cl	-20.514948	-0.00785437	0.219635	9.8432
NO3	4.204117	-0.002216797	0.97845	0.62361
SO4	-18.43824	0.003713361	0.12518	8.164965
DO	-8.774454	0.001616993	0.0585	0.99652
TDS	-524.7807718	0.23636642	0.693945	93.7526
HT	-105.43542	0.057546539	0.4973	31.84685
CO2	61.309755	-0.0202325	-0.75629	7.36357
CaH	-107.9133744	0.04877957	0.6332	21.20382
Mg	-33.1266569	0.01637035	0.74646	6.03686
Ca	52.100317	-0.029337278	-0.587308	13.74929
Fe	0	0	0	0

Well 7	A	B	r	Standard Deviation
pH	1.2076706	-0.000414101	-0.604477	0.18856
EC	-7.080956	0.000305006	0.6410668	0.130985
Alk	-107.3809352	0.0416802	0.936031	12.2565
Cl	6.3507047	-0.001327835	-0.3876566	0.94281
NO3	0.07808	0.000185668	0.12518	4.0825
SO4				
DO	-2.47058	0.001181095	0.597718	0.54389
TDS	-368.86637	0.16115107	0.99345	44.6492
HT	-116.98635	0.05558866	0.78537	19.48218
CO2	112.2357	-0.0526179	-0.933152	15.52059
CaH	-19.7208	0.008826567	0.977807	2.48465
Mg	-6.341266	0.003782168	0.845539	1.23413
Ca	1.45572	-0.001259626	-0.221831	1.5629
Fe				

Well 8	A	B	r	Standard Deviation
pH	4.195612	-0.001523622	-0.520617	0.80554
EC	-0.20611218	0.000105225	0.611319	30.73904
Alk	285.211257	-0.115535	-0.9921236	2.82843
Cl	130.026587	-0.0526723	-0.56017	0.09428
NO3	-0.83890578	0.00339834	0.9921338	8.16496
SO4	62.137055	-0.027344	-0.921803	0.86538
DO	31.432219	-0.0136546	-1.033455	52.9297
TDS	37.033104	-0.01527009	0.744132	32.12475
HT	-145.25482	0.070082	-0.0645669	6.236095
CO2	7.6564079	-0.001462905	-0.9921338	24.0652
CaH	221.1407027	-0.0867426	0.843539	4.6372
Mg	-6.34126618	0.003782168	-0.8048	15..09572
Ca	108.07988	-0.0441383	0.782405	0.165395
Fe	-1.3950141	-0.000470141		

Well 9	A	B	r	Standard Deviation
pH	2.92055268	-0.001226553	-0.99315	2.78248
EC	-0.0855026	0.000046574	0.12077	0.106145
Alk	59.097867	-0.0375951	-0.177011	63.0467
Cl	76.06565	-0.0387446	-0.536949	19.8662
NO3	-1.3544178	0.000334203	0.12518	0.92736
SO4	10.1917657	-0.010352	-0.60447	4.714045
DO	-11.240086	0.005571078	0.959819	1.59936
TDS	13.633369	-0.0202796	-0.153147	18.92675
HT	53.653453	-0.03538016	-0.293335	21.312489
CO2	14.413927	0.000551285	0.010549	14.3836
CaH	264.71078	-0.131805	-0.895067	40.53255
Mg	134.626476	-0.0661296	-0.52688	41.83821
Ca	116.824875	-0.057706	-0.708675	22.41309
Fe	59.0973	-0.02911927	0.460063	0.20116
Well 10	**A**	**B**	**r**	**Standard Deviation**
pH	1.6778115	-0.000679668	-0.992133	0.18856
EC	0.73555087	-0.00025194	-0.30237	0.22934
Alk	39.674579	-0.01669	-0.425954	15.08494
Cl	1.07.05226	-0.061485	-0.94085	17.98765
NO3	0.04194528	-0.169917075	0.99213386	0.00471404
SO4	182.925675	-0.0834913	-0.699565	32.85036
DO	-6.933829	0.003374037	0.919513	1.00999
TDS	-151.57613	0.01873619	0.11678608	44.1588
HT	-5.396989	-0.002025629	-0.0306613	18.1842
CO2	166.231743	-0.0850524	-0.6025566	10.6562
CaH	-49.30459	0.008002373	0.33130533	40.53255
Mg	14.3092613	0.003575671	0.9880507	4.21203
Ca	76.695857	-0.0462207	0.6381769	22.0863
Fe	-163.5866289	0.066267	0.99213386	0.20116

Well 9	**A**	**B**	**r**	**Standard Deviation**
pH	2.92055268	-0.001226553	-0.99315	2.78248
EC	-0.0855026	0.000046574	0.12077	0.106145
Alk	59.097867	-0.0375951	-0.177011	63.0467
Cl	76.06565	-0.0387446	-0.536949	19.8662
NO3	-1.3544178	0.000334203	0.12518	0.92736
SO4	10.1917657	-0.010352	-0.60447	4.714045
DO	-11.240086	0.005571078	0.959819	1.59936
TDS	13.633369	-0.0202796	-0.153147	18.92675
HT	53.653453	-0.03538016	-0.293335	21.312489
CO2	14.413927	0.000551285	0.010549	14.3836
CaH	264.71078	-0.131805	-0.895067	40.53255
Mg	134.626476	-0.0661296	-0.52688	41.83821
Ca	116.824875	-0.057706	-0.708675	22.41309
Fe	59.0973	-0.02911927	0.460063	0.20116
Well 10	**A**	**B**	**r**	**Standard Deviation**
pH	1.6778115	-0.000679668	-0.992133	0.18856
EC	0.73555087	-0.00025194	-0.30237	0.22934
Alk	39.674579	-0.01669	-0.425954	15.08494
Cl	1.07.05226	-0.061485	-0.94085	17.98765
NO3	0.04194528	-0.169917075	0.99213386	0.00471404
SO4	182.925675	-0.0834913	-0.699565	32.85036
DO	-6.933829	0.003374037	0.919513	1.00999
TDS	-151.57613	0.01873619	0.11678608	44.1588
HT	-5.396989	-0.002025629	-0.0306613	18.1842
CO2	166.231743	-0.0850524	-0.6025566	10.6562
CaH	-49.30459	0.008002373	0.33130533	40.53255
Mg	14.3092613	0.003575671	0.9880507	4.21203
Ca	76.695857	-0.0462207	0.6381769	22.0863
Fe	-163.5866289	0.066267	0.99213386	0.20116

Well 11	**A**	**B**	**r**	**Standard Deviation**
pH	5.738646	-2.437355	-0.896503	0.77833
EC	-0.899906	0.000442076	0.582456	0.20891
Alk	160.685385	-0.04636157	-0.633145	20.15495
Cl	76.539874	-0.03265558	-0.9994014	8.9938
NO3	2.034084	-9.0686089	-0.882393	0.28288
SO4	-39.383809	0.0165979	0.3876566	11.7851
DO	4.5977.77	-1.5167675	-0.940158	0.4446
TDS	-427.50998	0.23873877	0.8502875	77.28302
HT	-58.849074	0.0611023	0.4696002	35.814336
CO2	221.345457	-0.088458	-0.94473	25.7725
CaH	198.511806	-0.06446	-0.6081207	29.17802
Mg	-15.1920899	0.0119281	0.496309	6.615236
Ca	65.862452	-0.0278717	-0.8362011	9.17446
Fe	-0.796904	0.000322842	0.992133	0.68956
Well 12	**A**	**B**	**r**	**Standard Deviation**
pH	3.2180934	1.210802	-0.668032	0.49888
EC	-0.899906	4.4207565	0.582456	0.0696
Alk	8.3507047	-0.00327834	-0.387656	0.94281
Cl	-65.928932	0.0360539	0.999066	9.93311
NO3	1.4063902	-6.614402	-0.615988	0.29555
SO4	39.506769	-0.0173854	-0.443037	10.80123
DO	1.9164499	-5.705201	-0.2686822	0.58446
TDS	-530.121645	0.239448	0.998988	65.9747
HT	-73.4793	0.04231	0.489417	23.7954
CO2	11.095882	-5.176267	-0.604477	2.35702
CaH	12.112896	-7.88988	-0.027742	7.828056
Mg	-0.9477717	2.467749	0.120946	5.61614
Ca	46.181116	-0.0215107	-0.792196	7.56591
Fe	-1.050305	0.00036245	0.6031926	0.165395

Well 13	A	B	r	Standard Deviation
pH	2.1602763	-0.000613277	-0.99315	0.16996
EC	-0.285259	0.000184207	0.4501136	11264
Alk	22.158938	0.009024699	0.47321	5.24933
Cl	46.011647	-0.022888	-0.6929	9.09212
NO3	0.049145	-1.69917E-05	-0.992133	4.714045
SO4	-285.17878	0.1152285	0.93302	33.99346
DO	-142.25716	0.0585946	0.571577	5.6899
TDS	-568.66146	243352	0.99357	67.41579
HT	-54.756232	0.0431356	0.843895	14.07914
CO2	71.035756	-0.023045	-0.93302	6.7986
CaH	159.57945	-0.060518	-0.44146	40.22056
Mg	-10.133032	0.007466275	0.260237	7.8969
Ca	-16.932203	-0.0381559	-0.9941219	10.5645
Fe	-2.558945	0.00140338	0.613459	0.62965

Well 14	A	B	r	Standard Deviation
pH	3.0342526	-0.00108589	-0.96691	0.497004
EC	-58.4253	0.0299806	0.60476	0.11359
Alk	230.0771	-0.086286	-0.9873	24.05549
Cl	-85.605749	0.038552	0.8607	12.3282
NO3	4.359526	-2.415739	-0.501715	1.32532
SO4	-116.52086	0.043942	0.843614	14.3372
DO	5.528997	0.002174938	-0.99213	0.60339
TDS	-345.74579	0.172246	0.97644	48.5546
HT	-99.462946	0.061375	0.62839	26.8824
CO2	166.997348	-0.066155	-0.824102	22.09575
CaH	-56.953547	0.0302045	0.591148	14.06461
Mg	-25.62174	0.0137668	0.5787537	6.54765
Ca	30.564381	-0.0152897	-0.278947	15.08706
Fe	2.36899	-0.000942758	-0.99986	0.2595

Well 15	**A**	**B**	**r**	**Standard Deviation**
pH	3.410688	-0.00157426	0.88043	0.492161
EC	1.0404526	5.436774	0.737143	0.18739
Alk	91.057418	-0.019534	-0.39543	13.59738
Cl	24.476595	-0.005788386	-0.17701	8.9938
NO3	4.6189002	-0.00190058	-0.568537	0.92014
SO4	35.2876486	-0.0155288	-0.604477	7.07106
DO	8.5473568	-0.003259706	-0.9999975	0.89725
TDS	-739.9678455	0.32536327	0.89834	99.7727
HT	-92.603153	0.059527	0.86569	18.9267
CO2	155.246755	-0.0631843	-0.94473	18.4089
CaH	-196.0114514	0.0944133	0.91187	28.4987
Mg	70.48491	0.0363733	0.49125	20.3801
Ca	32.079267	-0.0188769	-0.202269	25.6878
Fe	-0.1057817	0.00005975	0.387656	0.04243
Well 16	**A**	**B**	**r**	**Standard Deviation**
pH	4.9709644	-2187539	-0.9218	0.653197
EC	-1.0373578	0.00048056	0.55689	0.23752
Alk	696.43991	-0.27479	-0.96058	78.74007
Cl	60.038686	-0.0267142	-0.4846	15.17307
NO3	1.95844	-0.00094838	-0.91485	0.285345
SO4	61.26029	-0.0240246	-0.77812	8.498365
DO	-0.35726	0.000603148	0.831933	0.19955
TDS	-262.076208	0.1150367	0.45098	70.21079
HT	-108.1860178	0.060517	0.438824	37.95904
CO2	33.56999	-0.015506	-0.744238	5.73488
CaH	-132.9291	0.05806	0.760807	21.00587
Mg	88.6487	0.0461503	0.59597	21.314605
Ca	196.99275	-0.0911339	-0.854811	29.3451
Fe	0.5094528	-0.000169917	-0.992133	0.64714

Well 17	A	B	r	Standard Deviation
pH	4.449593	-0.001914096	-0.921803	0.571547
EC	0.338635	-0.000203442	-0.132607	0.42227
Alk	410.71313	-0.1651908	-0.99421	45.73352
Cl	0	0	0	0
NO3	-1.65438	0.000270674	0.279563	0.98861
SO4	8.43824	0.00371336	-0.12518	8.16496
DO	-0.461816	0.000613954	0.46974	0.35975
TDS	-146.5446	0.05642109	0.288537	53.8227
HT	-132.42752	0.0629705	0.880434	19.6843
CO2	47.975297	-0.016271	-0.52395	8.52447
CaH	-166.6262705	0.07295	0.66277	30.13824
Mg	-79.90999	0.039445	0.690649	15.72064
Ca	-36.45143	0.015432	0.188514	22.8347
Fe	0.1817258	-9.31728	-0.60477	0.4226
Well 18	**A**	**B**	**r**	**Standard Deviation**
pH	-0.756441	0.00040622	0.8965	0.12472
EC	0.226686	-0.000120293	-0.497904	0.14617
Alk	-74.860126	0.026488	0.407018	17.91337
Cl	32.41658	-7.224335	-0.279359	7.11805
NO3	0.041945	-1.6991707	-0.99213	4.714045
SO4	10.095882	-5.1762671	-0.604477	2.35702
DO	-1.50085	0.000936242	0.169605	1.579415
TDS	-109.2600157	0.0281317	0.3104	24.94438
HT	-170.120476	0.079264	0.64206	33.98038
CO2	78.06593	-0.034647	-0.98596	9.67241
CaH	-69.47976	0.030578	0.99219	8.48292
Mg	-9.498595	0.00371938	0.968101	1.05749
Ca	-90.655025	0.048812	0.3574	37.5908
Fe	-0.23507	0.000132783	0.38765	0.43204

Well 19	A	B	r	Standard Deviation
pH	4.5471346	-0.001898345	-0.940158	0.55577
EC	-0.1170544	6.10461E-05	0.395438	0.04249
Alk	72.548664	-0.043661	-0.344128	34.92213
Cl	-17.12882052	8.124517	0.8965	2.443
NO3	1.6263846	-0.000743582	0.8354114	0.2499
SO4	0	0	0	0
DO	11.2541923	-0.004634785	-0.62337	2.04648
TDS	189.378394	-0.0914063	-0.977198	25.7466
HT	-42.14788	0.0255887	0.552238	12.75408
CO2	-83.87654	0.036177	0.436029	22.83759
CaH	-20.9548206	0.008942448	0.9821001	2.50626
Mg	-5.309448	0.00243302	0.6456007	1.03742
Ca	4.563946	-0.00216091	-0.753406	0.78949
Fe	0	0	0	0
Well 20	**A**	**B**	**r**	**Standard Deviation**
pH	104589	-0.000421976	-0.31042	0.37416
EC	-0.136366	7.26253E-05	0.54946	0.03638
Alk	-65.496549	0.039677	0.340256	32.09707
Cl	16.7781157	-0.00679668	0.9921338	1.885618
NO3	0	0	0	0
SO4	-96.27394	0.0423666	0.65809	0
DO	55.07422	0.00868724	0.180126	1.02123
TDS	-46.109533	0.023518	0547972	13.27487
HT	-96.273943	0.042366	0.658091	11.81336
CO2	0.5010826	5.97863	0.04628	17.72004
CaH	-0.060894	0.00006053	0.02762	12.81348
Mg	6.2129118	-2.95762	-0.517605	0.60301
Ca	-0.105717	0.00005975	0.38765	1.57279
Fe	0	0		0.042426

Table 4. 22 Rainfall andFluctuations in chemical parameters in mg/L (2000- 2003)

Year	Rainfall	pH	EC	Alk	Cl^-	NO^{3-}	SO_4^{2-}	DO	TDS	HT	CO_2	CaH	Mg	Ca	Fe
Well 1															
00-'01	2507.7	0	0.09	0	4	-0.3	0	-0.94	37	36	-23	0.01	1.92	0	0
01-'02	2423.3	0.1	-0.01	2	4	-0.01	0	-1.44	-19	2	8	-4	-0.74	-1.6	0
02-'03	1886.2	0.4	0.01	5	0	0.1	0	0.08	-17	12	-16	-2.01	-1.22	-0.8	0
Well 2															
00-'01	2507.7	0	0.01	2	14	0	0	-1.44	-58	22	15	2	-1.7	0.8	0
01-'02	2423.3	-0.1	0.08	4	8	-2.5	0	2.08	-2	4	-18	1.01	2.11	0.4	0
02-'03	1886.2	0.4	0	0	2	0.8	0	3.08	-80	6	-11	1	0.04	0.8	0
Well 3															
00-'01	2507.7	0.2	0.08	-6	-4	5.5	0	-1.78	-27	26	-27	1	1.67	1.4	0
01-'02	2423.3	-0.6	0.03	0	0	1.44	0	1.56	-13	2	3	-6.03	-0.47	-2.4	0
02-'03	1886.2	0.6	0.02	4	4	-0.2	0	1.92	-48	8	11	-5.01	0.14	-2	0
Well 4															
00-'01	2507.7	0	0.08	-2	-2	0.8	0	-1.06	-16	20	-26	-5	1.17	-5.83	0
01-'02	2423.3	0.1	-0.01	0	0	-0.49	0	2.46	-35	0	-10	6	4.41	2.4	0.09
02-'03	1886.2	0.2	-0.02	6	0	0.6	0	0.64	-66	-4	-15	1.99	0.45	0.8	-0.5
Well 5															
00-'01	2507.7	-0.2	0.08	-2	0	0.5	0	1.86	-43	20	-17	3.01	0.36	-2	0
01-'02	2423.3	0	0.01	2	2	-1	0	1.8	-15	10	-9	0	1.95	0	0
02-'03	1886.2	0.2	0.04	0	0	0.4	0	4.64	-48	4	8	-10	-2.48	-4	0
Well 6															
00-'01	2507.7	0.2	0.31	60	10	-1.5	0	0.8	144	70	16	32.9	3.4	-34	0
01-'02	2423.3	0.2	0.08	28	-14	-1	-20	-1.56	-40	-2	6	-11.1	11.8	-4.48	0
02-'03	1886.2	0.2	0.09	56	-4	0	-10	0.16	-67	8	24	-13	-2.96	-5.2	0
Well 7															
00-'01	2507.7	0	0.17	2-Jan	4	1	0	0	41	36	-26	3	3.89	-3.42	0
01-'02	2423.3	0.4	-0.1	-12	2	0	0	0.96	15	2	-8	0.99	1.96	0.39	0
02-'03	1886.2	0.4	-0.12	-28	4	0.5	0	-0.32	-64	-10	12	-2.98	0.91	-1.19	0
Well 8															
00-'01	2507.7	-0.4	0.17	6	0	0	-10	-0.16	109	50	11	7.01	2.66	-12.7	-0.1
01-'02	2423.3	1.4	0	0	0	0	0	1.94	-13	-2	-4	7.01	2.43	12.8	-0.4
02-'03	1886.2	1.2	-0	68	-6	-0.2	10	0.64	10	80	6	58.1	12.4	23.2	-0.5
Well 9															
00-'01	2507.7	-0.2	0.15	-100	-40	0.3	-20	2.24	-93	-18	32	-86.1	-1.44	-45.7	0.19
01-'02	2423.3	0	-0.11	43	4	-1.5	-10	2.86	-55	-40	-3	-31	8.83	-2.4	-0.1
02-'03	1886.2	0.6	0.02	-22	0	-0.6	-10	-0.8	-51	12	18	13	2.84	5.18	0.39
Well 10															
00-'01	2507.7	0	0.35	-18	-54	0	0	1.08	-154	10	-14	-22.2	-5.63	-56.5	0
01-'02	2423.3	0	-0.16	14	-34	0	-50	1.76	-49	-34	-8	-38.1	23.1	-15.3	0
02-'03	1886.2	0.4	0.3	14	-10	0.01	29.6	-0.64	-124	-6	11	-33.1	-7.61	-13.2	-0.4

Table 4. 23 Rainfall and Fluctuations in chemical parameters in mg/L (2000- ' 03)

	Rainfall	pH	EC	Alk	Cl^-	NO^{3-}	SO_4^{2-}	DO	TDS	HT	CO_2	CaH	Mg	Ca	Fe
Year	**Well 11**														
00-'01	2507.7	[illegible]	0.4	62	-2	-0.39	-10	0.96	217	130	-10	63	8.25	-9.7	0
01-'02	2423.3	-0.5	-0.05	28	0	0.01	15	0.72	98	48	18	12.1	21.2	4.88	0
00-'01	2507.7	0.6	0.16	6	24	0.01	-15	1.12	67	56	-4	19	-1.04	-12.9	-0.3
01-'02	2423.3	-0.2	0	4	22	-0.5	10	-0.2	54	2	1	0	12.3	0	0
02-'03	1886.2	1	0.03	6	2	0.2	5	0.94	-79	10	1	12	2.72	4.8	-0.4
	Well 13														
00-'01	2507.7	0.6	0.29	50	-4	0	-10	-0.8	3	62	16	49.1	0	-20	0.4
01-'02	2423.3	0.7	0.03	38	-18	0	10	12.8	31	40	12	-34.8	17.9	-14	1.49
02-'03	1886.2	1	0.08	40	4	0.01	70	3.36	-111	28	28	51.9	2.6	4.76	0
	Well 14														
00-'01	2507.7	0.4	0.29	18	4	-2.99	-15	0.16	98	78	-13	6.01	2.88	-24.1	0
01-'02	2423.3	0.3	0.06	16	16	0	0	0.16	58	22	23	31	14.7	12.4	0.09
02-'03	1886.2	1	0.05	68	-14	-0.4	-35	1.44	-19	20	40	-1.99	-0.6	-0.84	0.59
	Well 15														
00-'01	2507.7	-0.8	0.45	28	0	-1	-10	0.38	126	46	-10	27.6	0.73	-43.6	0
01-'02	2423.3	-0.1	0.13	60	22	1	5	0.64	-8	64	10	48	40.8	19.1	0.09
02-'03	1886.2	0.4	0.01	52	12	0.9	5	2.4	-11	18	35	-20	-5.02	-7.98	0
	Well 16														
00-'01	2507.7	-0.8	0.39	32	8	-0.29	-5	1.28	97	82	-1	28	7.8	-48.7	0.09
01-'02	2423.3	0	-0.13	2	-22	-0.49	10	0.96	-65	-6	-9	-10	45.5	-4	0.09
02-'03	1886.2	0.8	-0.1	182	12	0.19	15	0.8	-34	12	5	-21	-4.63	22.4	0.19
	Well 17														
00-'01	2507.7	-0.6	0.3	2	-2	-1.99	-10	0.72	53	36	-1	-9	6.2	-40.1	-0.1
01-'02	2423.3	0.1	-0.7	4	-2	0	10	1.44	-77	8	18	39.5	30.5	15.8	0
02-'03	1886.2	0.8	0.03	100	-2	0.2	0	0.64	-31	-12	16	-33	-7.52	-13.2	0
	Well 18														
00-'01	2507.7	0.2	-0.01	10	22	0	-5	-0.84	-12	58	-7	6.01	-0.47	-7.8	0
01-'02	2423.3	0.3	-0.14	-32	6	0	0	2.72	-72	-12	-8	6	-0.14	73.4	0.2
02-'03	1886.2	0	0.01	-22	20	0.01	0	0	-52	-16	13	-12	-2.53	-4.8	1
	Well 19														
00-'01	2507.7	0	0.08	0	2	-0.39	0	-2	-46	34	30	2	-0.1	-1.44	0
01-'02	2423.3	-0.3	-0.02	-76	4	0	0	2.28	-25	6	-23	0.1	1.62	0	0
02-'03	1886.2	1	0.01	-4	-2	0.2	0	2.4	16	8	-12	-4	-0.86	0.4	0
	Well 20														
00-'01	2507.7	0	0.08	0	0	0	0	-1.82	-48	24	25	-2	0.77	-2.72	0
01-'02	2423.3	0.9	0	70	0	0	0	0.66	-17	-2	-11	6.58	-0.7	0.8	0.09
02-'03	1886.2	0.6	0.01	4	4	0	0	-0.86	-41	0	-14	1	0.16	0.4	0

Table 5.1 Bacteriological Parameters Year I

Wells	MPN	Presence of lactone fermenting organisms in 24 hours	Presence of lactone fermenting organisms in 48 hours	Number of Colonies on Agar in 24 hours/CC	Number of Colonies on Agar in 48 hours/CC
Pre Monsoon					
1	1100	0.1	0.1	6	18
2	1100	0.1	0.1	30	43
3	93	1	1	5	11
4	9	-100	10	2	6
5	1100	0.1	0.1	18	31
6	4	-100	-100	2	3
7	1100	0.1	0.1	19	25
8	240	1	1	4	12
9	1100	0.1	0.1	24	36
10	1100	0.1	0.1	Over grown	Over grown
Monsoon					
1	1100	0.1	0.1	Over grown	Over grown
2	1100	0.1	0.1	25	31
3	1100	0.1	0.1	14	19
4	Nil	-100	-100	Nil	Nil
5	1100	0.1	0.1	4	9
6	460	1	1	Nil	Nil
7	93	1	1	Nil	Nil
8	1100	1	1	Nil	Nil
9	1100	0.1	0.1	Nil	Nil
10	1100	0.1	0.1	33	38
Post Monsoon					
1	Nil	-100	-100	Nil	Nil
2	Nil	-100	-100	Nil	Nil
3	Nil	-100	-100	Nil	Nil
4	150	10	1	Nil	Nil
5	Nil	-100	-100	Nil	Nil
6	Nil	-100	-100	Nil	Nil
7	460	1	1	Nil	Nil
8	Nil	-100	-100	Nil	Nil
9	1100	1	0.1	4	7
10	1100	0.1	0.1	30	Over grown

Table 5. 2 Bacteriological Parameters Year I

Wells	MPN	Presence of lactone fermenting organisms in 24 hours	Presence of lactone fermenting organisms in 48 hours	Number of Colonies on Agar in 24 hours/CC	Number of Colonies on Agar in 48 hours/CC
Pre Monsoon					
11	1100	0.1	0.1	7	12
12	460	1	1	1	2
13	4	-100	-100	Nil	12
14	1100	1	0.1	Over grown	Over grown
15	1100	1	0.1	36	47
16	1100	1	0.1	34	39
17	1100	1	0.1	16	28
18	Nil	-100	-100	Nil	Nil
19	43	10	10	Nil	Nil
20	1100	0.1	0.1	6	10
Monsoon					
11	1100	0.1	0.1	16	19
12	1100	0.1	0.1	20	24
13	9	-100	10	Nil	2
14	1100	0.1	0.1	12	19
15	1100	0.1	0.1	Over grown	Over grown
16	43	10	10	Nil	5
17	240	1	1	Nil	Nil
18	9	-100	10	Nil	1
19	1100	0.1	0.1	22	29
20	1100	0.1	0.1	21	28
Post Monsoon					
11	1100	0.1	0.1	Nil	Nil
12	150	1	1	Nil	Nil
13	Nil	-100	-100	Nil	Nil
14	Nil	-100	-100	Nil	Nil
15	Nil	-100	-100	Nil	Nil
16	43	-100	10	Nil	Nil
17	1100	0.1	0.1	3	6
18	Nil	-100	-100	Nil	Nil
19	Nil	-100	-100	Nil	Nil
20	Nil	-100	-100	Nil	Nil

Table 5.3 Bacteriological Parameters Year II

Wells	MPN	Presence of lactone fermenting organisms in 24 hours	Presence of lactone fermenting organisms in 48 hours	Number of Colonies on Agar in 24 hours/CC	Number of Colonies on Agar in 48 hours/CC
Pre Monsoon					
1	Nil	-100	-100	Nil	Nil
2	Nil	-100	-100	Nil	Nil
3	Nil	-100	-100	Nil	Nil
4	Nil	-100	-100	Nil	Nil
5	Nil	-100	-100	Nil	Nil
6	9	10	10	Nil	Nil
7	Nil	-100	-100	Nil	Nil
8	Nil	-100	-100	Nil	Nil
9	Nil	-100	-100	Nil	Nil
10	240	1	1	3	5
Monsoon					
1	1100	0.1	0.1	Nil	Nil
2	Nil	-100	-100	Nil	Nil
3	Nil	-100	-100	Nil	Nil
4	4	-100	10	Nil	Nil
5	Nil	-100	-100	Nil	Nil
6	93	1	1	Nil	2
7	43	10	10	Nil	Nil
8	1100	0.1	0.1	grown	grown
9	1100	1	0.1	18	25
10	93	1	1	6	12
Post Monsoon					
1	Nil	-100	-100	Nil	Nil
2	Nil	-100	-100	Nil	Nil
3	Nil	-100	-100	Nil	Nil
4	240	10	1	2	35
5	Nil	-100	-100	Nil	Nil
6	Nil	-100	-100	Nil	Nil
7	23	10	10	Nil	Nil
8	Nil	-100	-100	Nil	Nil
9	23	10	10	Nil	2
10	23	10	10	Nil	12

Table 5. 4 Bacteriological Parameters Year II

Wells	MPN	Presence of lactone fermenting organisms in 24 hours	Presence of lactone fermenting organisms in 48 hours	Number of Colonies on Agar in 24 hours/CC	Number of Colonies on Agar in 48 hours/CC
Pre Monsoon					
11	Nil	-100	-100	Nil	Nil
12	43	10	1	6	10
13	Nil	-100	-100	Nil	Nil
14	Nil	-100	-100	Nil	Nil
15	Nil	-100	-100	Nil	Nil
16	4	1	10	Nil	Nil
17	Nil	-100	-100	Nil	Nil
18	Nil	-100	-100	Nil	Nil
19	93	10	1	Nil	Nil
20	43	1	1	Nil	Nil
Monsoon					
11	1100	0.1	0.1	25	40
12	1100	1	0.1	8	13
13	460	1	1	2	6
14	Nil	-100	-100	Nil	Nil
15	1100	0.1	0.1	20	40
16	1100	0.1	0.1	Over grown	Over grown
17	1100	0.1	0.1	6	25
18	Nil	-100	-100	Nil	Nil
19	1100	10	0.1	Nil	3
20	Nil	-100	-100	Nil	Nil
Post Monsoon					
11	1100	1	0.1	7	Over grown
12	93	1	1	Nil	7
13	Nil	-100	-100	Nil	Nil
14	Nil	-100	-100	Nil	Nil
15	1100	1	0.1	11	14
16	23	10	10	Nil	23
17	460	1	0.1	5	19
18	Nil	-100	-100	Nil	Nil
19	Nil	-100	-100	Nil	Nil
20	Nil	-100	Nil	Nil	Nil

Table 5.5 Bacteriological Parameters Year III

Wells	MPN	Presence of lactone fermenting organisms in 24 hours	Presence of lactone fermenting organisms in 48 hours	Number of Colonies on Agar in 24 hours/CC	Number of Colonies on Agar in 48 hours/CC
Pre Monsoon					
1	240	1	1	6	7
2	9	10	10	nil	nil
3	23	10	10	nil	nil
4	460	1	0.1	nil	
5	460	1	0.1	nil	
6	240	10	1	26	32
7	43	-10	1	2	3
8	240	1	1	nil	nil
9	1100	0.1	0.1	69	over grown
10	1100	0.1	0.11	86	over grown
Monsoon					
1	21	-100	1	3	3
2	nil	-100	-100	nil	nil
3	43	1	1	8	10
4	7	1	1	1	1
5	nil	-100	-100	nil	nil
6	43	1	1	over grown	over grown
7	nil	-100	-100	nil	nil
8	460	1	0.1	11	14
9	1100	0.1	0.1	over grown	over grown
10	460	10	0.1	3	4
Post Monsoon					
1	nil	-100	-100	nil	nil
2	nil	-100	-100	nil	nil
3	nil	-100	-100	nil	nil
4	4	-100	-100	nil	2
5	nil	-100	-100	nil	nil
6	460	10	1	nil	35
7	4	-100	-100	nil	nil
8	150	1	1	2	3
9	43	10	10	nil	4
10	460	1	1	12	16

Table 5.6 Bacteriological Parameters Year III

Wells	MPN	Presence of lactone fermenting organisms in 24 hours	Presence of lactone fermenting organisms in 48 hours	Number of Colonies on Agar in 24 hours/CC	Number of Colonies on Agar in 48 hours/CC
Pre Monsoon					
11	21	10	1	nil	1
12	240	1	-100	nil	20
13	nil	-100	1	nil	nil
14	93	1	1	3	3
15	1100	0.1	0.1	over grown	over grown
16	23	10	10	7	10
17	1100	0.1	0.1	8	8
18	nil	-100	-100	nil	nil
19	1100	0.1	0.1	nil	nil
20	nil	-100	-100	nil	nil
Monsoon					
11	23	10	10	45	over grown
12	1100	0.1	0.1	over grown	over grown
13	240	1	1	over grown	over grown
14	7	-100	1	nil	nil
15	1100	0.1	0.1	over grown	over grown
16	240	1	1	over grown	over grown
17	93	10	1	over grown	over grown
18	nil	-100	-100	nil	nil
19	43	10	1	11	15
20	23	10	10	nil	nil
Post Monsoon					
11	150	1	1	6	9
12	1100	1	0.1	nil	nil
13	2400	0.1	0.1	over grown	over grown
14	nil	-100	-100	nil	nil
15	2400	1	0.1	45	49
16	2400	0.1	0.1	over grown	over grown
17	2400	0.1	0.1	82	over grown
18	nil	-100	-100	nil	nil
19	21	-100	1	1	7
20	nil	-100	-100	nil	nil

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Table 7.1 Analysis of soil Samples

Soil	pH	TSS EC in mhos/Cm.	Org. Carbon% as a measure of Nitrogen	Phosporus (Kg/ha)	Potassium (Kg/ha)
Sample 1	6.1(acidic)	0.01 (Normal)	0.64 (medium)	9.2 (low)	111 (low)
Sample 2	5.7 (acidic)	0.01 (Normal)	0.64 (medium)	12.8 (medium)	202 (Medium)
Sample 3	6.4 (acidic)	0.01 (Normal)	0.38 (low)	18.4 (low)	245 (medium)
Sample 4	5.9 (acidic)	0.01 (Normal)	0.83 (medium)	6.4 (low)	183 (medium)
Sample 5	4.7 (acidic)	0.01 (Normal)	0.58 (medium)	16.8 (medium)	63 (low)
Sample 6	5.1 (acidic)	0.01 (Normal)	0.26 (low)	28 (high)	122 (medium)
Sample 7	7 (Nuetral)	0.01 (Normal)	0.7 (medium)	19.2 (medium)	418 (high)
Sample 8	7 (Nuetral)	0.01 (Normal)	0.77 (medium)	28 (high)	115 (low)
Sample 9	4.9 (acidic)	0.01 (Normal)	0.7 (medium)	>36 (high)	397 (high)
Sample 10	5.6 (acidic)	0.01 (Normal)	0.64 (medium)	28 (high)	280 (high)
Sample 11	7 (Nuetral)	0.01 (Normal)	0.77 (medium)	>36(high)	77 (low)
Sample 12	5.4 (acidic)	0.01 (Normal)	0.45 (medium)	20 (medium)	120 (medium)
Sample 13	5.9 (acidic)	0.01 (Normal)	0.38 (low)	8.8 (low)	127 (medium)
Sample 14	5.1(acidic)	0.01 (Normal)	0.64 (medium)	4.8 (low)	137(medium)
Sample 15	4.8 (Acidic)	0.01 (Normal)	0.38 (low)	>36 (high)	79 (low)
Sample 16	6.4 (acidic)	0.01 (Normal)	0.9 (medium)	>36 (high)	129 (medium)
Sample 17	5 (acidic)	0.01 (Normal)	0.64 (medium)	>36 (high)	122 (medium)
Sample 18	5.9 (acidic)	0.01 (Normal)	1.02 (medium)	>36 (high)	280 (high)
Sample 19	7 (Nuetral)	0.01 (Normal)	0.77 (medium)	8 (low)	647 (high)
Sample 20	5.2 (acidic)	0.01 (Normal)	0.7 (medium)	16 (medium)	229 (high)

Table 7.2 Analysis of heavy metals in soil samples

Site	Copper (ppm)	Cadmium (ppm)	Zinc (ppm)	Mecury (ppm)	Lead (ppm)
Site 1	0.003	-0.002	0.008	0.002	0.002
Site 2	0	-0.001	0.008	0.03	-0.001
Site 3	0.002	-0.003	0.073	0.026	0.001
Site 4	0.003	-0.003	0.07	0.044	0.004
Site 5	0.002	-0.002	0.035	0.063	-0.003
Site 6	0.003	-0.008	0.008	0.097	-0.004
Site 7	-0.001	-0.001	0.006	0.094	0.001
Site 8	0.004	-0.005	0.008	0.06	0.004
Site 9	0	-0.001	0.007	0.049	0.001
Site 10	0.001	-0.001	0.042	0.022	-0.002
Site 11	0.002	-0.001	0.008	0.021	-0.004
Site 12	0.004	-0.005	0.018	0.016	0.003
Site 13	0.008	-0.002	0.096	0.008	-0.001
Site 14	0	-0.005	0.097	0.005	-0.006
Site 15	0.001	-0.002	0.017	0.001	0.001
Site 16	0.001	-0.003	0.002	0.001	0.002
Site 17	0.001	-0.002	0.014	0.007	0.001
Site 18	0.004	-0.002	1.621	0.005	-0.003
Site 19	0.003	-0.001	0.107	0.003	-0.005
Site 20	0.003	-0.004	0.045	0.003	-0.006

ANALYSIS OF VARIANCE of ALKALINITY

```
                      Sum of                 Mean                Sig
Source of Variation   Squares        DF     Square        F      of F
---------------------------------------------------------------------
Main Effects        614744.761       21   29273.560    27.964    .000
SEASON               26012.478        2   13006.239    12.424    .000
WELL                588732.283       19   30985.910    29.600    .000
Explained           614744.761       21   29273.560    27.964    .000
Residual            165399.300      158    1046.831
------------------------------------------------------------------------
Total               780144.061      179    4358.347
------------------------------------------------------------------------
180 cases were processed.
0 cases (.0 pct) were missing.
------------------
```

ANALYSIS OF VARIANCE of pH

```
                       Sum of                Mean                  Sig
Source of Variation    Squares       DF     Square         F       of F
------------------------------------------------------------------------
Main Effects            54.601       21     2.600      17.781      .000
SEASON                   2.249        2     1.125       7.691      .001
WELL                    52.352       19     2.755      18.843      .000
Explained               54.601       21     2.600      17.781      .000
Residual                23.104      158      .146
-----------------------------------------------------------------------
Total                   77.706      179      .434
-----------------------------------------------------------------------
180 cases were processed.
0 cases (.0 pct) were missing.
---------------------
```

ANALYSIS OF VARIANCE of Electrical Conductivity

```
                       Sum of                Mean                 Sig
Source of Variation    Squares       DF     Square       F        of F
-----------------------------------------------------------------------
Main Effects           6.135         21      .292      1.367     .142
SEASON                  .224          2      .112       .524     .593
WELL                   5.911         19      .311      1.456     .109
Explained              6.135         21      .292      1.367     .142
Residual              33.766        158      .214
----------------------------------------------------------------------
Total                 39.901        179      .223
-----------------------------------------------------------------------
180 cases were processed.
0 cases (.0 pct) were missing.
--------------------------
```

ANALYSIS OF VARIANCE of Total Hardness

```
                            Sum of                  Mean                 Sig
Source of Variation         Squares       DF        Square       F       of F
----------------------------------------------------------------------------

Main Effects              937422.778   21        44639.180   61.048    .000

SEASON                     13080.133    2         6540.067    8.944    .000

WELL                      924342.644   19        48649.613   66.533    .000

Explained                 937422.778   21        44639.180   61.048    .000

Residual                  115531.422  158          731.212
----------------------------------------------------------------------------
Total                    1052954.200  179         5882.426
-----------------------------------------------------------------------------
180 cases were processed.
0 cases (.0 pct) were missing.
---------------------------
```

ANALYSIS OF VARIANCE of CO_2

```
                          Sum of                Mean                 Sig
Source of Variation       Squares       DF      Square       F       of F
---------------------------------------------------------------------------
Main Effects              32437.694     21      1544.652     8.067   .000

SEASON                     1455.633      2       727.817     3.801   .024

WELL                      30982.061     19      1630.635     8.516   .000

Explained                 32437.694     21      1544.652     8.067   .000

Residual                  30255.256    158       191.489

-----------------------------------------------------------------------------
Total                     62692.950    179       350.240
-----------------------------------------------------------------------------
180 cases were processed.
0 cases (.0 pct) were missing.
-----------------------
```

ANALYSIS OF VARIANCE of Calcium Hardness

```
                           Sum of                  Mean                  Sig
Source of Variation        Squares         DF      Square         F      of F
-----------------------------------------------------------------------------
Main Effects             680919.085        21      32424.718    55.881   .000
   SEASON                  3087.848         2       1543.924     2.661   .073
   WELL                  677831.237        19      35675.328    61.483   .000
Explained                680919.085        21      32424.718    55.881   .000
Residual                  91678.432       158        580.243
-----------------------------------------------------------------------------
Total                    772597.518       179       4316.187
-----------------------------------------------------------------------------
180 cases were processed.
0 cases (.0 pct) were missing.
-----------------------
```

ANALYSIS OF VARIANCE of Mg

```
                        Sum of                  Mean                 Sig
Source of Variation    Squares       DF        Square        F      of F
--------------------------------------------------------------------------
Main Effects          16156.897      21        769.376     6.156     .000
SEASON                 1271.054       2        635.527     5.085     .007
WELL                  14885.844      19        783.465     6.268     .000
Explained             16156.897      21        769.376     6.156     .000
Residual              19747.875     158        124.987
---------------------------------------------------------------------------
Total                 35904.772     179        200.585
---------------------------------------------------------------------------
180 cases were processed.
0 cases (.0 pct) were missing.
----------------------
```

ANALYSIS OF VARIANCE of Ca

```
                        Sum of                  Mean                 Sig
Source of Variation    Squares      DF         Square        F      of F
--------------------------------------------------------------------------
Main Effects          90264.430     21        4298.306    21.615    .000
SEASON                 2143.071      2        1071.536     5.389    .005
WELL                  88121.359     19        4637.966    23.324    .000
Explained             90264.430     21        4298.306    21.615    .000
Residual              31418.895    158         198.854
---------------------------------------------------------------------------
Total                121683.325    179         679.795
---------------------------------------------------------------------------
180 cases were processed.
0 cases (.0 pct) were missing.
----------------------------
```

ANALYSIS OF VARIANCE of Fe

```
                        Sum of                  Mean                 Sig
Source of Variation    Squares      DF         Square        F      of F
--------------------------------------------------------------------------
Main Effects             5.988     21           .285     1.141      .312
SEASON                    .053      2           .027      .106      .899
WELL                     5.935     19           .312     1.249      .225
Explained                5.988     21           .285     1.141      .312
Residual                39.498    158           .250
---------------------------------------------------------------------------
Total                   45.485    179           .254
---------------------------------------------------------------------------
180 cases were processed.
0 cases (.0 pct) were missing.
------------------------
```

ANALYSIS OF VARIANCE of DO

```
                          Sum of                    Mean                     Sig
Source of Variation      Squares       DF         Square          F         of F
--------------------------------------------------------------------------------
Main Effects              63.514       21          3.024        2.121       .005
   SEASON                 29.887        2         14.943       10.480       .000
   WELL                   33.628       19          1.770        1.241       .231
Explained                 63.514       21          3.024        2.121       .005
Residual                 225.286      158          1.426
--------------------------------------------------------------------------------
Total                    288.801      179          1.613
--------------------------------------------------------------------------------
180 cases were processed.
0 cases (.0 pct) were missing.
--------------------
```

ANALYSIS OF VARIANCE of Oxygen Absorbed

```
                          Sum of                Mean                     Sig
Source of Variation      Squares        DF     Square          F         of F
--------------------------------------------------------------------------------
Main Effects               6.372        21      .303        1.323        .168
   SEASON                   .349         2      .174         .760        .469
   WELL                    6.023        19      .317        1.382        .143
Explained                  6.372        21      .303        1.323        .168
Residual                  36.238       158      .229
--------------------------------------------------------------------------------
Total                     42.610       179      .238
--------------------------------------------------------------------------------
180 cases were processed.
0 cases (.0 pct) were missing.
---------------------------
```

ANALYSIS OF VARIANCE of TDS

```
                        Sum of                   Mean                      Sig
Source of Variation    Squares           DF      Square           F         of F
-------------------------------------------------------------------------------
Main Effects         2219233.711         21    105677.796      24.882       .000
SEASON                 17401.733          2      8700.867       2.049       .132
WELL                 2201831.978         19    115885.894      27.286       .000
Explained            2219233.711          21   105677.796      24.882       .000
Residual              671040.489         158     4247.092
--------------------------------------------------------------------------------
Total                2890274.200         179   16146.783
--------------------------------------------------------------------------------
180 cases were processed.
0 cases (.0 pct) were missing.
--------------------
```

ANALYSIS OF VARIANCE of Na

```
                         Sum of                Mean                Sig
Source of Variation     Squares      DF       Square       F       of F
------------------------------------------------------------------------
Main Effects           56905.851     21     2709.802     .901      .589
SEASON                  3046.687      2     1523.343     .507      .603
WELL                   53859.164     19     2834.693     .943      .531
Explained              56905.851     21     2709.802     .901      .589
Residual              474946.561    158      3005.991
------------------------------------------------------------------------
Total                 531852.412    179      2971.243
-------------------------------------------------------------------------
180 cases were processed.
0 cases (.0 pct) were missing.
-----------------------
```

ANALYSIS OF VARIANCE of K

```
                         Sum of              Mean                  Sig
Source of Variation     Squares      DF     Square        F        of F
------------------------------------------------------------------------
Main Effects              .466       21      .022      171.753     .000
SEASON                    .001        2      .000        3.082     .049
WELL                      .465       19      .024      189.508     .000
Explained                 .466       21      .022      171.753     .000
Residual                  .020      158      .000
----------------------------------------------------------------------
Total                     .487      179      .003
------------------------------------------------------------------------
180 cases were processed.
0 cases (.0 pct) were missing.
----------------------
```

ANALYSIS OF VARIANCE of Temperature

```
                         Sum of               Mean                 Sig
Source of Variation     Squares      DF      Square       F        of F
-------------------------------------------------------------------------
----
Main Effects            831.469      21      39.594     60.968     .000
SEASON                  827.669       2     413.835    637.238     .000
WELL                      3.800      19        .200       .308     .998
Explained               831.469      21      39.594     60.968     .000
Residual                102.608     158        .649
------------------------------------------------------------------------
Total                   934.078     179       5.218
------------------------------------------------------------------------
180 cases were processed.
0 cases (.0 pct) were missing.
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```