COMPARISION OF GROUNDWATER HYDROGEOCHEMISTRY OF TWO DISTRICTS OF U.P. - BALLIA AND GHAZIPUR, WITH SPECIAL REFERENCE TO As CONTAMINATION

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MASTER OF PHILOSOPHY

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CERTIFICATE

This is to certify that the research work embodied in this dissertation entitled ***"COMPARISON OF GROUNDWATER HYDROGEOCHEMISTRY OF TWO DISTRICTS OF U.P.-BALLIA AND GHAZIPUR, WITH SPECIAL REFERENCE TO As CONTAMINATION"*** has been carried out in School of Environmental Sciences, Jawaharlal Nehru University, New Delhi for the partial fulfillment of the award of degree of Master of Philosophy. This work is original and has not been submitted in part or full for any degree or diploma in any university.

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DEDICATED TO

MY FAMILY

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INTRODUCTION

"The ability to see, hear and speak is useless in the absence of adequate water. Water is the basis of life. Most life forms are born in water and live in it. "O" water stream come near me. You are the elixir of immortality". - Atharvaved, 3:13:6

1.1: Background-

Water is a prime natural resource, a basic human need and a precious asset, in the absence of this no socio-economic developmental activities can sustain. The main principle guiding the water resources development in India, since independence, has been to ensure adequate supplies of water for various uses such as irrigation, urban and rural drinking water, sanitation, industrial water and others like preserving/conserving the eco-system. There are 326 trillion gallons of water on Earth. Ninety-seven percent of all the water on our planet is salt water. Just 3% takes the form of fresh water, and 80% of that number is more or less frozen away forever in the polar ice caps and in glaciers scattered throughout the globe. That leaves less than 1% of all the water on the earth for people to use (Berner and Berner, 1987).

The human body itself is 70% water. Each of us carries about 10 gallons in our bodies at any given moment, and this supply must be constantly replenished. Water lubricates our joints, rids our systems of wastes, and carries nutrients, hormones, antibodies and more to distant points via a bloodstream that's 83% water itself. That's why replacing the water we lose through respiration, perspiration, and waste elimination is vital to our health.

Most groundwater originates as meteoric water from precipitation in the form of rain or snow. If it is not lost by evaporation, transpiration or to stream runoff, water from these sources may infiltrate into the ground. Initial amounts of water from precipitation onto dry soil are held very tightly as a film on the surfaces and in the micro pores of soil particles in a belt of soil mixture. At intermediate levels, films of water cover the solid particles, but air is still present in the voids of the soil. This region is called *unsaturated zone or zone of aeration*, and the water present is *vadose water.* At lower depths and in presence of adequate amounts of water, all voids are filled to produce a *zone of saturation*, the upper level of which is the *water table.* Water present in a zone of saturation is called *groundwater.*

The porosity and structure of the ground determine the type of aquifer and underground circulation. Groundwater may circulate and be stored in the entire geological stratum: this is the case in porous soils such as sand, sandstone and alluvium. It may circulate and be stored in fissures or faults in compact rocks that are not themselves permeable, like most of volcanic and metamorphic rocks. Water trickles through the rocks and circulates because of localized and dispersed fissures. Compact rocks of large fissures or caverns are typical of limestone.

1.2: Quantity in the earth -

Approximately 95-96% of the water on the earth is in the ocean, 2.97% is locked in the ice-caps and glaciers, including the polar region. rivers have only 0.0001% of the water where as groundwater contributes 1.05%of water to the hydrological cycle (Berner and Berner, 1996). It means, on the earth, approximately 3% of the total water is fresh water: of this, groundwater comprises 95%, surface water 3.5 % and soil moisture 1.5 %. Out of all the fresh water on the earth, only 0.36 % is readily available to use (Leopold, 1974).

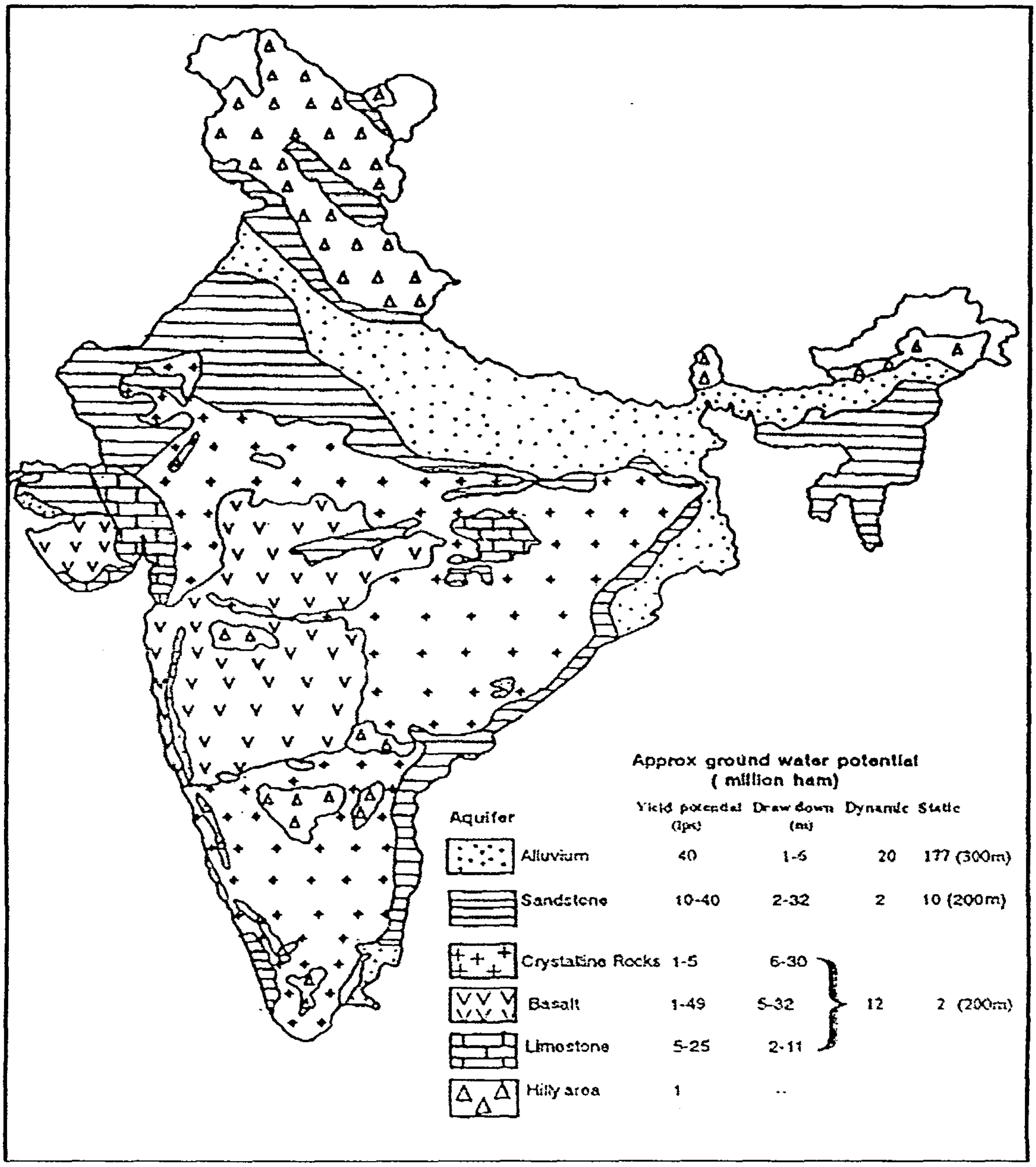
Groundwater is an important source of water supply. Groundwater is also a major source of industrial and agricultural uses. The water in some aquifers is millennia old and lies beneath what are now some of the driest regions on Earth. Although people have drown water from springs and wells since the earliest civilizations, in the past 50 years multiplying populations have needed more food and water and the rate of withdrawal has increased dramatically.

India receives an annual rainfall of about 4000 cubic meter and an estimated 19 billion kilolitres of fresh water is available in the rivers. With the onset of green revolution in the mid-sixties in some parts of the country, groundwater depletion has emerged as a major problem in both rural and urban India. Agriculture accounts for as much as 93 % of total water withdrawals in comparison with mere 4 % for industrial use (Fig.1.1).

Water is undoubtedly the elixir of life. Whether it be for irrigation, drinking, and sanitation, or for the protection of natural ecosystems and providing goods and services for growing populations, without water, life on earth is just impossible.

Worldwide agriculture is the single biggest drain on water supplies, accounting for about 69 per cent of all use. About 23 per cent of water meets the demands of industry and energy and just 8 per cent goes for the domestic and commercial use. In India, agriculture uses as much as 93 per cent of water while industry uses 3 per cent. Four per cent water is used by the domestic and commercial sectors.

Fig. 1.1: Distribution of major aquifers in India (Source: Raju, 2003)



Agriculture is also the largest polluter of water in most developed and developing countries as a result of poor land management and unwise use of fertilizers and pesticides. They end up polluting our rivers, ground water and ponds. Provision of water at low costs and its subsidized supply also causes its wasteful use.

Among domestic uses, an exorbitant amount of water is used by flush toilets, which is released as sewage into our waterways, thereby causing organic pollution. Rapidly growing population and increasing urbanization, ninety per cent of it in the developing countries, leading to more mega cities (cities with populations of 10 million or more) will significantly influence future freshwater demands.

The natural environment requires water of sufficient quantity and quality to maintain a diverse array of ecosystem functions and bio-diversity resources. An unmistakable result of the cumulative impact of human-related activities is the dramatic loss of freshwater bio-diversity. Many freshwater fish, amphibians, mussels, crayfish and dragonflies are threatened or endangered, while many others are already extinct. Over the century our water use and abuse has increased six-fold. Across the globe a billion people do not have access to safe drinking water, 3-4 billion people lack safe sanitation facilities and one third of the world's population is experiencing serious water problems. The proportion is expected to double by 2025 if current trends continue. It has been estimated that every day at least 25,000 people die from their use of water. Dirty water and poor sanitation account for 80 per cent of all diseases afflicting developing countries. In India two-thirds of all illnesses are related to water-borne diseases such as typhoid, jaundice, cholera, diarrhea and dysentery and during the monsoons these assume epidemic proportions. To feed the world in the next 20-30 years, the agriculture sector will need at least 17 % more water than it needs today and nobody knows where it will come from.

Continental *weathering and erosion* are major components of the exogenic cycles of elements on the earth. Weathering breaks down the rocks and the resulting dissolved particulate materials are transported by rivers into the sea. Chemical weathering of rocks and minerals determines the flux of dissolved materials carried by rivers whereas physical weathering regulates the particulate transport. This makes the study of dissolved and particulate components of rivers important to characterize and quantify weathering and erosion. The study of chemical composition of river water is important not only for determining erosion rates, but also to learn about sources of elements to rivers, mineral weathering and elemental mobility and uptake of CO_2 during chemical weathering. In addition, information on river chemistry is essential to assess water quality for domestic, agricultural and industrial usage. Among the river basins studied, those from the Himalaya have received more attention mainly to elucidate the coupling between tectonics, weathering and climate. In recent years, there have also been studies of rivers draining the Deccan traps to determine the role of their weathering in contributing to global riverine fluxes and atmosphere CO_2 draw down.

India has a number of rivers all of which are fed mainly by water from monsoon rains. In addition, the rivers draining the Himalaya receive water from glaciers/snow melt during summer. The water discharge from India accounts for ~ 4.5% global river discharge. The pattern of monthly discharge of rivers mimics that of rainfall, with maximum for most rivers during July–August, coinciding with the peak of the more intense southwest (SW) monsoon rainfall. Some of the rivers draining the eastern and peninsular part of India also receive water from NE monsoon rains, their discharge therefore show effect of these rains as well.

Groundwater is generally a renewable resource. However, the natural supply of groundwater in hard rock is limited in time and space. Further, the quality of available fresh water resource is under severe threat. One of the most important issues in groundwater management is extending minimum negative effects to the environment while exploiting it for maximum economic benefits. Saline water intrusion either directly from sea or by means of upcoming, leads to major contamination problems in costal-environment.

The natural quality of water depends upon the physical environment, and the origin and movement of water as the water moves through the hydrological cycle, various chemical, physical and biological processes change its original quality through reaction with soil, rocks and organic matter. Natural processes and human activities cause changes in ground water quality directly or indirectly. Groundwater is degraded when its quality parameters are change beyond their natural variation, by the introduction or removal of certain substances. The most concern pollutants get into water from both natural and human (agricultural and urban) activities.

1.3: Movement of Groundwater

Groundwater is in constant motion, although the rate at which it moves is generally slower than it would move in a stream because it must pass through the intricate passageways between free spaces in the rock. First groundwater moves downward due to the pull of gravity. But it can also move upwards because it will flow from higher-pressure areas to lower pressure areas. The rate of groundwater flow is controlled by two properties of the rock:

Porosity and permeability-

- *Porosity* is the percentage of the volume of the rock that is open space (pore space). This determines the amount of water that a rock can contain. In sediments or sedimentary rocks the porosity depends on grain size, grain shapes, the degree of sorting, and the degree of cementation.
- *Permeability* is a measure of the degree to which the pore spaces are interconnected, and the size of the interconnections. Low porosity usually results in low permeability, but high porosity does not necessarily imply high permeability. It is possible to have a highly porous rock with little or no interconnections between pores. A good example of a rock with high porosity and low permeability is a vesicular volcanic rock, where the bubbles that once contained gas give the rock a high porosity, but since these holes are not connected to one another the rock has low permeability.

Discharges and velocity-

The rate at which groundwater moves, through the saturated zone depends on the permeability of the rock and the hydraulic gradient. The hydraulic gradient is defined as the difference in elevation divided by the distance between two points on the water table. Velocity, V, is then:

$$\mathbf{V = K\,(h_2 - h_1)/L}$$

Where K is the coefficient of permeability. If we multiply this expression by the area, A, through which the water is moving, and then we get the discharge Q (*Darcy's Law*).

$$\mathbf{Q = AK\,(h_2 - h_1)/L}$$

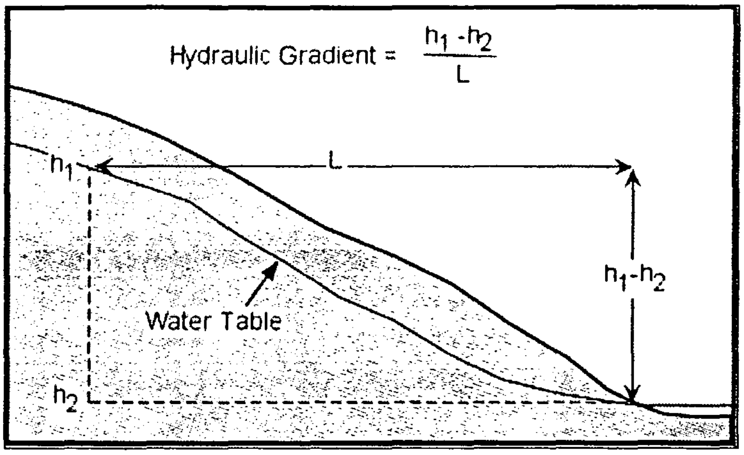
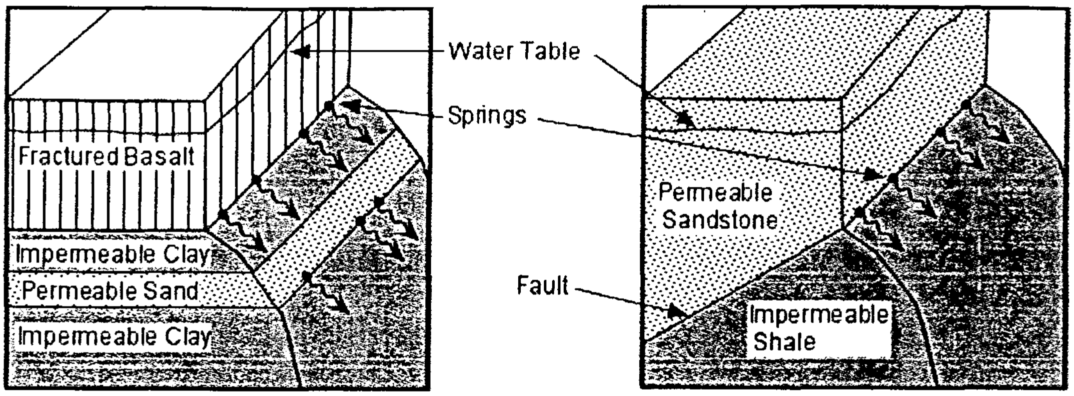


Fig. 1.2

Springs and wells:

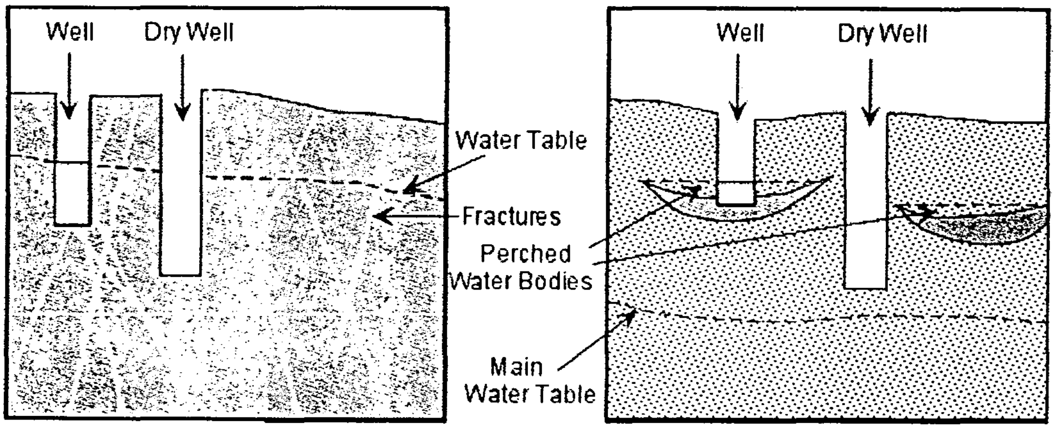
A *spring* is an area on the surface of the Earth where the water table intersects the surface and water flows out of the ground. Springs occur when an impermeable rock (called an aquiclude) intersects a permeable rock that contains groundwater (an aquifer). The occurrence of springs is closely related to the geology of an area. If an impervious layer of rock, such as a clay deposit, underlies a layer of saturated soil or rock, then a line of springs will tend to appear on a slope where the clay layer outcrops. Igneous rocks are also impervious to water, yet they are often extensively fractured, and springs commonly appear where these fractures come to the surface. Fractures in limestone are often enlarged by the dissolving action of groundwater, forming small underground channels.

A *well* is human-made hole that is dug or drilled deep enough to intersect the water table. If the well is dug beneath the water table, water will fill the open space to the level of the water table, and can be drawn out by a bucket or by pumping. An *artesian well* is a deep drilled well through which water is forced upward under pressure.



Spring

Fig.1.3



Well

Fig.1.4

The geologic conditions necessary for an artesian well are an inclined aquifer sandwiched between impervious rock layers above and below that trap water in it. Water enters the exposed edge of the aquifer at a high elevation and percolates downward through interconnected pore spaces. The water held in these spaces is under pressure because of the weight of water in the portion of the aquifer above it. If a well is drilled from the land surface through the overlying impervious layer into the aquifer, this pressure will cause the water to rise in the well. In areas where the slope of the aquifer is great enough, pressure will drive the water above ground level in a spectacular, permanent fountain. Water from an artesian well or spring is usually cold and free of organic contaminants, making it desirable for drinking.

Groundwater is water that exists in the pore spaces and fractures in rock and sediment beneath the Earth's surface. It originates as rainfall or snow, and then moves through the soil into the Groundwater system, where it eventually makes its way back to surface streams, lakes, or oceans. It is naturally replenished from above, as surface water from precipitation, streams, and rivers infiltrates into the ground. Groundwater is a long-term *reservoir* of the natural ***water cycle*** (Fig. 1.5) as opposed to short-term water reservoirs like the atmosphere and fresh surface water.

The Groundwater table is the surface of the Groundwater exposed to an atmospheric pressure beneath the surface of the saturated zone. A water table may vary in elevation. Groundwater is often contained in aquifers: an *aquifer* is an underground water saturated stratum of formation that can yield usable amounts of water to a well. There are two different types of aquifers based on physical characteristics: if the saturated zone is sandwiched between layers of impermeable material and the Groundwater is unfed pressure, it is called a confined aquifer; if there is no impermeable layer immediately above the saturated zone, it is called an unconfined aquifer. In an unconfined aquifer the top of the saturated zone is the water table as defined above. Usually an aquifer can produce an economically feasible quantity of water to a well or spring. A saturated region that, due to lower hydraulic conductivity, does not yield a sustainable amount of water in an economic fashion is called *aquitard*.

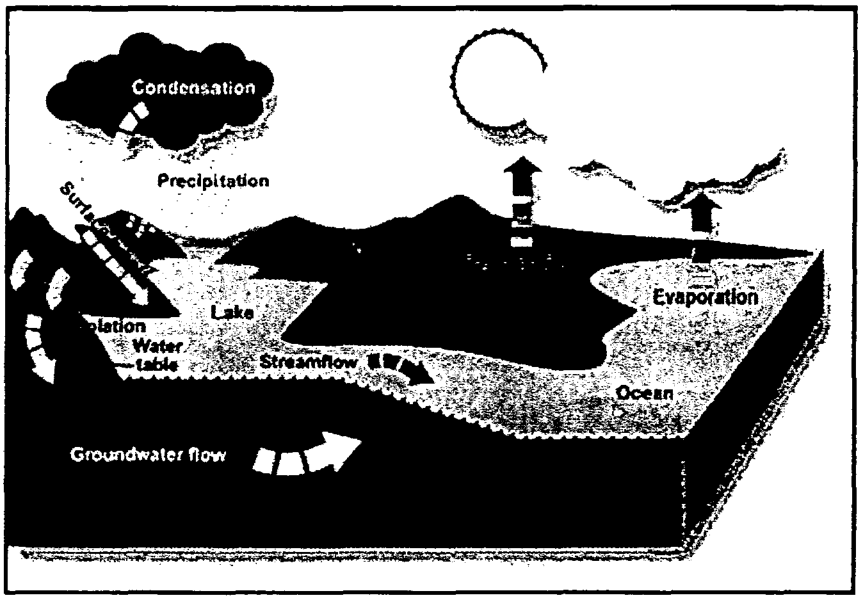


Fig. 1.5: Water Cycle (Source: USGS)

1.4: Threats to Groundwater-

1. Threats to quantity

An increased quantity of groundwater is being withdrawn to meet the demands of a growing population. Some of the typical threats associated with this include overdraft, drawdown and subsidence.

Overdraft occurs when groundwater is removed faster than recharge can replace it. This can result in.

- A permanent loss of a portion of its storage capacity.
- A change that can cause water of unusable quality to contaminate good water.
- In coastal basins, salt-water intrusion can occur.

Generally, any withdrawal in excess of safe yield (the amount that can be withdrawn without producing an undesirable result) is an overdraft.

Drawdown differs significantly from overdraft. It results in a temporarily lowered water table generally caused by pumping. In this situation, the water table recovers when the supply is replenished.

Subsidence is one of the dramatic results from over pumping. As the water table declines, water pressure is reduced. This causes the fine particles that held water to become compacted. In addition to permanently reducing storage capacity, the land above the aquifer can sink from a few inches to several feet, causing a sinkhole. This can damage property and fields.

2.Threats to quality

Inorganic compounds, pathogens and organic compounds can harm water quality, affecting the health of humans, fish and wildlife.

Each state is responsible for designating uses for groundwater, surface waters, wetlands, etc. Designated uses include fishable, swimmable, drinkable, recreational, agricultural, aquatic life, and more. Each state is also responsible for developing water quality standards for each use. For example, while most rivers are designated to be used for fishing, a few river sections are designated to be used for drinking water. The same is true for groundwater. A few groundwater uses and standards (Table-1.1) are:

Table-1.1: Showing ground water uses and standards

Groundwater uses	**Use Standards**
Drinking water	Meet MCL* for pollutants
Industrial process	Quality & quantity criteria
Stream base flow	Discharge quantity & quality

*MCL: Maximum Contaminant Level

For most groundwater uses, quality and quantity, both are important, while for surface water uses; generally quality is the primary concern (with the realization the quantity affects quality).

Inorganic Compounds include all compounds that do not contain carbon. Nutrients (nitrogen and phosphorus) and heavy metals are two examples.

- *Nitrates* can cause problems in drinking water or marine waters
- *Phosphorus* can reduce uses of fresh surface waters
- *Heavy metals* include selenium, arsenic, iron, manganese, sulfur, cadmium and chromium and others. Some (iron, manganese and arsenic) occur naturally

Pathogens, including bacteria and viruses, have been credited with causing more than 50% of the waterborne disease outbreaks in the U.S. *Cryptosporidium, Parvum* and *Giardia* both commonly cause illnesses when consumed.

Organic Compounds include Volatile Organic Compounds (VOCs) like benzene, toluene, xylene; semi-volatile compounds like Naphthalene and phenol; PCBs and pesticides.

1.5: Potential sources of pollution-

1. ***Point sources*** are easily identified because they usually come out of a "pipe."

Examples include sewage treatment plants, large injection wells, industrial plants, livestock facilities, landfills, and others.

2. ***Nonpoint sources*** refer to widespread, seemingly insignificant amounts of pollutants, which cumulatively threaten water quality and natural systems.

Examples of nonpoint sources include septic systems, agriculture, construction, grazing, forestry, recreational activities, careless household management, lawn care, and parking lot and other urban runoff.

Nonpoint sources are not required to have a permit. Individually, each may not be a serious threat, but together they may be a significant threat.

3. Other sources that aren't classified under point or nonpoint sources include underground petroleum storage systems and many large and small businesses like dry cleaners, restaurants, and automotive repair shops. Although a large number of underground storage tanks have been removed or upgraded, a significant number remain.

Industries/Businesses can threaten groundwater with a wide variety of potentially contaminating substances (Table-1.2).

Some of the most typical characteristics of groundwater are weak turbidity, a constant temperature and chemical composition and almost overall absence of oxygen. Circulating groundwater can have extreme variation in the composition with the appearance of pollutants and various contaminants. Furthermore, groundwater is often very pure microbiologically. Surface water is different than ground water in few aspects (Table-1.3).

Table-1.2: Groundwater contaminant sources (Source: EPA, 2000)

Source	Contaminant
Salting practices & storage	Chlorides
Snow dumping	Chlorides
Agricultural fertilizers	Nitrates
Manure handling	Nitrates, pathogens
Home fertilizer	Nitrates
Septic systems	Nitrates, pathogens
Urban landscapes	Hydrocarbons, pesticides, pathogens
Agricultural dealers	Hydrocarbons, pesticides, nitrates
Agricultural feedlots	Nitrates, pathogens
Solid waste landfills	Hazardous materials
Industrial uses RCRA 'C'	Hazardous materials
Industrial uses RCRA 'D'	Hazardous materials
Small quantity generators	Hazardous materials
Households	Hazardous materials
Gas stations	Hydrocarbons
Auto repair shops	Hydrocarbons
Recycling facilities	Hydrocarbons
Auto salvage yards	Hydrocarbons
Underground storage tanks	Hydrocarbons
Industrial floor drains	Hydrocarbons
Injection wells	Hydrocarbons
Junkyards	Hydrocarbons

Table –1.3: Difference between Surface water and Groundwater (Freeze and Cherry, 1979)

Characteristic	Surface Water	Ground Water
Temperature	Varies with season	Relatively constants
Turbidity, SS	Level variable, sometimes high	Low or nil (except in Karst soil)
Colour	Due mainly to SS (clays, algae) except in very soft or acidic waters (humic acids)	Due above all to dissolved solids
Mineral content	Varies with soil, rainfall, effluents, etc.	Largely constant, generally appreciably higher than in surface water from the same area
Divalent Fe and Mn in solution	Usually none, except at the bottom of lakes and ponds in the process of eutrophication	Usually present
Aggressive CO_2	Usually none	Often present
Dissolved O_2	Often near saturation level, absent in very polluted water	Usually none
H_2S	Usually none	Often present
NH_4	Found only in polluted water	Often found
Nitrates	Level generally low	Level sometimes high
Silica	Usually moderate proportions	Level often high
Mineral and organic micro-pollutants	Can be present but liable to disappear rapidly once the source is removed	Usually none but any accidental pollution lasts a very long time
Living organisms	Bacteria, viruses, plankton	Iron bacteria frequently found
Chlorinated solvents	Rarely present	Often present
Eutrophic nature	Often. Increased by high temperatures	None

1.6: Geochemical processes affecting groundwater quality-

The geochemical properties generally depend on those of recharge of water which atmospheric precipitation, in land surface water and seawater and surface geochemical processes. Temporal changes in origin and constitution of recharge water, hydrologic and human factors cause periodic chances in ground water quality. The knowledge of geochemical processes, often leads to an understanding of groundwater quality and occasionally aid in making useful predictions. The different geochemical process which influence groundwater greatly is given below (Todd, 1980, Drever, 1982): -

A) Reduction

The important constituents to be affected by this process are sulphates and nitrates. The important of sulphate is generally due to microbial activity (Scholler, 1962) and is accompanied by subsequent oxidation of available organic matter (by released oxygen) resulting in production of CO_2, which in turn produces large quantities of HCO_3^-, H^+ and CO_3^{-2} ions.

B) Ion exchange

The replacement of structural and adsorbed ions of the geochemical materials by the ions present in the solution has been termed as *ion exchange* (Garrel and Christ, 1965; Hem, 1985). However there is not a single replaceability series for inter changeability of ions. The degree to which the ion exchange (both cation and anion exchange) occurs, depend on: -

a) Concentration of exchangeable ions in the solution

b) The type of solid material or sediments in contact with solution

c) The state of the ion in the solid structural adsorbed and

d) Degree of saturation of that ions in the solid

The exchangeability of an adsorbed ion is far greater then that of structural ion. The common exchange is, therefore, between the ions adsorbed by the solid, which is commonly seen in clay minerals, Zeolites and organic substances. The adsorption capacity of some mineral is also influenced by other characteristics of adsorbed ions, besides its charge, e.g. ion radius and degree of hydration.

Scholler (1962) has explained two types of base exchange-

i) Positive, when alkaline (Na^+, K^+) in water get exchanged for alkaline earth (Ca^{2+}, Mg^{2+}) in the aquifer material.

ii) Negative, when alkaline earth in the water get exchanged with alkalis in the rock.

Former is generally the case, when saline water inters the fresh aquifers and later takes place in the areas of inland saline water or in transition cone between the fresh water and saline water.

C) Evaporation and dissolution

The processes of evaporation and dissolution control the concentration of aqueous solution to greater extent, which in turn is influenced by the climatic factors.

Scholler (1962) listed main factors influencing the main process of mineralization as dissolution and concluded that the ground water is commonly highly mineralized due to large residence time is sub surface formation under relatively higher temperature gradients (resulting in considerable depths), thus allowing greater rock water interaction.

D) Sea water encroachment

Simple mixing of two water of different composition can result in a new kind of water, which may not necessarily retain the qualities of the individual water. Seawater during encroachment into coastal aquifers can modify the composition of the ground water by base exchange, sulphate reduction and substitution of carbonic and other weak acid radicals and also by solution and precipitation.

1.7 : Gangetic plain in India

The river Yamuna from the west at Allahabad joins the Ganga basin, then the rivers Ramganga, Gomti and Tons from the north and the Chambal, Betwa, Sinda and Ken from the south. In India the Ganges basin covers 8 states: Uttar Pradesh (34.2%), Himachal Pradesh (0.5%), Haryana (4%), Rajasthan (13%), Madhya Pradesh (23.1%), Bihar (16.7%), West Bengal (8.3%) and Delhi (0.2%). The catchment area of the Ganga basin is 1.06 million sq. km. out of which 861,404 sq. km. lies in India. Physiographically, the Indo-Gangetic Plains in India can divided into 3 parts: a) The Himalayan ranges and the Siwaliks to the north and north-west, b) the plains that range from east to west, and c) the highlands comprising the Malwa plateau, the Bundelkhand uplands, the Vindyachal-Baghelkhand plateau and the Chotanagpur plateau (Wadia, 1978). The average annual rainfall ranges from 400-500 mm from parts of Punjab to 1200 mm in West Bengal. Parts of the plateau highlands in the south also receive high rainfall as much as 2000 mm annually. The pattern of concentration of well density and availability of groundwater show variation across the plain areas. Freshwater parts of the western plains have shown high degree of development and there is extensive depletion of groundwater over vast areas, whereas saline groundwater areas in the western plains are showing signs of rising water tables. Towards the eastern plains, there is lesser intensive and profitability in exploiting groundwater, therefore, the degree of development is not as high (Ambast et. al., 2005). Saline tracts of groundwater exist in the in central parts of the Ganga basin plain areas. The eastern parts of the basin are affected by arsenic contamination and some areas have high iron content in groundwater.

In the plain areas, the rice-wheat cropping system is the most common. In the Trans Indo-Gangetic Plain, which earlier supported crops like maize, cotton and sorghum during kharif season and wheat during rabi season, introduction of rice crop was largely a consequence of waterlogging in canal irrigated areas and development of intensive network of shallow tubewell technology. The average productivity of rice-wheat sequence in this part is quite impressive against the average in the Indo-Gangetic Plain (IGP). However, these significant gains are over-shadowed by the emerging sustainability issue of declining groundwater and adverse salt and water balance problems on regional scale. The problem of groundwater decline is mainly concern in the areas where groundwater quality is either good or marginal. The groundwater decline can be reversed either through structural artificial groundwater recharge) or by policy options of adopting suitable land and water management policies, which either encourages rainwater conservation or reduces irrigation water demand (Central Soil and Salinity Research Institute, 2003).

The entire middle Gangetic plain shows a vast presence of groundwater resource. The presences of these huge ground water resource combined with availability of tube well technology (Tiwari, 2003) and energy availability (diesel, electricity) have contributed to the boom in groundwater development. But these developments have been ignoring the ground water quality deterioration threat to central part of Ganga

Skin problem in Foot, in Tiwari Tola, Ballia, U.P.

Arsenic effected skin in woman in Tiwari Tola, Ballia,U.P.

basin. As such no systematic study on ground water (quality and quantity) in the middle Ganga plains has been carried except some unpublished reports (discussed in detail in literature review chapter) from government agencies. There is also few newspaper report on alarming level of As in these zone, there arises a need for systematic documentation of the ground water quality data base. Hence keeping these in mind this study has been initiated.

1.8: Objective

Due to the deteriorating trend reported on the ground water quality in the middle Gangetic plain, which is yet to be scientifically documented in the two districts of Ballia and Ghazipur , this study on ground water quality with special emphasis on the Arsenic distribution has been attempted with the following objectives:

(1) Study of ground water quality and its classification in space and time.

(2) Identification of geochemical processes controlling the water chemistry.

(3) Assessment of weathering and anthropogenic influence on the groundwater quality.

(4) Arsenic enrichment in the ground water of shallow and deep aquifers

(5) Statistical analysis of the water quality data.

CHAPTER- 2

STUDY AREA DETAILS

2.1 : Ballia –Study area details

Location, Boundaries, Area and Population

- **Location and Boundaries** - The district is the easternmost part of the State and borders on Bihar State. It comprises an irregularly shaped tract extending westward from the confluence of the Ganga and the Ghaghra, the former separating it from Bihar in the south and the latter from Deoria and Bihar in the north, and east respectively. The boundary between Ballia and Bihar is determined by the deep streams of these two rivers. It is bounded on west by Mau, on the north, by Deoria, on the north-east and south-east by Bihar and on the south-west by Ghazipur (Fig. 2.1). The district lies between the parallels of 25°33' and 26°11' North latitudes and 83°38" and 84°39' East longitudes.

Area - According to the central statistical organization the district had an area of 3,183 sq. km.

Population - According to the census of 2001, the district population is 2,752,412 and the population density is 923/sq.km

Topography

The district is a level plain, intersected by numerous streams. Though there are no hills, the level surface is varied because of the high banks of the great rivers and the gentle slope from the central watershed towards the Ganga, the Ghaghra and the Saryu. There are depressions of varying depth and extent in which the drainage water collects prior to its draining into the main systems of the river.

The district can be divided into two natural divisions: the interior upland and the lowland tract. In area the two divisions are approximately equal. The upland has an average altitude of 64 m above sea level and comprises the western half of the district, including the whole of the Bhadaon. Lakhnesar and Kopaohit parganas, most of Sikandarpur, the interior portion of Garha and a narrow strip of land extending eastwards into the Kharid and Ballia parganas. Here the boundary is marked roughly on the south by the railway line as far as Sahatwar and then bends back in a direction generally parallel to that of the Ghaghra, close to the town of Bansdih, from which place it curves westwards and then north to Maniar, a town standing on," the bank of the Ghaghra. There is a second ridge of the same nature near Qutabganj but between these two spots the bed widens out into an extensive alluvial tract. In the west of Qutabganj there is another stretch of low alluvial land, continuing as far as Bilthra, where the high bank touches the river. On the south-west the tracts that are higher terminate in the valley of the Saryu, which has a deep channel of no great width. In the interior the level is only broken by scattered depressions. The soil is for the most part a light loam with a fair admixture of sand. The proportion of sand increases on the higher ridges and the soil becomes very light, though not unfertile. In the depressions the soil is mostly clay and in these tracts paddy is the chief crop. The western portion of the upland is characterised by wide stretched of usar, which is very common in the Kopachit, Lakhnesar, Bhadaon parganas and part of the Sikandarpur pargana.

The lowland tract comprises the rest of the district but is far from being of a uniform character. The main distinction is between the more recent and the ancient alluvium, the former lying near the banks of the river and the latter including those lands which have remained untouched for a long time and are marked by great fertility.

The surface of the lowland is usually very uneven, being scored in every direction by irregular depressions marking the old courses of the rivers, some almost resembling tributary streams and others surviving as narrow lagoons. As a rule the level is about 4.5 meter below that of the upland, though it varies from place to place.

River System and Water Resources (Lakes and Tals)

There are only three main rivers in the district: the Ghaghra, the Ganga and the Saryu.

Rivers- Ghaghra, Ganga and Chhoti Saryu

Ghaghra River –

This is a great river and flows on the northern border of the district. It has its origin in the mountains of Kumaon and is formed of the combined waters of the Chauka, the Kauriala, the Rapti and other smaller streams. During the rains it swells to a great extent and as the current becomes very strong and rapid it causes much damage to the adjoining area. The course of the river is interrupted by *kankar* reefs at a few places such as Turtipur, Qutnbganj and Ailasgarh and the variations in the channel are continuous but the greatest changes are those, which occur east of Maniar. In this part of the district the whole tract south of the river is low alluvium, which gets submerged during the floods. It includes all the land north of the towns of Bansdih and Reoti. The changes made by the Ghaghra are more sudden and sweeping than those of the Ganga. The Ghaghra is' much more unstable, both in its action and effects. It is generally not possible to predict its course as sometimes it confines itself to a comparatively narrow bed, at others it fans but into several channels, sometimes leaves behind it fertile deposits of land and sometimes nothing but barren and sandy waste.

- **Tributaries of Ghaghra –**

The Ghaghra receives very little drainage in this district and so its tributaries are insignificant. The first, the Hahaor Ahar, is a small stream which joins the Ghaghra about 4.8 km. west of Turtipar after forming for a short distance the boundary between this district and that of Azamgarh. It rises in the Ratoi Tal in pargana Natthupar of Azamgarh and its effect on the drainage is very slight. Another tributary is a small stream, the Bahera, which falls into the Ghaghra" near Maniar and drains part of Sikandarpur East. It is a small and unimportant stream and flows into the Mundiari Dab Lake and then into the Ghaghra to the east of Maniar. Still another tributary is the Tengraba, which is actually a backwater of the Ghaghra. It first leaves the Ghaghra a short distance east of, Maniar and flowing through the northern pargana of Kharid in a tortuous course, passes into Doaba and rejoins the main river in the village of Chand Diara.

Ganga River –

The Ganga first touches the boundary of the district in the extreme south of pargana Garha where it flows between Korantadih and Buxar, each of which stands on a high bank of kankar formation. From there its course lies through alluvial land. From Buxar eastwards its course is a succession of loops and bends. The permanent banks, which are not subject to erosion, are about 15 to 30 km. apart but between these limits the course of the river is variable. At one place it encroaches on Ballia and a little further down it sweeps round, cutting into Bhojpur and depositing tracts of new alluvium on the north. The changes are great in pargana Doatia, almost the whole of which is submerged during the rains, the silt deposited being of great fertility. In the district the river flows in a north-easterly direction as far as the town of Ballia and from there it turns towards the south-east and after flowing for some distance it turns northeast. Reaching Majhawa it again bends towards the south and afterl flowing some kilometers it turns east and flows into district Bhojpur (in Bihar).

Saryu River - The chief tributary of the Ganga in this district is the Saryu, which first touches the boundary of the district in pargana Bhadaon and then for several kilometers separates Ballia from Ghazipur. Near Pradhanpur it enters pargana Kopachit West, afterwards flowing in a south-easterly course through Kopachit East and pargana Ballia, and joining the Ganga near. Bansthana, about 5 km west of the town of Ballia.

Other Streams - The Mangai river unites with the Saryu before the latter's junction with the Ganga. It enters pargana Garha from Ghazipur, about 3 km. south of Karaon. It then continues in a north-easterly direction past Narahi and several other large villages, carrying off the drainage of the upland portion of pargana Garha. The Budhi river-is another tributary of the Saryu, which joins it near Baragaon. It takes its origin in a chain of jhils (in pargana Sikandarpur west) known as Basnahi Tal. It is not a very significant stream. Another stream is the Katehar nala which carries off the overflow from Suraha Tal intb the Ganga It leaves the lake on the eastern side and then curves to the southwest, passes to the west of the town of Ballia and then joins the Ganga.

Lakes

- **Surha Tal** - The most important lake in the district is the great Suraha Tal, which covers a large area. Its circumference is about 25.6 km. In the deeper parts of the lake, large quantities of the weed called *siwar* are grown. It is drained or filled by the *Katehar Nala*, which connects it with the Ganga. It al so receives a large amount of drainage from the adjoining area. Two small channels on the west, one of which follows the boundary of the Ballia and Kharid parganas and the other, known as the *Garari*, which flows somewhat to the north, drainage a portion of Kharid, and Kopachit East, pour their water into this lake.

- **Other Lakes** - Among other lakes the largest is the Mundiari Dah, which lies between Maniar and Bansdih. -It is of a narrow, semi-circular shape, its overflow passing into the Ghaghra. At times the lake is liable to be inundated by the floodwater pouring into it from the north. Reoti Dah, which lies to the west of the town of that name also pours its water into the Ghaghrau A third lake in the Ghaghra lowlands is that of Sikandarpur, a short distance east of the town. In tahsil Ballia there is Kawal Dah to the north-east of the district headquarters. Tahsil Rasra possesses several lakes such as Garha Tal near Ratanpura and Intaura in pargana Bhadaon, about 5 km. to the west. Others. are Taliji Tal to the south of Rasra, Goka Tal, a short distance north of Ratanpura, and an extensive lake near Haldi in the north of the tahsil.

Geology

The geology of the district exposes nothing except the ordinary Gangetic alluvium. The mineral products are few being confined to the saline earth from which saltpetre and salt are produced, and to the limestone conglomerate known as *kankar*. Saltpetre is found in the Rasra tahsil, though patches are also found elsewhere. Kankar is found in all parts of the district except in Doaba and the lower tracts of pargana Ballia. At some places it is found in masses on the surface, at others at a considerable depth and at some places it exists as a solid arid compact mass but usuall v it occurs in small nodules. Often it takes the form of block *kankar* and in this shape it is quarried at

Sihachaur on the road from Phephna to Rasra. It is used for road metal for concrete and for producing lime (Gazette-Ballia).

Soils - The land around the village sites, which is rich in manure, is known as goind and outlying fields is *paliwar*. There are also other natural soils such as *matiyar* or clay, *bhur* or sand and dumat or loam, a wide term, which includes other soils that do not come under the first two categories. The clay soils vary in character, as much of the land so termed is very stiff and can only be used for the cultivation of rice during the rains though elsewhere it can be ploughed for a second crop in the following winter. The *bhur* ranges from a very light loam to soil filled with *kankar* or which is almost pure sand, excellent crops often being grown in the former; where it becomes more broken and sandy, it produces only the inferior staples such as *bajra* and *arhar* and in its worst state only *masoor*. The loam of the district is light, fertile soil, shading off into clay in the rice-growing tracts and near the rivers into sand. The soil can also be divided into rabbi and rice land. The rice land is classed as *dhan*, grows only *ekfasli*, late or early rice and depends more or less on the vagaries of the monsoon. It has been classed s *dhan* I, II and III according as it is fertile, secure or unsafe and precarious.

The class of rabi land depends on the kind of soil, the distance from the homestead and the irrigation facilities available. The soil classed under rabi lands are *kachhciana*, *goind* I and II (wet and dry), *dumat* I, II and III, *bhur* land II. *tarai* land II and kachchar land II. The vegetable plots, which are heavily manured and skilfully and intensively cultivated, and pan gardens are classed as *kachchiana*. Fairly manured rabi land and slopping fertile land falling below the standard of goind is demarcated as dumat I, which is well-irrigated and well-manured soil, while dumat II is comparatively inferior land where irrigated rabi crops are rarely grown. Dumat III

SOILS

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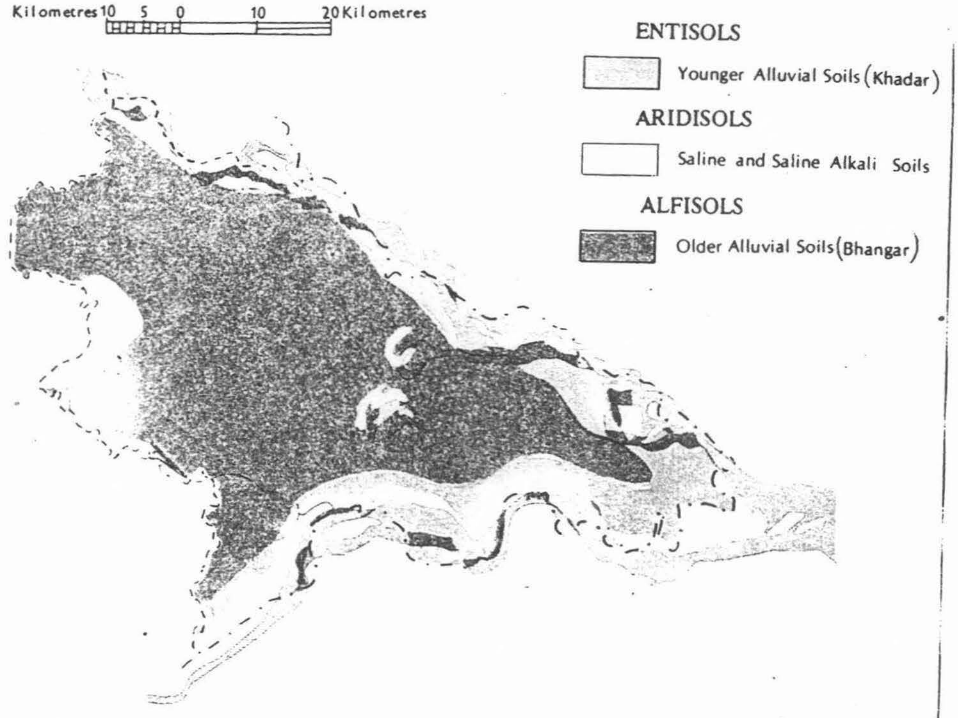

Source National Atlas Maps

GENERAL LAND USE AND CROPPING PATTERN

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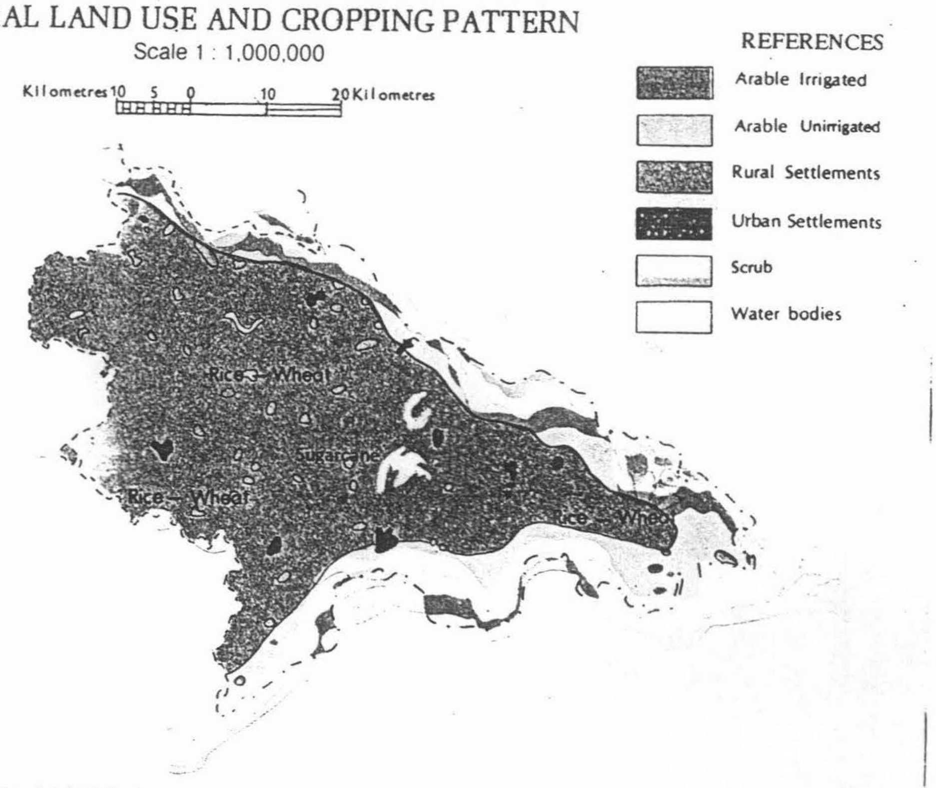


Source : National Atlas Maps

Ballia Thematic Maps

consists of *usar* blocks including the poor, *ekfasli rabi* fields. Tarai lands are submerged areas in the beds of lakes and malas or on their edges, which get flooded during the rains and grow *ekfasli rabi* without being irrigated. The fertile *kachchar* land with clay alluvial silt is kachchar I. The rest of the *kachchar* generally clay is classed as dumat *matiar,* an average loam as dumat *dorasa* and sandy loam as dumat *baluhi.*

Climate

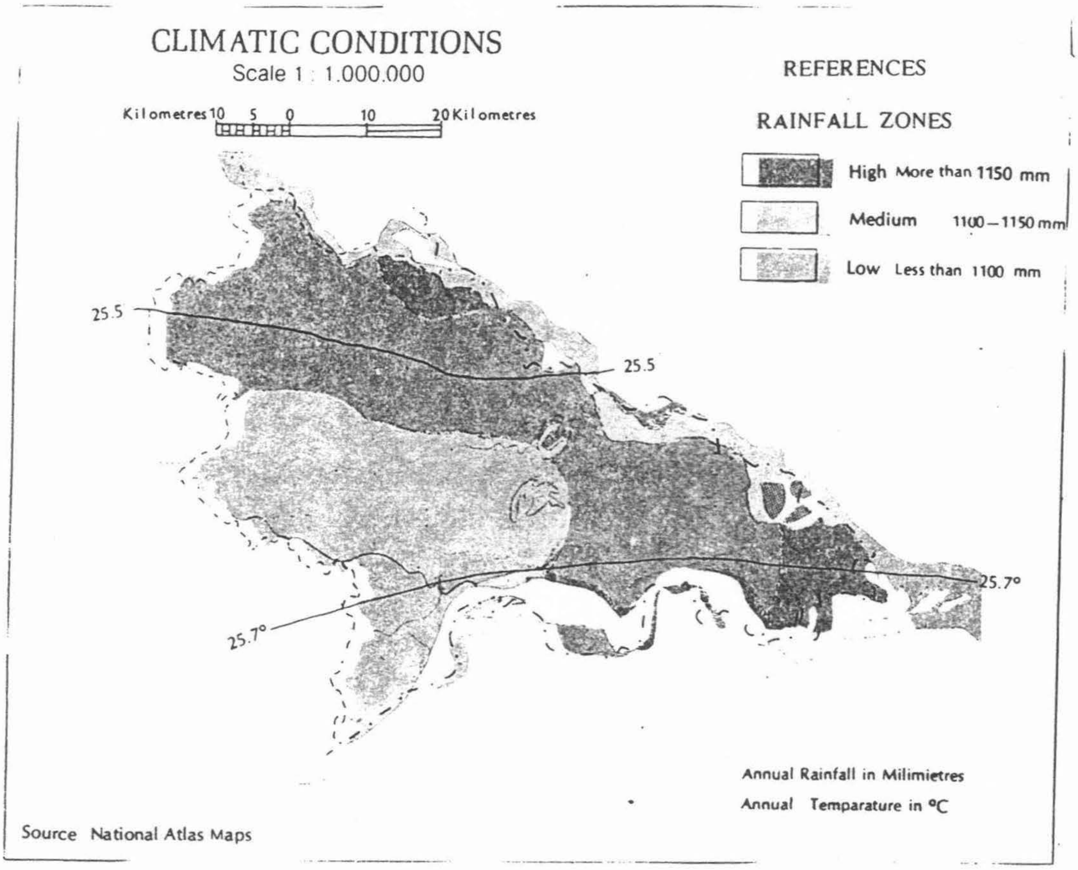
The climate of the district is moist and relaxing except in the summer and cold seasons. The year may be divided into four seasons: the cold, which lasts from about the latter half of November to February: the hot, from March to about the middle of June; the south-west monsoon season, which constitutes the period from about the middle of June to the end of September: and the post-monsoon or transitional season which covers October and the first half of November.

- **Rainfall**

About 88 per cent of the annual rainfall is received during the southwest monsoon months (June to September), August being the rainiest month. Except for the area around Sikandarpur, which gets less rainfall, the variation in the rainfall from place to place in the district is not much nor is the variation from year to year large.

- **Temperature**

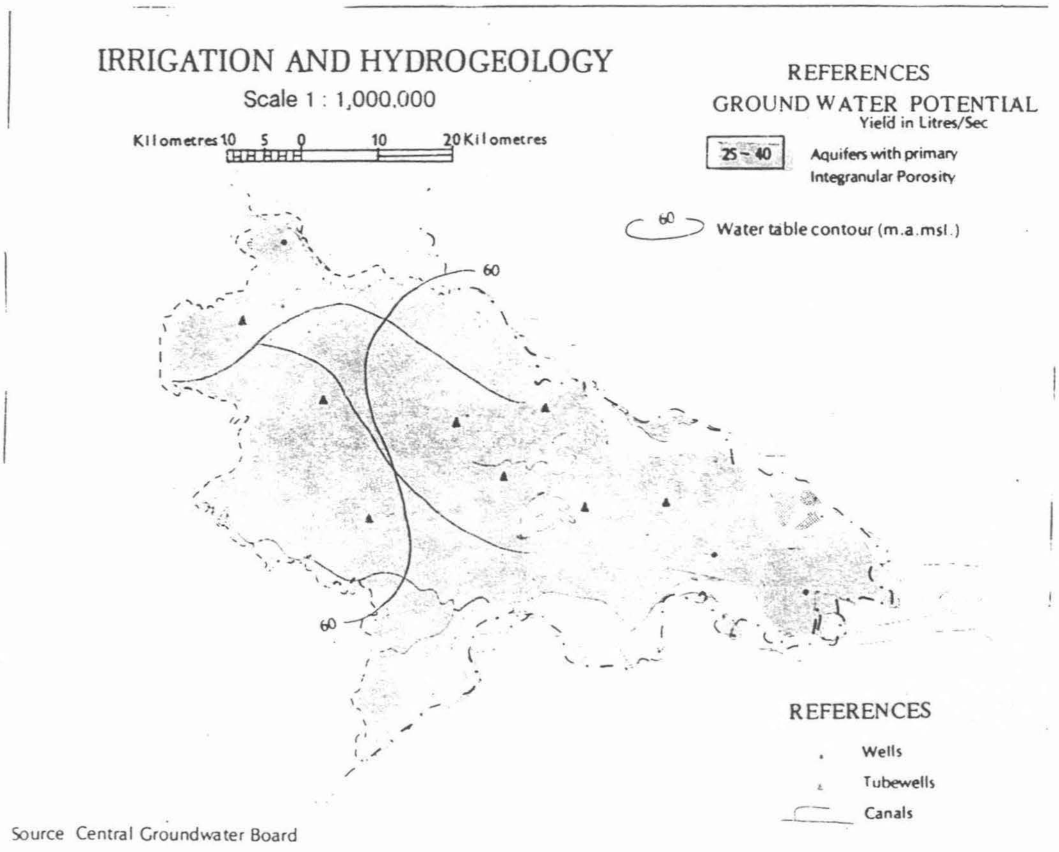
Ballia is the only place in the district where there is an observatory and meteorological records are available for only a short period for this station. The description, which follows, is based on -these records supplemented by the records of observatories in the neighbouring districts, which have a similar climate.



CLIMATIC CONDITIONS

Scale 1 : 1.000.000

Source National Atlas Maps



IRRIGATION AND HYDROGEOLOGY

Scale 1 : 1,000,000

Source Central Groundwater Board

Ballia Thematic Maps

2.2: Ghazipur- Study area details

Location, Boundaries, Area and Population

- **Location and Boundaries** - The district of Ghazipur forms, the eastern part of the Varanasi Division. It lies between the parallels of 25° 19' and 24° 54' N latitude and 83° 4' and 83°'58' E longitude. It is bounded on the north-west by Azamgarh, on the north-east by Ballia and on the south-east by Bihar state, (Fig. 2.1) from which it is separated by the Karamnasa river. The boundaries are generally conventional though at places they are marked by natural features, such as the Sarju (Tons), Karamnasa and other small streams.

  Area - According to the central statistical organisation the district had an area of 3,381 sq. km.

  Population - According to the census of 2001, the district population is 3,049,337 and population density is 903/sq km.

Topography

The general slope of the district is from north-west to south-east this being the direction generally taken by the subsidiary drainage lines though the Ganga itself leaves the district in a higher latitude than at its point of entry, while the north-easterly course of the Karamnasa points to the existence of a reversed slope on the south hank of the Ganga. The soils and the general topography of the district depend directly on the drainage. The district can be divided into three physical divisions the northern uplands; the central lowlands and the southern uplands.

The northern uplands, which comprise all the country north of the Ganga, with the exception of parts of Saidpur and Ghazipur and the greater portion of Muhammadabad, mostly resemble the ordinary uplands of the Gangetic plain. The higher levels are sandy and on the slopes inland from the banks of the streams the soil becomes good fertile loam (usually of somewhat light character) but in the depressions this merges into a stiff clay which turns into *usar* wherever saturation occurs and the grey *dhankur* being fitted (as its name implies) for the cultivation of The light sandy soil is generally known as *balua*, the loam as *doras* (corresponding to dumat of other parts) and clay as *matiyar*. In most parts, of the upland there is a large amount of *kankar* in the subsoil.

The alluvial lowlands, generally known as- terai comprise a small portion of the Saidpur and Ghazipur parganas, almost the whole of Karanda and the greater part of Muhammadubad from the Ganga to the road, which goes from Ghazipur to Lathudih and Ballia. South of the Ganga the alluvial area includes half of the Zaniania tahsil, the limit being marked roughly by a line from the town of Zaniania to Nagsar and then to Gahmar. Here the soil varies from the sand found on the banks of the Ganga to the fine loam deposit left by the river and the characteristic *karail* (dark soil). There are two *karail* tracts, one in Muhammadabad, where it includes all the land from Korantadih and Ballia road on the south to the banks of the Mangai on the north, stretching westward to within 3 km.of Muhammadabad itself; and the other in the centre of Zamania, forming a three-cornered area with Nagsar, Sohwal and Karahia at the three angles.

The central portion of Zamania constitutes the southern uplands, which have the ordinary loam and clay soils of the northern uplands. There is a stretch of fertile karail on the north of the Karamnasa River from the boundary of Varanasi on the west to the village of Dewalon the east.

River system and water resources

The Ganga is the most important river of the district, the rivers Gomati, Gangi, Besu, Mangai, Sarju and the Karamnasa being directly or indirectly its main effluents.

Ganga - This river first touches this district in the extreme south- of pargaoa Saidpur and forms the boundary between Ghazipur and Vajanasi for a long distance. After the first 3 km. it changes direction at Aunrihar, bending to the south-east and after some distance turns north-eastward. Near Nari Pachdeora in Saidpur it takes a sharp beud to the south-east flowing fast Chochakpur and Paharapur. From Mainpur the Ganga sweeps to the north-east but a few kilometres beyond the district headquarters it bends to the south-east through a wide expanse of alluvium. For many years it used to work its .wsy through three distinct channels, enclosing large islands biu the current has now shifted wholly to the right hand channel. Thus from Zamania to Bara the course of the river forms an immense arc encompassing the Zamania pargana, with the town of Ghazipur in the centre on the outer side. At Bara the bed narrows and the stream flows eastward as far as Chaunsa in Shahabad, where it turns to the north-east separating pargana Muhammadabad from Bihar. The total length from its first point of contact in this district to its exit at Rasulpur is about 102 km.

Gomati - The first tributary to join the Ganga in this district is the Gomati, which flows along the southern boundary of the Saidpur tahsil, separating it from Varanasi. The Gomati is here a navigable stream subject at times to heavy floods, which are intensified by the action of the Ganga in holding up the water at the junction. The land along the Gomati is broken by ravines some of which extend inland for a long distance, one of the chief being the Sarwa, a small watercourse that forms the boundary between this district and Jaunpur.

Gangi - The next tributary on the left bank is the Gangi, a stream rises near Jaunpur and makes its way in a south-easterly direction through the clay lands along the borders of Jaunpur and Azamgarh. At its entry into this district at Soniapar near Nek Dih, it is joined by a minor drainage channel, called Pachhadi and then it flows for a few kilometres along the Azamgarh boundary, afterwards separating the parganas of Bahriabad and Saidpur. At Dahara it is fed by a small affluent, which carries down the drainage from the country to the west, and then it passes into pargana Saidpur where its course is marked by a succession of loops and bends, the general direction being east-south-east. It forms the boundary between the Karanda and Ghazipur parganas and joins the Ganga at Mainpur.

Mangai - This is a big river which rises near Dostpur in the Sultanpur district and then flows through the north of Jaunpur and the south of Azamgarh, entering Ghazipur district in .the north of pargana Shadiabad. Then it maintains a south-easterly course, though its channel is very tortuous, as far as Sheikhpur, where it is crossed by the road from Ghazipur to Gorakhpur. From that point it bends to the north-east for several kilometres but again turns south-eastward through the Muhammadabad pargana till it readier, Hata from where it again flows north-eastward along the edge of the uplands to Lathudih where it once more takes a south-easterly course into the Ballia district and finally joins the Sarju (or Tons) just before the junction of the latter with the Ganga. The total length of the river in this district is about 99 km. It drains a very large area but it receives no affluent of any importance. The Sota, which is a small stream, traverses the north-west corner of the Muhaminadabad tahsil, rises near Kaglwipur and falls into the main stream on the left bank at Gathia. Like other rivers, the Mangai carries a large volume of water during the rains but in 'dry seasons it shrinks considerably.

Sarju - The Sarju (often known as the Tons and also as the Chhoti Sarju to distinguish it from the greater river of this name) contains the combined water of the Tons and the Chhoti Sarju, the two streams uniting near Mau in Azamgarh and then passing into pargana Zahurabad near Bahadurganj. After receiving the Bhainsahi on its right bank, the Sarju flows along the northern boundary of pargana Zahurabad for a considerable distance, separating the district from Ballia into which it passes from pargana Dehma. Its only tributary besides the Bhainsahi is a small stream called the Godhni, which has its origin in a line of jhiis of which Singhera Tal is the chief, after running through pargana Zahurabad, for about 15 km. it, fails into the Sarju near the village of Fateii Sarai. The Sarju is a considerable river flowing in a broad valley: During the rains it becomes deep and rapid. The floods often attain large dimensions but unlike those of the Ganga are injurious as they.genel rally leave behind nothing but sand.

Karamnasa - The Karamnasa, known as the ill-omened stream its name meaning the destroyer of pious deeds—was avoided by the superstitious or the orthodox. Basing in the Kaimur hills, it passes through the districts of Mirzapur ami Varanasi aid, flowing towards the northeast, forms the boundary of the district, which it separates, from Bihar. It joins the Ganga near Bara at Chaunsa. It drains a considerable area of the southern uplands and is fed by several small channels, of which the chief is the Ekqaiya, which join it at Diwaitha.

Lakes - Though the rivers drain the district, there are certain "tracts particularly in the north of the district especially in the tracts between the Mangai on the south and the Bhainsahi and Sarju on the north, in which there is hardly any natural drainage and where there are' depressions from which the surface water finds no proper outlet. Shallow jhils and lagoons are to be found here which extend in an irregular line and follow the general slope of the ground. Where the depressions are so shallow that jhils or swamps cannot be formed, they are utilized for the growing of rice. The surface water, essential for the growth of rice, is held by means of low earthern dams. The most northerly of these lines is in Pachotar, where the long

Singhera Tal with its many branches sends its overflow eastward to the Godhni, assisted by another string of swamps at Sulemanpur, Mahudpur and other villages, extending north-eastward. A more important line is that which originates in the Malhcr or Nada Tal near Jalalabad and continues in a south-easterly direction to the Manadar or Majhan jhll, that at Kothia on the Shadiabad border and the large Udain and Sheda Tals near Bonga from where the line extends right across Pachotar into Muham-madabad at Kaghzipur, there forming the source of the Sota stream. The smaller jhils usually dry up during the cold weather. In the south-east of Zahurahad there is a large jhil near Barachaur. A similar line of swamps, known as the Parna jhil, extends through the north of Saidpur in the tract between the Besuand the Gangi. There, is another line of swamps in Khanpur and the east of Saidpur, which discharges overflow into the Gangi. In the extreme west of pargana Ghazipur there is an extensive depression called the Reonsa Tal near Nandganj as well as the jhils at Faiehullahpur.

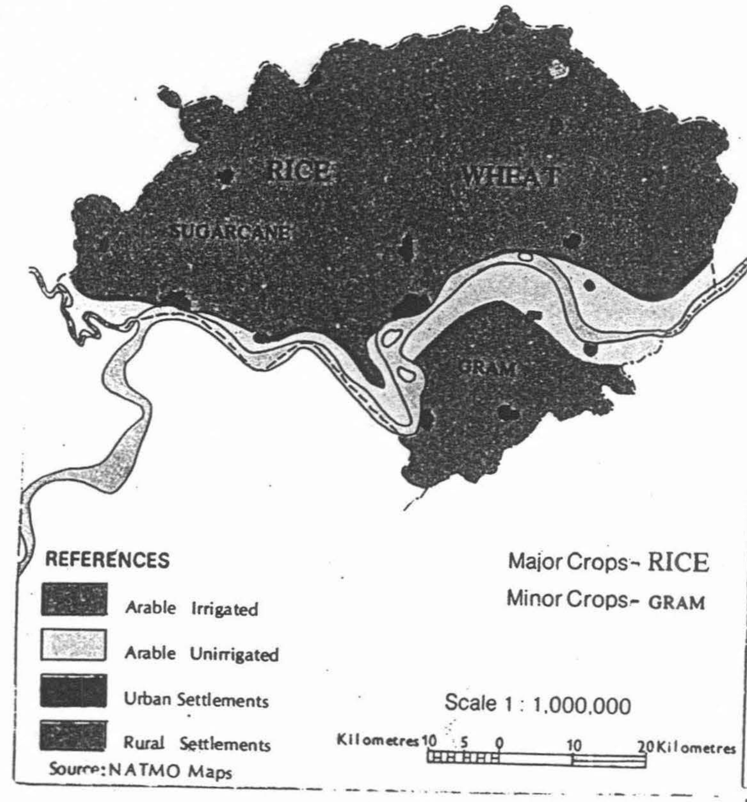
Geology

As the district lies in the alluvial plain of the Ganga, its mineral products are limited. The most valuable and most common is *kankar* (limestone conglomerate), which occurs, in extensive strata throughout the upland area, at varying depths below the surface. Where possible it is quarried for ballast, road metal and for lime-burning. Clay suitable for making bricks is obtained everywhere (Gazette- Ghazipur). Saline earth is to be found in all parts of the district especially in the rice tract between the Mangai and the Bhainsahi.

Climate

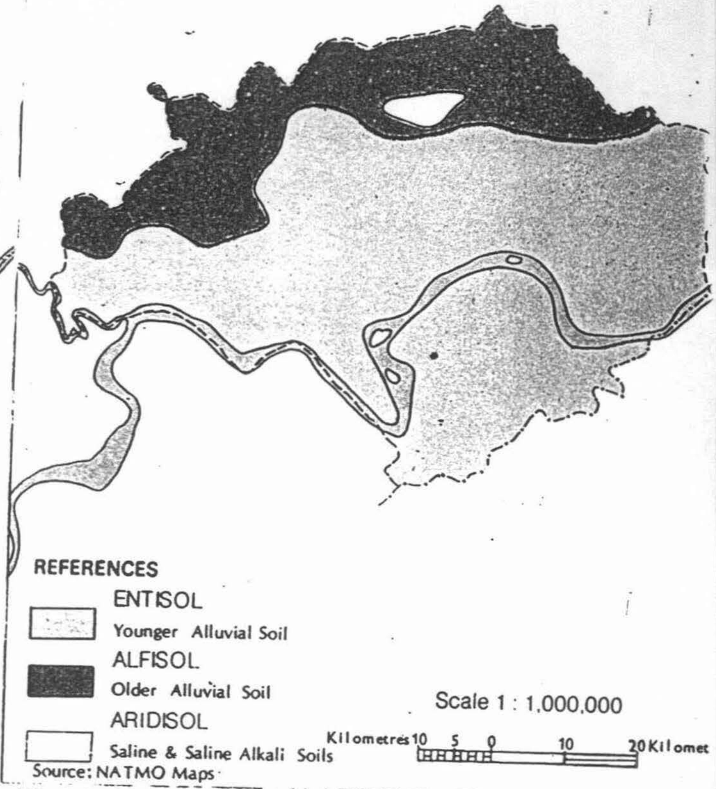
The district has an extreme type of climate with hot summers and cold winters. The year may be divided into four seasons. The cold season from about the middle of

GENERAL LANDUSE AND CROPPING PATTERN



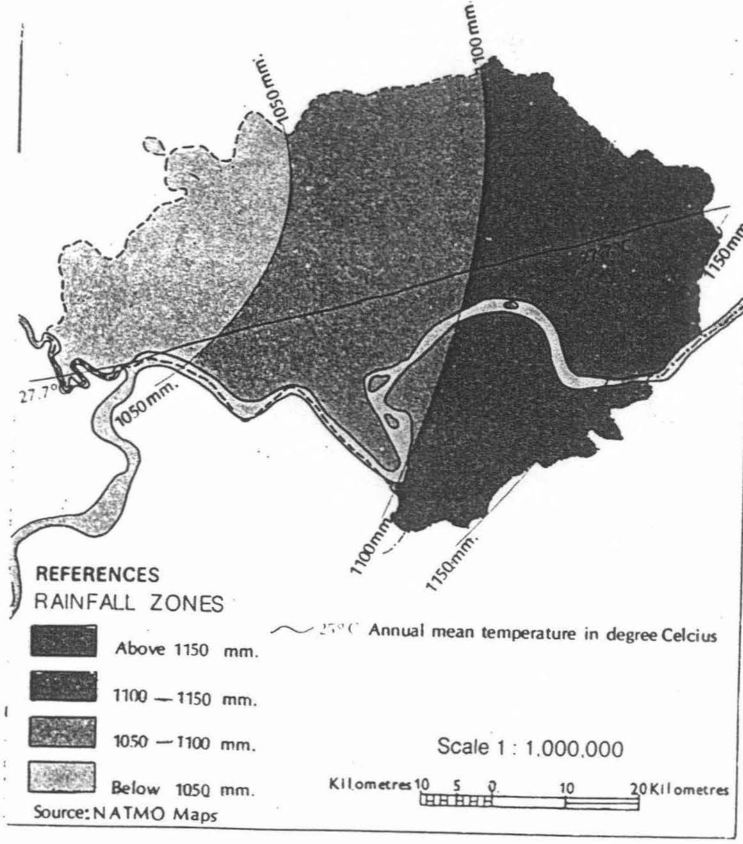
Source: NATMO Maps

SOILS



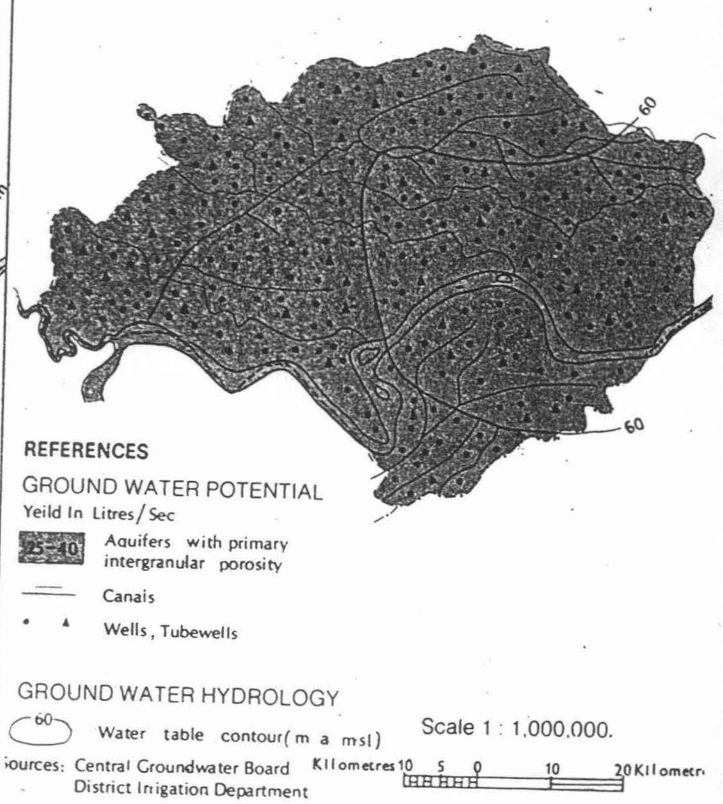
Source: NATMO Maps

CLIMATIC CONDITIONS



Source: NATMO Maps

IRRIGATION AND HYDROGEOLOGY



Sources: Central Groundwater Board
District Irrigation Department

Ghazipur Thematic Maps

November to February is followed by the summer season from March 10 about the middle of June. The period from mid-June to the end of September constitutes the southwest monsoon season, the succeeding period till the middle of November is the post-monsoon season.

- **Rainfall** - The southwest monsoon usually arrives in the district by about the middle of June and withdraws .by the end of September. About 88 per cent of the annual normal rainfall in the district is received in the south-west monsoon season, August being the rainiest month, which alone accounts for as much as 30 per cent. The variation in the rainfall from year to year is fairly considerable.
- **Temperature** - May is usually the hottest month with the mean daily maximum temperature at about 41- 44°C and the mean daily minimum at about 26-27°C. The summer is intensely hot and on individual days the maximum temperature during May or early June occasionally exceeds 47°C. With the advent of the monsoon by about the middle of June there is an appreciable drop in the day temperature though the nights continue to be warm. Even in July and August, when the south-west monsoon is well established, day temperatures on some days during breaks in the rains may reach over 40°C. The day temperatures do not decrease even after the withdrawal of the monsoon early in October but the nights become cooler. After October both the day and night temperatures decrease rapidly. January is generally the coldest month. In the cold season, in association with passing western disturbances, the district experiences cold waves when the minimum temperature may go down to degree or 2 degrees above freezing point.

Fig.2.1: Map of Study Area with Sampling Locations: Ballia and Ghazipur District, Uttar Pradesh, India.

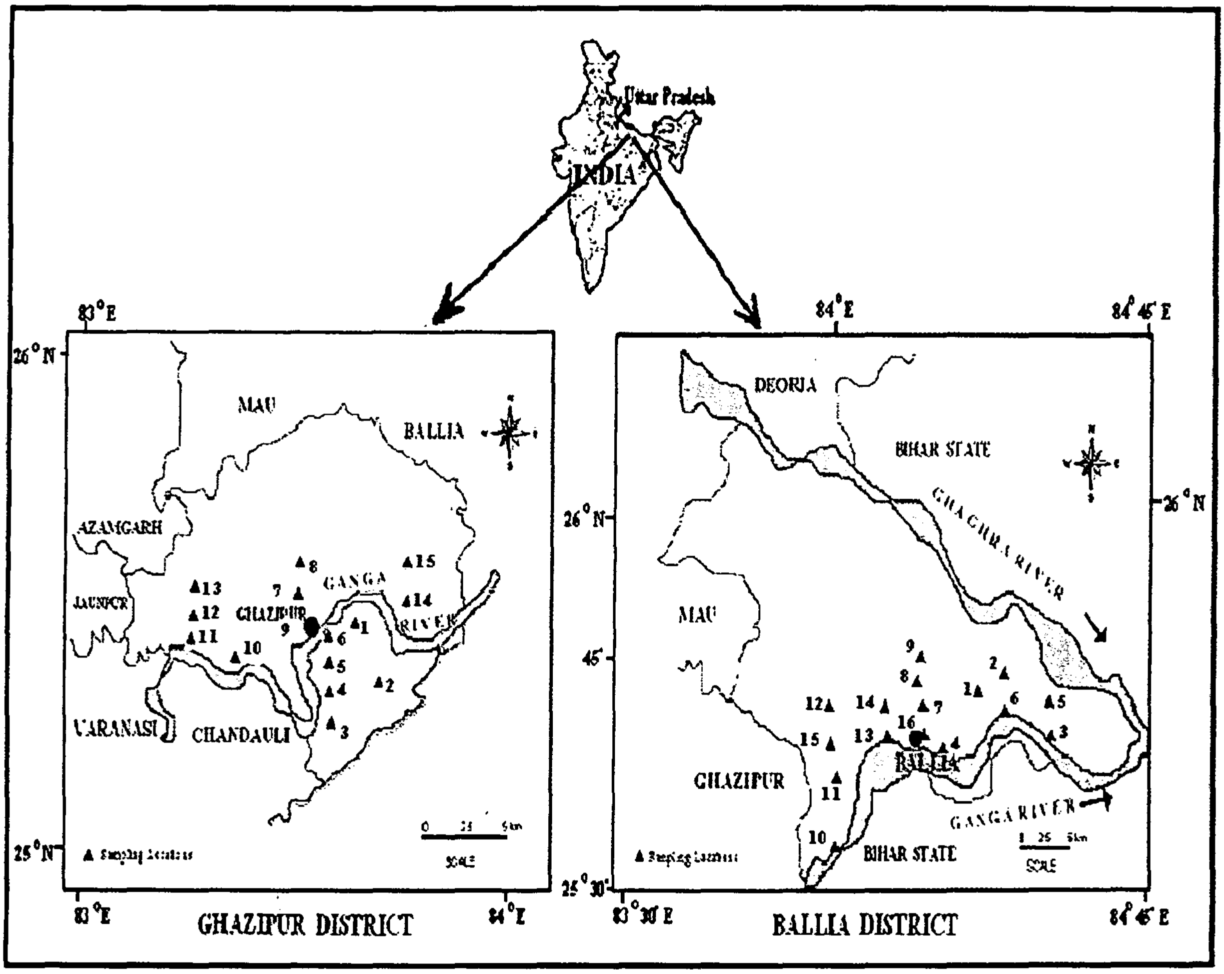


Table-2.1: Sampling No. and Sampling site with Latitude and Longitude in study area.

Sample No.	Sampling Location	Latitude	Longitude	Sampling Location	Latitude	Longitude
	Ballia			**Ghazipur**		
1	Chhitauni H.P.	84°15′E	25°34′N	Gaura H.P.	83°36′ E	25°29′ N
	Chhitauni P.S.			Gaura P.S.		
2	Mun Chhapra H.P.	84°18′ E	25°36′ N	Bhadura H.P.	83°42′ E	25°19′ N
	Mun Chhapra P.S.			Bhadura P.S.		
3	Bahuara H.P.	84°24′ E	25°29′ N	Zamania H.P.	83°33′ E	25°18′ N
	Bahuara P.S			Zamania P.S		
4	Suremanpur H.P.	84°10′ E	25°28′ N	Tajpr Manjha H.P.	83°33′ E	25°22′ N
	Suremanpur P.S.			Tajpr Manjha P.S.		
5	Bairia H.P.	84°23′ E	25°33′ N	Sabalpur (Deoria) H.P.	83°33′ E	25°25′ N
	Bairia P.S.			Sabalpur (Deoria) P.S.		
6	Majhawa H.P.	84°18′ E	25°32′ N	Tarighat H.P.	83°32′ E	25°28′ N
	Majhawa P.S.			Tarighat P.S.		
7	Hanumanganj H.P.	84°07′ E	25°33′ N	Jangipur H.P.	83°28′ E	25°33′ N
	Hanumanganj P.S.			Jangipur P.S.		
8	Basantpur H.P.	84°07′ E	25°36′ N	Sekhpur H.P.	83°33′ E	25°37′ N
	Basantpur P.S.			Sekhpur P.S.		
9	Surujpura H.P.	84°07′ E	25°39′ N	Ghazipur H.P.	83°30′ E	25°29′ N
	Surujpura P.S.			Ghazipur P.S.		
10	Sohaw H.P.	83°57′ E	25°16′ N	Nandganj H.P.	83°20′ E	25°25′ N
	Sohaw T.W.			Nandganj T.W.		
11	Narahi H.P.	83°57′ E	25°24′ N	Saidpur H.P.	83°13′ E	25°27′ N
	Narahi P.S.			Saidpur P.S.		
12	Jigni H.P.	83°56′ E	25°33′ N	Dahia H.P.	83°13′ E	25°29′ N
	Jigni P.S.			Dahia P.S.		
13	Sagarpali H.P.	84°03′ E	25°29′ N	Bhimanpur H.P.	83°13′ E	25°32′ N
	Sagarpali T.W.			Bhimanpur T.W.		
14	Bisukia H.P.	84°03′ E	25°33′ N	Muhammadabad H.P.	83°43′ E	25°31′ N
	Bisukia P.S.			Muhammadabad P.S.		
15	Chitbaragaon H.P.	83°57′ E	25°28′ N	Mubarakpur H.P.	83°43′ E	25°36′ N
	Chitbaragaon P.S.			Mubarakpur P.S.		
16	Ballia City H.P.	84°08′ E	25°30′ N			

*** H.P.- Hand Pump; P.S.- Pumping Set; T.W.- Tube Well**

CHAPTER – 3

LITERATURE REVIEW

The hydrogeochemical character of groundwater and groundwater quality in different aquifer over space and time proved to be an important technique in solving the problem (Chebotareb, 1955; Hem, 1959; Gibbs, 1970; Chandrasekharan, 1988; Jankowski and Jacobson, 1989; Hem, 1991; Jain, 1996, 1997; Atwia et. al., 1997; Ballukraya and Ravi, 1999; Anandhan et. al, 2000. Hydrogeochemical evaluation and relative studies were done in detailed by Back and Hanshaw (1965).

Water chemistry can vary tremendously over very short distances depending upon whether a sample is drawn from an actively flowing conduit or from rock matrix. (Quinlan and Ewers, 1985). Water chemistry also varies over time in response to seasonal changes in recharge and dilution effects of individual stream (Hess and White, 1988). Along subsurface flow path, water can be modified by CO_2, mineral dissolution and/or precipitation, and mixing (Dreybrodt, 1981;Herman and Lorah, 1986; Holland et.al., 1964).

The hydrogeochemical interpretation of the data obtained and their graphical representation for meaningful interpretation was put forth by Piper (1944). Later modification of Piper diagram was done by Durov (1984) and Handa (1975). Using various standard diagrams, the representation of chemical analysis data was also developed by various scientists/authors.

The chemical concentration of various ions in absolute and relative values will be used in the interpretation of chemical evolution of groundwater and to observe salinity. Large lateral variation in chloride concentration indicate that in some part of the India's Delhi area local recharge to the unconfined aquifer is more dominant than recharge through lateral flow. Local recharge is associated with low salinity water of Ca-Mg-HCO_3 type. Highly saline and brackish groundwater in the north-western and southwestern parts of the area seem to be associated with long history of evaporation and to oxidation of sulfur gases in low lying areas (Datta and Tyagi, 1996).

Abu–Taleb (1999) studied in detail the infiltration studies and artificial recharge. Aquifer recharge studies using different isotopes help in the determination of infiltration capacities, permeability and other aquifer parameters. This technique was adopted for hydro-geological studies (Singh et. al., 1999).

Significant quantities of evaporated surface run-off water and rain water infiltrate along with nitrate and fluoride salts in the soil (Datta et. al., 1999).

In the study area Delhi, experiments carried out by Kakkar (1985) showed that salinity is in patches, which cannot be caused by airborne salts. Using selected chemical data, Datta et. al., (1996) found that the local recharge is associated with low salinity water of Ca-Mg-HCO_3 type . Highly saline and brackish ground waters in the northwestern and southwestern parts of the areas have long history of evaporation and oxidation of sulphur gases in the low lying areas. (Datta et.al., 1996).

The salinity problem in groundwater is increasing in coastal areas including some part of Haryana, Rajasthan, Uttar Pradesh and Punjab state. The leakage in Jhamarkota phosphorites mines in Rajasthan has been also studied by Kulkarni et. al., (1998) using hydrochemistry of groundwater and environmental isotopes. It was found that recycled water reaches mines through the high permeable geologic formation in the vicinity of the mines.

Identification of recharge sources and location of recharge zone are one of the most important areas of studies that needs immediate attention of the scientific community to save the zones of recharge of deeper aquifers from the anthropological activities and contamination. It has been observed that in most of the cases, the details about the recharge sources and location of recharge zones for deeper aquifers are not available in India. The information about interconnection is also very useful to understand the availability of groundwater in different aquifers and to take necessary measures for saving aquifers from contamination. But, it seems that no sincere efforts have been made in this direction to study aspects of different aquifer systems in the country (Rao et. al., 2000).

Shallow rural domestic wells are most likely to be contaminated with nitrate especially in the areas where nitrogen based fertilizers are used. Other sources include disposal of sewage and industrial wastes, and handling of animal's manures. A number of researchers have reported on the nitrate contamination in the various aquifers (Singh and Sekhon, 1978; Hill, 1982; Jacks and Sharma, 1983; Tesoriero and Voss, 1997; Keshari, 1999, 2003) carried out a study for prognosis of nitrate distribution in the Faridabad-Ballabhgarh aquifer. Local disturbances that affects nitrogen cycling can lead to large nitrogen losses as nitrate to ground water (Keeney 1980; Frazer et. al., 1990; Dillon et. al., 1991).

For the Piper Diagram, groundwater is treated as though it contained three cations constituents (Ca^{2+}, Mg^{2+}, $Na^{+}+K^{+}$) and three anions constituents ($F^{-}+Cl^{-}+NO_3^{-}$, SO_4^{2-}, HCO_3^{-}) expressed as percentages in mille-equivalent per liter of cation and anion respectively (Todd, 1980).

Most of the ground water samples tend to show a charge imbalance mainly in favour of positive charge excess, but some inversely with a negative charge deficit. Positive charge excess higher than 5% agrees with the database of the dissolve load. This imbalance of negative charges could be related to the fact that no analysis was made of organic matter. (Berner-Kay and Berner, 1987; Edmond et. al., 1995; Huh et. al., 1998),which is mainly produced by biological activities during summer and spring.

In the hydrological evaluation, if the evaporation process is dominant, assuming that no mineral species are precipitated, the Na/Cl ratio would be unchanged. If halite dissolution is responsible for sodium, the Na/Cl molar ratio should be approximately equal to one, whereas a ratio greater than one is typically interpreted as Na released from a silicate weathering reaction (Meyback, 1987).

If the ratio Ca/Mg is equal to one, dissolution of Dolomite should occur, whereas a higher ratio is indicated of greater Calcite contribution. Higher Ca/Mg molar ratio >2 indicate the dissolution of silicate minerals, which contributes Ca and Mg to groundwater (Llyod and Heathcode, 1985).

Manchanda (1976) provided block wise ground water quality details for he state of Haryana. The contribution of poor ground water quality towards total ground water development in arid and semi arid region of India is a proximately 32 to 84 % (Minhas and Gupta, 1992) in poor quality regions, the average extent of saline, sodic and saline – sodic water are approximately, 20, 37 and 43% respectively (Yadav and Kumar, 1995). A chloride concentration of 600mg/l has been considered as the highest acceptable salinity level for human consumption (Rosenthal, 1994).

Bicarbonate is mainly derived from rock weathering and the pollution contribution is minimal (Meybeck, 1979). The ground water can be classified based on the TDS concentration as fresh water 0–1000 mg/l; brackish water 1000-10,000mg/l; saline water 10,000- 100,000mg/l (Freeze and Cherry, 1979). Ground water flowing through a normal and active hydrological gradient is characterized by Na/ Cl ratio of 0.86- 1.00 (Rosenthal, 1994). The higher ratio than normal ratio indicates no/ lesser mixing of seawater and fresh water within the aquifer.

In recent times the interest in fluoride has greatly increased, owing to its importance in the precipitation of fixation of phosphate in mineral like flurapatite and to the recognition of pathological condition in man and animals, described as flourosis (Agrawal et. al., 1997; Rao et. al., 1998). Under acidic circulation, solution, fluoride is readily adsorbed in clays structure, while, in alkaline environment, it is desorbed (Deshmukh et. al., 1995).

Nigam (1999) investigates the hydrogeochemistry of Fluoride in ground water of Agra district. (U.P). The study shows concentration of fluoride ranges from 0.09 to 7mg/l and fluoride is showing good correlation with Bicarbonate ion. The high concentration of fluoride in ground water of the study area is due to rock water interaction i.e. between ground water and easily weathered fluoride bearing mineral like fluorite, fluor-apatite etc. High fluoride in groundwater samples in Gngetic plain have been reported by Chanda and Tamta (2001) for some villages in Unnao district in Uttar Pradesh.

Sub-surface water constitute of water present in the unsaturated zone (vadose zone) known as soil moisture and water present below the water table i.e. in saturated zone known as ground water. Results reported by Laney (1977) and by McQueen and

Miller (1972) showed that water in the unsaturated zone may have the relatively high solute concentrations compared with the underlying water.

Initial studies in ground water mainly related with the effect of lithology on the water composition. Kimmel and Braids (1980) worked on the hydrochemistry of quartz sand aquifer on long Island, Freeze and Cherry (1979) investigate the change in the composition of ground water as it moves through aquifer due to addition of constituents.

Shanyengana et.al., (2003) investigated the major-ion chemistry and ground–water salinization in ephemeral floodplains in some arid regions, according to them the dominant process occurring in the area which determine the hydrochemical shift are refreshing by recharge water, concentration by evaporation, dissolution of saline sediments (mainly evaporates) mixing with older and more saline ground water. Mayer (1999) investigate the spatial and temporal variation of ground water chemistry in petty johns cave, North-west Georgia, U.S.A, describe important process which control the ground water chemistry of Karst region are evolution via Carbonate dissolution along sub-surface flow paths, mixing and seasonal variation in the Pco_2 in overlaying soil. Eckhardt and Stackelberg (1995) and Bruce and McMahon (1996) found land use to be correlated with ground-water quality in suburban Long Island, New York, and Denver, respectively.

Rugge et. al., (1995) indicate that concentrations of organic compounds can be very high in the landfill lechates that can have effect on the oxidation-reduction potential of ground water, and indicate that it may decrease the oxidation-reduction potential (ORP), which can mobilize toxic metals. Kelly et. al., (1996) indicate that soils in industrial areas are commonly contaminated with heavy metals, which may potentially leach into shallow ground water. The calculation of mineral saturation index and thermodynamic equilibrium studies were initiated by Garrels and Christ (1964). Similar works were done by many workers (Back, 1963; Roberson, 1964; Krauskopf, 1983). The hydrogeochemical interpretation of the data obtained and their graphical interpretation were put forth by Piper (1944). Later, the modification of piper diagram has been done by Durov (1948).

Meng and Maynard (2001) investigated chemical data from the Botucatu Sandstone aquifer in the Sao Paulo State part of the Paraná Basin, Brazil, by using geochemical methods and two statistical analyses: cluster analysis and factor analysis. The characteristic chemicals, changing from the recharge area to the center of the basin, are: SiO_2—(HCO_3^- and Ca^{2+})—(Na^+, CO_3^{2-}, and SO_4^{2-}). The distribution of the chemicals is interpreted as controlled by different water–rock interaction processes in the different regions. In the recharge area, dissolution of alkali–feldspar minerals in the sandstone is the main reaction observed; in the mid-section of the basin, calcite dissolution results in high calcium and bicarbonate concentration; in the center of the basin, leakage from underlying layers becomes the governing factor.

In India ground water research is mainly focus toward analyzing ground water for determining its suitability for various uses such as irrigation purpose, water supply for public use etc.

Jacks (1983) investigated the effect of crop farming on ground water quality of Coimbatore district of southern India. The area is comprises of igneous rocks. Ground water is used for irrigation purpose so it often subject to intense evapotranspiration amounting to 600-1300mm per harvest. High salinities are caused by the evapotranspiration together with the hydrological factor. Singh and Sekhon (1976) investigate the nitrate pollution of ground water from nitrogen fertilizer and animal waste in the Punjab, India. They found that the nitrate concentration decreases with the depth of water table, and animal wastes are the major contributor to the nitrate level in ground water near village area.

Tamta (1999) studied the occurrence and origin of ground water salinity in Bhatinda District, Punjab. The study indicates occurrence and origin of ground water salinity in Bhatinda district, being largely due to simple dissolution of minerals in the aquifers, low ground water flow, mixing of ground water and infiltration of evaporated irrigation water along with fertilizers NO_3 and K to ground water system.

Som and Bhattacharya (1992) investigate the Ground water geochemistry of recent weathering at Panchpatimali Bauxite-bearing plateau, Koraput district, Orissa. During their study they found that ground water are feebly acidic with positive oxidation potential which transform $Fe^{2+}$to Fe^{3+}, kaolinite is the major weathering product with marginal development of gibbsite. Relative mobility of Al is nil, Fe low and Mg, Ca, and Na conc. is high which are important for the development of aluminum silicate and iron oxide/hydroxide.

Pawar (1993) investigate Geochemistry of Carbonate precipitation from the groundwater in the basaltic aquifer, he found that most groundwater are saturated with respect of calcite and dolomite. The molar Ca/Mg values are less than unity in most of samples Na/Ca values are much higher than unity in a majority of the samples. The higher Na/Ca value is supporting evidence for the precipitation of calcite particularly in monsoon season.

Rao et. al., (1998) studied the impact of industrial effluent on ground water quality of Venkatapuram area, Visakhapatnam, Andhra Pradesh. Study indicates that leakage of surface water from the effluent tank and along the stream course forms a major source of ground water contamination.

Pawar and Nikumbh (1999) studied the trace elements in the Behedi basin, Nasik district. Their study reveals that the trace metal like Fe, Mn, Cu, Zn have entered into the aquifer due to rain-fed recharge. They attributed the spatial variation due to lithologic and anthropogenic sources, such as application of fertilizers and pesticides. Mehrotra and Mehrotra (1999) studied the pollution of ground water by Manganese in Hindon-Yamuna Doab district. Gaziabad. Anthropogenic activities coupled with natural hydrogeochemical environment in the area are responsible for high metal concentration in the area.

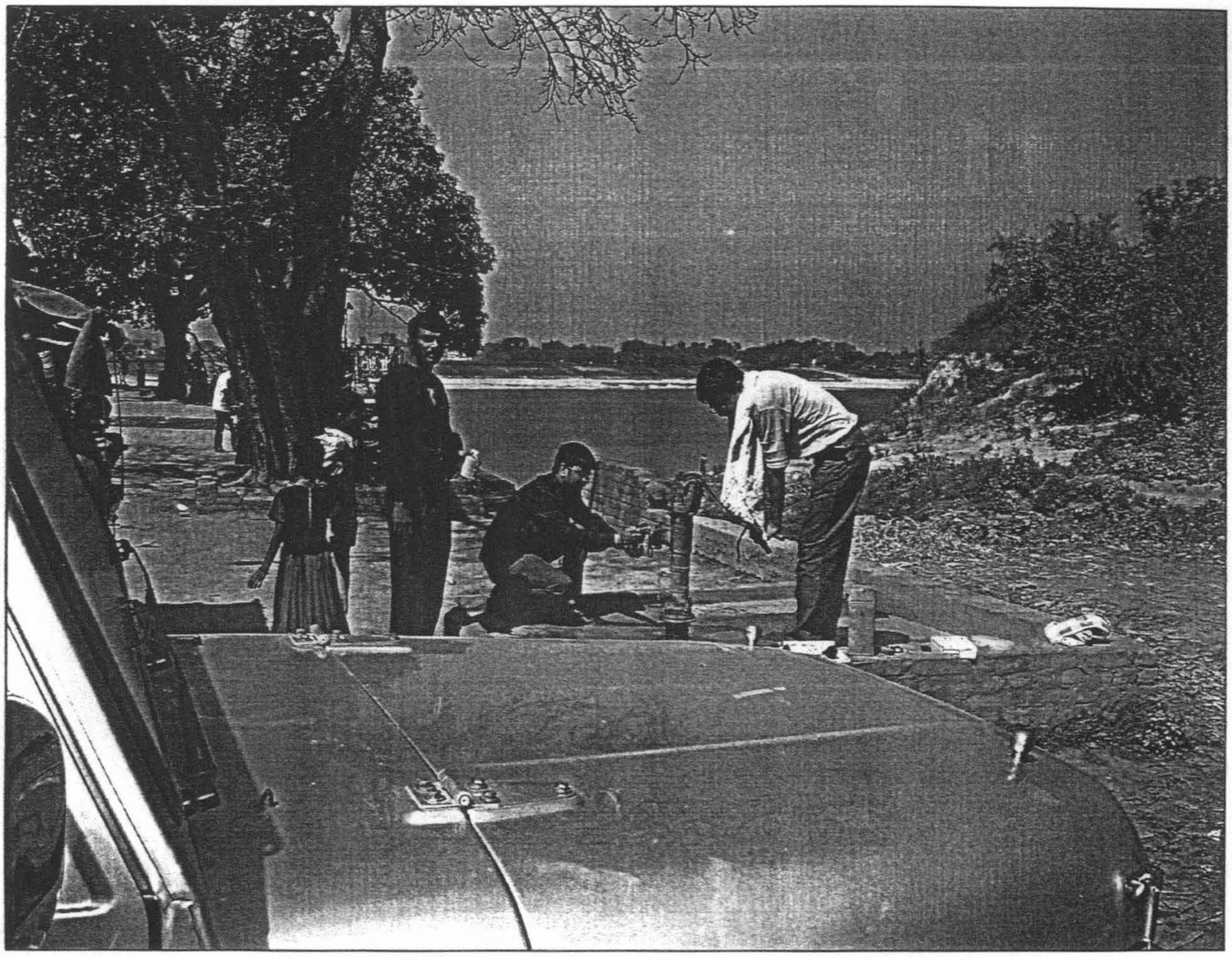
Mahadevan and Krishnaswamy (1984) studied the impact of different surface and sub-surface sources of pollution on the quality of ground water in Madurai, India. They considered the effect of type, number and the proximity of the visible surface sources of pollution on the extent and degree of pollution in the neighboring water sources. Arsenic concentration at elevated levels are encountered in groundwaters of sedimentary aquifers in several South-East Asian countries, such as Bangladesh, India, China, Taiwan, Thailand, Vietnam and lately Nepal and Cambodia (Bhattacharya, 2002). However, world wide, contaminated drinking water is the chief source of chronic human intoxication (Gabel, 2000). The current drinking water quality guideline of Arsenic is $10 \mu g \; l^{-1}$ (WHO, 1993).

The occurrence of Arsenic in Upper and middle Gangetic plain ground waters are fairly new because most of the documented cases are reported from Bengal basin of Bangladesh (Ahmed et. al., 2004; Ben et. al., 2003). The predominance of arsenic poisoning due to contaminated groundwater in west Bengal, India and all of Bangladesh has been thought to be limited to the Ganges Delta (the lower Ganga plain). Early surveys have been conducted on arsenic contamination in ground water of west Bengal (Saha, 1984, 1995; Mazumder et. al., 1988) and groundwater in the

Union Territory of Chandigarh and its surroundings in the northwestern upper Ganga plain and recent findings in the Tarai areas of Nepal (Chakraborti et. al, 2003). Arsenic has entered the groundwater by reductive dissolution of ferric oxyhydroxides, to which arsenic was adsorbed during fluvial transport. Depth profiles of arsenic in pumped groundwater, porewater, and aquifer sediments show consistent trends (Ravenscroft et. al., 2005).

. The arsenic contamination in the ground water particularly in the alluvium plain of Gangetic plain may cause secondary effect as well which results from agricultural activities and ultimately enters the human food chain. High arsenic in the groundwater of Lower Gangetic plain of Bangladesh and West Bengal was reported by (Bhattacharya et. al, 1997). Several authors suggested that reductive dissolution of Fe (III)-oxyhydroxides in strongly reducing conditions of the young alluvial sediments is the cause of mobilization of arsenic (Ahemed et. al., 2004, Bhattacharya et. al., 1997; Harvey et. al., 2002; Mc Arthur et. al., 2004; Nickson et. al, 1998).

Above extensive literature reviews indicate that there is no study on general hydrochemistry and enrichment of arsenic in the ground water of Ballia and Ghazipur is available. Hence an attempt has been made in this study in two districts of middle Gangetic plain.



Groundwater Sampling with AL. Ramanathan (Sir) near Ganga River

CHAPTER – 4

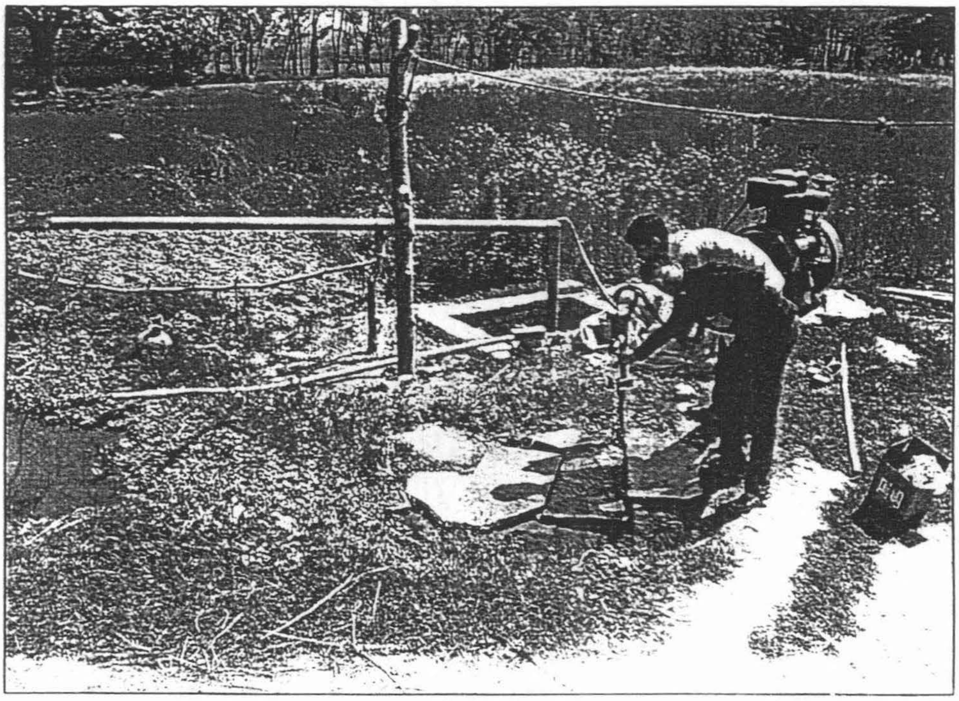
MATERIALS AND METHODS

4.1: Field Methods-

Initially, to understand the general variation in groundwater chemistry over the study area, a well inventory survey was carried out during August 2005 and March 2006 and electrical conductivity (EC) and pH were measured. A global positioning system (GPS) was used for location and elevation reading (Topographic sheets made available from Geological Survey of India supported this). These data were used to select the representative wells and hand pumps for groundwater sampling. Sampling wells were selected in such a way that they represent different geological formations as well as land-use pattern at varying topography of this area. A total 122 ground water samples were collected in the flood plain of middle Gangetic plain of District Ballia and Ghazipur during August 2005 to March 2006 in both the season of pre and post-monsoon from shallow and deep aquifers.

Water samples were collected in clean polyethylene bottles. At the time of sampling, bottles were thoroughly rinsed 2-3 times with groundwater to be sampled. In the case of bore wells and hand pumps, the water samples were collected after pumping the water for 10 minutes. In case of open wells, water samples were collected 30 cm below the water level using a depth sampler. This was done to remove groundwater stored in the well itself and to obtain representative samples. In-situ measurements included EC, pH, ORP and bicarbonate that were measured using a portable field kit and titration respectively as per WHO (1993) recommendation that this

Groundwater Sampling in Ballia District, Uttar Pradesh



Groundwater Sampling in Ghazipur District, Uttar Pradesh should be made in-situ, or in the field immediately after water sample has been obtained, since these parameters change with storage time.

Samples collected were brought to the laboratory and were filtered using 0.45 mm Millipore filter paper and acidified with nitric acid (Ultrapure Merck) for cation analyses and HBO_3 acid was used as preservative for nitrate analysis (Kumar, 2004). For anion analyses, these samples were stored below in cold room at 1-4°C temperature in order to avoid any major chemical alteration for various physiochemical analysis (APHA, 1995).

pH and Conductivity (EC)-

The pH and conductivity was measured in unfiltered water samples. CD-MOS used technique pH meter was used to measure the pH which makes the instrument more versatile and reliable. The pH was measured by Rachho (model no.123) pH Meter. The glass electrode was conditioned (4M KCl as filling solution) and calibrated with buffer solutions of pH 4, 7and 9.2. The temperature knob was set in accordance with the temperature of the water samples. The samples were stirred continuously in order to maintain homogeneity before noting down the pH.

The conductivity was measured in µS/cm using Systronics Conductivity Meter 306. The instrument was calibrated and set for 0.01m KCl standard (1413 µS/cm at 25°C).

ORP-

This parameter has been carried out by using same instrument i.e. ORP electrode was used for this parameter (Platinum electrodes were used for ORP)

Bicarbonate-

The bicarbonate content was determined by the potentiometer titration method (APHA-1995). Bicarbonate standards ranging from 100-1000 mg l^{-1} was prepared from $NaHCO_3$. 50 ml sample and a series of bicarbonate standards were titrated against 0.02 N HCl. The end point was noted at pH 4.5. A standard graph was plotted between bicarbonate standards and volume of acid consume. The readings of samples were found out from this graph.

4.2: Laboratory methods-

- **Phosphate-**

Phosphate was measured by Ascorbic Acid Method (APHA, 1995). Phosphate standard ranging from 0.01-0.5 mgl^{-1} was prepared from KH_2PO_4. 40 ml of each sample and standard solution was pipetted out in 50 ml volumetric flask and 5ml of molybdate antimony solution (prepared by dissolving 4.8 g of ammonium molybdate and 0.1 g potassium Antimony-tartarate in 400 ml 4 N H_2SO_4 and making the total volume to 500 ml with the same acid) and 2 ml of ascorbic acid solution (2.0 % w/v) was added and mixed well. The mixture was diluted to 50 ml and optical density was measured at 650 nm using Cecil Spectrophotometer (Model No.594). A graph was plotted between standard concentration and optical density and sample concentration were obtained from this graph.

- **Chloride-**

Chloride was estimated by Argentometric method for which K_2CrO_4 indicator was used which prepared by dissolving 5 g of K_2CrO_4 in distilled water and subsequent adding of $AgNO_3$ solution till rate precipitation of 10. Let it stand for 12 hrs.,filter and make upto 100 ml then $AgNO_3$ of 0.0141 N prepared by dissolving 1.1975 gm of $AgNO_3$ in 500 ml distill water. It was stored in brown bottle then standard was prepared from NaCl (dried at 140 C).

$$1000\ mg\ l^{-1} = 1.648\ g/l = 0.1648\ g/100\ ml$$

Samples + Indicator was titrated with $AgNO_3$ and at the end point volume of $AgNO_3$ consumed was noted.

- **Flouride-**

Determination of fluoride (by SPADNS method)

Requirements: Instrument - Spectrophotometer

Chemicals - Zirconyl chloride; Octahydrate Sodium arsenite; Hydrochloric acid conc.; Sodium fluoride.

Glassware - Boiling tubes, 50 ml.

Reagents: 1. Acid Zirconyl - SPADNS reagent

Reagent A: Weigh 958 mg (0.958 g) SPADNS. Dissolved and make up to 500 ml with double distilled H_2O.

Reagent B: Dissolve 133 mg (0.133 g) $ZrOCl_2.8H_2O$ in – 25 ml Double distilled H_2O. Add 350 ml conc. HCl. Make up to 500 ml with double distilled H_2O.

Mix. Reagent A and Reagent B. The reagent is stable for two years.

2. Stock fluoride (1 ml = 1mg F): Weigh 1.105 g anhydrous NaF. Dissolve and make up to 500 ml with double distilled H_2O.
3. Standard fluoride (1ml = mg F): Take 5 ml Stock fluoride and make up to 500 ml with double distilled H_2O.
4. Control stock (1ml = 1mg): Weigh 2.21 g anhydrous NaF. Dissolve and make up to 1000 ml. with double distilled H_2O.
5. Control Standard (1ml= 0.005 mg): Take 5 ml Control stock and dilute to 1000 ml with double distilled H_2O.

Procedure:

1. Sample: Take 25 ml of filtered sample. Add 5ml SPADNS. Measure O.D (OD sample)
2. Control standard: Take 5ml Control standard. Make up to 25 ml. Add 5 ml SPADNS. Measure O.D (OD Control Std)

Calculation: Fluoride mgl^{-1} = OD sample x Correction factor

Where, Correction factor = 1/OD control std.

- **Sulphate-**

Sulphate ion concentration was measured by turbiditeric method. The method is based on the principle that SO_4^{-2} is precipitated in acetic medium with barium chloride ($BaCl_2$), so as to form barium sulphate crystal of uniform size. Light absorbance of barium sulphate suspension is measured by photometer at 420nm and the concentration is determined by comparison of the reading with the standard curve. 100 ml of standard solution and samples were measured in a volumetric flask and 20ml of buffer solution (prepared by dissolving 30 g of $MgCl_2.6H_2O$, 5 g of $CH_3COOH.3H_2O$, 1 g of KNO_3 and 0.111 g of Na_2SO_4 and 20 ml of acetic acid (99 %) in 500ml distilled water and then a total volume made up to 1000 ml was added and mixed with the help of magnetic stirrer. While stirring, spoon full of $BaCl_2$ crystal was added. This was stirred for 60 seconds with constant speed. After the stirring period, solution was poured into the absorbance cell of the photometer and absorbance reading was taken after five minutes.

Sulphate ion concentration was determined by comparing reading with calibration curve prepared by carrying sulphate standard through the entire procedure.

- **Nitrate**

Nitrate was estimated by Brucine method on spectrophotometer for that Brucine reagent was prepared by dissolving 0.25 g of Brucine in 10 ml of $CHCl_3$ then final sample was prepared by mixing 10 ml of water sample 0.2 ml Brucine reagent and 20 ml of H_2SO_4 and total volume made to 50 ml. Yellow colour was developed and absorption was measured at 410nm.

Major Cations

- **Sodium, Potassium and Magnesium**

These were analyzed using AIMIL Flame photometer.

- **Calcium**

The analysis of major cation was carried out on Shimadzu-AA-6800, Atomic absorption Spectrophotometer. Calcium was analyzed in absorption mode at the wavelength of 422.7nm. The instrument was calibrated with different chemical standard.

Heavy metal- Iron and Arsenic

Fe metal analyses were done by using Shimadzu-AA-6800, Atomic absorption Spectrophotometer (AAS).

For Arsenic detection Grafite-furnace-AAS was used. First the instrument Atomic absorption Spectrophotometer (AAS) was calibrated by using known concentration of arsenic sample and a standard curve was drawn between absorbance and concentration, from this graph concentration of filtered water samples were calculated.

4.3: Contour Diagram

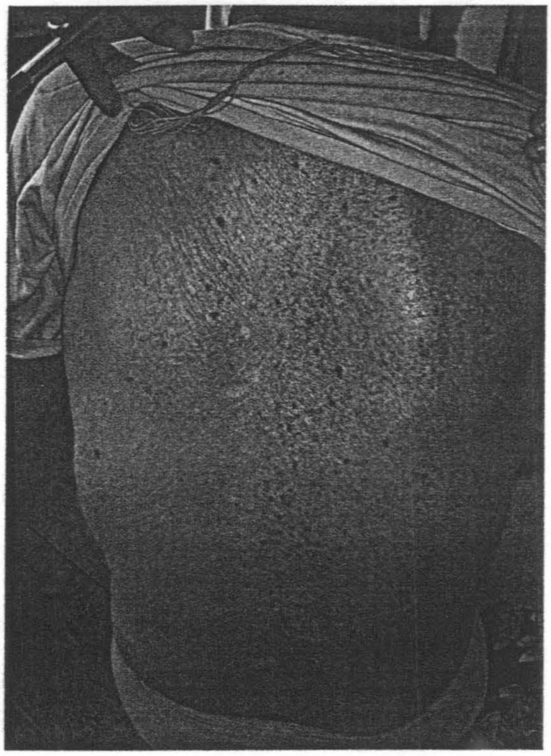
Contour Diagram of various water quality parameter concentrations were drawn by using Golden Surfur (8) software. First area map was geo-referenced by using ERDAS GIS package, taking Everest as base, after geo-referencing by using Latitude and Longitude values of sampling point's contours are drawn in SURFUR.

4.4: Mineral Stability Diagram:

Mineral Stability Diagram was plotted using WATCLAST Software.

4.5: Statistical Analysis

With help of SPSS software different statistical analysis (factor analysis and Correlation matrix) have been done in order to well interpretation of data.



Dense black-moles on back of a man in Tiwari-Tola, Ramgarh, Ballia, U.P.

Arsenic detection by Special Arsenic Kit on sampling site, Tiwari Tola, Ballia, U.P.

CHAPTER 5

RESULTS AND DISCUSSION

5.1. Geochemistry of groundwater of Ballia-

The ground water in general is slightly alkaline as it is evident from the average value of pH, which was 7.79 and 7.73 in pre and post-monsoon respectively (Table-5.1). Precipitation induced dissolution processes might have affected the pH of ground water. Increase of pH in the post-monsoon suggests that soil is very reactive which eventually enhances dissolution (Subramanian and Saxena, 1983).

The value of EC varied from 152.10- 419.30 (µS/cm) in pre-monsoon, but in post-monsoon it ranged between 13.19 -164.25 (µS/cm) (Table-5.1). The higher value of EC in the pre-monsoon suggests the dilution effect of monsoon. Very high standard deviation in EC for Ballia suggests local variation in soil type, multiple aquifer system and agricultural activities in the area. ORP was higher in post-monsoon, which varied from 400.50 to 747.36 mV and 345.73 to 640 mV in pre-monsoon (Table-5.1).

Alkalinity of water is the measure of its capacity of neutralization. Bicarbonate represents the major sources of alkalinity. In Ballia, bicarbonate concentration ranged between 25.52 to 124.32 mg l^{-1} in pre-monsoon and 127 to 621.6 mg l^{-1} in post-monsoon (Table-5.1). Bicarbonate is slightly higher in post-monsoon period indicating the contribution from chemical weathering process. Bicarbonate concentration is high in intermediate to deep aquifers, may be due to contribution from the carbonaceous sandstones, the HCO_3^- is high due to dominance of carbonate lithology. Phosphate concentration varied from 0.01 to 0.27 mg l^{-1} in pre-monsoon while in post-monsoon it ranged from 0.02 to 0.22 mgl^{-1} (Table-5.1).

The phosphate was higher in those areas where paddy cultivation is high. This may be due to input of fertilizer to enhance the farmland productivity. Cl^- ranged from 66-302.60 mg l^{-1} in pre-monsoon and 39-178 mg l^{-1} in post-monsoon (Table-5.1). In most natural water SO_4^{-2} is found in smaller concentration than the Cl^-. SO_4^{-2} concentration varied from 20.38-88.98 mg l^{-1} in pre-monsoon and 1.42- 35.66 mg l^{-1}in post-monsoon (Table-5.1). This indicates sulfate enrichment is high in pre-monsoon due to breakdown of organic material and agriculture runoff carrying unutilized SO_4^{-2} (Anderson et al., 1979). In Ballia, NO_3^- varied significantly from 0.05-81.79 mg l^{-1}in pre-monsoon and 0.07-114.87 mg l^{-1}in post-monsoon (Table-5.1), which indicate the input from agricultural activities and microbial mineralization (Jacks and Sharma, 1983).

The Ca^{2+} is dominant cation followed by Na^+, Mg^{2+} and K^+. The concentration of Ca^{2+} varied from 33.92 to 289.00 mgl^{-1} in pre-monsoon and 23.70 to 214.00 mg l^{-1} in post-monsoon season (Table-5.1). In pre-monsoon season high concentration of Ca may be due to weathering of carbonate and plagioclase feldspar minerals, which is abundant in flood plain regions (Bhattacharya et al., 1997). There is a slight variation in seasonal and spatial distribution of all the ions and are very significant at certain locations. In pre-monsoon the Mg^{2+} concentration varied from 11.87 to 101.00 mg l^{-1} while in post-monsoon season it was ranged between 8.30 to 74.80 mg l^{-1} (Table-5.1). The result for Na^+ and K^+ followed the similar pattern those were high in pre-monsoon than that of post-monsoon season (Table-5.1).

The $(Ca^{2+} + Mg^{2+})/ T_z^+$ ratio is 0.53 (pre-monsoon) and 0.58 (post-monsoon) reflect the abundance of $(Ca^{2+}+Mg^{2+})$ in the ground water attributed to carbonate weathering which is consistent with the carbonate lithology in the area. The $(Ca^{2+}+Mg^{2+})$ vs T_z^+ plot (R^2=0.9554 and R^2=0.9671) of groundwater has a linear trend line indicating that (Ca^{2+}+Mg^{2+}) accounts for most of cations. In Ballia ground water, the average ratio (Na^++K^+)/T_z^+ for pre-monsoon and post-monsoon seasons are 0.47 and 0.42 respectively (R^2= 0.4866 and R^2 = 0.1872) and trend line between (Na^+ + K^+) and T_z^+ showing very poor relationship. These ratios infer that the contribution of cations via silicate weathering is low in comparison to carbonate weathering. The ratio (Ca^{2+}+Mg^{2+})/(Na^++K^+) varied from 1.36 in pre-monsoon and 2.09 in post-monsoon indicates the dominance of carbonate rock weathering in the Ballia ground water (Fig. 5.1 and 5.2). The molar Mg^{2+}/Ca^{2+} ratio in pre-monsoon and post-monsoon is less than <0.5 which indicates low saturation index and carbonate precipitation.

Piper plot is very useful in determining chemical relationships in groundwater in more defined terms than the possibility with other plotting methods (Fig. 5.3 and 5.4). The piper plot for Ballia shows that almost all the groundwater samples of pre-monsoon fall in Ca-Na-HCO_3, Ca-Mg-HCO_3 and Ca-Mg-Cl-HCO_3 facies but a few samples also fall in the field of mixed Ca-Na-SO_4-Cl type of water (Table-5.2). The post-monsoon samples fall in the field of Na-Ca-Cl-SO_4-HCO_3 and Ca-Na-HCO_3 type of facies that indicates sufficient recharge of ground water (Table-5.2). It is clearly evident from (Table- 5.3 and 5.4) that alkaline earth metals (Ca^{2+} and Mg^{2+}) significantly exceed the alkalis (Na^+ and K^+). The groundwater shows secondary salinity, as indicated by high Cl^- and SO_4^{2-}.

Table- 5.1: Statistical summary of chemistry of groundwater in Ballia

(n=31)

Pre-monsoon (March 2006)				Post-monsoon (August 2005)			
Parameter	**Minimum**	**Maximum**	**Average**	**Parameter**	**Minimum**	**Maximum**	**Average**
pH	7.40	8.20	7.79	**pH**	7.19	8.12	7.73
ORP	345.73	640.00	425.65	**ORP**	400.50	747.36	485.33
EC	152.10	419.30	219.93	**EC**	13.19	164.25	139.64
***NO$_3^-$**	0.05	81.79	18.40	***NO$_3^-$**	0.07	114.87	25.84
***SO$_4^{-2}$**	20.38	88.98	42.74	***SO$_4^{-2}$**	1.42	153.93	35.66
***HCO$_3^-$**	25.52	124.32	76.91	***HCO$_3^-$**	127.61	621.60	381.74
***Cl$^-$**	66.30	302.60	155.71	***Cl$^-$**	39.00	178.00	90.40
***Na$^+$**	23.90	105.21	58.74	***Na$^+$**	12.47	63.00	33.18
***K$^+$**	10.02	37.25	20.47	***K$^+$**	3.96	22.89	14.39
***Ca^{++}**	33.92	289	83.6	***Ca^{++}**	23.7	214	72.63
***Mg^{++}**	11.87	101	29.2	***Mg^{++}**	8.3	74.8	25.42
***Fe**	0.17	1.61	0.62	***Fe**	0.01	0.37	0.10
***F$^-$**	0.01	0.09	0.04	***F$^-$**	0.02	0.75	0.23
***PO$_4^{-3}$**	0.01	0.27	0.07	***PO$_4^{-3}$**	0.02	0.22	0.10
****As**	5.52	259.49	46.98	****As**	4.37	205.51	37.21

***Concentration in mg l^{-1}; ** Concentration in µg l^{-1} ;ORP in (mV); EC in (µS/cm); except pH**

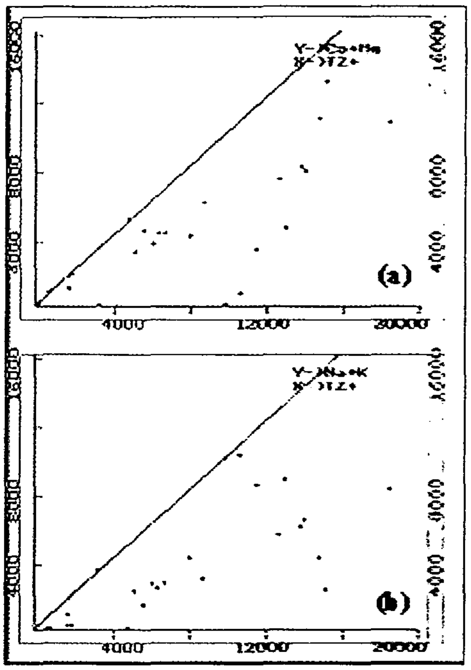


Fig.5.1: Pre-monsoon groundwater samples, Ballia, U.P.

(a) (Ca+Mg)/Tz$^+$; (b) (Na+K)/Tz$^+$ (all values in micro-eq./l)

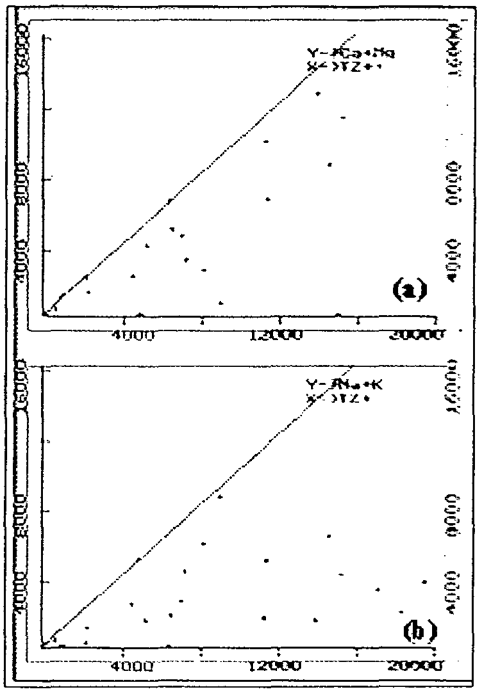


Fig. 5.2: Post-monsoon groundwater samples, Ballia, U.P.

(a) (Ca+Mg)/Tz$^+$;(b) (Na+K)/Tz$^+$ (all values in micro-eq./l)

Table- 5.2: Water classification of pre and post monsoon groundwater samples in Ballia district, Uttar Pradesh (n = 31)

Sampling Location	Water Type (Pre Monsoon)	Water Type (Post Monsoon)
	(March 2006)	(August 2005)
Chhitauni H.P.	Ca-Na-Cl	Ca-Na-HCO_3
Chhitauni P.S.	Ca-Mg-Cl-HCO_3	Ca-Mg-HCO_3
Munchhapra H.P.	Ca-Na-Cl	Na-Ca-Cl-SO_4-HCO_3
Munchhapra P.S.	Ca-Na-Cl-HCO_3	Ca-Na-Cl
Bahuara H.P.	Ca-Na-Cl	Ca-Mg-Cl-HCO_3
Bahuara P.S	Na-Ca-Cl-HCO_3	Ca-Na-HCO_3
Dubhad H.P.	Na-Ca-Cl	Na-Ca-HCO_3
Dubhad P.S.	Ca-Na- HCO_3	Ca-Na-HCO_3
Bairia H.P.	Ca-Na-Cl-HCO_3	Na-Ca-HCO_3-Cl
Bairia P.S.	Ca-Na- HCO_3-Cl	Ca-Na-HCO_3
Majhawa H.P.	Ca-Na-Cl	Ca-Na-Cl-SO_4
Majhawa P.S.	Ca-Mg-Cl-SO_4-HCO_3	Ca-Mg-HCO_3
Hanumanganj H.P.	Ca-Na-Cl	Ca-Na-HCO_3-Cl
Hanumanganj P.S.	Ca-Na-Cl-HCO_3	Ca-Na-HCO_3
Basantpur H.P.	Ca-Mg-Cl	Ca-Na-HCO_3-Cl
Basantpur P.S.	Ca-Mg-Cl	Ca-Mg-HCO_3-Cl
Surujpura H.P.	Ca-Na-HCO_3	Ca-Mg- HCO_3
Surujpura P.S.	Ca-Na-Cl	Ca-Na-HCO_3-Cl-SO_4
Sohaw H.P.	Ca-Mg-HCO_3	Ca-Mg-Cl
Sohaw T.W.	Ca-Na-HCO_3Cl	Na-Ca-Cl-SO_4-HCO_3
Narahi H.P.	Ca-Mg-Cl-SO_4	Ca-Mg- HCO_3-Cl
Narahi P.S.	Ca-Na-Cl	Ca-Mg-HCO_3-Cl
Jigni H.P.	Na-Ca-Cl-SO_4-HCO_3	Ca-Na-HCO_3
Jigni P.S.	Na-Ca-Cl	Na-Ca-HCO_3
Sagarpali H.P.	Ca-Mg-Cl-HCO_3	Ca-Mg-HCO_3-Cl-SO_4
Sagarpali T.W.	Na-Ca-Cl-HCO_3	Na-Ca- HCO_3
Bisukia H.P.	Na-Ca-Cl-HCO_3	Na-Ca- HCO_3
Bisukia P.S.	Ca-Na-Cl	Ca-Mg- HCO_3
Chitbaragaon H.P.	Ca-Mg-Cl-SO_4-HCO_3	Ca-Mg-HCO_3-Cl
Chitbaragaon P.S.	Ca-Mg-Cl-HCO_3	Na-Ca- HCO_3
Ballia City H.P.	Ca-Na-Cl	Ca-Na-HCO_3

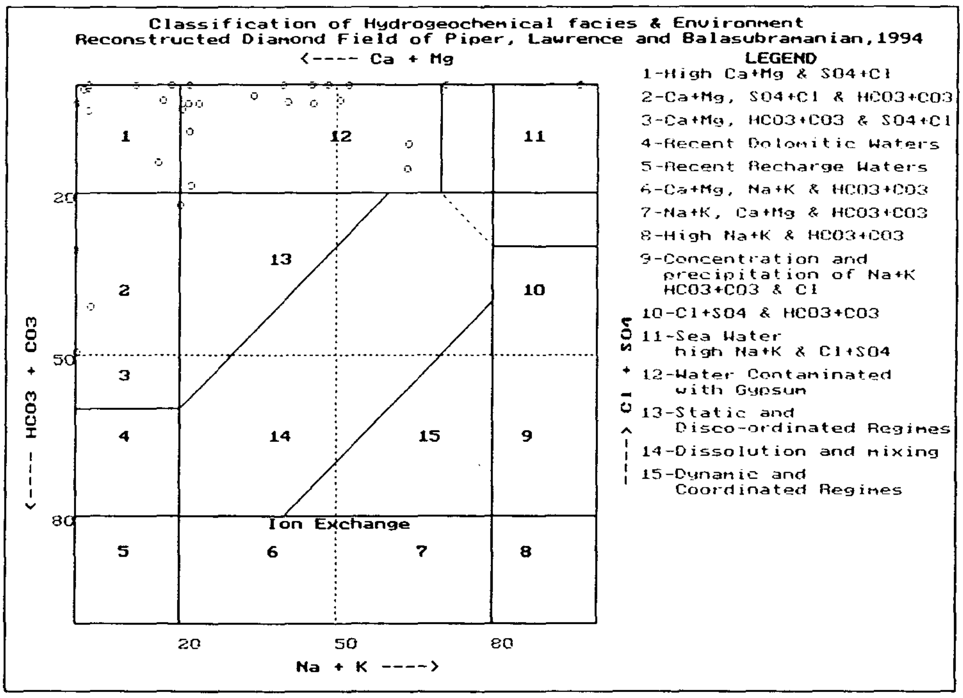


Fig.5.3: Classification of hydrogeochemical facies and environment reconstruction diamond field of Piper diagram in Pre-monsoon, Ballia, U.P.

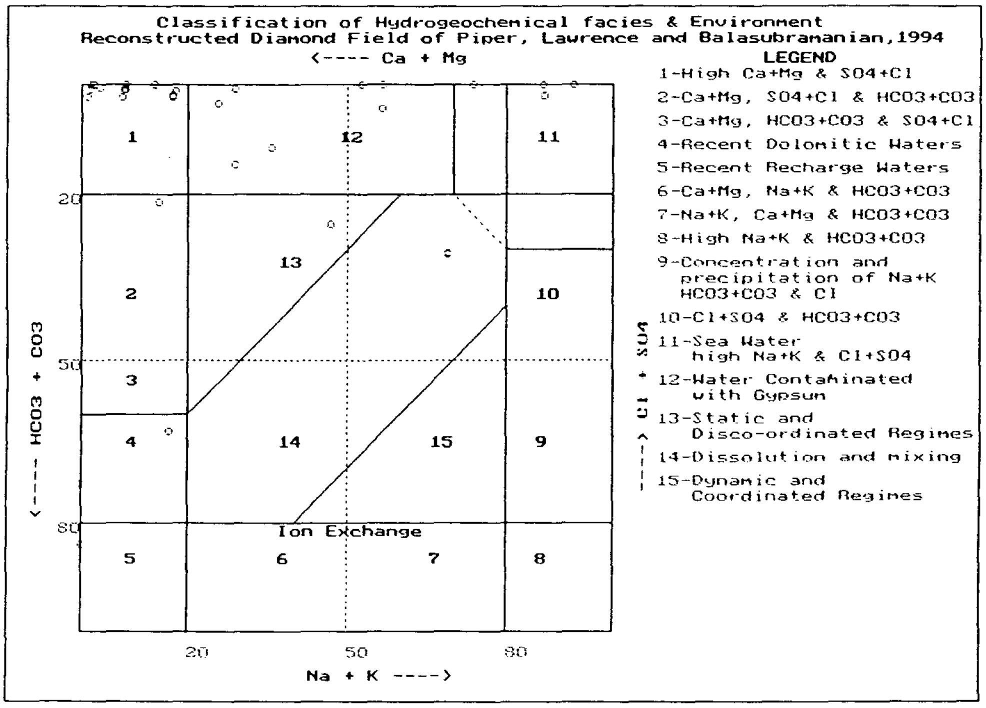


Fig. 5.4: Classification of hydrogeochemical facies and environment reconstruction diamond field of Piper diagram in Post-monsoon, Ballia, U. P.

Table-5.3: Ballia: Groundwater analysis in Pre-monsoon (March 2006) [n=31]

Sampling Location	W L	pH	ORP	EC	$^*NO_3^-$	$^*SO_4^{-2}$	$^*HCO_3^-$	$^*Cl^-$	*F-	$^*PO_4^{-3}$	$^*Na^+$	$^*K^+$	$^*Ca^{+2}$	$^*Mg^{+2}$	*Fe	**
	(F)		(mV)	(µS/cm)												
Chhitauni H.P.	65	7.9	351.98	369.10	15.45	31.08	38.70	199.20	0.22	0.04	48.85	21.49	45.25	15.84	0.04	13.
Chhitauni P.S.	90	7.6	352.60	391.10	23.92	20.38	122.67	66.30	0.18	0.02	37.12	21.28	39.58	13.85	0.06	6.4
Mun Chhapra H.P.	67	7.8	363.73	199.70	81.79	88.98	35.42	289.00	0.41	0.04	105.2	28.56	118.8	41.58	0.05	17.
Mun Chhapra P.S.	110	7.7	365.12	162.80	10.17	71.72	120.21	71.40	0.40	0.06	53.81	25.04	79.17	27.71	0.10	25.
Bahuara H.P.	50	8.1	370.23	193.20	0.997	44.95	25.52	272.50	0.33	0.03	36.37	13.94	51.47	17.82	0.14	173
Bahuara P.S	90	7.9	359.41	181.40	17.14	23.97	111.97	79.90	0.22	0.01	23.9	15.17	33.92	11.87	0.27	50.
Suremanpur H.P.	45	7.9	364.72	189.20	1.994	23.11	39.52	71.57	0.17	0.09	42.69	19.19	39.58	13.85	0.11	20.
Suremanpur P.S.	95	7.8	354.94	172.60	17.94	38.11	123.5	73.10	0.66	0.07	62.07	10.02	50.91	17.82	0.05	35.
Bairia H.P.	55	8.2	371.02	180.40	8.224	46.55	37.87	242.40	0.38	0.05	51.7	21.39	39.58	13.85	0.09	222
Bairia P.S.	90	7.7	359.20	165.80	0.05	38.09	124.32	83.30	0.36	0.01	33.52	17.63	117.3	37.93	0.06	42.
Majhawa H.P.	50	8	345.73	190.10	5.333	35.7	29.64	243.60	0.30	0.02	94.09	34.59	79.17	27.71	0.02	259
Majhawa P.S.	89	7.8	351.28	172.60	15.45	52.11	116.09	69.70	0.20	0.03	74.55	30.5	62.23	21.78	0.04	65.
Hanumanganj H.P.	61	8	368.61	152.10	22.53	36.55	32.93	173.60	0.24	0.02	30.81	21.07	33.92	11.87	0.04	36.
Hanumanganj P.S.	154	7.9	362.41	160.90	13.41	37.97	114.44	73.10	0.61	0.06	39.08	20.53	39.58	13.85	0.03	12.
Basantpur H.P.	57	7.7	367.79	186.20	16.35	57.61	40.34	302.60	0.36	0.05	41.04	17.15	113.1	39.6	0.01	46.5
Basantpur P.S.	95	7.5	421.00	177.50	4.436	36.54	32.92	257.20	0.62	0.09	60.72	16.83	56.63	19.82	0.13	14.
Surujpura H.P.	52	7.6	613.00	185.30	8.872	27.72	115.28	86.70	0.91	0.07	61.32	17.74	56.57	19.81	0.14	42.4
Surujpura P.S.	127	7.5	494.00	201.80	54.82	28.07	40.97	294.40	0.66	0.02	80.86	37.25	232	81.18	0.01	12.1
Sohaw H.P.	80	7.6	640.00	213.50	9.12	40.32	123.14	83.30	0.84	0.01	53.81	19.19	62.23	21.78	0.03	96.7
Sohaw T.W.	170	7.4	622.00	172.60	11.96	38.11	117.58	76.50	0.55	0.04	50.95	22.73	101.8	35.64	0.04	16.4
Narahi H.P.	50	8	409.00	201.80	37.88	57.54	34.62	184.30	0.56	0.02	54.41	26.05	131.9	63.36	0.03	91.8
Narahi P.S.	100	7.9	571.18	202.80	11.46	31.36	37.86	197.50	0.84	0.04	62.83	14.47	45.18	15.8	0.01	14.8
Jigni H.P.	40	7.6	385.70	206.70	30.45	41.44	124.32	79.90	1.19	0.06	85.67	13.4	288.5	101.1	0.04	19.4
Jigni P.S.	67	7.6	345.73	197.90	18.25	20.38	25.52	66.30	0.40	0.03	23.9	12.9	41.53	13.34	0.07	9.18
Sagarpali H.P.	41	7.9	640.00	212.60	81.79	88.98	124.32	302.60	1.29	0.04	105.21	28.37	288.5	88.94	0.27	27.
Sagarpali T.W.	200	7.7	481.10	197.90	0.05	41.22	75.64	155.27	1.40	0.05	55.89	21.10	81.64	29.18	0.06	16.5
Bisukia H.P.	35	8	414.30	212.60	18.68	38.11	123.51	272.50	0.42	0.03	84.32	19.19	51.47	17.82	0.06	18.4
Bisukia P.S.	60	7.9	413.00	205.70	0.05	38.09	32.93	199.20	1.5	0.02	72.5	17.63	39.58	13.85	0.06	13.5
Chitbaragaon H.P.	35	7.8	445.70	345.60	4.436	52.11	115.28	73.10	0.55	0.09	67.9	20.53	62.23	21.78	0.13	18.4
Chitbaragaon P.S.	120	7.6	457.20	396.90	9.11	57.61	111.97	104.30	1.61	0.03	54.6	14.47	56.57	19.8	0.03	9.04
Ballia City H.P.	40	7.8	433.40	419.30	18.25	40.32	35.41	82.60	0.72	0.01	71.23	15.17	52.37	14.92	0.06	5.51

H.P. – Hand Pump (Shallow Aquifer) ; P.S. –Pumping Set (Deep Aquifer)

***Concentration in mg l^{-1}; ** Concentration in µg l^{-1}; F-feet**

Table-5.4: Ballia: Groundwater analysis Post monsoon (August 2005) [n=31]

Sampling Location	W.L	pH	ORP)	EC	$*NO_3^-$	$*SO_4^{-2}$	$*HCO_3^-$	$*Cl^-$	$*F^-$	$*PO_4^{-3}$	$*Na^+$	$*K^+$	$*Ca^{+2}$	$*Mg^{+2}$	*Fe	**As
	(F.)		(mV	(µS/cm)												
Chhitauni H.P.	45	7.8	410.12	153.60	21.70	30.15	193.48	117.20	0.21	0.07	29.25	16.04	31.64	11.07	0.06	10.57
Chhitauni P.S.	75	7.9	411.08	125.25	33.60	45.96	613.37	39.00	0.15	0.04	22.23	15.88	27.68	9.69	0.08	5.08
Mun Chhapra H.P.	45	7.6	428.20	147.98	114.87	153.93	177.01	170.00	0.32	0.08	63.00	12.67	83.08	29.08	0.07	14.21
Mun Chhapra P.S.	95	7.4	430.34	139.50	14.28	20.29	601.02	42.00	0.37	0.06	32.22	19.78	55.36	19.38	0.15	20.49
Bahuara H.P.	45	7.7	438.20	145.50	1.40	3.19	127.61	160.30	0.10	0.08	21.78	10.40	35.60	12.46	0.20	137.54
Bahuara P.S	75	7.8	421.56	132.75	24.08	33.31	559.85	47.00	0.06	0.05	14.31	11.32	23.72	8.30	0.37	39.64
Suremanpur H.P.	38	7.9	429.72	138.75	2.80	5.05	197.59	42.10	0.40	0.04	25.56	14.32	27.68	9.69	0.16	16.43
Suremanpur P.S.	63	8.1	414.67	127.50	25.20	34.80	617.49	43.00	0.54	0.06	37.17	7.48	35.60	12.46	0.07	28.11
Bairia H.P.	47	7.9	439.41	146.25	11.55	16.67	189.36	142.60	0.26	0.14	30.96	15.96	27.68	9.69	0.13	176.49
Bairia P.S.	72	7.8	421.23	132.75	0.07	1.42	621.60	49.00	0.32	0.09	20.07	13.16	213.64	74.77	0.08	33.75
Majhawa H.P.	40	7.7	400.50	117.00	7.49	11.28	148.19	143.30	0.42	0.08	56.34	10.12	55.36	19.38	0.03	205.51
Majhawa P.S.	63	7.8	409.05	123.75	21.70	30.16	580.44	41.00	0.12	0.02	44.64	22.76	43.52	15.23	0.05	52.15
Hanumanganj H.P.	38	8.0	435.70	143.25	31.64	43.36	164.66	102.10	0.31	0.17	18.45	15.72	23.72	8.30	0.05	29.20
Hanumanganj P.S.	125	8.0	426.17	136.50	18.83	26.34	572.20	43.00	0.24	0.12	23.40	15.32	27.68	9.69	0.04	9.89
Basantpur H.P.	45	8.1	434.44	142.50	22.96	31.83	201.70	178.00	0.11	0.14	42.87	12.80	79.12	27.69	0.01	36.84
Basantpur P.S.	73	7.9	525.00	155.25	6.23	9.61	164.60	151.30	0.13	0.11	36.36	12.56	39.60	13.86	0.18	11.15
Surujpura H.P.	45	7.7	547.00	164.25	12.46	17.89	576.40	51.00	0.47	0.18	36.72	13.24	39.56	13.85	0.19	33.64
Surujpura P.S.	110	7.2	636.00	132.75	77.00	103.62	204.83	173.20	0.07	0.16	48.42	22.72	162.20	56.77	0.01	9.64
Sohaw H.P.	62	7.6	655.00	155.25	12.81	18.35	615.72	49.00	0.23	0.17	32.22	14.32	43.52	15.23	0.04	76.64
Sohaw T.W.	148	7.8	502.00	156.00	16.80	23.66	587.90	45.00	0.20	0.16	30.51	16.96	71.20	24.92	0.06	13.00
Narahi H.P.	37	7.4	506.00	159.00	53.20	72.02	173.10	108.40	0.06	0.02	32.58	19.44	126.60	44.31	0.04	72.76
Narahi P.S.	80	8.0	747.36	152.25	16.10	22.72	189.30	116.20	0.10	0.03	37.62	10.80	31.60	11.10	0.01	11.75
Jigni H.P.	38	7.6	462.00	163.50	42.77	58.15	621.60	47.00	0.21	0.22	51.30	10.00	201.76	70.62	0.05	15.40
Jigni P.S.	45	7.8	553.50	143.09	25.63	35.38	378.22	91.33	0.15	0.18	34.26	14.51	64.29	22.50	0.09	7.28
Sagarpali H.P.	35	8.1	655.00	164.25	114.87	153.93	621.60	178.00	0.19	0.08	56.76	16.65	213.64	74.77	0.37	21.78
Sagarpali T.W.	175	7.2	400.50	134.67	0.07	1.42	127.61	39.00	0.02	0.02	14.31	22.89	32.60	11.30	0.01	13.12
Bisukia H.P.	30	7.2	445.67	13.19	26.24	36.19	215.39	53.03	0.14	0.12	12.47	3.96	57.46	20.11	0.08	14.60
Bisukia P.S.	45	7.8	421.23	132.75	0.07	1.42	621.60	49.00	0.12	0.04	20.07	13.16	213.64	74.77	0.08	10.73
Chitbaragaon H.P.	30	7.9	624.58	155.25	6.23	9.60	164.60	151.30	0.75	0.15	36.36	12.56	39.60	13.86	0.18	14.59
Chitbaragaon P.S.	105	7.6	415.07	155.25	12.81	18.34	615.72	49.00	0.10	0.07	32.22	14.32	43.52	15.23	0.04	7.16
Ballia City H.P.	35	7.7	599.00	139.40	25.63	35.37	390.17	91.03	0.12	0.03	34.18	14.41	79.53	27.84	0.08	4.37

H.P. – Hand Pump (Shallow Aquifer) ; P.S. –Pumping Set (Deep Aquifer)

***Concentration in mg l^{-1}; ** Concentration in µg l^{-1}; F-feet**

Statistical analysis of groundwater-

Factor analysis of seasonal data of major ions along with physico-chemical parameters of Ballia ground waters indicates five trends for post- monsoon and pre-monsoon. The total variability accounted for five factors is 76.52 % in pre-monsoon season and 75.63 % in post- monsoon. The number of significant factors within the data is established by considering only those with an Eigen value >1.0. The degree of association between each variable and each factor is given by its loading on that factor. Table-5.5 (pre-monsoon) and Table-5.6 (post-monsoon) indicate the loading of each variable on each factor and the communality of each variable accounted for in the analysis.

In pre-monsoon season, factor 1 shows the strong geochemical associations between NO_3^-, SO_4^{2-}, Na^+, K^+, Ca^{2+} and Mg^{2+}. The role of silicate weathering and anthropogenic factors is responsible for the strong associations of these parameters. Factor 2 represents the relationship between pH and Cl^- that may be result of dissolution and percolation of salts and halite deposits due to excessive irrigation of farmlands. Factor 3 is accounted for ORP and F^- that indicates the precipitation of fluoride bearing minerals. Factor 4 explains the strong relationship between pH and Fe that accounts for release of iron in ground water. Factor 5 does not represent relationship for As with other variables. This indicates the multiple sources controlling the occurrence of As in Ballia ground water.

In post monsoon season, factor 1, 2, 3, 4 and 5 represent (NO_3^-, SO_4^{2-}, Cl^-, and Na^+), (HCO_3^-, Ca^{2+}, and Mg^{2+}), (pH and Fe), (Cl^- and As) and (F^- and PO_4^{3-}) respectively. Factor 1 describes the contribution from weathering of silicate minerals along with biological and anthropogenic activities responsible for the significant relationship between those parameters. Factor 2 explains the weathering of carbonate minerals. Factor 3 shows the pH dependent release of Fe in ground water system, which is also observed in pre-monsoon season indicating high pH and redox condition. The factor 4 reveals an unusual association of As with Cl^- indicates the anthropogenic contribution mainly through herbicides application in the agriculture fields. The evaporite/halite deposits may influence the tight association between As and Cl^- in ground water after percolation. Factor 5 reveals the association between F^- and PO_4^{3-} that may be due to the application of phosphate fertilizers that contain fluoride.

Correlation matrix of the physico-chemical parameters is given in Table-5.7 (pre-monsoon) and Table-5.8 (post-monsoon). In pre-monsoon season the stronger association corresponding to the pairs - pH-As, ORP-F^-, SO_4^{2-}-NO_3^-, Ca^{2+}-NO_3^-, Mg^{2+}-NO_3^-, Na^+-SO_4^{2-}, Ca^{2+}-Na^+, Mg^{2+}-Na^+ and Mg^{2+}-Ca^{2+}, Ca^{2+}-TDS and Ca^{2+}-EC were observed. These pair wise relationship between physico-chemical parameters are consistent with observations made from factor analysis i.e., carbonate and silicate weathering along with the anthropogenic sources mainly fertilizers control the geochemistry of pre-monsoon ground water. In post-monsoon season, strong correlation was observed for Na^+-NO_3^-, Na^+-SO_4^{2+}, and Na^+-Cl^- suggesting the increased anthropogenic sources contributing these ions to the groundwater.

Table-5.5: Factor analysis for groundwater of Pre-monsoon, Ballia [n= 31]

Parameters	F1	F2	F3	F4	F5	Communalities
pH		0.618		0.509		0.794
ORP			0.823			0.745
EC						0.807
NO_3^-	0.868					0.807
SO_4^{2-}	0.637					0.637
HCO_3^-						0.782
Cl^-		0.761				0.782
F^-			0.862			0.822
PO_4^{3-}						0.836
Na^+	0.679					0.678
K^+	0.629					0.635
Ca^{2+}	0.871					0.857
Mg^{2+}	0.865					0.842
Fe				0.837		0.754
As					0.523	0.771
% of variance	25.29	15.85	13.93	10.83	10.62	
% of cumulative variance	25.29	41.14	55.07	65.90	76.52	
Eigen value	3.794	2.071	1.790	1.325	1.294	

Table-5.6: Factor analysis for groundwater of post-monsoon, Ballia[n=31]

Parameters	F1	F2	F3	F4	F5	Communalities
pH			0.763			0.674
ORP						0.527
EC						0.867
NO_3^-	0.905					0.915
SO_4^{2-}	0.905					0.915
HCO_3^-		0.553				0.808
Cl^-	0.696			0.576		0.865
F^-					0.555	0.551
PO_4^{3-}					0.816	0.702
Na^+	0.638					0.688
K^+						0.803
Ca^{2+}		0.926				0.931
Mg^{2+}		0.926				0.931
Fe			0.745			0.647
As				0.885		0.812
% of variance	20.41	17.29	13.14	12.58	12.21	
% of cumulative variance	20.41	37.70	50.84	63.42	75.63	
Eigen value	3.062	2.294	1.671	1.588	1.532	

Table –5.7: Correlation Matrix of Pre-monsoon groundwater samples, Ballia [n=31]

	pH	ORP	EC	*NO_3^-	*SO_4^{2-}	*HCO_3^-	*Cl^-	*F-	*PO_4^{3-}	*Na^+	*K^+	*Ca^{2+}	*Mg^{2+}	*Fe	**As
PH	1														
ORP	-0.36	1													
EC	-0.12	0	1												
*NO_3^-	-0.03	0.17	-0.01	1											
*SO_4^{2-}	0.14	0.12	-0.05	0.56	1										
*HCO_3^-	-0.34	0.27	0.04	-0.01	0.11	1									
*Cl^-	0.34	0.04	-0.17	0.41	0.36	-0.53	1								
*F^-	-0.26	0.53	0.16	0.07	0.23	0.18	0.02	1							
*PO_4^{3-}	-0.12	0	-0.14	-0.16	0.07	0.09	-0.1	0.04	1						
*Na^+	0.02	0.28	0.05	0.55	0.52	0.05	0.43	0.36	0.07	1					
*K^+	0.04	0.07	-0.14	0.46	0.32	-0.1	0.37	-0.19	-0.19	0.49	1				
*Ca^{2+}	-0.26	0.26	-0.12	0.65	0.43	0.19	0.28	0.32	-0.02	0.53	0.38	1			
*Mg^{2+}	-0.25	0.22	-0.14	0.64	0.42	0.16	0.27	0.3	-0.03	0.5	0.39	0.99	1		
*Fe	0.18	0.14	-0.07	0.15	0.16	0.22	0.02	-0.01	0.19	-0.03	-0.1	0.1	0.04	1	
**As	0.54	-0.16	-0.26	-0.2	0.04	-0.27	0.29	-0.27	-0.19	0.04	0.25	-0.09	-0.06	0.02	1

*Concentration in mg l^{-1} except pH; ** Concentration in μg l^{-1}; ORP in (mV); EC in (μS/cm)

Table –5.8: Correlation Matrix of Post-monsoon groundwater samples, Ballia [n=31]

	pH	ORP	EC	*NO_3^-	*SO_4^{2-}	*HCO_3^-	*Cl^-	*F-	*PO_4^{3-}	*Na^+	*K^+	*Ca^{2+}	*Mg^{2+}	*Fe	**As
PH	1														
ORP	0.08	1													
EC	0.33	0.29	1												
*NO_3^-	-0.06	0.25	0.11	1											
*SO_4^{2-}	-0.06	0.25	0.11	1	1										
*HCO_3^-	0.15	-0.06	0.12	0	0	1									
*Cl^-	0.15	0.34	0.22	0.44	0.44	-0.63	1								
*F^-	0.32	0	0.1	-0.12	-0.12	0.03	0.01	1							
*PO_4^{3-}	0.02	0.23	0.13	0.06	0.06	0.04	0.15	0.26	1						
*Na^+	0.1	0.31	0.35	0.61	0.61	-0.03	0.53	0.2	0.18	1					
*K^+	-0.26	0.04	0.37	0.15	0.15	0.02	-0.02	-0.28	-0.18	0.06	1				
*Ca^{2+}	-0.13	0.12	0.1	0.41	0.41	0.33	0.12	-0.12	0.14	0.3	0.04	1			
*Mg^{2+}	-0.13	0.12	0.1	0.41	0.41	0.33	0.12	-0.12	0.14	0.3	0.04	1	1		
*Fe	0.26	0.11	0.14	0.16	0.16	0.18	0.13	0.14	-0.05	-0.05	-0.15	0.07	0.07	1	
**As	-0.03	-0.18	-0.02	-0.2	-0.2	-0.28	0.3	0.1	0.02	0.14	-0.11	-0.13	-0.13	0.04	1

*Concentration in mg l^{-1} except pH; ** Concentration in μg l^{-1}; ORP in (mV); EC in (μS/cm)

5.2. Geochemistry of groundwater of Ghazipur-

The ground water of Ghazipur is slightly alkaline ranging from 7.1 to 8.01 in pre- monsoon with the average value of pH 7.44 and 7.23 to 8.74 in post-monsoon respectively (Table-5.9). pH of ground water might have been affected by dissolution. Due to increase of pH, soil becomes very reactive which accelerate the dissolution very reactive, which eventually enhances dissolution (Subramanian and Saxena, 1983). ORP, which is, varied 400 to 914 mV and 388 to 440 mV in pre and post monsoon respectively (Table-5.9).

The value of EC varied from 193.5 to 1484.00 (μS/cm) in pre-monsoon, but in post-monsoon it ranged between 148.8 to 1910.8 ((μS /cm) (Table-5.9). EC is higher in pre-monsoon than post-monsoon suggests the presence of higher amount of total dissolved solids. Very high standard deviation in EC for Ghazipur may be due to variation in ionic strength of water samples at different sampling locations, which could be affected by variation in land use, highly dense networked of aquifer system along with intensive agricultural activities in the area.

In Ghazipur, bicarbonate concentration ranged between 89.93 to 550.50 mg l^{-1} in pre-monsoon and 115 to 704 mg l^{-1} in post-monsoon (Table-5.9). Higher bicarbonate in post-monsoon period indicates the contribution from weathering of carbonate lithology. Bicarbonate concentration is high in intermediate to deep aquifers, may be due to the enhanced presence of carbonaceous material (Bhattacharya et al., 1997). Average phosphate concentration varied from 0.03 to 0.14 mg l^{-1} in pre-monsoon and post-monsoon respectively (Table-5.9). The Paddy cultivation requires higher phosphate fertilizer input for better yield (FAO, 2004) in this area. Cl^- ranged from 4.55-625.30 mg l^{-1} in pre-monsoon and 28.2- 674 mgl^{-1} in post-monsoon (Table-5.9). In this paddy and wheat cultivated region, the main cause of elevated level of Cl^- is evidence of salinity effect due to intensive irrigation through canal systems along with evaporation or/and use of fertilizer. In most natural water SO_4^{-2} is found in smaller concentration than the Cl^-. SO_4^{-2} concentration varied from 11.02 to 379.45 mg l^{-1} in pre-monsoon and 24.5 to 367 mg l^{-1} in post-monsoon (Table-5.9). This higher sulphate enrichment in pre-monsoon may be due to breakdown of organic material and agriculture runoff carrying unutilized SO_4^{-2} (Anderson et al., 1979). In Ghazipur, NO_3^- varied significantly from 7.99 to 120 mg l^{-1} in pre-monsoon and 15.02 to 120 mg l^{-1} in post-monsoon, which shows mineralization by microbial activities and higher agricultural input (Table-5.9).

The concentration of Ca varied from 18.20 to 88.10 mg l^{-1} in pre-monsoon and 25.2 to 122.2 mg l^{-1} in post-monsoon season (Table-5.9). In post-monsoon season high concentration of Ca may be due to weathering of carbonate rich minerals, abundant in flood plain regions (Bhattacharya et al., 1997). In pre-monsoon the Mg concentration varied from 5.40 to 23.69 mgl^{-1} while in post-monsoon season it was ranged between 7.49 to 32.86 mg l^{-1} (Table-5.9). The Na concentration is higher than K in both pre-monsoon and post-monsoon season (Table-5.9).

The $(Ca^{2+} + Mg^{2+})/ T_z^+$ ratio is 0.33 (pre-monsoon) and 0.56 (post-monsoon), reflect the abundance of $(Ca^{2+}+Mg^{2+})$ in the post-monsoon ground water attributed to carbonate weathering which is consistent with the carbonate lithology in the area. The $(Ca^{2+}+Mg^{2+})$ vs T_z^+ plot of post-monsoon groundwater (R^2=0.5742) has a linear trend line indicating that $(Ca^{2+}+Mg^{2+})$ accounts for most of cations. In Ghazipur ground water, the average ratio $(Na^++K^+)/T_z^+$ for pre-monsoon and post-monsoon seasons are 0.66 and 0.44 respectively (R^2= 0.8863 and R^2 = 0.337) and trend line between $(Na^+ + K^+)$ and T_z^+ showing very good relationship for pre-monsoon season. These ratios infer that the contribution of cations via silicate weathering is high in pre-monsoon season while post-monsoon season is favorable for carbonate weathering i.e. seasonal variation is being important for qualitative and quantitative changes in Ghazipur ground water. The ratio (Ca^{2+}+Mg^{2+})/(Na^{+}+K^{+}) varied from 0.63 in pre-monsoon and 1.75 in post-monsoon indicates the dominance of silicate weathering and carbonate rock weathering respectively in the Ghazipur ground water. The molar Mg^{2+}/Ca^{2+} ratio in pre-monsoon and post-monsoon is less than <0.5 which indicates low saturation index and carbonate precipitation.

The piper plot for Ghazipur shows that almost all the groundwater samples of pre-monsoon fall in Ca-Na-HCO_3, Ca-Mg-HCO_3 and Ca-Mg-HCO_3-Cl facies but a few samples also fall in the field of mixed Ca-Na-Cl-SO_4-HCO_3 type of water (Table-5.10). The post-monsoon, more samples fall in the field of Na-Ca-HCO_3 and Ca-Mg-HCO_3 type of facies that indicates sufficient recharge of ground water (Table-5.10) It is clearly evident from the (Table-5.11 and 5.12) that in more groundwater, alkaline earth metals (Ca^{2+} and Mg^{2+}) significantly exceed the alkalis (Na^{+} and K^{+}) in the post monsoon. The groundwater has secondary salinity, as indicated by high Cl^{-} and SO_4^{2-}.

Table- 5.9: Statistical Summary of Chemistry of ground water, Ghazipur

[n=30]

Ghazipur Pre-Monsoon (March-2006)

Parameter	Min	Max.	Aver.
pH	7.10	8.01	7.44
EC	193.50	1484.00	566.97
ORP	400.00	914.00	543.17
*Ca^{++}	18.20	88.10	50.37
*Mg^{+}	5.40	23.69	13.96
*Na^{+}	15.81	228.00	82.16
*K^{+}	2.40	168.3	67.3
F^{-}	0.01	3.80	0.57
*HCO_3^{-}	89.93	550.50	291.56
*Cl^{-}	4.55	625.30	154.11
*NO_3^{-}	7.99	120.00	55.85
PO_4^{-3}	0.00	0.09	0.03
*SO_4^{--}	11.02	379.45	127.91
*Fe	0.01	1.94	0.36
**As	3.20	164.00	38.60

Ghazipur Post-Monsoon (August 2005)

Parameter	Min	Max.	Aver.
pH	7.23	8.74	7.692333
EC	148.8	1910.8	461.7733
ORP	388	440	411.7
Ca^{++}	25.2	122.22	69.857
*Mg^{+}	7.49	32.86	19.35867
*Na^{+}	8.44	97.2	58.30333
*K^{+}	3.63	48.84	11.0465
F^{-}	0.02	0.75	0.229
*HCO_3^{-}	115	704	372.8333
*Cl^{-}	28.2	674	230.1933
*NO_3^{-}	15.02	120	59.48333
PO_4^{-3}	0.01	0.81	0.144
*SO_4^{--}	24.5	367	107.2067
*Fe	0.05	1.6	0.368333
**As	2.5	127.93	30.10667

*Concentration in mg l^{-1}; ** Concentration in $\mu g\ l^{-1}$;ORP in (mV); EC in ($\mu S/cm$); except pH

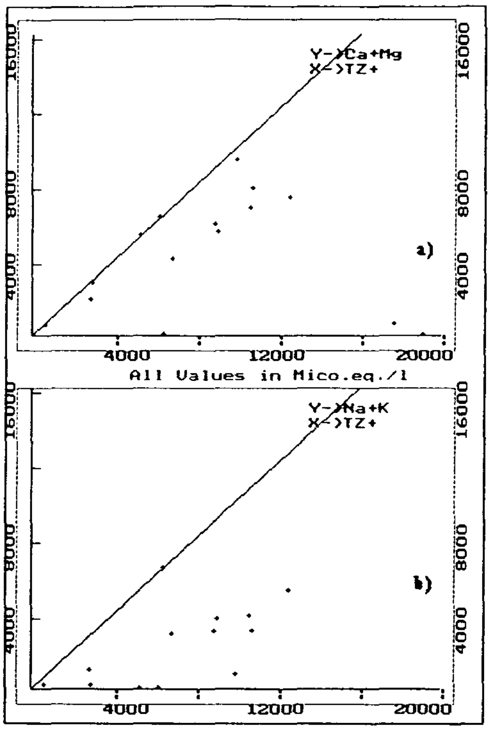


Fig. 5.5: In Pre-monsoon groundwater samples, Ghazipur.

(a) (Ca+Mg)/Tz$^+$; **(b)** (Na+K)/Tz$^+$ (all values in micro-eq./l)

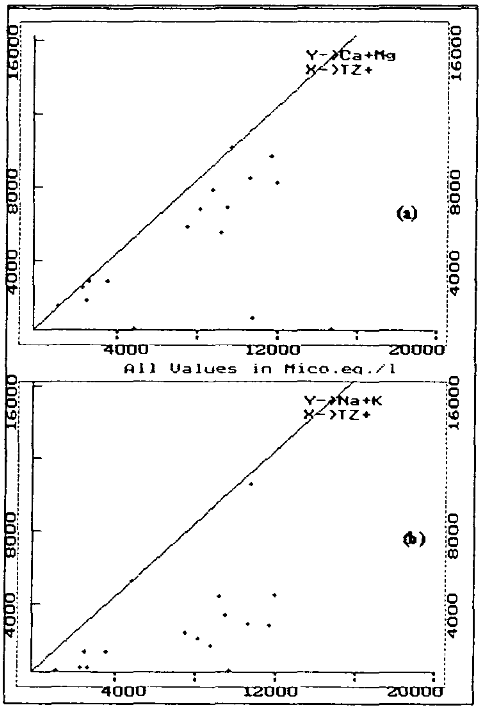


Fig. 5.6: In Post-monsoon groundwater samples, Ghazipur.

(a) (Ca+Mg)/Tz$^+$; **(b)** (Na+K)/Tz$^+$ (all values in micro-eq./l)

Table- 5.10: Water classification of pre and post monsoon ground water samples in Ghazipur district, Uttar Pradesh [n=30]

Sampling Location	Water type	Water type
	(Pre-monsoon)	(Post-monsoon)
	(March 2006)	(August 2005)
Gaura H.P.	Ca-Na-HCO3	Ca-Na-HCO3
Gaura P.S.	Ca-Mg-HCO3	Ca-Mg-HCO3-SO4
Bhadura H.P.	Ca-Na-Cl-HCO3	Na-Ca-HCO3
Bhadura P.S.	Ca-Mg-HCO3	Ca-Mg-Cl
Zamania H.P.	Ca-Na-Cl-HCO3	Na-Ca-HCO3
Zamania P.S	Ca-Na-Cl-SO4-HCO3	Na-Ca-Cl-HCO3
Tajpr Manjha H.P.	Ca-Na-HCO3-Cl	Ca-Na-HCO3
Tajpr Manjha P.S.	Na-Cl	Ca-Na-HCO3-Cl
Sabalpur (Deoria) H.P.	Ca-Na-HCO3	Na-Ca-HCO3
Sabalpur (Deoria) P.S.	Ca-Na-HCO3	Ca-Na-HCO3
Tarighat H.P.	Ca-Na-Cl-SO4-HCO3	Ca-Na-Cl
Tarighat P.S.	Ca-Mg-HCO3-Cl-SO4	Ca-Mg-HCO3
Jangipur H.P.	Na-Ca-HCO3-Cl	Ca-Mg-HCO3
Jangipur P.S.	Ca-Na- HCO3-Cl	Ca-Mg-HCO3
Sekhpur H.P.	Ca-Mg-HCO3-SO4	Na-Ca-HCO3
Sekhpur P.S.	Ca-Mg-Cl-SO4-HCO3	Na-Ca-HCO3
Ghazipur H.P.	Ca-Mg-HCO3	Ca-Na-HCO3
Ghazipur P.S.	Ca-Na-HCO3-Cl	Ca-Na-Cl-SO4-HCO3
Nandganj H.P.	Ca-Mg-Cl	Na-Ca-SO4-HCO3
Nandganj T.W.	Na-Ca-HCO3-Cl	Ca-Na-SO4-HCO3
Saidpur H.P.	Ca-Mg-HCO3-SO4	Ca-Na-SO4-Cl-HCO3
Saidpur P.S.	Ca-Na-HCO3-SO4	Na-Ca-Cl
Dahia H.P.	Na-Ca-Cl-HCO3	Na-Ca-HCO3
Dahia P.S.	Na-Cl-HCO3	Na-Ca-HCO3
Bhimanpur H.P.	Ca-Mg-HCO3-SO4	Na-Ca-Cl-HCO3
Bhimanpur T.W.	Ca-Mg-Cl	Ca-Na-Cl-SO4-HCO3
Muhammadabad H.P.	Ca-Na-Cl-SO4-HCO3	Ca-Na-Cl-HCO3
Muhammadabad P.S.	Ca-Mg-HCO3-SO4	Ca-Na-Cl-HCO3
Mubarakpur H.P.	Ca-Mg-HCO3-Cl-SO4	Ca-Mg-Cl-HCO3
Mubarakpur P.S.	Na-Ca-HCO3-SO4	Na-Ca-Cl-HCO3

H.P. – Hand Pump (Shallow Aquifer) ; P.S. –Pumping Set (Deep Aquifer)

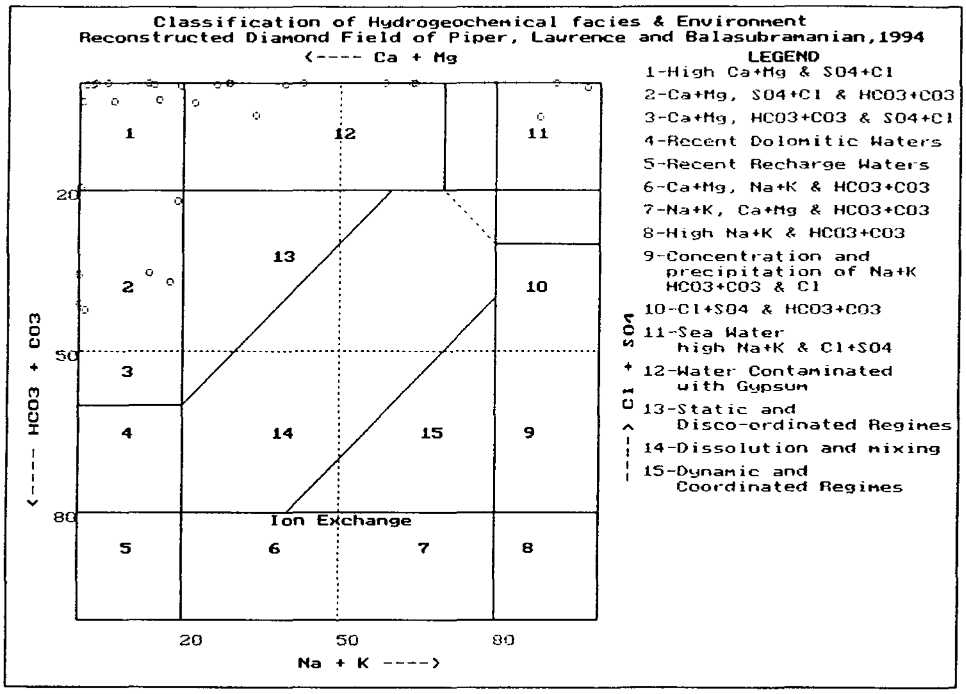


Fig. 5.7: Classification of hydrogeochemical facies and environmental reconstruction diamond field of Piper diagram in Pre-monsoon, Ghazipur.

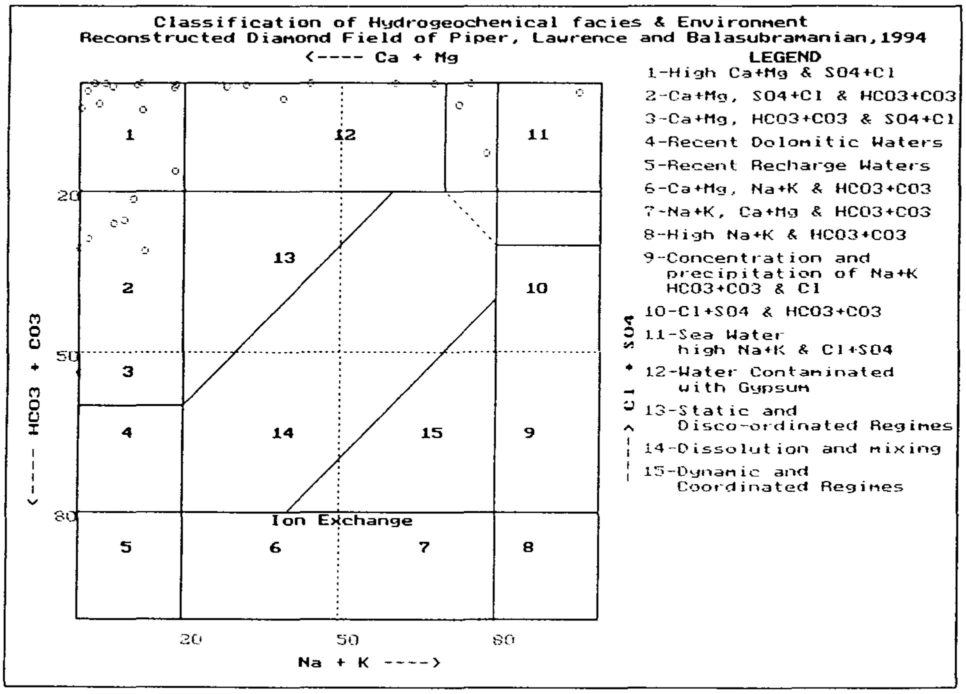


Fig. 5.8: Classification of hydrogeochemical facies and environmental reconstruction diamond field of Piper diagram in Post-monsoon, Ghazipur.

Table- 5.11: Ghazipur: Ground water analysis in Pre-monsoon (March 2006) [n=30]

Sampling Location	W.L	pH	EC	ORP	*Ca^{+2}	*Mg^{+2}	*Na^{+}	*K^{+}	F^-	*HCO_3^-	*Cl^-	*NO_3^-	*PO_4^{-3}	*SO_4^{--}	*Fe	**As
	(F)		(µS/cm)	(mV)												
Gaura H.P.	60	7.1	337.50	400.00	24.00	8.40	19.31	6.30	0.01	129.80	14.25	28.89	0.04	14.61	0.14	34.32
Gaura P.S.	150	7.6	265.50	597.00	56.30	23.69	18.97	2.40	0.04	312.00	8.75	45.60	0.00	27.23	0.06	14.70
Bhadura H.P.	65	7.1	738.00	666.00	26.20	7.31	20.33	45.36	0.03	242.40	63.92	32.88	0.00	44.49	0.22	17.80
Bhadura P.S.	120	7.3	472.50	462.00	74.60	19.26	65.30	68.05	0.39	89.93	116.80	76.02	0.01	41.57	0.02	6.40
Zamania H.P.	140	7.2	661.50	914.00	46.90	13.56	40.78	52.89	0.04	550.50	103.90	44.07	0.00	56.53	1.14	112.80
Zamania P.S	180	7.3	603.00	547.00	25.10	7.21	110.50	41.82	0.32	166.60	182.00	106.10	0.01	95.13	0.22	45.20
Tajpr Manjha H.P.	80	7.2	436.50	530.00	79.10	17.37	61.03	11.58	0.09	153.30	100.80	82.34	0.08	33.49	0.09	21.32
Tajpr Manjha P.S.	120	7.6	238.50	640.00	82.10	19.76	119.20	90.05	3.80	262.80	625.30	49.96	0.06	15.45	0.02	8.37
Sabalpur (Deoria) H.P.	83	7.6	193.50	585.00	26.20	7.88	15.81	56.94	0.05	269.00	12.77	37.10	0.05	11.02	0.10	17.77
Sabalpur (Deoria) P.S.	135	7.6	211.50	647.00	75.90	18.83	29.41	101.80	0.13	239.30	4.55	55.66	0.01	11.53	0.03	7.54
Tarighat H.P.	146	7.3	882.00	497.00	63.20	17.85	100.00	15.80	0.15	153.30	192.30	17.16	0.00	186.74	1.54	156.30
Tarighat P.S.	106	7.1	607.50	619.00	24.90	7.29	20.70	60.55	0.12	222.90	169.50	12.02	0.03	96.52	0.61	82.56
Jangipur H.P.	85	7.4	396.00	614.00	23.80	6.87	52.40	50.97	0.03	394.10	128.20	60.38	0.02	20.27	0.07	14.22
Jangipur P.S.	120	7.4	391.50	495.00	79.60	17.93	75.06	16.27	0.06	262.80	190.40	77.81	0.01	32.92	0.02	6.80
Sekhpur H.P.	45	7.2	468.00	435.00	36.50	10.27	55.41	62.25	0.08	226.00	40.63	17.73	0.00	113.04	0.04	7.80
Sekhpur P.S.	75	8.0	238.50	500.00	18.20	5.40	102.30	42.00	0.02	169.70	146.30	109.10	0.08	287.35	0.01	3.20
Ghazipur H.P.	60	7.1	486.00	467.00	64.00	17.85	59.21	45.66	0.65	368.30	16.83	64.30	0.09	51.58	1.94	164.00
Ghazipur P.S.	158	7.6	333.00	440.00	68.40	18.72	83.03	95.05	0.32	440.30	182.00	76.02	0.02	131.66	0.54	53.01
Nandganj H.P.	110	7.5	387.00	566.00	19.70	5.47	153.40	120.60	1.16	220.50	499.80	24.04	0.03	76.44	0.47	42.40
Nandganj T.W.	210	7.1	270.00	517.00	56.80	15.96	98.03	40.25	0.39	252.60	116.80	74.93	0.01	20.26	0.14	12.33
Saidpur H.P.	55	7.3	994.50	526.00	49.00	14.35	88.24	120.30	1.97	381.60	39.01	7.99	0.01	338.64	1.72	163.40
Saidpur P.S.	85	7.3	1098.00	506.00	24.00	6.85	228.00	72.12	1.98	282.30	21.20	86.28	0.04	309.46	0.52	34.76
Dahia H.P.	50	7.7	1484.00	574.00	37.20	11.30	217.10	99.15	0.33	444.20	184.50	9.35	0.05	58.02	0.15	16.34
Dahia P.S.	180	7.3	1143.00	462.00	34.40	9.89	150.00	168.30	1.80	368.30	625.30	119.60	0.03	147.36	0.04	7.05
Bhimanpur H.P.	35	8.0	1197.00	507.00	51.70	14.69	74.26	88.46	0.60	451.20	65.10	30.71	0.00	379.45	0.09	11.57
Bhimanpur T.W.	70	7.6	963.00	545.00	57.10	15.53	91.03	78.89	0.08	279.20	387.30	47.04	0.04	58.02	0.02	4.21
Muhammadabad H.P.	90	7.5	283.50	507.00	57.80	18.93	62.26	99.20	0.06	200.20	83.03	65.25	0.03	256.04	0.67	54.60
Muhammadabad P.S.	120	7.6	238.50	496.00	88.10	21.07	96.03	102.00	0.74	285.40	118.00	45.05	0.01	269.85	0.12	15.78
Mubarakpur H.P.	65	7.6	594.00	526.00	74.30	19.99	60.26	52.03	0.63	460.60	150.90	120.00	0.01	332.80	0.10	14.55
Mubarakpur P.S.	110	7.8	396.00	508.00	66.00	19.28	97.54	112.00	1.01	467.60	33.03	52.03	0.00	319.76	0.08	6.75

H.P. – Hand Pump (Shallow Aquifer); P.S. –Pumping Set (Deep Aquifer)

***Concentration in mg l^{-1} ; except pH ; ** Concentration in µg l^{-1}; F-feet**

Table-5.12: Ghazipur: Ground water analysis in Post-monsoon (August 2005) [n =30]

Sampling Location	W.L	pH	EC	ORP	*Ca^{+2}	*Mg^{+2}	*Na^{+}	*K^{+}	F^{-}	*HCO$_3^-$	*Cl$^-$	*NO$_3^-$	*PO$_4^{-3}$	*SO$_4^{-2}$	*Fe
	(F.)		(µS/cm)	(mV)											
Gaura H.P.	45	7.9	259.60	403.00	33.35	11.65	23.03	3.90	0.21	166.00	54.20	22.89	0.09	36.50	0.10
Gaura P.S.	125	7.8	204.20	416.00	78.02	32.86	17.03	4.17	0.15	399.00	28.20	40.06	0.05	42.20	0.17
Bhadura H.P.	47	7.5	567.70	417.00	36.32	10.14	34.42	6.34	0.32	310.00	82.00	39.88	0.11	37.30	0.20
Bhadura P.S.	90	7.8	363.50	399.00	103.43	26.72	82.05	6.07	0.37	115.00	103.00	120.00	0.81	26.60	0.13
Zamania H.P.	110	7.4	508.80	406.00	64.98	18.80	86.94	8.24	0.10	704.00	93.00	45.07	0.11	89.40	1.00
Zamania P.S	165	8.0	463.80	411.00	34.81	9.99	95.58	3.90	0.06	213.00	180.00	45.10	0.07	31.10	0.20
Tajpr Manjha H.P.	65	7.4	335.80	429.00	109.71	24.09	64.66	3.63	0.40	196.00	63.00	102.10	0.05	43.30	0.10
Tajpr Manjha P.S.	100	7.7	183.50	389.00	113.84	27.40	52.82	6.89	0.54	336.00	322.00	66.02	0.08	31.30	0.26
Sabalpur (Deoria) H.P.	62	7.6	148.80	394.00	36.33	10.93	54.12	6.40	0.26	344.00	76.00	41.12	0.05	76.10	0.10
Sabalpur (Deoria) P.S.	117	7.3	162.70	419.00	105.30	26.11	52.83	4.17	0.32	306.00	674.00	45.12	0.07	29.50	0.34
Tarighat H.P.	128	7.5	678.50	404.00	87.66	24.76	9.53	3.90	0.42	196.00	63.00	25.13	0.28	31.40	1.30
Tarighat P.S.	94	7.6	467.30	415.00	34.52	10.12	8.44	10.96	0.12	285.00	154.00	70.12	0.11	24.50	0.50
Jangipur H.P.	70	8.1	304.60	439.00	32.96	9.53	51.20	6.89	0.31	504.00	143.00	55.36	0.09	75.70	0.10
Jangipur P.S.	105	7.4	301.20	409.00	110.42	24.86	28.47	6.61	0.24	336.00	164.00	82.73	0.03	97.20	0.05
Sekhpur H.P.	35	7.4	360.00	414.00	50.61	14.24	65.27	9.60	0.11	289.00	66.40	16.62	0.05	40.10	0.42
Sekhpur P.S.	65	7.8	183.50	404.00	25.20	7.49	92.87	12.32	0.13	217.00	128.00	55.05	0.01	42.00	0.12
Ghazipur H.P.	45	7.4	373.80	424.00	88.74	24.76	79.34	16.67	0.47	471.00	167.00	15.02	0.11	87.00	1.60
Ghazipur P.S.	125	8.7	256.20	429.00	94.83	25.97	60.50	16.67	0.07	563.00	447.00	120.00	0.08	367.00	0.50
Nandganj H.P.	95	7.9	297.70	399.00	27.38	7.58	53.15	7.16	0.23	282.00	58.00	54.30	0.09	151.00	0.40
Nandganj T.W.	185	7.3	207.70	389.00	78.83	22.13	50.66	23.19	0.20	323.00	121.00	21.03	0.81	223.00	0.10
Saidpur H.P.	45	7.4	765.00	440.00	67.98	19.90	48.49	11.23	0.06	488.00	382.00	76.12	0.03	305.00	1.50
Saidpur P.S.	65	7.5	844.60	435.00	33.28	9.50	52.28	9.80	0.10	361.00	635.00	35.21	0.04	145.00	0.40
Dahia H.P.	40	7.9	1910.80	419.00	51.62	15.67	90.16	18.84	0.21	568.00	284.00	51.90	0.03	148.00	0.10
Dahia P.S.	145	7.5	879.20	411.00	47.70	13.71	96.66	48.84	0.15	471.00	109.00	70.92	0.01	132.00	0.06
Bhimanpur H.P.	30	7.7	920.80	436.00	71.74	20.37	90.70	13.95	0.19	577.00	518.00	68.02	0.11	233.00	0.10
Bhimanpur T.W.	55	7.2	740.80	411.00	79.14	21.54	79.20	4.71	0.02	357.00	219.00	105.00	0.03	202.00	0.13
Muhammadabad H.P.	65	8.1	218.10	398.00	80.13	26.26	55.28	19.21	0.14	256.00	326.00	85.23	0.27	56.00	0.60
Muhammadabad P.S.	105	8.3	183.50	402.00	122.22	29.22	52.08	3.80	0.12	365.00	274.00	62.25	0.54	42.00	0.10
Mubarakpur H.P.	45	7.9	456.90	388.00	103.07	27.72	24.14	28.63	0.75	589.00	585.00	42.03	0.07	274.00	0.27
Mubarakpur P.S.	95	7.9	304.60	402.00	91.59	26.74	97.20	4.71	0.10	598.00	387.00	105.10	0.04	97.00	0.10

H.P. – Hand Pump (Shallow Aquifer); P.S. – Pumping Set (Deep Aquifer)

***Concentration in mgl^{-1} except pH ; ** Concentration in µgl^{-1}; F-feet**

Statistical analysis of ground water-

Factor analysis of seasonal data of major ions along with physico-chemical parameters of Ghazipur ground waters indicates five trends for post- monsoon and pre-monsoon. The total variability accounted for five factors is 79.28 % in pre-monsoon season and 77.77 % in post- monsoon. The number of significant factors within the data is established by considering only those with an Eigen value >1.0. The degree of association between each variable and each factor is given by its loading on that factor. Table-5.13 (pre-monsoon) and Table-5.14 (post-monsoon) indicate the loading of each variable on each factor and the communality of each variable accounted for in the analysis.

In pre-monsoon season, factor 1 shows the strong geochemical associations between Fe and As which shows a strong relation of iron and arsenic; it may be due to weathering of Arseno-pyrite mineral that mobilize Arsenic in groundwater (In post monsoon the same association shows in Factor 3). Factor 2 represents the relationship between Ca^{2+} and Mg^{2+} that may be result of weathering of silicate mineral in pre-monsoon. Factor 3 is accounted for Na^{+}, F^{-} and Cl^{-} that indicates the result of dissolution and percolation of salts and halite deposits due to excessive irrigation of farmlands. Factor 4 represents the strong relationship in pH, EC, HCO_3^- and SO_4^{2-} explain the bicarbonate and sulphate act as proton donor for weathering of carbonate minerals, which results in high variability of EC. Factor 5 is accounted for HCO_3^- and ORP that indicates alkalinity plays important role to decide the ORP and vice-versa.

In post monsoon season, factor 1 explains the weathering of carbonate minerals of Ca^{2+} and Mg^{2+}. The association of bicarbonate and EC (Factor 2) indicates more release of bicarbonate in post-monsoon due to more carbonate weathering. Factor 3 shows the strong association between iron and arsenic. Several authors suggested that reductive dissolution of Fe (III)-oxyhydroxides in strongly reducing conditions of the young alluvial sediments is the cause of mobilization of arsenic (Ahemed et al., 2004, Bhattacharya et al., 1997; Harvey et al., 2002; Mc Arthur et al., 2004; Nickson et al, 1998). Factor 4 shows ORP influences Cl^-. Factor 5 shows relationship between Na^+ and NO_3^- reveals the dissolution of salt bearing mineral and mineralization of organic compounds.

Correlation matrix of the physico-chemical parameters is given in Table-5.15 (pre-monsoon) and Table-5.16 (post-monsoon). In pre-monsoon season the stronger association corresponding to the couples pH-SO_4^{2-},Ca^{2+}-Mg^{2+}, Na^+-F^-, Na^+-Cl^-, Cl^--F^- and Fe-As were observed. These relationships of pair between physico-chemical parameters are consistent with observations made from factor analysis that suggests the silicate and anthropogenic sources are responsible for these relationships. In post-monsoon season, strong correlation was observed for EC-ORP, EC-HCO_3^-, Ca^{2+}-Mg^{2+}, Ca^{2+}-NO_3^-, K^+-SO_4^{2-}, Fe-As suggests that carbonate along with the anthropogenic sources mainly fertilizers, use in agriculture, control the geochemistry of post-monsoon ground water.

Normalized Charge Balance-

The charge balance [ΔT_z] (Huh et al., 1998) obtained for Ballia and Ghazipur reveals high value of anions than cations . This indicates rapid mineralization of organic matter (Berner and Berner, 1987; Edmond et al., 1995; Huh et al., 1998) and further those anions may be contributed by anthropogenic activities mainly excess use of fertilizers. Another reason for low cations than anions may be due to slow weathering of carbonate and silicate minerals. This result further complying with data base generated by analysis of ground water samples of Ballia and Ghazipur district in different sampling seasons.

Table-5.13: Factor Analysis of groundwater of Pre-monsoon, Ghazipur [n=30]

Parameter	F1	F2	F3	F4	F5	Communalities
pH				0.558		0.775
EC				0.585		0.671
ORP					0.869	0.788
*Ca^{+2}		0.953				0.916
*Mg^{+2}		0.961				0.935
*Na^{+}			0.711			0.805
*K^{+}						0.756
*F^{-}			0.806			0.711
*HCO_3^{-}				0.583	0.549	0.687
*Cl^{-}			0.827			0.758
*NO_3^{-}						0.405
*PO_4^{-3}						0.660
*SO_4^{-2}				0.846		0.829
*Fe	0.969					0.955
**As	0.971					0.954
% Variance	17.845	16.592	16.503	16.054	12.292	
% Cumulative variance	17.845	34.437	50.940	66.994	79.286	
Eigen value	2.377	2.189	2.175	2.108	1.544	

Table- 5.14: Factor Analysis of groundwater of Post-monsoon, Ghazipur [n=30]

Parameters	F1	F2	F3	F4	F5	Communalities
pH						0.81
EC		0.538				0.603
ORP				0.727		0.716
*Ca^{+2}	0.968					0.959
*Mg^{+2}	0.923					0.89
*Na^{+}					0.701	0.697
*K^{+}		0.831				0.787
*F^{-}						0.714
*HCO_3^{-}		0.705				0.676
*Cl^{-}				0.507		0.654
*NO_3^{-}					0.595	0.728
*PO_4^{-3}						0.686
*SO_4^{-2}		0.715				0.712
*Fe			0.956			0.95
**As			0.977			0.963
% Variance	18.77	17.39	16.11	13.68	11.82	
% Cumulative variance	18.77	36.16	52.27	65.95	77.77	
Eigen value	2.515	2.309	2.116	1.752	1.623	

***Concentration in mg l^{-1}; ** Concentration in µg l^{-1} ;ORP in (mV); EC in (µS/cm); except pH**

Table- 5.15: Correlation Matrix of Pre-monsoon groundwater samples, Ghazipur [n=30]

	pH	EC	ORP	*Ca^{++}	*Mg^{+}	*Na^{+}	*K^{+}	*F^{-}	*HCO$_3^{-}$	*Cl^{-}	*NO$_3^{-}$	*PO$_4^{-3}$	*SO$_4^{--}$	*Fe	**As
pH	1														
EC	0.05	1.00													
ORP	-0.08	0.01	1.00												
*Ca^{++}	0.13	-0.24	-0.09	1.00											
*Mg^{+}	0.17	-0.23	-0.08	0.93	1.00										
*Na^{+}	0.19	0.54	-0.20	-0.12	-0.19	1.00									
*K^{+}	-0.21	-0.15	-0.05	0.06	0.07	0.08	1.00								
F^{-}	0.09	0.17	-0.02	0.14	0.08	0.51	-0.01	1.00							
*HCO$_3^{-}$	0.29	0.34	0.34	0.09	0.17	0.13	-0.04	0.15	1.00						
*Cl^{-}	0.10	0.16	0.04	0.01	-0.09	0.43	-0.02	0.54	-0.02	1.00					
*NO$_3^{-}$	0.04	-0.17	-0.20	0.14	0.08	0.16	0.11	0.06	-0.03	0.18	1.00				
*PO$_4^{-3}$	0.04	-0.06	-0.13	-0.09	-0.19	0.20	-0.13	0.19	-0.18	0.19	0.17	1.00			
*SO$_4^{--}$	0.48	0.31	-0.29	0.04	0.08	0.30	-0.15	0.24	0.30	-0.15	0.13	-0.16	1.00		
*Fe	-0.33	0.21	0.09	0.01	0.07	0.00	-0.08	0.09	0.17	-0.18	-0.29	0.09	0.17	1.00	
**As	-0.36	0.19	0.11	-0.02	0.04	-0.07	-0.11	0.05	0.12	-0.17	-0.32	0.06	0.13	0.98	1.00

Table- 5.16:Correlation Matrix of Post-monsoon groundwater samples,Ghazipur [n=30]

	pH	EC	ORP	*Ca^{++}	*Mg^{+}	*Na^{+}	*K^{+}	*F^{-}	*HCO$_3^{-}$	*Cl^{-}	*NO$_3^{-}$	*PO$_4^{-3}$	*SO$_4^{--}$	*Fe	**As
pH	1														
EC	-0.12	1.00													
ORP	-0.03	0.36	1.00												
*Ca^{++}	0.01	-0.22	-0.18	1.00											
*Mg^{+}	0.07	-0.21	-0.18	0.93	1.00										
*Na^{+}	0.03	0.28	0.11	-0.07	-0.12	1.00									
*K^{+}	0.03	0.32	-0.08	-0.07	-0.04	0.22	1.00								
F^{-}	-0.08	-0.13	-0.29	0.38	0.29	-0.30	0.10	1.00							
*HCO$_3^{-}$	0.15	0.35	0.27	0.09	0.17	0.28	0.36	-0.05	1.00						
*Cl^{-}	0.14	0.17	0.24	0.30	0.27	0.08	0.14	0.08	0.40	1.00					
*NO$_3^{-}$	0.29	-0.01	0.11	0.39	0.31	0.29	-0.03	-0.20	0.06	0.17	1.00				
*PO$_4^{-3}$	0.08	-0.21	-0.39	0.33	0.31	-0.05	0.00	0.09	-0.31	-0.16	0.05	1.00			
*SO$_4^{--}$	0.17	0.29	0.24	0.10	0.12	0.10	0.43	-0.11	0.58	0.46	0.25	-0.07	1.00		
*Fe	-0.19	0.07	0.24	0.07	0.13	-0.13	-0.01	0.08	0.16	0.03	-0.24	-0.06	0.14	1.00	
**As	-0.12	0.11	0.24	-0.02	0.04	-0.18	-0.04	0.02	0.12	-0.08	-0.22	-0.05	0.11	0.96	1.00

***Concentration in mg l^{-1}; **Concentration in µg l^{-1} ;ORP in (mV); EC in (µS/cm)**

5.3 Variation in groundwater chemistry of Ballia and Ghazipur-

Charge balance shows that anions are dominating the cations in the ground water of both districts and the ion strength of ground water in Ghazipur is higher than Ballia. Higher nitrate and chloride values are observed in the groundwater of Ghazipur compared to Ballia indicating the anthropogenic activities integrated along with natural processes are influencing the quality of ground water. The hydrochemistry of Ballia groundwater indicates that seasonal variation in cations and anions is lower compared to Ghazipur district. Carbonate weathering are prominent in both seasons (pre and post-monsoon) in Ballia where as in Ghazipur, silicate and carbonate weathering are more in the pre-monsoon followed by the dominance of carbonate weathering in post-monsoon seasons.

5.4: Arsenic distribution in two districts of middle Gangetic plain

Arsenic (As) is a ubiquitous element found in the atmosphere, soils and rocks, natural waters and organisms. It is mobilized in the environment through a combination of natural processes such as weathering reactions, biological activity and volcanic emissions as well as through a range of anthropogenic activities. Most environmental arsenic problems are the result of mobilization under natural conditions, but man has had an important impact through mining activity, combustion of fossil fuels, the use of arsenical pesticides, herbicides and crop desiccants and the use of arsenic as an additive to livestock feed, particularly for poultry. However, world wide, contaminated drinking water is the chief source of chronic human intoxication (Gabel, 2000). The current drinking water quality guideline by WHO is 10 $\mu g\ l^{-1}$ (WHO, 1993).

The occurrence of Arsenic in Upper and middle Gangetic plain ground waters are fairly new because most of the documented cases are reported from Bengal basin of Bangladesh (Ahmed et al., 2004; Ben et al., 2003) The Upper, Middle and Lower Ganga Plains are the most thickly populated areas of India. The Primary states located in the Upper and Middle Gangetic plain are Uttar Pradesh (238,000 km^2 area) and Bihar (94,163 km^2 area).

The predominance of arsenic poisoning due to contaminated groundwater in west Bengal, India and all of Bangladesh has been thought to be limited to the Ganges Delta (the lower Ganga plain). Early surveys have been conducted on arsenic contamination in ground water of west Bengal (Saha, 1984, 1995; Mazumder et al., 1988) and groundwater in the Union Territory of Chandigarh and its surroundings in the northwestern upper Ganga plain and recent findings in the Tarai areas of Nepal (Chakraborti et al, 2003). The arsenic contamination in the ground water particularly in the alluvium plain of Gangetic plain may cause secondary effect as well which results from agricultural activities and ultimately enters the human food chain. High arsenic in the groundwater of Lower Gangetic plain of Bangladesh and West Bengal was reported by (Bhattacharya et al, 1997). Several authors suggested that reductive dissolution of Fe (III)-oxyhydroxides in strongly reducing conditions of the young alluvial sediments is the cause of mobilization of arsenic (Ahemed et al., 2004, Bhattacharya et al., 1997; Harvey et al., 2002; Mc Arthur et al., 2004; Nickson et al, 1998 and 2000). But this pioneer study assess the availability of As problem in the middle Gangetic plain particularly Ballia and Ghazipur district of Uttar Pradesh, India.

Distribution of arsenic in Ballia-

High concentration of arsenic is present in the region of Sohaw, Bairiya, Majhauwa, Munchhapra and Tiwari Tola, which are near to river basin (Table-5.3 and 5.4). In these regions, arsenic values are higher than WHO standards of drinking water (10 μg l^{-1}).

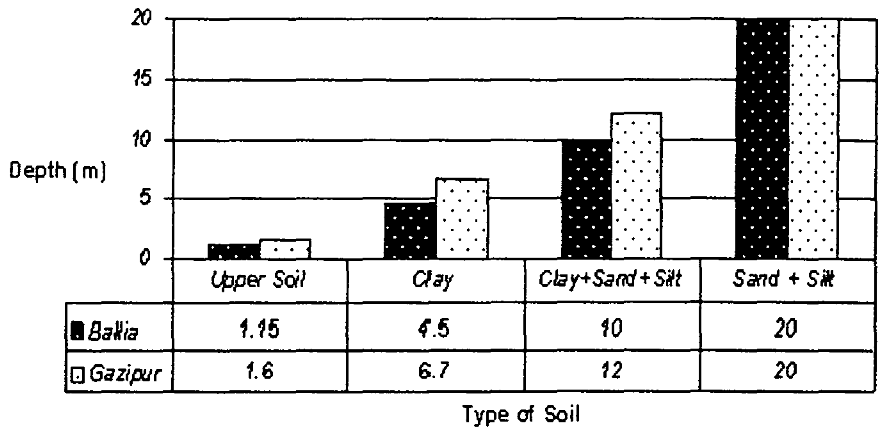
The strong correlation between As and pH in pre-monsoon shows that release of arsenic under high pH condition may be related to more negative surface charge of iron, thus high pH zone released arsenic is highly mobile (Bhattacharya et al., 2006). The association of chloride and arsenic in post-monsoon reveals that the anthropogenic activities like high fertilizer uses and irrigation and natural processes like evaporation are controlling the arsenic release in groundwater. In pre-monsoon it varies from 5.52 μg l^{-1} to 259.49 μg l^{-1}, but in post-monsoon it varies from 4.37 μg l^{-1} to 205.51 μg $l^{-1.}$

The higher arsenic concentration along the Ganga river basin is observed in shallow aquifers (Fig. 5.9). Subsurface lithology of high arsenic affected areas comprising of medium to coarser channel materials (sand) and migration river system seems to influence the land formation as well as type of alluvium. Arsenic would have been subsequently sorbed and co-precipitated with secondary iron and aluminum phases, mainly present as colloidal suspension along with the flow of the river that ultimately deposited in the lower part of delta depending on the topography and the physiography of the basin (Bhattacharya et.al., 1997). The Vertical profile of Fe and As are showing decrease in concentration down the depth in both seasons.

Distribution of arsenic in Ghazipur -

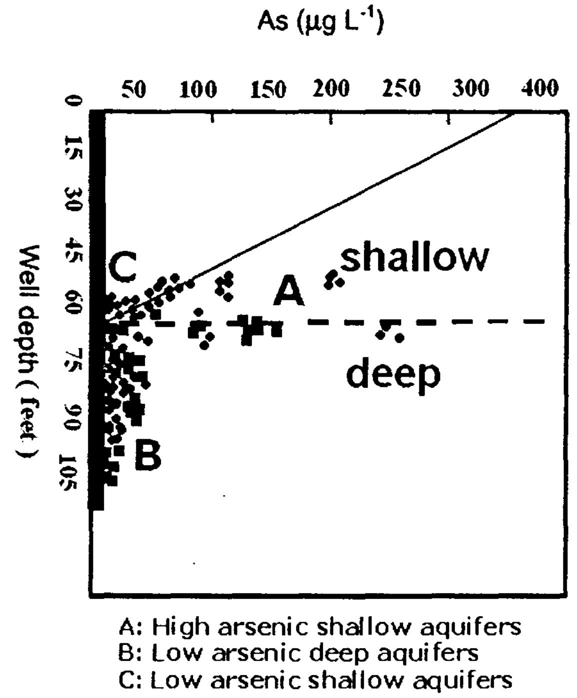
The average concentration of arsenic in Ghazipur aquifers is lesser than Ballia. In pre-monsoon, it varied from 3.2 $\mu g\ l^{-1}$ to 164 $\mu g\ l^{-1}$ with average value higher than post-monsoon, where it ranges from 2.5 $\mu g\ l^{-1}$ to 127.93$\mu g\ l^{-1}$. The strong relation between arsenic and iron favours that the natural processes is governing the arsenic distribution in different aquifers. Arsenic concentration is high in Tarighat, Ghazipur-city and Saidpur region in Ghazipur district, which are near to Ganga River. In these regions, arsenic values are higher than WHO standards of drinking water i.e.10 $\mu g\ l^{-1}$ (Table-5.11 and 5.12). Subsurface lithology of high arsenic affected areas comprising of medium to coarser channel materials as like Ballia, and river migration is causing the land formation as well as type of alluvium. The higher arsenic concentration along the Ganga river basin is observed in shallow aquifers (Fig. 5.9). In above three regions, As concentration is above 150 $\mu g\ l^{-1}$ in pre-monsoon case but in post monsoon it is relatively lower, but above the WHO standard. The Vertical profile of As are showing decrease in concentration down the depth in both seasons. The high correlation seems to be that Arsenic is adsorbed as arseno-pyrite, which release on changing of redox potential in the aquifer.

Fig. 5.8A: Litholog of two districts (Ballia and Ghazipur) of Uttar Pradesh, India. (20m drilling)



	Upper Soil	Clay	Clay+Sand+Silt	Sand + Silt
■ Ballia	1.15	4.5	10	20
□ Gazipur	1.6	6.7	12	20

Fig. 5.9: Arsenic distribution in different aquifers in Ballia and Ghazipur (Pre and post-monsoon season)



SEASON / DISTRICT	PRE-MONSOON	POST-MONSOON
BALLIA	●	●
GHAZIPUR	■	■

5.5: Spatial and temporal distribution :Ballia -

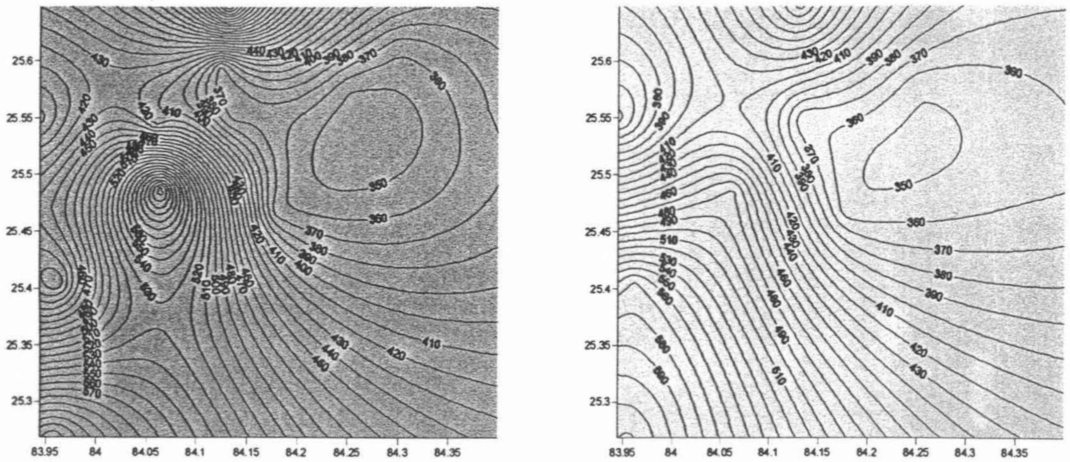
The comparative spatial and temporal distribution of ORP, Fe and As (Fig. 5.10a,b,c and 5.11a,b,c) between shallow and deep aquifers (within season and between seasons) is highly variable which is consistent with the ANOVA (analysis of variance) analysis of the pre and post monsoon data.

The spatial variability of ORP in different aquifers shows higher standard deviation within season. Not much inter-seasonal variability change is observed in ORP. However, the variability is higher in post monsoon in case of iron , where as the spatial variability of arsenic is higher in pre- monsoon. The variation in ORP and iron is large in different aquifers of varying depth.

5.6 Spatial and temporal distribution: Ghazipur-

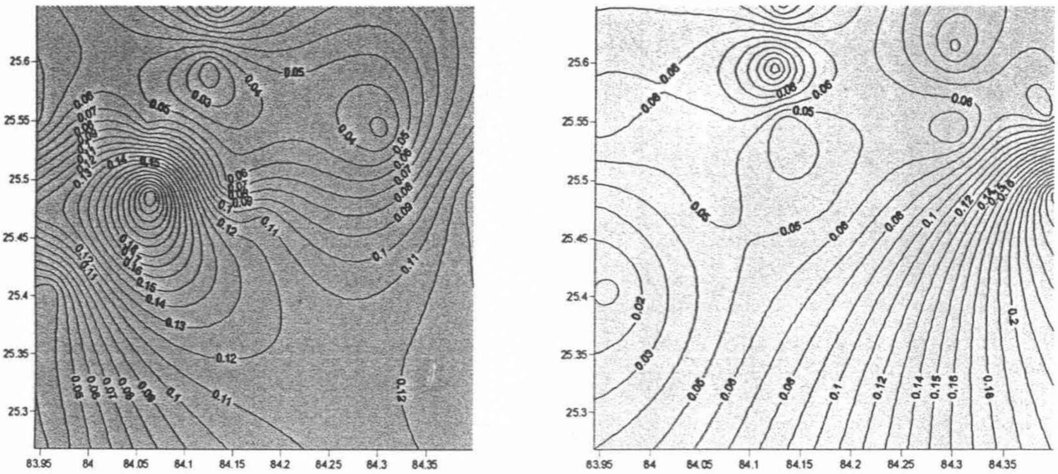
The comparative spatial and temporal distribution of ORP, Fe and As (Fig. 5.12a,b,c and 5.13a,b,c) between shallow and deep aquifers (within season and between seasons) reveals strong relationship between these parameters in the centrally located sampling sites in the Ghazipur, which is also consistent with the ANOVA (analysis of variance) analysis of the pre and post monsoon data.

The spatial variability of iron and arsenic is higher in pre-monsoon. Where as ORP contour diagrams show that higher change in standard deviation between pre and post-monsoon.



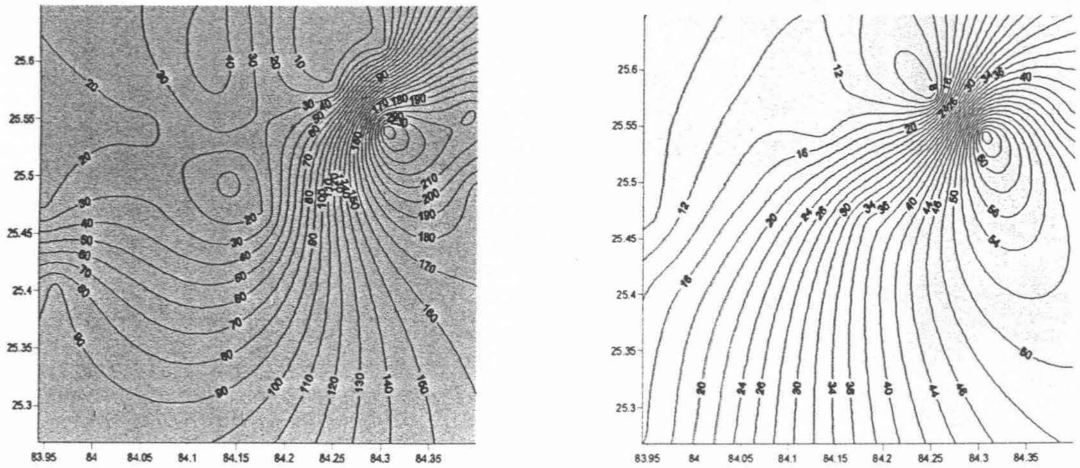
Shallow Aquifer Deep Aquifer

Fig. 5.10a:ORP in Groundwater of Ballia, Uttar Pradesh, India (Pre-monsoon Season)



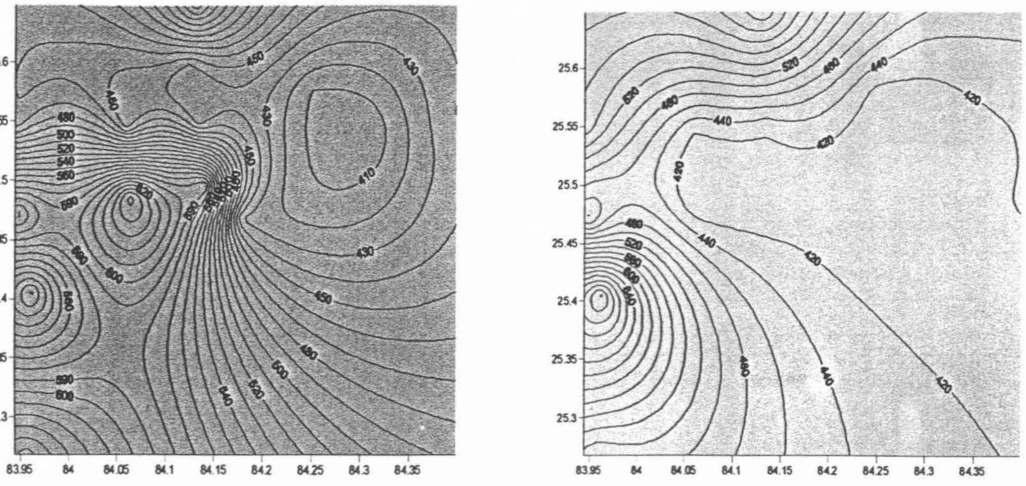
Shallow Aquifer Deep Aquifer

Fig. 5.10b: Fe in Groundwater of Ballia, Uttar Pradesh, India (Pre-monsoon Season)



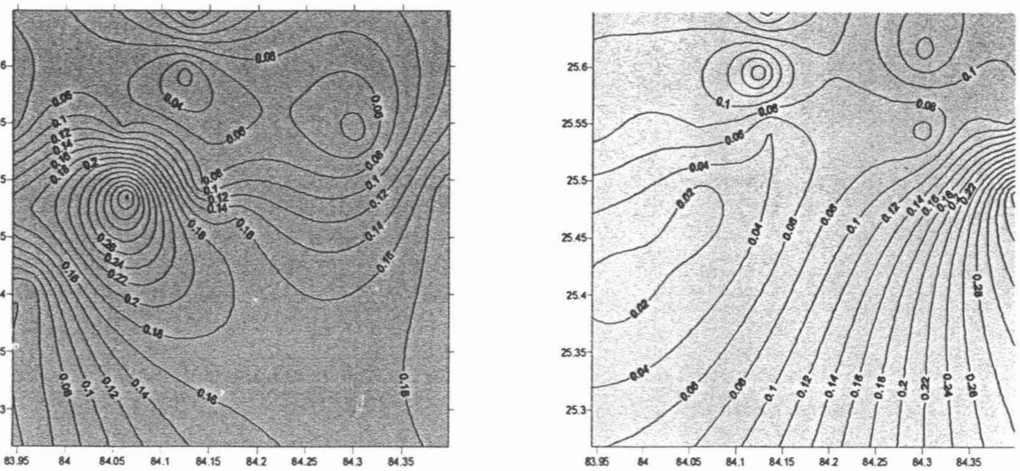
Shallow Aquifer Deep Aquifer

Fig.5.10c: As in Groundwater of Ballia, Uttar Pradesh, India (Pre-monsoon Season)



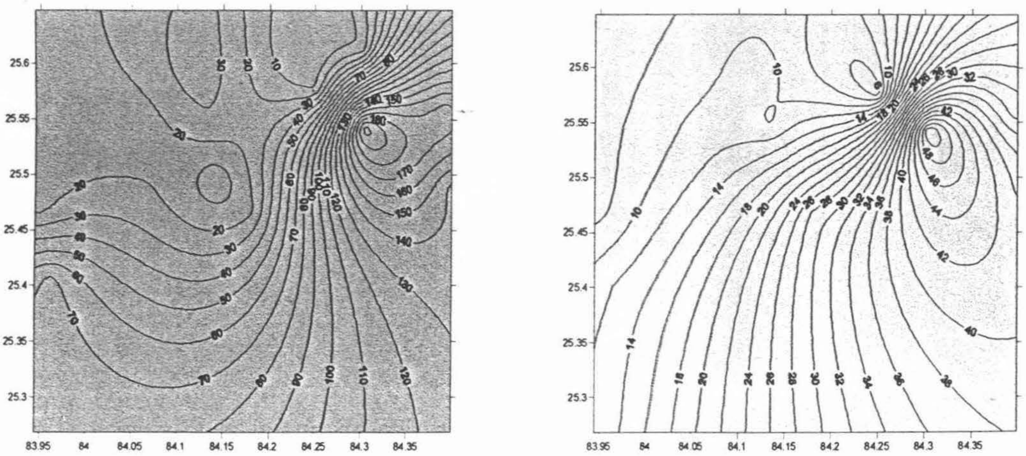
Shallow Aquifer **Deep Aquifer**

Fig. 5.11a: ORP in Groundwater of Ballia, Uttar Pradesh, India (Post-monsoon Season)



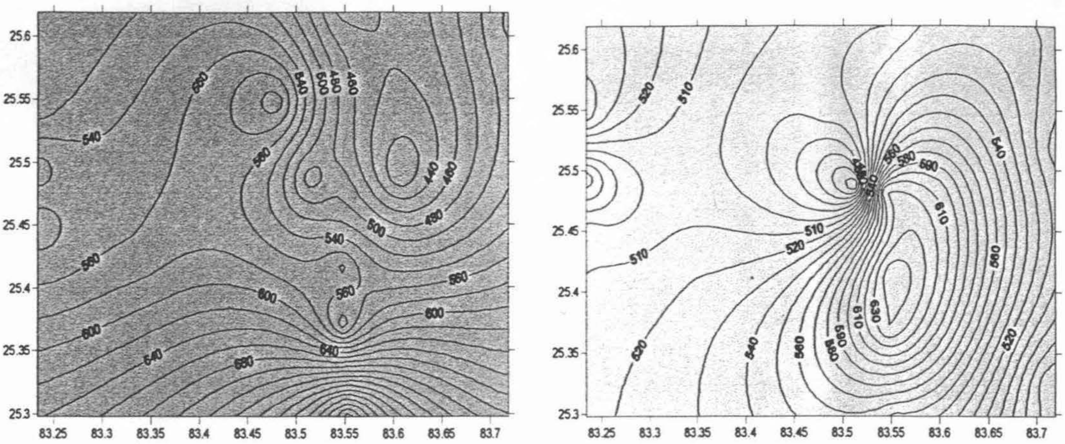
Shallow Aquifer **Deep Aquifer**

Fig. 5.11b: Fe in Groundwater of Ballia, Uttar Pradesh, India (Post-monsoon Season)

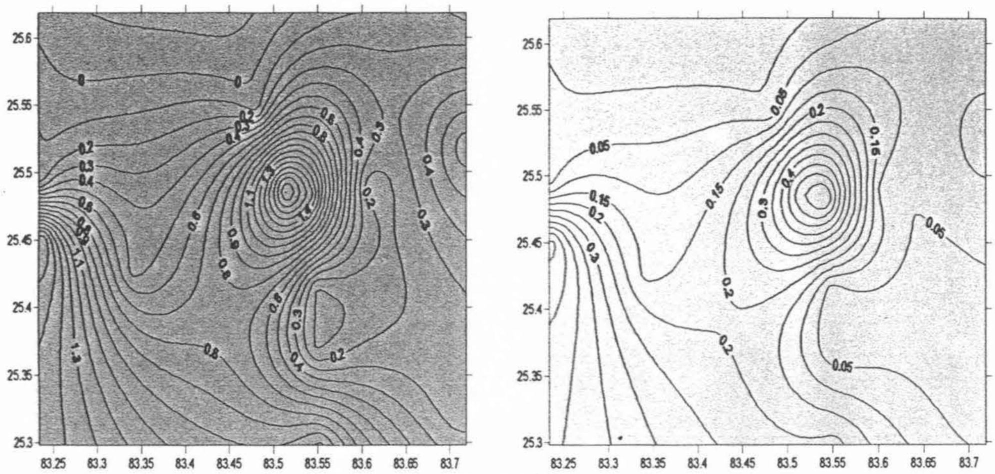


Shallow Aquifer **Deep Aquifer**

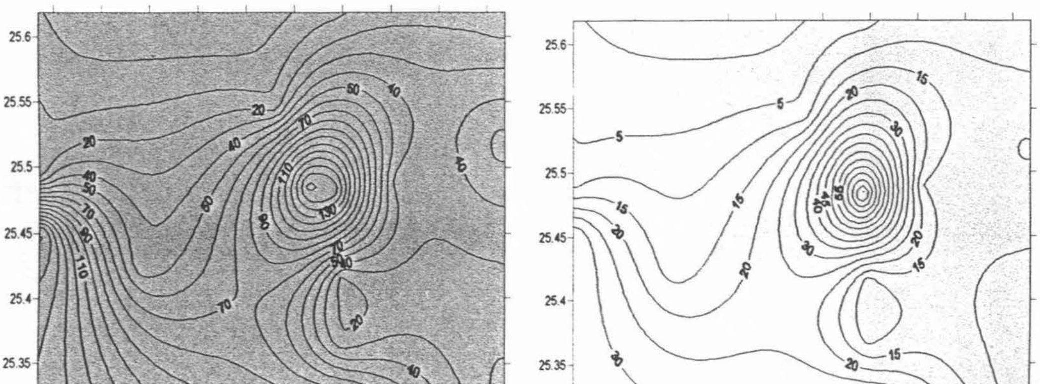
Fig. 5.11c: As in Groundwater of Ballia, Uttar Pradesh, India (Post-monsoon Season)



Shallow Aquifer- ORP **Fig. 5.12a** **Deep Aquifer-ORP**

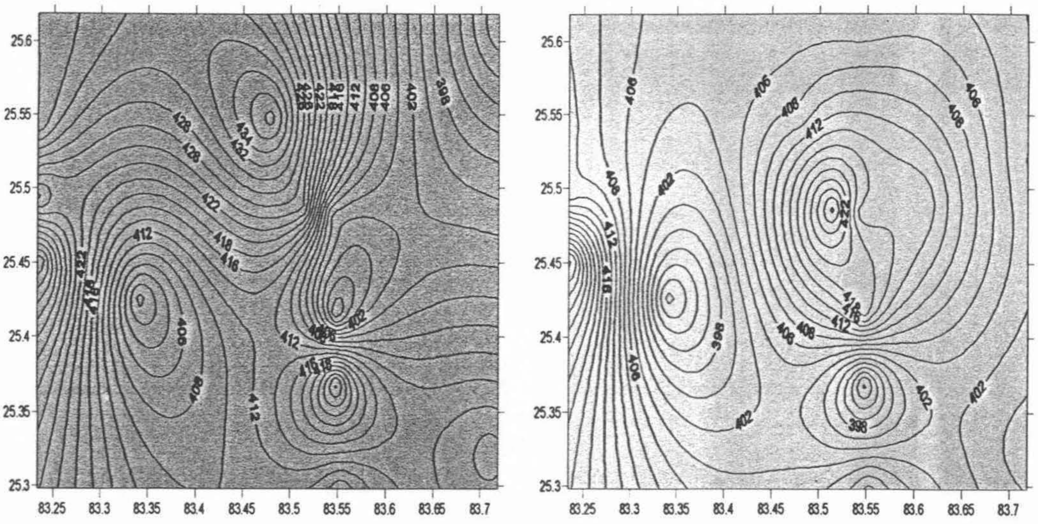


Shallow Aquifer - Fe **Fig. 5.12b** **Deep Aquifer – Fe**

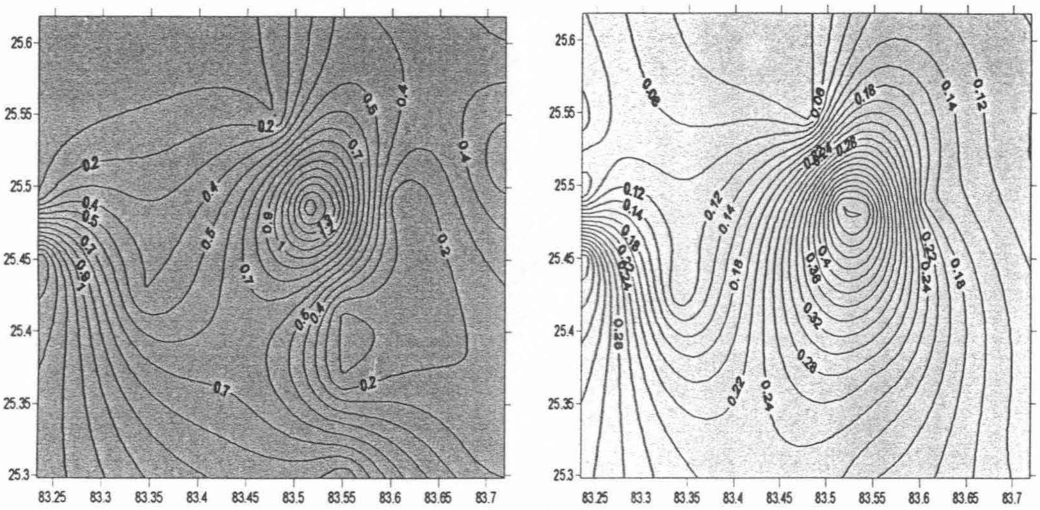


Shallow Aquifer- As **Fig. 5.12c** **Deep Aquifer -As**

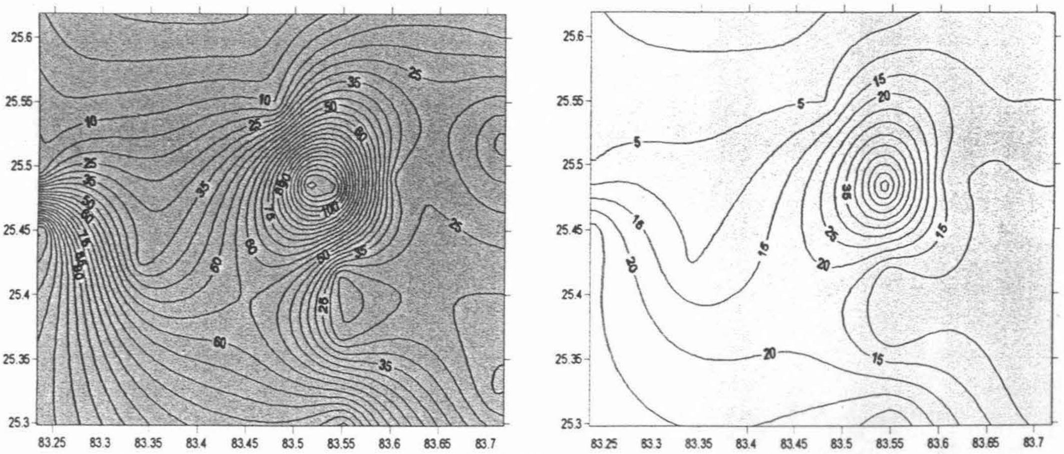
Fig. 5.12a- ORP; 5.12b- Fe and 5.12c- As, Contour diagrams in Pre-monsoon samples of Ghazipur, Uttar Pradesh



Shallow Aquifer- ORP **Fig. 5.13a** **Deep Aquifer-ORP**



Shallow Aquifer - Fe **Fig. 5.13b** **Deep Aquifer – Fe**



Shallow Aquifer- As **Fig. 5.13c** **Deep Aquifer -As**

Fig. 5.13a- ORP; 5.13b- Fe, and 5.13c-As, Contour diagrams in Post-monsoon samples of Ghazipur, Uttar Pradesh

CHAPTER – 6

SUMMARY AND CONCLUSION

Chapter one deals with the general aspects of water and ground water. Quantity of water with distribution of major aquifers in India, quality deterioration, which threatens the groundwater along with groundwater movement were discussed. The ground water deterioration is more in the lower Gangetic plain and is severely affected by arsenic contamination and now middle Gangetic plain is being affected.

The detailed ideas of Ganga basin including tributaries and physiography in Ballia and Ghazipur have been discussed. The sampling locations with map of study area etc. were also described. The geology, climate, rainfall and temperature etc. are summarized. The evaluation of hydrogeochemical character of groundwater and the relative study is very important tool in solving the problem. All these aspects have been discussed in chapter three. The natural and anthropogenic activities cause groundwater pollution in different aquifers in India. The nitrate and fluoride problems are prominent along Gangetic plain.

Chapter three highlights the arsenic problem in lower Gangetic plain. Very few studies have been occurred in middle Gangetic plain but no any detailed study has been done in Ballia and Ghazipur related to arsenic contamination in aquifers.

Chapter four has included material and methods. Total ground water samples (n=122) have been collected during sampling in two seasons (pre and post-monsoon) from both districts. pH, ORP, EC and bicarbonate have been done on field site and other chemical parameters (major cation, anions and metal specially Arsenic and Iron) have analyzed in laboratory of School of Environmental Sciences, JNU, New Delhi.

Chapter five discussed hydrochemistry of groundwater of Ballia and Ghazipur districts with statistical analysis, comparison of groundwater quality in two districts, with special reference to arsenic distribution along middle Gangetic plain in these two districts. The anthropogenic activities are dominating/controlling major hydrogeochemical processes in both districts, which affect the water quality. Arsenic contaminations to shallow aquifers are localized in some areas near to Ganga River.

Conclusion

- **Hydro geochemistry of groundwater in both districts-**

The geochemistry of groundwater from pre-monsoon and post-monsoon seasons shows significant change in ionic strength of water. The cation and anion ratios reflect the seasonal variability in the weathering pattern of carbonate and silicate minerals. The groundwater from Ballia district is directly and/or indirectly influenced by the anthropogenic activities mainly extensive and intensive agriculture practices, which is main source of socio-economic growth and development. The principal component analysis and correlation matrix of physico-chemical parameters reveals the association of As with pH (pre-monsoon) and Cl^- (post-monsoon), which can be considered as the natural and man made assemblages in Ballia ground water.

The geochemistry of ground water in Ghazipur indicates the seasonal variation in cations and anions, which is more than Ballia district. The silicate weathering is predominant in pre-monsoon season while carbonate weathering is exclusively controlling the geochemistry in post-monsoon season., where as in Ballia district carbonate weathering is dominant in both seasons.

- **Arsenic in both districts**

The high arsenic concentration was observed in Sohaw, Bairiya, Majhauwa and Munchhapra regions of Ballia district and Tarighat, Ghazipur-city and Saidpur of Ghazipur district show that the middle Ganga-Ghaghra plain is being affected by arsenic mobilization at the shallow depth aquifers. This is the first systematic report on As that shows the arsenic concentration is high and is going to be lethal in near future as well it may spread to neighboring districts as well depend upon the movement of ground water. Since both the rivers, Ganga and Ghaghra, are flowing through Himalayan regions, thereby, they are contributing arsenic to this flood plain region. Since Ballia and Ghazipur regions experience frequent floods every year by south-west monsoon and is having channelized natural water system, the ground water interact with the surface water, which accelerate the weathering and other hydrogeochemical processes and consequently trigger the sediment load and accumulation of As in these aquifers. The association of As with Fe in Ghazipur is illustrating the high redox potential of these ground water which favors natural association between As and Fe. But in Ballia, man-made alterations seems to be accelerating the As contribution to these aquifer.

The probable process occurring here may be:

Arsenic is adsorbed by iron oxide, which form a part of fine-grained sediments. These sediments are rapidly reducing because the rich organic matter consumes oxygen. As a result, a series of geochemical reaction occurs leading to the release of arsenic in groundwater (Reduction theory); arsenic present in pyrite-deposited in to the aquifer systems, when the iron is exposed to oxygen, its capacity to adsorb arsenic reduces and therefore arsenic starts leaching to the aquifer (Pyrite Oxidation theory). Oxygen enters the aquifer because of heavy groundwater withdrawal, favouring the oxidation of arsenic rich iron sulphide, which in turn mobilizes arsenic into the water.

Observation: Mobilization of As in the ground waters of two districts might have been caused by rise in water demand and uncontrolled extraction of ground water for irrigation of paddy fields and domestic requirements. This may be responsible for the deterioration of ground water condition, which is being manifested in the form of heterogeneous distribution of arsenic (elemental signature) in aquifers around the Ballia and Ghazipur districts.

Future Scope

The future study will involve sediment characteristics mainly texture analysis, grain size analysis, heavy metal analysis and arsenic speciation. This can enhance the knowledge on As mobilization and migration which will help us to better manage the ground water resource in Ballia and Ghazipur districts of Eastern Uttar Pradesh. They will also reveal interrelationship between water and clay mineralogy, which will throw a lot of useful information concerning the natural process responsible for the Arsenic problem in Ballia and Ghazipur. Moreover, analysis of sediment samples always means integration over certain time period. Thus, sediment analyses represent a longer time period than single situation analyses of water samples.

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