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GROUNDWATER QUALITY VARIATIONS IN SAHARANPUR DISTRICT (U.P.)

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ABSTRACT

The quality of groundwater is of great importance in determining the suitability of a particular ground water for a certain use (public water supply, irrigation, industrial application, cooling heeting, power generation, etc.). The quality of groundwater is the resultant of all processes and reactions that have acted on the water from the moment it condensed in the atmosphere to the time it is discharged by a well or spring. Therefore, the quality of groundwater varies from place to place, with the depth of water table, and from season to season and is primarily governed by the extent and composition of dissolved solids in it. The kind and concentration of dissolved solids depends upon source of salts and sub-surface environment.

In the present report, the results of the analysis of ground water sample from shallow unconfined aquaifers of Saharanpur district have been presented. Temporal variation of groundwater quality have also been marked.

The main use of these shallow wells is for agriculture and domestic purposes. Therefore, suitability of water for irrigation and drinking purpose has been tested with reference to available standards. The results indicate that the quality of ground water in the area under study is in general good for irrigation as well as for drinking purposes. There is not much variation in the quality of water in premonsoon and postmonsoon seasons due to less rainfall.

The quality of groundwater is of great importance in determining the suitability of a particular ground water for a certain use(public water supply, irrigation, industrial application, cooling, heeting, power generation, etc.). The quality of groundwater is the resultant of all processes and reactions that have acted

1.0 INTRODUCTION

1.1 General

In nearly every corner of the globe, men is making increasing demands upon his surroundings and thereby altering his own natural environment and that of the other organisms living with him on the earth. The demands are increasing not only because of the rapid growth of human population but also due to the increase in the living standard.

The intensive use of natural resources and the large production of wastes in modern society often pose a threat to groundwater quality and has already resulted in many incidents of ground water contamination. Degradation of ground water quality can take place over large areas from plane or diffuse sources like deep percolation from intensively farmed fields, or it can be caused by point sources such as septic tanks, garbage disposal sites, cementaries, mine spoils, oil spills or other accidental entry of pollutants into the underground environment. A third possibility is contamination by line sources of poor quality water, like seepage from polluted streams.

Because ground water tends to move very slowly, therefore many years may elapse between start of pollution and its reflection in a well. For the same reason, many years may be required to rehabilitate contaminated aquifers after the source of pollution has been eliminated. This long delay can force abandonment of wells and may require costly development of alternate water supplies. Prevention of contamination thus is the best way for protecting ground water quality.

Slow movement of groundwater, however, is a favourable factor when the contaminants are degradable (biological, bacteriological or radioactive contaminants) with time. In these cases long underground detention times may result in essentially complete removal of the undesired substances. On the other hand, slow movement causes long contact with the subsurface minerals, most of which are soluble in water and may cause natural degradation of subsurface water.

Contaminated groundwater generally show increased levels of Cl^-, SO_4^{2-}, and Na^+ ions. Depending upon the redox potential, high levels of nitrate or ammonia may also be present. Elevated nitrate levels upto 50-100 mg/L are not exceptional in contaminated ground water (Csaki and Endredi, 1981; Zoctman et al., 1981). Leachate of domestic waste tips may contain concentrations in the order of g/L of Na^+, K^+, NH_4^+, Cl^- and CO_3^{2-}/HCO_3^- (Kooper et al. 1981).

The minerals carried in water, determine its usefulness for various purposes. Presence of some ions, beyond a certain limit, may make water injurious for irrigation, drinking or industrial purposes. For example, high levels of nitrate (More then 45 mg/L) may cause methenoglobinemia or blue baby disease, and fluoride more than 1.5 mg/L can cause dental, skeletal and non skeletal manifestations. High levels of Na^+ can be hazardous to the agricultural activities. Hence, it becomes necessary to monitor the groundwater quality in an area to assess its suitability for various uses.

1.2 Scope of the Present Work

The quality of groundwater varies from place to place as well as from strata to strata. It may also vary with seasonal changes. A water drown from a strata at a particular time of the year may be unsuitable where as it may be good enough at the other times of the year.

Ground water quality variation problem can be understood only by the regular monitoring of quality of water. In Western Uttar Pradesh rapid industrial and agricultural growth has taken place during the last two decades. This is likely to become manifold in near future with increasing industrialisation particularly in areas like Saharanpur where the necessary industrial nucleus already exists. Therefore, it has been proposed to take up monitoring work in district Saharanpur(Fig.1). Samples from twenty two dug wells, representing the shallow unconfined aquifer, were collected and analysed for various physical and chemical parameters.

The study was aimed at (i) to see the regional variation in the quality of shallow ground water and (ii) to see the seasonal variation in the ground water quality, (iii) to delineate the bad water quality zones for irrigation and drinking purposes, if any and (iv) possible source of pollution, if any.

2.0 SOURCES OF GROUNDWATER CONTAMINATION

There are many sources that contribute contaminants to the groundwater zone. The major sources which contribute to pollution problems are: (i) land disposal of solid wastes, (ii) sewage disposal on land, (iii) Agricultural activities (iv) Petroleum leakage and spills, (v) Deep well disposal of liquid wastes and (vi) Urban runoff and polluted surface water. There sources are discussed in brief here.

2.1 Land Disposal of Solid Wastes

Solid wastes (mostly garbage and industrial waste) is disposed in land fills where it decomposes and produces a leachate that can contaminate underlying groundwater. Landfills range from unmanaged dumps where refuse is piled up with little or no regard for environmental effects, to carefully designed and operated "Sanitary" landfills.

The amount of leachate produced in a landfill depends on amount and distribution of rainfall, hydraulic conductivity of cover soil (if any), evaporation from cover soil and freezing and thawing. If the soil below the fill is relatively impermeable, percolation of leachate to underlying ground water is retarded. The chemical composition of landfill leachate depends on the nature of the refuse, on the leaching rate and on the age of the fill.

The hardness of leachate and contaminated ground water is due to the dissolution of Ca & Mg compounds by CO_2 (which forms carbonic acid) produced by the decomposition of the refuse. The type of leachate produced depends upon the type of refuse.

Landfills are point source of pollution and the leachate movement in the sub soil forms a narrow band or plume, unless of course, the ground water is stagnant.

2.2 Sewage Diposal on Land

Sewage enters the ground intentionally from septic tanks, cesspools and systems where sewage is applied to land for crop irrigation, ground water recharge or simply disposal, Unintentional entry of sewage into the underground environment include leakage from sewers, sewage lagoons and from streams or dry washes in which sewage effluent is discharged.

The capability of soil to remove suspended and dissolved constituents from sewage is utilized in land treatment systems, where sewage is applied to land with sprinklers, irrigation furrows or borders, or infiltration basins.

2.3 Agricultural Activities

Modern agriculture is based on extensive use of fertilizers and pesticides to obtain high crop yield. Some of the chemicals applied to farm land, however, move down with the deep percolating water from the root zone and can contaminate underlying groundwater. Manure piles, feedlots and similar concentrations of animal waste are other possible sources of ground water contamination. Deep percolation water from irrigation fields in arid region tends to have high salt content, which adversely affects underlying ground water.

With the exception of manure piles, agriculture is an area wide or diffuse source of groundwater contamination. In humid areas the major contaminant is nitrate, where as TDS and NO_3 are of most concern in arid irrigated areas.

2.4 Petroleum Leakage and Spills

Gasoline and other petroleum products can enter soils and aquifers from leaking pipelines or storage tanks and from accidents involving tank trucks or rail road cars. Most ground water contamination cases are caused by underground tanks from gasoline stations. The main problem of petroleum contamination of ground water is taste. Toxicity is not a problem because the water is already undrinkable due to taste and odour well before concentrations reach toxic levels.

2.5 Deep Well Disposal of Liquid Wastes

Injection of liquid wastes, mainly of industrial origin, has been widely adopted as a waste disposal practice. The purpose of this procedure is to isolate hazardous substances from the biosphere. As the discharge of pollutants to rivers and lakes has become increasingly objectionable, and as legislation for protection of surface water resources have become more stringent, the use of deep permeable zones for liquid waste disposal has become an increasingly attractive waste management option for many industries.

Deep injection of liquid wastes causes a point source of ground water pollution and contaminates the deeper aquifers, otherwise safe from pollution. Due to deep injection, the pollutants traverse relatively a thin colum of soil and also the time lag between the pollution discharge and arrival of pollutants to ground water is reduced.

2.6 Urban Runoff and Polluted Surface Water

Many streams receive municipal and industrial waste water. Seepage of such water into underlying ground water may adversely affect ground water quality. Urban runoff may infiltrate directly into the ground through pavements after it has reached a stream, or via recharge pits or "dry wells" constructed for disposal of storm runoff.

3.0 MOVEMENT OF CONTAMINENTS IN THE SUBSURFACE ENVIRONMENT

The mechanism of ground water pollution is quite different from that of surface water and is more complicated. Surface water pollution is rapid and becomes evident in comparatively short time from perceptible changes in colour, taste, odour and at times by dead aquatic life. The process of ground water pollution is comparatively much slow and the time lag between pollution discharge at land surface and when pollutants reach ground water may be several years or decades.

The wide range of contamination sources is one of the many factors contributing to the complexity of ground water quality assessemnt. It is important to know the geochemistry of the chemical-soil-ground water interactions in order to assess the fate and impact of chemicals discharged into the ground. Chemicals will pass through several different hydrologic zones i.e. unsaturated (top soil, vadose zone, capillery fringe) and saturated zones, as they migrate through the soil to the water table.

3.1 Unsaturated Zone

The unsaturated zone is the buffer between human activity and the groundwater source. As such it serves two functions: as reactor and as storage reservoir. Unlike from a store room it is almost impossible to retrieve a pollutant from the unsaturated zone.

The uppermost region of the unsaturated zone (the soil zone) is the site of important processes leading to pollutant attenuation. Some chemicals are removed in this zone by adsorption onto organic material and chemically active silt and soil particles or by decomposition through oxidation and microbial activity or by consumption by vegetation.

In the vadose zone, as the contaminant-bearing water percolates through, oxidation and aerobic biological degradation continue to take place. Some chemicals are also adsorbed and precipitates may be filtered out.

In the capillary zone, spaces between soil particles may be saturated by water rising from the water table under capillary forces. Certain chemicals that are lighter than water will float on the top of the water table in this zone. These floating chemicals may move in the different directions and at different rates than contaminants dissolved in the percolating recharge.

So, a pollutant which enters the top soil is transferred by the water movement through big reactor (the soil), if it is not decomposed or consumed by vegetation or attached to the soil material, it will finally reach the aquifer and contaminate the groundwater. Thus unsaturated zone can be considered as a pollutant filled time bomb, which ticks slowly, but will explode sometime later.

3.2 Saturated Zone

Once dissolved contaminants reach the water table, they enter the ground water flow system-the direction of which depends upon the hydraulic gradients Fig.1. All pore spaces

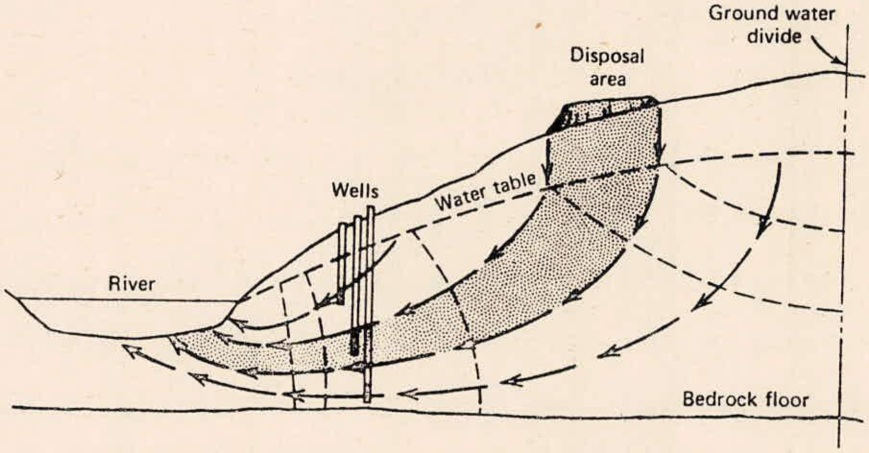


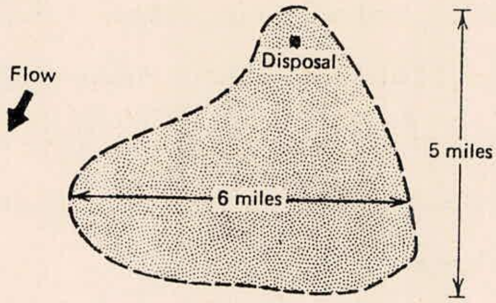
Figure 1 Flow of contaminants in a water table aquifer (humid region).

between soil particles below the water table are saturated. The relative unavailability of dissolved oxygen in the saturated zone limits the potential for oxidation of chemicals. Varying levels of attenuation may take place, depending on the geologic conditions.

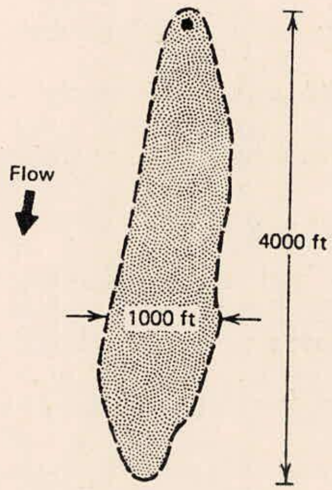
Groundwater flow rates in aquifers generally range from a few inches to a few feet per day. A body of contaminated ground water may contain the accumulation of decades of leachate discharge; and it may take many years for contaminants to be detected in a near by water supply. Because ground water flows in laminar fashion, dissolved chemicals will follow ground water flow lines and form distinct plumes. The shape and size of a plume depends on a number of factors, including the local geologic framework, local and regional ground water flow, the type and concentration of contaminants, and variations in the rates of leaching. Fig.2 illustrates the shapes of two plumes of contamination in the different geologic settings and the length of time it took for them to develop.

The density of contaminated fluides is another important factor in the formation and movement of a plume. Some chemicals will tend to flow on top of the water table, while others tend to sink to the bottom. Multiple discharge of different kinds of chemicals have led to a complex pattern of plumes at the site (Fig.3).

Discontinuous discharge may result in "slugs" of contaminated water, causing wide spatial and temporal fluctua-



(a) Chloride plume, Inel, Idaho
Aquifer : basalt
Time : 16 years



(b) Chromium plume, Long Island
Aquifer : sand and gravel
Time : 13 years

Figure 2 Effect of differences in geology on shapes of contamination plumes.

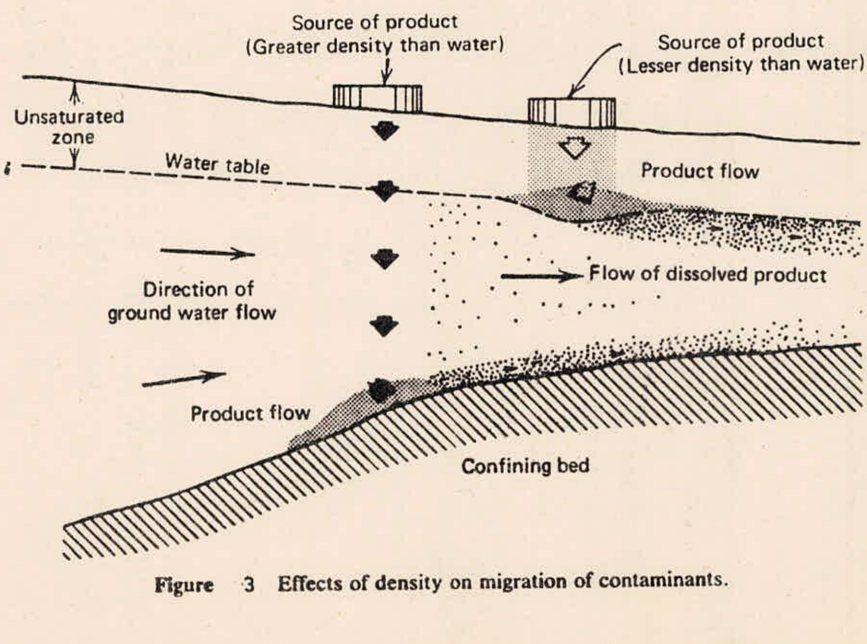


Figure 3 Effects of density on migration of contaminants.

ions in well water quality (Fig.4). Lenses of sand and clay an cause other variations by stratifying the contaminants.

Pumping from wells can also modify ground water low patterns and consequently alter the movement of a containant plume (Fig. 5).

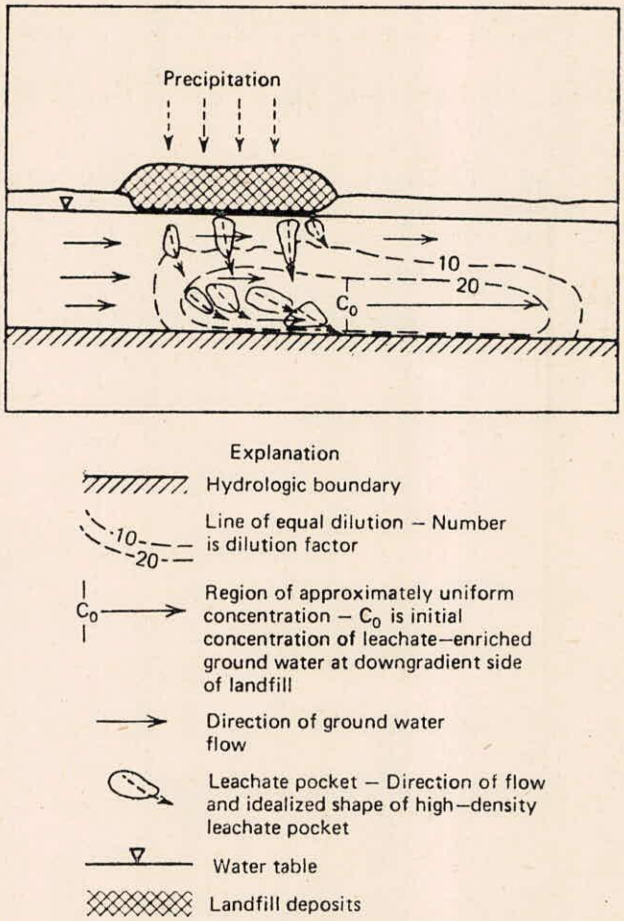


Figure 4 Leachate movement in ground water beneath a landfill.

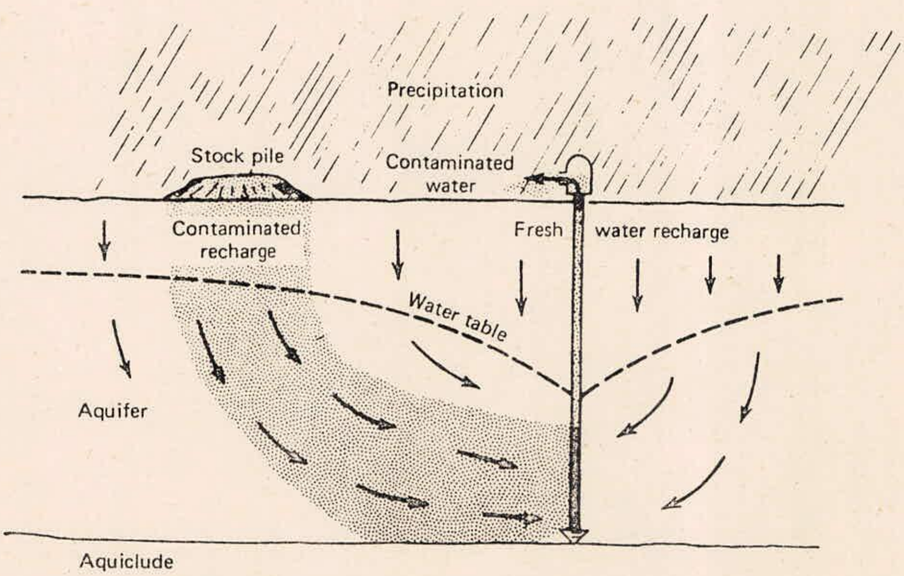


Figure 5 Influence of pumping on plume migration.

4.0 STATUS OF GROUND WATER POLLUTION IN INDIA

As a result of rapid unbanisation and industrialisation in several parts of the country, there has been several fold increase in generation of wastewater. For most of the cities and towns, domestic sewage is being discharged without proper treatment into the rivers or land for irrigation. In case of industrial units, effluents without adequate treatment are discharged on land near the factories in many cases or through unlined channels to low lying depressions resulting in percolation and eventually pollution of groundwater. In India, ground water pollution of all the three categories viz. point, line and diffuse, is taking place. Wastes from municipal sources such as sewage effluents and sludge cause point, line and diffuse pollution whereas industrial effluent cause point pollution mostly and when discharged on land may also cause line and diffuse pollution of ground water. Agricultural activities such as irrigation return flow, excessive use of fertilizers and soil amendments, pesticites and herbicides are conducive to diffuse pollution of groundwater. In India, the Central Ground Water Board (CGWB) is maintaining monitoring stations throughout the country to measure the condition and trends of groundwater quality and quantity in relation to standards and guidelines and is to a great extent, representing the total special situation particularly in Indo-Gangetic Valley. Regular monitoring on a national scale for groundwater quality started in 1969.

Some of the cases where ground water has been severely affected due to various kinds of pollution are as follows:

4.1 Municipal Wastes

Municipal wastes of most of the cities and towns without proper treatment are discharged into the nearest available water course. In case water course is not available, sewage effluents are discharged on waste land or these sewage effluents are passed through unlined channels to nearby fields where farmers use it for irrigation purposes. In either case, sewage effluents find their way into ground water system which eventually results in ground water pollution.

Municipal wastes are being increasingly dumped in sanitary land fills near the big cities. Often these land fills are selected without taking into consideration of the hydrogeological conditions of the area with the result that leachate from these land fills percolates into saturated zone and adversely effects ground water quality.

4.2 Industrial Sources

Ground water pollution from discharge of untreated or inadequately treated effluents has reached alarming proportions in several parts of India. Most of the industries pass the effluents without proper treatment into unlined channels resulting in accumulation of wastewater near these factories or depressions leading to percolation of industrial wastes into the ground water system. Some of the cases where ground water has been severally effected due to industrial pollution include:

i) High levels of cyanide to the extent of 2.0 mg/L have been found in ground water in several areas of Ludhiana town in Punjab.

ii) High concentrations of chromium have been found in groundwater from Ludhiana (Punjab), Faridabad (Haryana), Kanpur(U.P.), Varanasi(U.P.).

iii) Groundwater in Pali (Rajasthan and Jetpur (Gujarat) has become highly coloured due to seepage of effluents from textile dye industries.

iv) Groundwater near Jalandhar (Punjab) near a distillery is pumping coloured water due to percolation of effluent into the saturated zone.

v) High levels of nickel and zinc have been found in ground water near Khetri mines (Rajasthan) and in parts of Udaipur(Rajasthan) respectively.

vi) Cadmium concentration at some places in Kanpur and Delhi have been observed to be in high concentration.

vii) Groundwater pollution in Warangal (A.P.) have been reported by Naram (1981) due to discharge of untreated tannery and textile wastes.

viii) Tanneries located along the palar river in Tamil Nadu discharge their untreated effluents containing both organic and inorganic matter, resulting pollution of groundwater (Krishnaswamy, 1981).

ix) Neutral to slightly alkaline nature of groundwater have been found in parts of upper catchment of Betwa River Basin in Central India (Das and Kidwai, 1981).

x) The waste discharge from the big and small industries of Kota (Rajasthan) is resulting in increasing pollution of Chambal river which is further manifested in the deteriorating quality of the well waters on either flank of the river. The extensive use of fertilizers and pesticides in the Command Area of Chambal irrigation system has caused further deterioration of the chemical quality of the adjoining groundwater due to leaching and return flows (Kachwaha, 1981).

4.3 Agricultural Pollution

Fertilizers are applied for almost all crops and vary with crope type, soil conditions and irrigation practices. The use of nitrogen, phosphate and potassium fertilizers has increased from 45,19,8 thousand tonnes in 1950-51 to 4734, 1356, 754 thousand tonnes in 1981-82 respectively. This is further going to increase with projected values of 9883 and 2558 thousand tonnes in 1990 for nitrogen and phosphate respectively.

Studies conducted by Central Ground Water Board and other agencies have revealed that there are high levels of nitrate in groundwater to the extent of several hundred mg/L in parts of southern Punjab, Southern Haryana, Rajasthan, U.P., Maharashtra, A.P. and several other states. In southern and south-western Haryana, nitrate levels exceeding 500 mg/L at shallow depths have been observed at several places (Kakar, 1981). High levels of potassium and phosphate have also been reported in groundwater from several places in Punjab, Haryana and Uttar Pradesh.

4.4 Natural Sources

Apart from groundwater quality and pollution problems emanating due to activity of man, there are water quality problems due to natural causes in several areas of the country.

Groundwater in several parts of Rajasthan, Gujarat, Punjab, Haryana, Delhi and many other areas in moderately to highly saline. Fluoride concentrations in ground water are high in several parts of the country particularly in semi-arid and arid tracts. In parts of Rajasthan, Southern Punjab, Haryana, U.P., Gujarat, A.P., Tamil Nadu and Karnataka, high concentrations of fluoride in ground water have been reported and there are cases of mottling of teeth, dental and skeletal fluorises at many places. In certain exceptional cases like Sagalia in Gujarat, the fluoride concentration has been found to be 19 mg/L (Raghava Rao, 1977). High concentrations of iron in ground water have been reported from several areas, particularly those of high rainfall in West Bengal, North Eastern states and Kerala. In Assam , iron concentrations in ground water to the extent of 20 mg/L has been reported.

5.0 DESCRIPTION OF THE AREA

The area under study is part of the indogangetic plains and lies between latitude $30^{o}26'N - 29^{o}34'N$ and longitude $78^{o}11'E - 77^{o}6'E$ in the Saharanpur district of Uttar Pradesh (India)(Fig. 6)

Saharanpur is one of the important towns of Uttar Pradesh. In Western U.P. rapid industrial and agricultural growth has taken place during last two decades. This is likely to become manifold in near future particularly in areas like Saharanpur where the necessary industrial nucleus already exists. A variety of industries already have been set up in the district such as paper, textile, sugar, food-processing, small scale steel industies and cottage industries etc.

5.1 Physiography

Physiographically the area is generally flat except Siwalik hills in the north and north east. The area is devoid of relief features of any prominence except from deep gorges cut by nalas and rivers flowing through the area. The district is bound by river Yamuna in the West and river Ganga in the east.

5.2 Drainage

Regarding the drainage of the area, the rivers generally flow from north to south. These rivers during most of the non-monsoon season carry water drained into them from ground water storage. Some of the important rivers of the district are, the Ganga, Yamuna, Hindon, Krishni and the

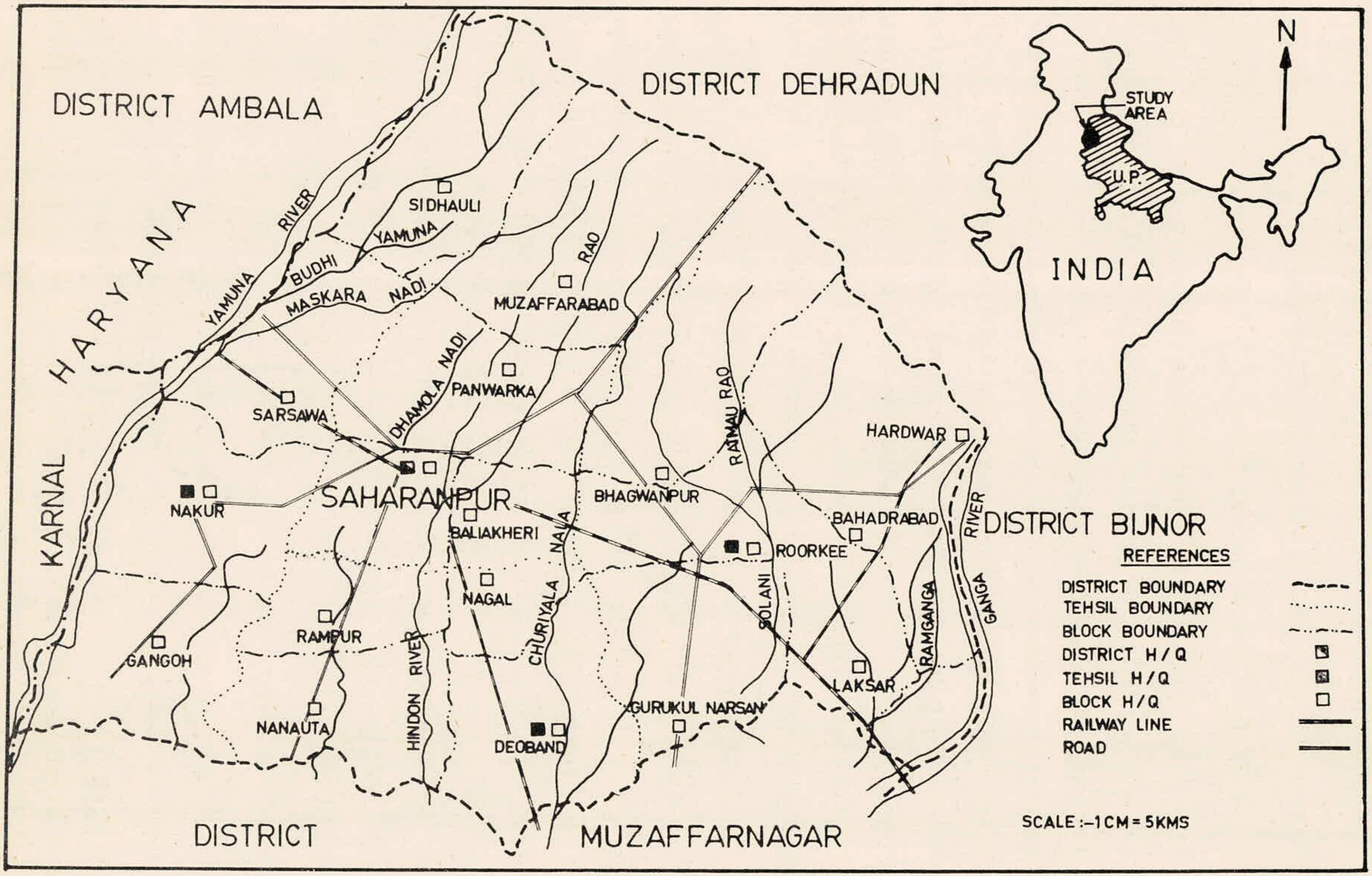


FIGURE 6 - INDEX MAP OF DISTRICT SAHARANPUR

Kali (West). Apart from these rivers, the western Ganga canal and Eastern Yamuna canal also drain the area.

5.3 Climate and Rainfall

The climate of the district Saharanpur as that of the greater part of Indian subcontinent is characterised by moderate type of subtropical monsoonic climate. In general, the average normal monsoon rainfall in the district is about 485.6 mm. The temperature ranges from 8^{o}c in winter to 40^{o} in summer. Major part of the rainfall (about 75%) is received during the monsoon period. It has been observed that the rainfall is heaviest in the northern region of the district, close to foot hills of Himalayas and becomes lesser southward.

5.4 Geology of the Area

The area under study is a part of west Indogangetic plain which is mainly composed of Pleistocene and subrecent alluvium brought down by river action from the Himalayan region. In other words alluvium is made up of recent unconsolidated fluviatile formations comprising of sand, silt, clay and kankar with occasional beds of gravel. The deposits of sand beds of varying thickness are the main source of ground water in the area.

5.5 Geohydrology of the Area

The groundwater conditions in all alluvial parts are considerably influenced by the varying lithology of the subsurface formations. As the general fluviatile nature of deposits of Indogangetic plains it has been observed that the strata exhibit great variation both laterally and vertically. The main source of water which sustains groundwater body in fine to coarse grained sands is rainfall. Other sources of groundwater replenishment are infiltration from rivers, canals and return flow from irrigation, and inflow from the neighbouring areas.

The most common groundwater structures in the area are shallow and deep tubewells. Dug wells are also used as source for drinking water as well as irrigation, but to a lower extent.

Based on the lithological logs and water table fluctuation data two types of aquifers have been delineated in the area (Singh et al, 1979). The upper one is the shallow unconfined aquifer which generally extents to depths around 25 m. The deeper aquifers are confined to semi-confined in nature and located at depths around 30 to 140 m, below ground level separated by three to four aquifers at average depths of 30 m to 55 m, 65 m to 90 m and 120 m to 140 m. Water table contours in the area indicate the southward trend of ground water flow both in unconfined aquifers and confined aquifers.

6.0 METHODOLOGY

6.1 Sampling

Sampling is one of the most important and foremost step in collection of representative water sample for ground water (or any water) quality studies. Moreover, the integrity of the sample must be maintained from the time of collection to the time of analysis.

Many factors are involved in the proper selection of sampling sites, e.g. objectives of the study, accessibility chemical source locations and menpower and facilities available to conduct the study. Further more, the hydrologist must be aware of the locations of point and non point sources of chemical and physical constituents, such as industrial complexes, sewage outfalls, agricultural wastes etc.

In the present study twenty two wells covering the Saharanpur district were choosen. Sampling was carried out in the months of June (Pre-monsoon) and Nov. (Post-monsoon).

The samples were collected by dip (or grab) sampling method. Depth integrated samples were collected by lowering the container in the open wells. The samples collected, were stored in clean plastic bottles fitted with screw caps. About two litres of water sample was collected. Another one litre was acidified ($pH<2$) with HNO_3 and stored in separate bottle for analysis of metal ions which may change before the samples reach the laboratory.

6.2 Water Quality Parameters

The quality of water depends on a large numbeı of individual hydrological, physical, chemical and biological factors. Some parameters are of special importance and deserve frequent attention and observation, other gives a rough picture of water body and its quality status.

During the present study the chemical properties and the constituents of water analysed are, pH, specific conductance (EC), colour odour, Hardness, Alkalinity (carbonates and bicarbonates) temperature and major cations and anions.

6.2.1 Physical parameters

Temperature

The temperature of water is one of the most important characteristics which determines the trends and tendencies of changes in its quality. The shifting of various dynamic equilibria such as concentration of carbonates, sulphides, or degree of alkalinity or electroconductivity are affected by temperature changes.

pH

pH value represents the concentration of hydrogen ions (H^+) in water and is a measure of acidity and alkalinity of water. A value of pH below 7.0 indicates acidic character while pH greater than 7.0 are inductive of alkaline character of water.

Electric Conductivity

Electric conductivity is a measurement of water's capacity for conveying electrical current and is directly related to the concentrations of ionized substance in the water. Solution of most inorganic acids, bases and salts are relatively good conductors. conductivity measurements are commonly used to determine the purity of demineralised water and total dissolved solids in boiler, cooling tower water, irrigation and domestic supply.

Colour

Colour in water may result from the presence of natural metallic ions, humus and peat material or industrial wastes. For drinking purpose the water should be colour less.

Odour and Taste

Disagreeable tastes and odours in water are associated with the presence of any of a great variety of living micro organisms or decaying vegetation or organic compounds. For drinking purposes the water should be odour less.

6.2.2 Major Anions

Carbonates and Bicarbonates

The presence of carbonates and bicarbonates is the most common cause of alkalinity in natural waters. Bicarbonates represent the major form since they are formed in considerable amounts from the action of carbonates upon the basic materials in the soil.

$$Co_2 + CaCo_3 + H_2o \longrightarrow Ca(HCO_3)_2$$

Sulphate

Sulphate appears in natural waters in a wide range of concentrations. Sodium and magnesium sulphate exert cathartic action and hence its concentration above 250 mg/L in potable water is objectionable. Sulphate cause a problem of scaling in industrial water supplies and problem of odour.

Chloride

Chloride is one of the major inorganic anion in water. It is present in all potable water supplies and in sewage, usually as a metallic salt. When sodium is present in drinking water, chloride concentrations in excess of 250 mg/L give a salty taste. High chloride concentrations in water are not known to have toxic effects on man, though large amounts may act corrosively on metal pipes and be harmful to plant life.

6.2.3 Major Cations

Sodium

Sodium, the sixth most common element, is present in nearly all natural waters. The levels may very from less then 1 mg/L to more than 500 mg/L. Ratio of sodium to total cations is important in agriculture and human pathology. Soil permeability can be harmed by a high sodium ratio.

Potasium

Potasium is less common cation in the groundwater. Its concentration in most drinking waters seldom reaches

20 mg/L. However, occasional brines contain more than 100 mg/L potassium.

Calcium

Calcium is one of the principle cations in groundwater. In the sedimentary rocks, calcium occurs as carbonates: and in alluvium it occurs in limestone. Calcium carbonate imparts the property of hardness to water together with sulphate, carbonates and bicarbonates.

Magnesium

After calcium, magnesium is the most important alkaline earth metal present in the groundwater. It is one of the important contributor to the hardness of water. The magnesium concentration in water may vary from practically zero to several hundred ppm, depending on the source of water.

6.2.4 Other Parameters

Hardness

The hardness of water was originally defined in terms of its ability to precipitate soap. calcium and magnesium ions are the principle causes although iron, alminium, manganese and hydrogen ions are capable of producing the same effect. Temporary hardness is caused by the presence of bicarbonates of calcium and magnesium, whereas permanent hard ness is mostly due to sulphates.

Nitrogen

In waters the forms of nitrogen of greatest interest are nitrate, nitrite, ammonia and organic nitrogen. All these forms of nitrogen are biochemically interconvertible and are components of the nitrogen cycle.

Total oxidized nitrogen is the sum of nitrate and nitrite nitrogen. Nitrate generally occurs in trace quantities in surface water but may attain high levels in groundwater. High levels of nitrate indicate the introduction of biological waste or contamination due to leaching from heavily fertilised fields.

Fluoride

Fluoride occurs naturally in some groundwater and normally 1 mg/L level is maintained in public drinking water supplies for the prevention of dental disorders. Excessive amount of fluoride cause an objectionable discoloration of teeth enamble called fluorosis.

Iron

Iron is present in most surface and subsurface waters. In polluted surface water, the concentration of iron varies from several micrograms to hundreds of micro grams per litre. In subsurface water it may be in the magnitude of gm/L.

6.3 Methods of Analysis and Equipment Used

The laboratory of the Institute is capable of analysing the basic parameters for water and waste water. However, for the measurements of some parameters such as pH, conductance and temperature, the portable water testing kit was used. The list of essential equipment used and methods of analyses are presented in Table 1. The preliminary studies to get acquainted with the field equipment was carried by the project team. Testing of the equipment and, preliminary calibrations have been prepared and used for each determinant.

Table 1 -Analysis Methods and Equipment Used in the Study

S.No.	Parameter	Analysis method	Equipment used
1.	Temperature	Thermometric	Portable kit (Naina Model NPC 358D)
2.	pH	Electrometric	"
3.	Conductance	Wheatstone bridge	"
4.	Turbidity	Photometric	Turbidimeter(High Model 16800)
5.	Alkalinity	Titrimetric	Digital titrators(Hach)
6.	Hardness	Titrimetric	Digital titrator(Hach)
7.	Ammonia-nitrgen	Nesslenization	Spectrophotometer(Hach DREL/5 System)
8.	Nitrate-nitrogen	Cadmium-reduction	"
9.	Nitrite-nitrogen	Diazotization	"
10.	Chloride	Mercuric nitrate	Digital titrator(Hach)
11.	Sulphate	Turbidimetric	Spectrophotometer(Hach DREL/5 System)
12.	Phosphate	Ascorbic acid	"
13.	Fluoride	SPADNS method	"
14.	Iron	1,10 phenanthroline	"
15.	Sodium	Flame emission	Flame photometer (Toshniwal Model RL 01.02)
16.	Potassium	Flame emission	"
17.	Calcium	Titrimetric	Digital titrator(Hach)
18.	Magnesium	Titrimetric	Digital titrator(hach)

7.0 RESULTS AND DISCUSSION

The quality of groundwater as determined by its chemical and biological constituents, its sediment contents and its temperature is of great importance in determining its suitability for a certain use, such as public water supply, irrigation, industrial application etc. The quality of water is as much important as its quantity. Groundwater quality is the resultant of all processes and reactions that have acted on the water from the moment it condensed in the atmosphere to the time it is discharged by a well or spring. Generally higher proportion of dissolved constituents are found in groundwater than in surface water because of greater interaction of groundwater with various materials in geologic strate.

The minerals carried in solution, though present in small quantities, determine its usefulness for various purpose. Presence of some minerals, beyond a certain limit may make it injurious for irrigation, drinking or industrial purposes. Water should therefore meet the standards for the specific use to which it is put. Water which is harmless for industrial and domestic use may be harmful for agriculture and vice versa.

The study of groundwater quality involves the study of various constitutents in groundwater and the relation of these constituents to water use. In the area of study ground water is extensively used for irrigation as well as drinking purposes.

The quality of groundwater also varies from place to place, strata to strata and season to season. The water drown from a place, from certain strate at particular time of year may be unsuitable where as it may be good enough at the other times of the year.

In the present study, groundwater quality variation at different places, (Fig.7) in pre-monsoon and post-monsoon period, of the shallow unconfined aquifers was carried out. The results of the chemical analysis of groundwater samples are presented in table 2.

Various methods are available to represent the quality of groundwater, most of the methods are graphical. The most common graphical method for the representation of data was developed by Piper (1944). The diagram permits the cation and anion compositions of many samples to be represented on a single graph in which major groupings or trends in the data can be discerned visually. The Piper's trilinear diagram represents the cations, expressed as percentage of total cations in epm, plot as a single point on the left triangle, while anions similarly expressed as percentage of total anions appears as a point in the right triangle. These two points are then projected into the central diamond shaped parallel to the upper edge of the central area. This single point is thus uniquely related to the total ionic distribution.

The diagram described above is useful for visually describing differences in a major ion chemistry in ground

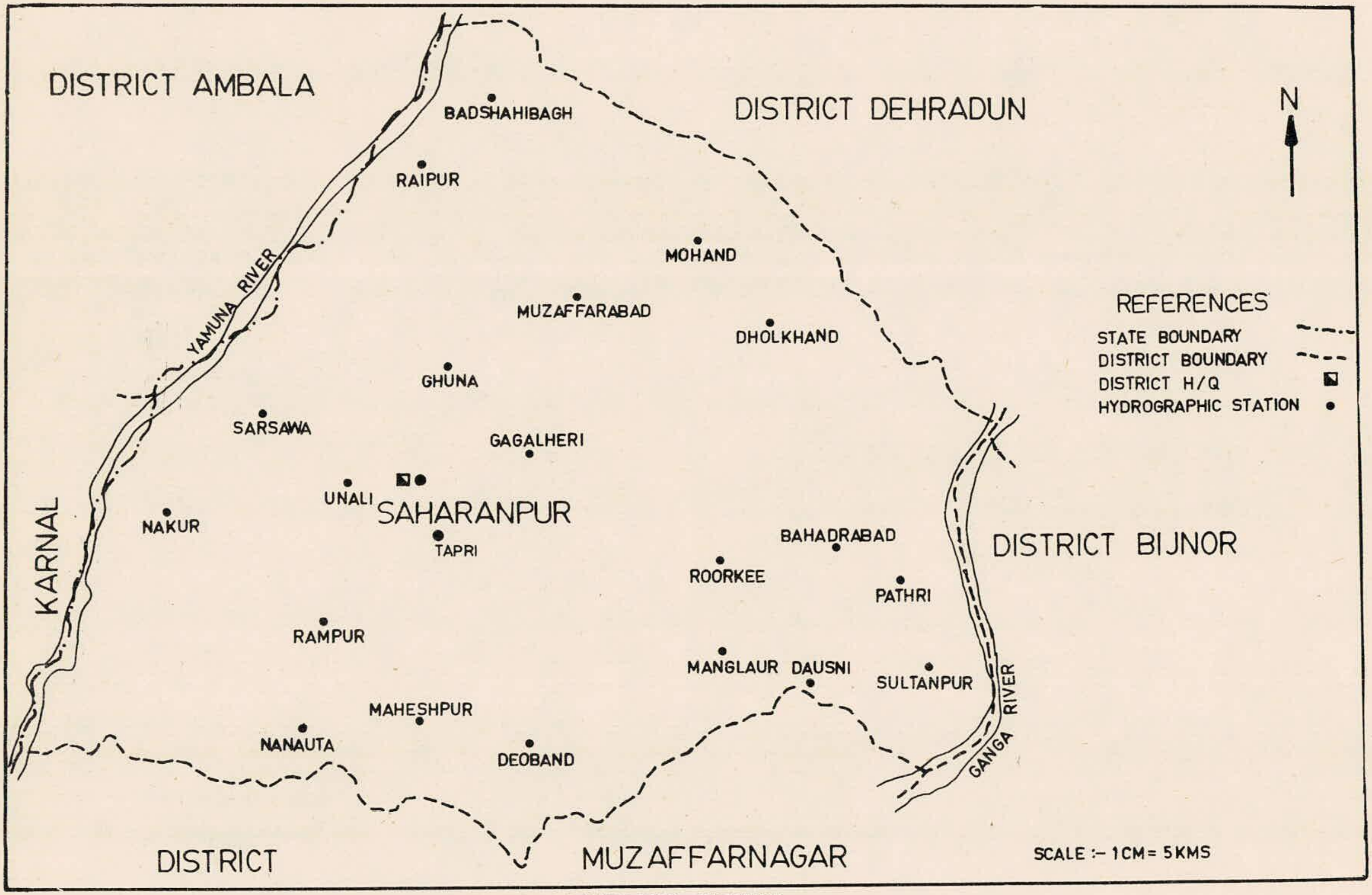


FIGURE 7 - MAP SHOWING GROUND WATER SAMPLING POINTS

Table 2. Results of Chemical Analysis of Ground Water in Unconfined Aquifers of District Saharanpur

A. Physical Parameters

S.No.	Location of well	Temperature (C)		Conductivity (uS/cm)		Colour		Odour		pH	
		1	2	1	2	1	2	1	2	1	2
1	Muzzafarabad	27.8	24.0	809	732	-	-	-	-	7.2	7.5
2	BadheshahiBag	27.4	22.5	409	428	-	-	-	-	7.6	7.6
3	Raipur	27.0	22.2	373	492	7	-	-	-	7.8	7.3
4	Ghunna	27.8	25.7	519	544	-	-	-	-	7.0	7.6
5	Sarsawa	27.5	24.4	901	921	-	-	-	-	7.1	7.3
6	Nakur	26.8	23.8	927	990	-	-	-	-	7.2	7.5
7	Unali	26.2	24.2	519	603	-	-	-	-	7.6	7.6
8	Rampur	26.1	24.8	804	674	-	-	-	-	7.3	7.5
9	Nanhauta	28.4	25.5	584	504	-	-	-	-	7.2	7.4
10	Maheshpur	28.4	25.3	792	906	43	16	-	-	7.4	7.5
11	Deoband	25.6	25.0	332	363	-	-	-	-	7.0	7.1
12	Gagalheri	27.2	25.2	621	657	-	-	-	-	7.5	7.5
13	Roorkee	27.7	24.6	685	639	-	-	-	-	7.6	7.8
14	Manglour	25.9	22.0	713	667	-	-	-	-	7.1	7.0
15	Dausni	24.7	20.0	647	500	-	-	-	-	7.4	7.3
16	Sultanpur	27.3	24.0	837	779	-	-	-	-	7.1	7.3
17	Pathri	26.9	21.3	356	317	-	-	-	-	7.1	6.9
18	Bahaderabad	26.5	23.5	1558	1516	-	-	-	-	7.0	7.2
19	Dholkhand	26.4	21.6	476	422	-	-	-	-	7.3	7.2
20	Mohand	25.8	20.7	906	817	-	-	-	-	7.0	6.9
21	Saharanpur	26.4	24.7	618	658	-	-	-	-	7.3	7.1
22	Tapari	26.8	24.3	576	605	-	-	-	-	7.2	7.4

Contd.....

B.Major Anions

S.No.	Location of well	CO_3^{2-} (mg/L)		HCO_3^- (mg/L)		SO_4^{2-} (mg/L)		Cl^- (mg/L)	
		1	2	1	2	1	2	1	2
1	Muzzafarabad	–	–	256	240	35	40	45	42
2	BadheshahiBag	–	–	180	168	22	14	24	13
3	Raipur	–	–	180	228	26	20	10	10
4	Ghunna	–	–	264	240	39	25	05	06
5	Sarsawa	–	–	360	364	42	43	48	34
6	Nakur	–	–	493	436	95	94	07	29
7	Unali	–	–	290	300	30	21	23	12
8	Rampur	–	–	288	276	41	46	32	27
9	Nanhauta	–	–	232	203	37	38	26	28
10	Maheshpur	–	–	577	530	45	31	15	32
11	Deoband	–	–	144	174	30	32	05	28
12	Gagalheri	–	–	356	317	31	26	11	30
13	Roorkee	–	–	399	332	22	24	26	29
14	Manglour	–	–	248	208	60	63	24	31
15	Dausni	–	–	293	260	33	36	30	19
16	Sultanpur	–	–	199	200	29	26	10	16
17	Pathri	–	–	157	136	19	19	07	06
18	Bahaderabad	–	–	385	356	95	108	24	101
19	Dholkhand	–	–	188	169	19	16	15	08
20	Mohand	–	–	347	314	29	13	24	16
21	Saharanpur	–	–	336	368	40	43	33	31
22	Tapari	–	–	315	349	37	39	28	26

C. Major Cations

S.No	Location of well	Na^+ (mg/L)		K^+ (mg/L)		Ca^{2+} (mg/L)		Mg^{2+} (mg/L)	
		1	2	1	2	1	2	1	2
1	Muzzafarabad	27	25	42	25	47	30	33	35
2	BadheshahiBag	15	17	4.3	7.0	45	32	13	12
3	Raipur	8.0	6.2	8.9	4.7	43	54	13	18
4	Ghunna	15	16	1.2	1.2	64	57	17	12
5	Sarsawa	73	84	11	4.7	58	51	22	21
6	Nakur	91	95	11	6.6	77	74	27	27
7	Unali	38	34	11	7.0	68	76	11	8.9
8	Rampur	43	42	9.4	3.1	63	53	20	26
9	Nanhauta	29	24	0.0	3.1	39	38	26	24
10	Maheshpur	175	166	1.6	0.0	49	36	18	24
11	Deoband	12	19	3.5	2.7	26	39	15	16
12	Gagalheri	42	31	4.3	2.7	59	64	24	26
13	Roorkee	39	30	4.7	4.3	73	66	28	26
14	Manglour	22	28	0.4	0.8	59	47	25	23
15	Dausni	26	21	4.7	1.9	63	60	17	11
16	Sultanpur	20	19	16	14	47	44	13	13
17	Pathri	8.0	7.1	12	2.3	33	33	10	9.2
18	Bahaderabad	69	56	54	55	117	124	12	11
19	Dholkhand	15	14	4.7	2.7	57	52	7.6	6.9
20	Mohand	26	22	28	20	87	80	5.3	5.8
21	Saharanpur	52	56	30	32	64	66	29	23
22	Tapari	17	19	06	09	74	78	16	18

D Other Parameters

S.No.	Location of well	Hardness (mg/L) 1	Hardness (mg/L) 2	NO_3-N (mg/L) 1	NO_3-N (mg/L) 2	NO_2-N (mg/L) 1	NO_2-N (mg/L) 2	NH_3-N (mg/L) 1	NH_3-N (mg/L) 2	F^- (mg/L) 1	F^- (mg/L) 2	Fe(Total) (mg/L) 1	Fe(Total) (mg/L) 2
1	Muzzafarabad	232	195	11	12	0.12	0.02	0.30	0.44	0.54	0.42	0.95	0.10
2	BadheshahiBag	157	120	2.1	1.2	-	0.02	0.21	0.34	0.45	0.20	0.18	0.06
3	Raipur	154	197	0.7	3.2	-	0.65	0.36	0.90	0.02	0.46	0.28	0.15
4	Ghunna	221	185	0.8	12	-	0.02	0.08	0.38	0.50	0.20	0.10	0.12
5	Sarsawa	225	200	5.5	4.6	0.12	0.12	0.31	0.28	0.35	0.19	0.30	0.03
6	Nakur	287	282	0.4	0.6	0.03	0.08	0.24	0.30	0.37	0.50	1.9	1.4
7	Unali	208	220	0.2	1.2	-	1.2	0.09	0.38	0.75	0.38	0.24	0.14
8	Rampur	204	224	2.0	2.1	0.08	0.05	0.19	0.50	0.62	0.52	0.20	0.80
9	Nanhauta	222	149	24	9.0	0.32	0.03	0.22	0.48	0.46	0.39	0.14	0.17
10	Maheshpur	197	172	2.4	4.4	0.10	0.21	0.17	0.52	0.40	0.22	0.96	0.42
11	Deoband	117	153	1.7	2.4	-	0.05	0.14	0.38	0.25	0.20	0.28	0.13
12	Gagalheri	232	245	0.9	1.2	-	0.04	0.06	0.70	0.46	0.30	0.20	0.80
13	Roorkee	279	256	0.8	1.3	0.02	0.04	0.38	0.40	0.44	0.31	0.45	0.30
14	Manglour	233	198	2.5	1.6	0.07	0.05	0.26	0.08	0.78	0.55	0.13	0.02
15	Dausni	214	187	1.4	0.9	-	0.02	0.19	0.10	0.73	0.50	0.19	0.08
16	Sultanpur	137	156	1.9	3.0	0.02	0.06	0.36	0.24	0.62	0.58	0.37	0.20
17	Pathri	117	115	0.7	1.4	-	0.02	0.27	0.14	0.95	0.52	0.25	0.15
18	Bahaderabad	336	349	29	21	0.08	0.07	0.14	0.24	0.79	0.56	0.05	0.02
19	Dholkhand	169	154	1.6	1.5	0.07	0.02	0.05	0.08	0.68	0.41	0.23	0.06
20	Mohand	236	219	7.5	8.0	-	-	0.14	0.12	0.84	0.54	0.05	0.02
21	Saharanpur	278	234	2.9	2.7	0.06	0.08	0.30	0.50	0.56	0.40	0.05	0.06
22	Tapari	248	268	2.0	2.3	0.09	0.13	1.0	1.3	0.28	0.32	0.07	0.08

water flow system. To be able to refer in a convenient manner to water composition, by identifiable groups or categories, the concept of hydrochemical facies was developed (Back, 1961, Seeber, 1962). Hydrochemical facies are distinct zones that have cations and anions concentrations describe within defined composition categories. The definition of a composition category is commonly based on subdivision, of the trilinear diagram in a manner suggested by Back(1961) and Back and Henshaw(1965).

In the present study, the chemical analysis data of all twenty two samples for major ions are plotted on the trilinear diagram for both the seasons (Fig. 8 & 9). The position of all points (except one, that of Bahadrabad) represents that the waters analysed are rich in Ca + Mg and $HCO_3 + CO_3$ This type of water is called calcium bicarbonate type of water or sometimes secondary alkaline water under the facies classification. The water of Bahadrabad lies in field in which non of the cations dominate.

A soil high in exchangeable sodium is very undesirable for agriculture because the soil can become deflocculated and tends to have relatively impermeable crust. The condition is prompted by waters of high SAR and is reversed by waters containing a high proportions of Ca and Mg (Hem, 1970). The SAR is calculated from the formula.

$$SAR \quad \frac{Na}{\sqrt{\frac{Ca + Mg}{2}}}$$

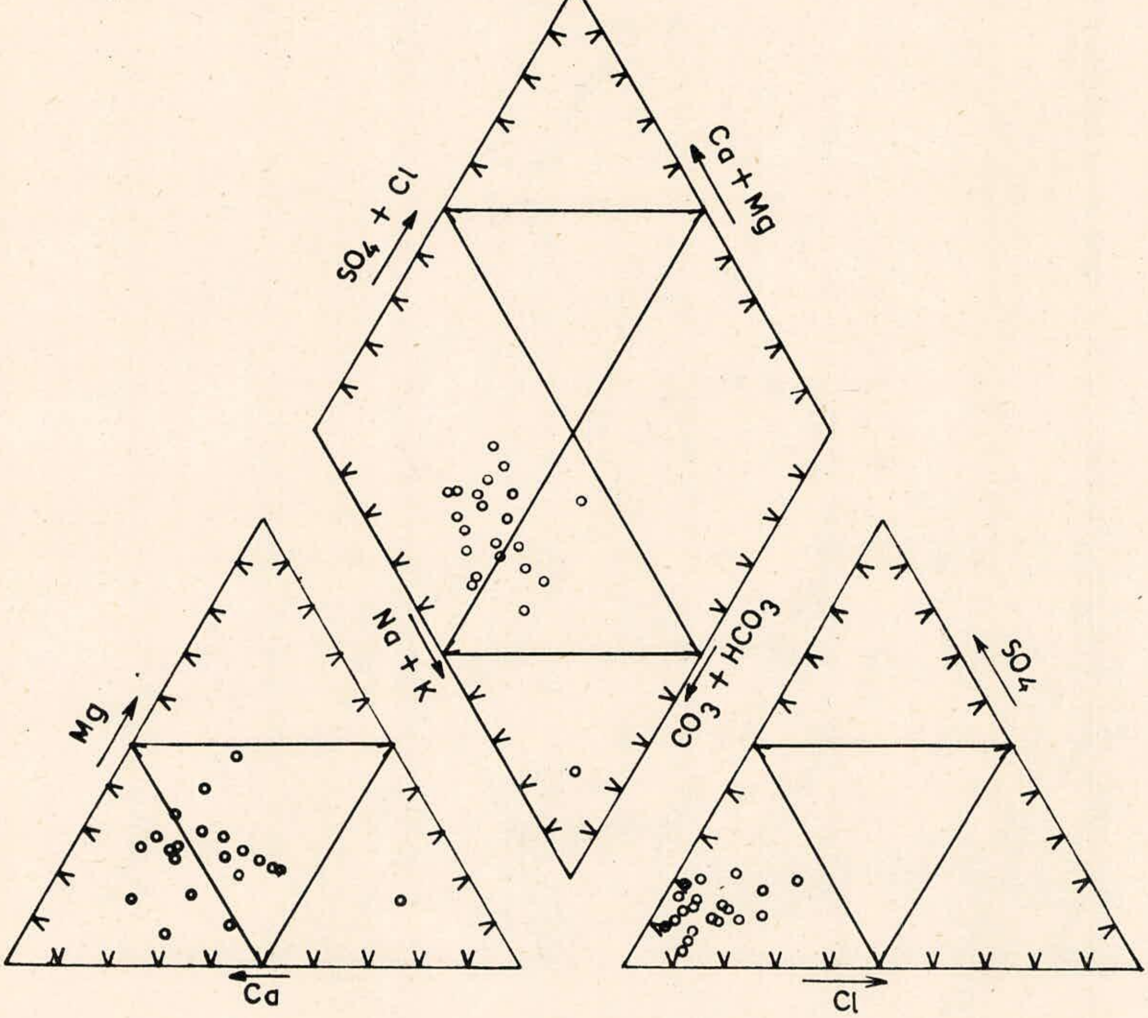


FIGURE 8 - PIPER TRILINEAR DIAGRAM SHOWING CHEMICAL CHARACTER OF GROUNDWATER FOR PRE-MONSOON PERIOD(1987)

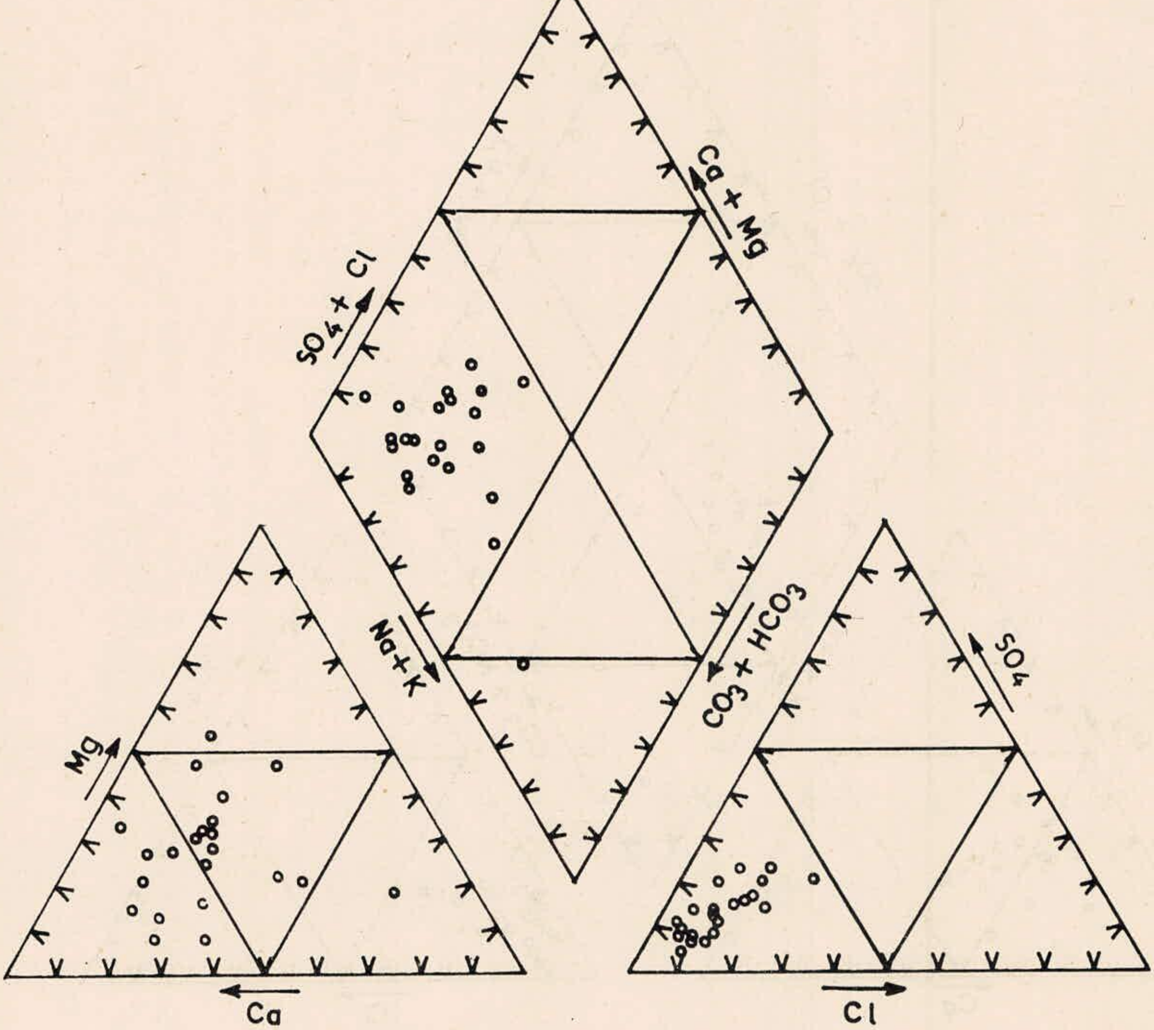


FIGURE 9 - PIPER TRILINEAR DIAGRAM SHOWING CHEMICAL CHARACTER OF GROUND WATER FOR POST-MONSOON PERIOD(1987)

The values of SAR in the water samples of the area varies from 0.275 to 5.882 in pre-monsoon and from 0.87 to 5.311 in the post-monsoon period (Table - 3).

The U.S. Salinity laboratory, Department of Agriculture, U.S.A. recommended the SAR as basis for classification for agriculture uses as given below:

SAR	Water Class
< 10	Excellent
10 - 18	Good
18 - 26	Fair
> 26	Poor

As per as the suitability of water for domestic purposes is concerned, the water is good for drinking, as the concentration of various parameters is within the acceptable limits laid by B.S.I.

There is not much variation in the pre-monsoon and post-monsoon quality of groundwater, which may be due to the failure of monsoon in 1987.

The water of Bahadrabad show high values of electrical conductivity, due to which the water is not very good for irrigation.

The water from Maheshpur, show very high value of sodium and hence high value of SAR. The high values in the area may be due the seepage of polluted water of river Hindon which is flowing by the side of the village Maheshpur. SAR

Table 3 Sodium Absorption Ratio's of Ground Water of District Saharanpur

S.No.	Location of Well	Pre-monsoon Season	Post-monsoon Season
1.	Muzzafrabad	0.749	0.728
2.	Badheshahi Bag	0.523	0.649
3.	Raipur	0.275	0.187
4.	Ghunna	0.421	0.498
5.	Sarsawa	2.063	2.500
6.	Nakur	2.280	2.385
7.	Unali	1.126	0.996
8.	Rampur	1.269	1.181
9.	Nanhauta	0.897	0.743
10.	Maheshpur	5.882	5.311
11.	Deoband	0.454	0.652
12.	Gagalheri	0.835	0.765
13.	Roorkee	0.983	0.788
14.	Manglaur	0.622	0.845
15.	Dausni	0.748	0.647
16.	Sultanpur	0.708	0.632
17.	Pathri	0.316	0.282
18.	Bahadrabad	1.609	1.289
19.	Dholkhand	0.509	0.478
20.	Mohand	0.744	0.637
21.	Saharanpur	1.267	1.243
22.	Tapri	1.168	1.185

countours indicate greater interaction of polluted surface water of river Hindon with the ground water of the area in the down stream direction i.e. South of Saharanpur City (Fig. 10 & 11).

The ground water of Saharanpur district, in general is good for irrigation as well as for domestic purposes.

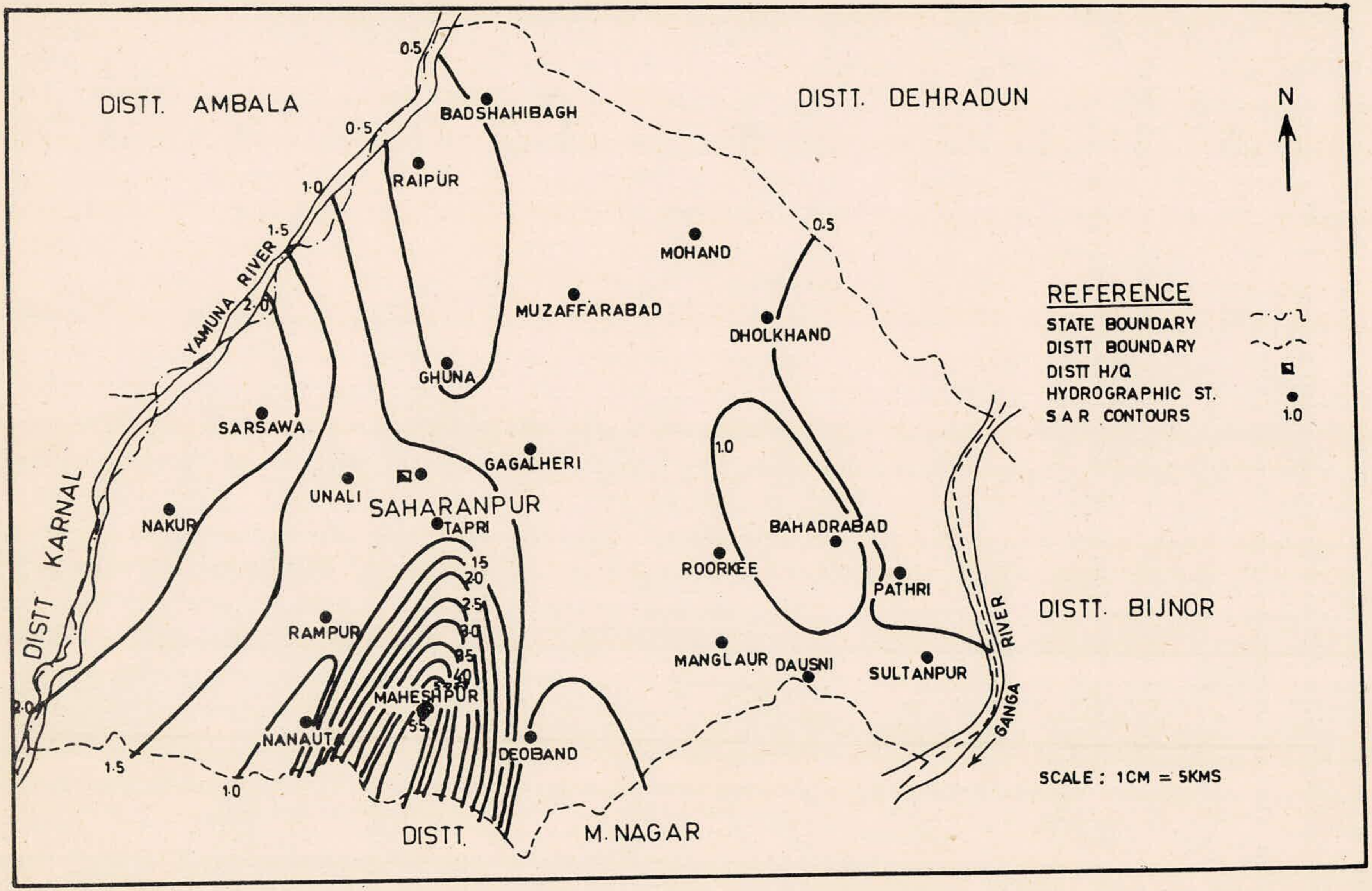


FIG.10. SAR CONTOUR MAP FOR PRE-MONSOON PERIOD (1987)

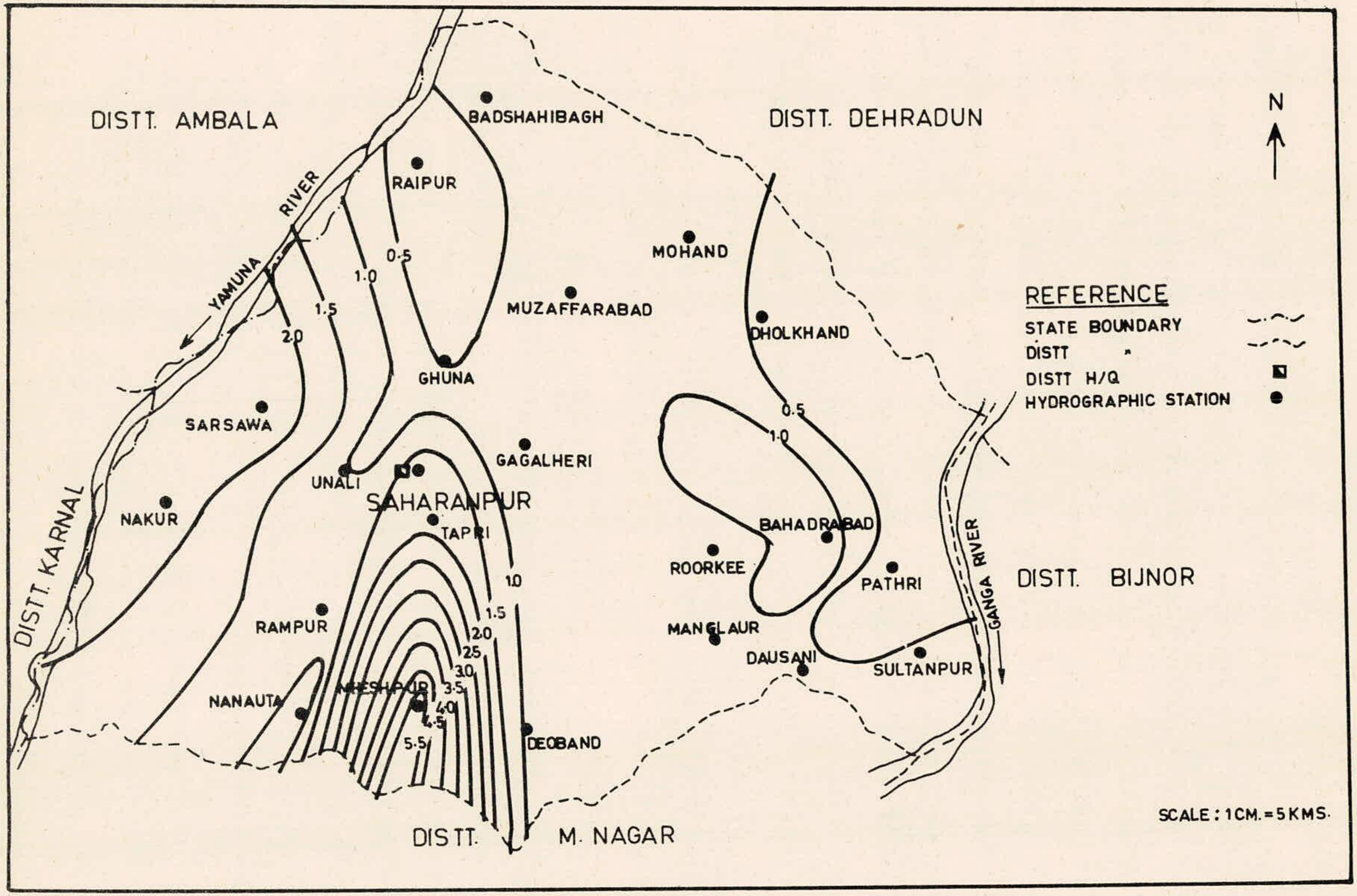


FIG. 11. SAR CONTOUR MAP FOR POST-MONSOON PERIOD (1987)

8.0 CONCLUSIONS

Water pollution in surface water bodies is visible and hence the reaction of the public and policy makers is instant and voceferous whereas by virtue of the nature of groundwater it is invisible and the pollutants move behind eyes and pollute the groundwater bodies slowly but steadly. This makes the public in the area, less aware and concious of the phenomena called groundwater pollution. Another important fact which is perhaps not known to the common man is that unlike surface water bodies, once the groundwater becomes polluted it is lost almost for few decades, if not for ever. Another important fact which should be kept in mind is that curative and pollution control measures as well as monitoring of ground water pollution is much more difficult and procuring of data for groundwater bodies than for surface water bodies.

The groundwater problems are more acute in the areas which are densely populated, are thickly industrialised and have shallow groundwater table. Keeping in view these factors, the National Institute of Hydrology undertook to study the groundwater pollution in the dug wells in the thickly polluted district of Saharanpur. This area is also having number of industries and agricultural activities are at the peak.

The report presents an analysis of the groundwater quality data obtained on the water samples from 22 open wells in the Saharanpur district. Mostly these open wells tap only the shallow unconfined aquifer. Various chemical constituents like pH, total dissolved solids, temperature, turbidity, alkalinity etc. were estimated in the water quality laboratory of the Institute. Further, temporal variation of groundwater quality at these 22 specified locations were also marked and analysed. The problems zones were delineated and spatial distribution of groundwater contamination in the area was attempted to be mapped. The sodium absorption ratio was also computed. This was attempted in the premonsoon season and the post monsoon season. This was further related to the suitability of water for irrigation purposes.

The study is focussed on the variation of groundwater quality in the area and the following points emerged from the analysis of the groundwater samples.

1. The chemical nature of shallow groundwater in the area shows that the water is suitable for irrigation projects as well as public supply.

2. The water in shallow aquifers is rich in bicarbonates and alkaline earth metals, as seen from pipe trilinear diagram.

3. Polluted Hindon River water is interacting with the ground water in the south of Saharanpur causing the deterioration of groundwater quality.

4. The lowering of electrical conductivity in the post-monsoon season, in general, reflects the dilution of ions in groundwater. There is not much variation in quality due to the failure of monsoon in 1987.

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