

Evaluation of Groundwater Quality in Shallow and Deep Aquifers: A Case Study

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Abstract: Groundwater is an essential and vital component of our life support system. The groundwater resources are being utilized for drinking, irrigation and industrial purposes. There is growing concern on deterioration of groundwater quality due to geogenic and anthropogenic activities. Groundwater, being a fragile must be carefully managed to maintain its purity within standard limits. So, quality assessment and management are to be carried out hand-in-hand to have a pollution free environment and for a sustainable use. In order to assess the quality for consumption by human beings and for use in agriculture, the groundwater from the shallow aquifers and deep aquifers. Spatial distribution of pH, total dissolved solids (TDS), fluoride, total iron, chloride (Cl^{k}) and electrical conductivity (EC) content of groundwater samples collected from the shallow and deep aquifers of Dhampur tahsil area, Bijnor district, Uttar Pradesh, India. In the Dhampur tahsil area, the shallow aquifers that supply water to dugwells of the catchments area of study have poor water quality than those of the borewells from the deep aquifers. Result shows the groundwater of both aquifers is found to be alkaline in nature with an average EC value of less than $300\mu S/cm$. The total iron content is found to be more than 0.5 mg/L in certain areas of the region. For the shallow aquifers the observed maximum TDS was 827.34 mg/L and 562.14 mg/L for the deep aquifers. In general, the concentration of EC and TDS in the groundwater of the shallow and deep aquifers reveals the shorter groundwater-rock-contact time. The chloride content is observed in both the aquifers invariably. The fluoride contents in both aquifers were found to be within the permissible limits. This makes the groundwater quality in shallow aquifers in the catchments area of study is found to be severely polluted and moderately polluted in deep aquifers. The level of pollution is maximum in shallow aquifers and unfit for human consumption. The study involved evaluation of groundwater quality both in shallow and deep aquifers in April 2007. [Report and Opinion 2010;2(9):75-87]. (ISSN: 1553-9873).

Key words: Groundwater quality; deep aquifers; pollution; severely

1. Introduction

Groundwater has long been regarded as the pure form of water compared to surface water, because of purification of the former in the soil column through anaerobic decomposition, filtration and ion exchange. This is one of the reasons for the excessive consumption of groundwater in rural and semi-urban areas all over the world (WHO, 1984; Saha et al., 2008). Most of the human activities including agriculture need ample quantities of water. Increasing demands of food grain by ever increasing population has resulted in the utilization of water resources to the limit. Groundwater, an underground reservoir, being the sustainable source of municipal and irrigation supplies suffered the most. It is estimated that approximately one third of the world's population uses groundwater for drinking purposes (UNEP, 1999). This is a well-recognized fact that the groundwater, through the ages, continues to be an essential commodity for a large number of users. The chemical composition of groundwater is determined

by a number of processes, which can chiefly be grouped into three - atmospheric inputs, interaction of water with soil and rock and anthropogenic activities. Precipitation, climate change and natural hazards add to the atmospheric inputs, while weathering and erosion of crustal materials result from the interaction of water with soil and rock (Babu et al., 2007). The anthropogenic disturbances through industrial and agricultural pollution, increasing consumption and urbanization degrade the groundwater and impair their use for drinking, agricultural, industrial and domestic uses (Simeonov et al., 2003; Sreedevi, 2004).

Groundwater, being a fragile and important source of drinking water, must therefore be carefully managed to maintain its purity within standard limits. Groundwater degradation occurs when its quality parameters are changed beyond their natural variations by the introduction or removal of certain substances (Ramesh, 2001). In regions of intense agricultural activities, the degradation results from

the addition of salts by dissolution during the irrigation process, from salts added as fertilizers or soil amendments and from the concentration of salts by evapo-transpiration. Because irrigation is the primary use of water in arid and semi- arid regions, irrigation return flow can be the major cause of groundwater pollution in such regions (Fuhrihan et al., 1971).

Increased industrialization, urbanization and agricultural activities during the last few decades have deteriorated the surface water and groundwater quality of Uttar Pradesh. The northern most state of India (CGWB, 2005). Groundwater contamination can often have serious ill effects on human health. Water pollution is the contamination of water bodies such as lakes, rivers, oceans, and groundwater. It occurs when pollutants are discharged directly or indirectly into water bodies without adequate treatment to remove harmful constituents. Water pollution is a major problem in the global context (Radha Krishnan et al., 2007). It has been suggested that it is the leading worldwide cause of deaths and diseases and that it accounts for the deaths of more than 14,000 people daily. Water for rural supply is mainly withdrawn from underground sources. Development of the city has been accompanied by increased waste production and discharge with progressively more serious groundwater pollution (Bajpayee, 2001). The sanitary-technical conditions of water pipelines, the characteristics of withdrawal facilities as well as their sanitary-technical state considerably affect potable water quality. Water is typically referred to as polluted when it is impaired by anthropogenic contaminants and either does not support a human use, like serving as drinking water, and/or undergoes a marked shift in its ability to support its constituent biotic communities, such as fish. Water pollution has many causes and characteristics (Rao et al., 2004). The specific contaminants leading to pollution in water include a wide spectrum of chemicals, pathogens, and physical or sensory changes such as elevated temperature and discoloration. While many of the chemicals and substances that are regulated may be naturally occurring (Chattopadhyay, 2005).

Bijnor occupies the north-west corner of the Moradabad Division and is a roughly triangular stretch of country with its apex to the north. The western boundary is formed throughout by the deep stream of the river Ganges, beyond which lie the four

districts of Dehradun, Saharanpur, Muzaffarnagar and Meerut. The Dhampur tahsil area with its four blocks i.e. Allehpur, Kasampur, Aapu, Budhanpur and Dhampur is a municipal board in Bijnor district in the state of Uttar Pradesh, India. One of the largest sugar producers in India, Dhampur Sugar mills, is located here. Dhampur' tehsil area main economy is based on agriculture, mainly sugarcane, wheat, and paddy. Hand-woven textile items produced by the weavers living in surrounding areas are known for their utility and designs.

1.1 Site location and Climatology

Dhampur tehsil area is situated, between latitude 29°19'N and 78°31'E and longitude 29 32°N and 78 52°E at 216 meters above the sea level (Figure 1). The study area has an average monthly temperature varying 41.9°C maximum in summer and 3.2°C in winter. Average weather condition allow to recognize six well-marked traditional seasons, i.e. spring (March-April), summer (May-June), monsoon (July-August), sharada (Sep-Oct), hemanta (Nov-Dec) and winter (Jan-Feb). The average annual rainfall variation is between 1122 and 1054 mm/year.

1.2 Geology

Some lithofacies of the deposits of Ganga Plain, are Mottled Silt, thick sheet like or lensoid units of well-sorted silt with little clay fraction. It represents sheet flow deposits on the higher sloping surface (Soman, 1977; Appelo and Postma, 2005), Variegated Clayey silt, thick, highly mottled clay rich sediment with intense burrowing showing clay coated sand grains, small mud pebbled, ferruginization and ferruginous nodules. This represent diagenetically modified sandy silt or silty, sand sediments, which can be laterally traced for 50-100m (Lehr et al. 1980).

1.3 Objectives and Scope

The main aim of the present study is to evaluate the groundwater quality in Dhampur tehsil area for the purposes of drinking and irrigation with reference to recommended standards prescribed by WHO (WHO, 1984). The concentration of chemical constituents in the aquifers of the area have been investigated. This study had to main objectives to evaluate the concentration of some of the major constituents of groundwater such as pH, EC, TDS, Fluoride, Chloride, and Total Iron in shallow and deep aquifers in April 2007.

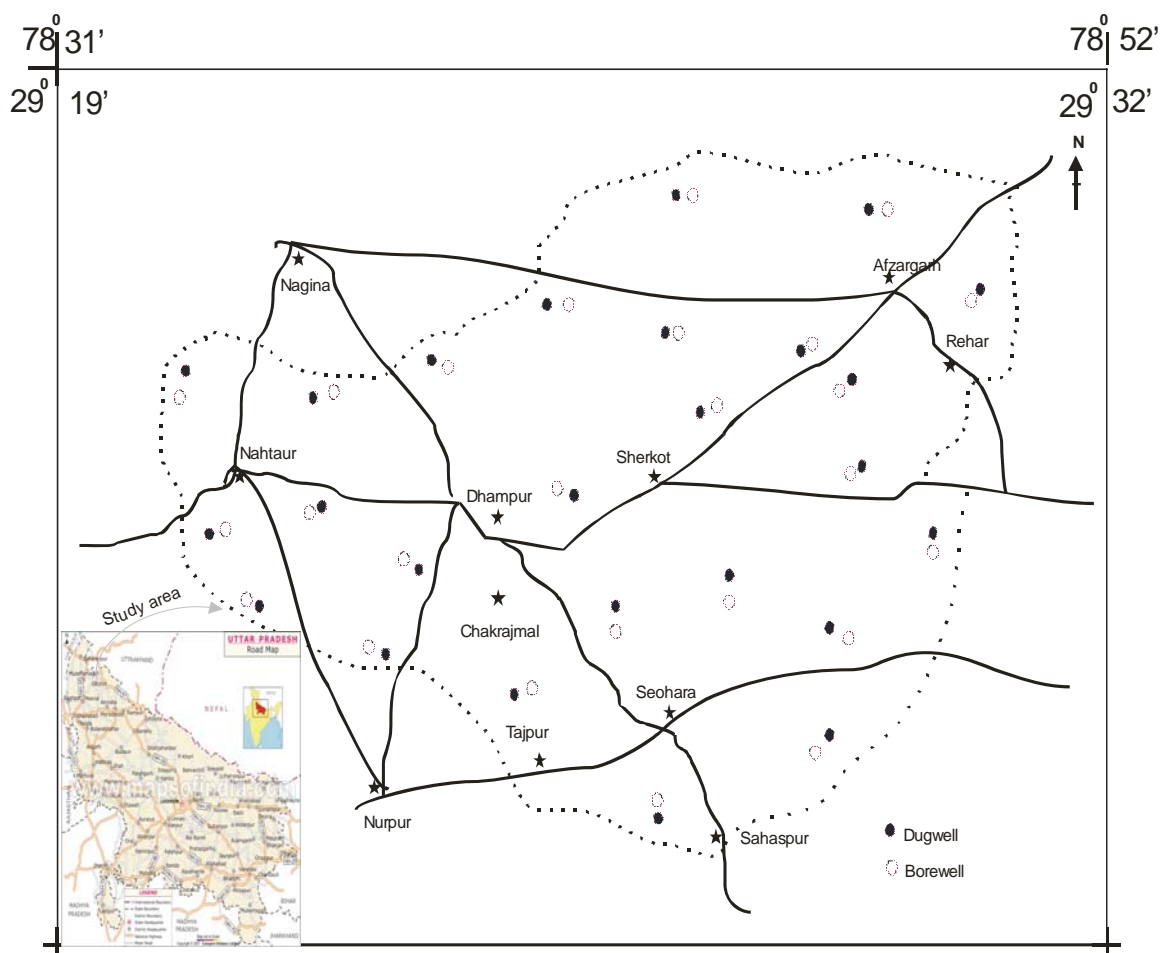


Figure 1. Base map and location map of dugwells and borewells in the Dhampur Tehsil area

2. Material and Methods

Fifty samples of groundwater, 25 each from the shallow, dugwells and deeper borewells in close proximity, were collected for comparative study and monitoring in April 2007 (Figure 1). The dugwells range in depth from 5 to 16m and borewells range from 50 to 100m. Samples were drawn with a precleaned plastic polyethylene bottle. Prior to sampling, all the sampling containers were washed and rinsed thoroughly with the groundwater. Water quality parameters such as pH, EC and TDS were measured using digital meters immediately after sampling. Sample of total iron were preserved by adding concentrated HCl, which were transported immediately to the laboratory and analyzed by using Varian Liberty Series II Inductively Coupled Plasma - Optional Emission spectrophotometer (ICP-OES). Chloride was determined by Mohr's argentometric titration using standard silver nitrate as reagent. Fluoride concentrations in the samples were measured by colorimetric methods using SPANDS

reagent. (APHA, 1995; Merck, 1974; Mishra and Saksena, 1993)

3. Result

pH values of groundwater varied from 7.0 to 8.2 for shallow aquifers and 7.1 to 8.1 for deep aquifers. EC values ranged from 140 to 456 μ S/cm for shallow aquifers whereas for deep aquifers it was 115-354 μ S/cm. Respective minimum and maximum TDS values observed were 210 and 562 mg/L for deep aquifers and 215 and 827 mg/L for shallow aquifers. The total iron values ranged from 0.1-2.65 mg/L for shallow aquifers and 0.1-1.61 mg/L for deep aquifers (Valsalakumar, 2003). The chloride values ranged from 148 to 386 mg/L for shallow aquifers, 115 to 276 mg/L for deep aquifers. Fluoride concentrations in both aquifers were found within permissible limits. The highest value observed was 0.6 mg/L for shallow aquifers. Spatial distributions of pH, EC, TDS, total

iron, fluoride and chloride in both aquifers are presented in thematic maps (Figures 2A and B, 3A and B, 4A and B, 5A and B, 6A and B and 7A and B).

4. Conclusions

4.1 pH

The pH of natural waters is often found slightly acidic (5.0-7.5). This may be due to the presence of dissolved carbon dioxide and organic acids (fulvic and humic acids), which are derived from the decay and subsequent leaching of plant materials (Langmuir, 1997). Waters with pH values above 10 are exceptional and may reflect contamination by strong base such as NaOH and $(\text{CaOH})_2$. The ranges for desirable limit of pH of water prescribed for drinking purpose by ISI (1983) and WHO (1984) as 6.5-8.5 while that of EEC (Lloyd and Heathcote, 1985) as 6.5-9.0.

Based on the pH distribution of the groundwater of the Dhampur tehsil area presented (Figure 3a and b), the region can be classified into three zones, viz. (i) 7.0-7.5, (ii) 7.5-8.0, (iii) >8.0. During the present investigation, pH values as 7.0-7.5 was recorded in most of the study region (almost 1/3 of the region). In general, the distribution of pH did not show any specific trend within the region. It's also found that at the eastern parts of region, the pH distribution did not show any variation in both aquifers. On the other hand, the north region showed an increase in pH values in shallow aquifers, while the southern part of region showed a decreasing in deep aquifers.

A low pH can cause corrosion of water carrying metals pipes, thereby releasing toxic metals such as zinc, lead, cadmium, copper etc. (Trivedy and Goel, 1986). Davies (1994) while carrying out hydrochemical studies of Madhupur aquifer, Bangladesh has also found a moderately high

concentration of zinc and attributed that to low pH of groundwater. Furthermore, low pH values in groundwater can cause gastrointestinal disorders like hyper acidity, ulcers and stomach pain with burning sensation (Rajesh et al., 2001).

4.2 Electrical Conductivity (EC)

EC is measured in microsiemens/cm ($\mu\text{S}/\text{cm}$) and is a measure of salt content of water in the form of ions (Karanth, 1987). In the present study, EC values ranged from 140 to $456\mu\text{S}/\text{cm}$ for shallow aquifers whereas it ranged from 115 to $354\mu\text{S}/\text{cm}$ for the deep aquifers. The distribution of EC values is presented in Figure 4a and b. It is clear that a vast majority of the area showed EC values less than $300\mu\text{S}/\text{cm}$. For the shallow aquifer, low EC values were found in an east west stretch running at the centre of the region while the northern, southern and southeastern and northwestern part of the region showed higher EC values ($>300\mu\text{S}/\text{cm}$). On the other hand for deep aquifers, most of the basin (except the northern part) showed low EC values. The occurrence of high EC values (Figure 4b) on the northwestern part of the study area might also be due to addition of some salts through the prevailing agricultural activities. Comparatively zones with low EC values ($<300\mu\text{S}/\text{cm}$) are found more in deep aquifers than for shallow aquifers and are due to dilution of soluble salt by rainfall. As low EC values were recorded for both the aquifers, the water is found to be safe for drinking and domestic purposes. Moreover, a low EC values further signifies the anoxic condition of groundwater (Raghunath et al., 2001).

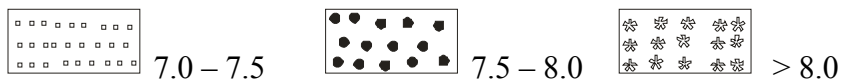
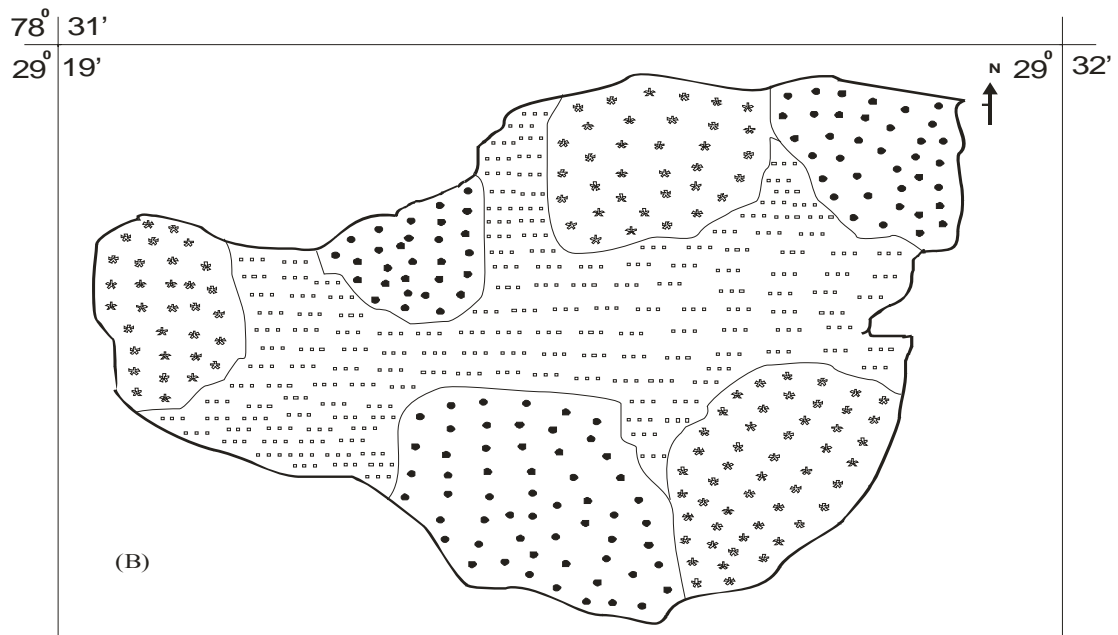
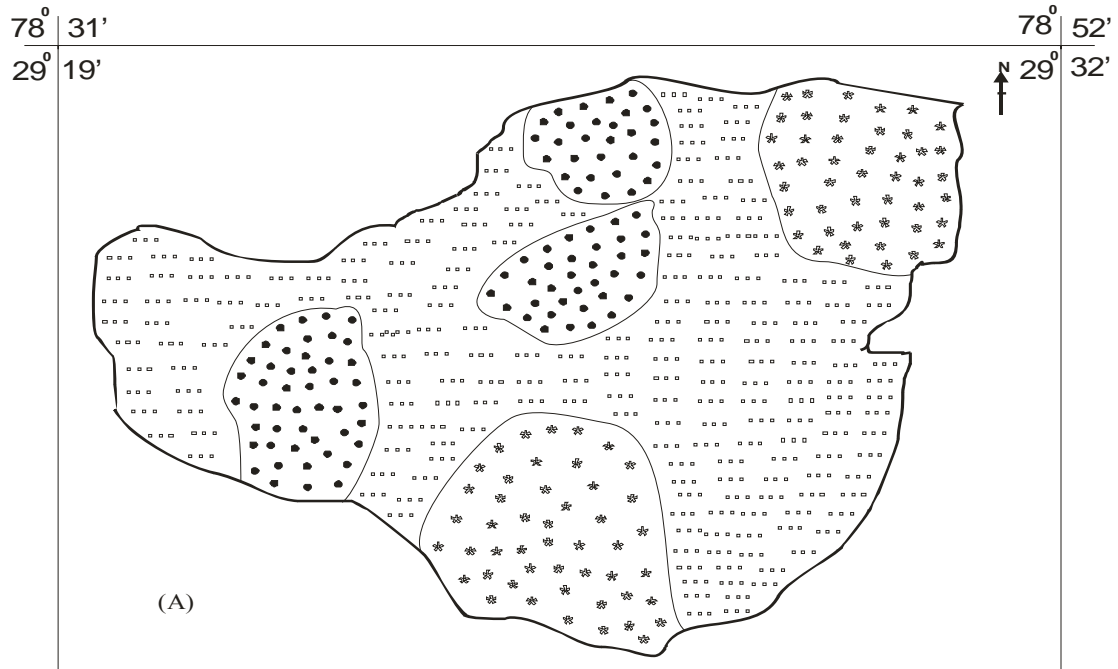


Figure 2. Distribution of pH in the Dhampur Tehsil area for (A) Shallow aquifers (B) Deep aquifers

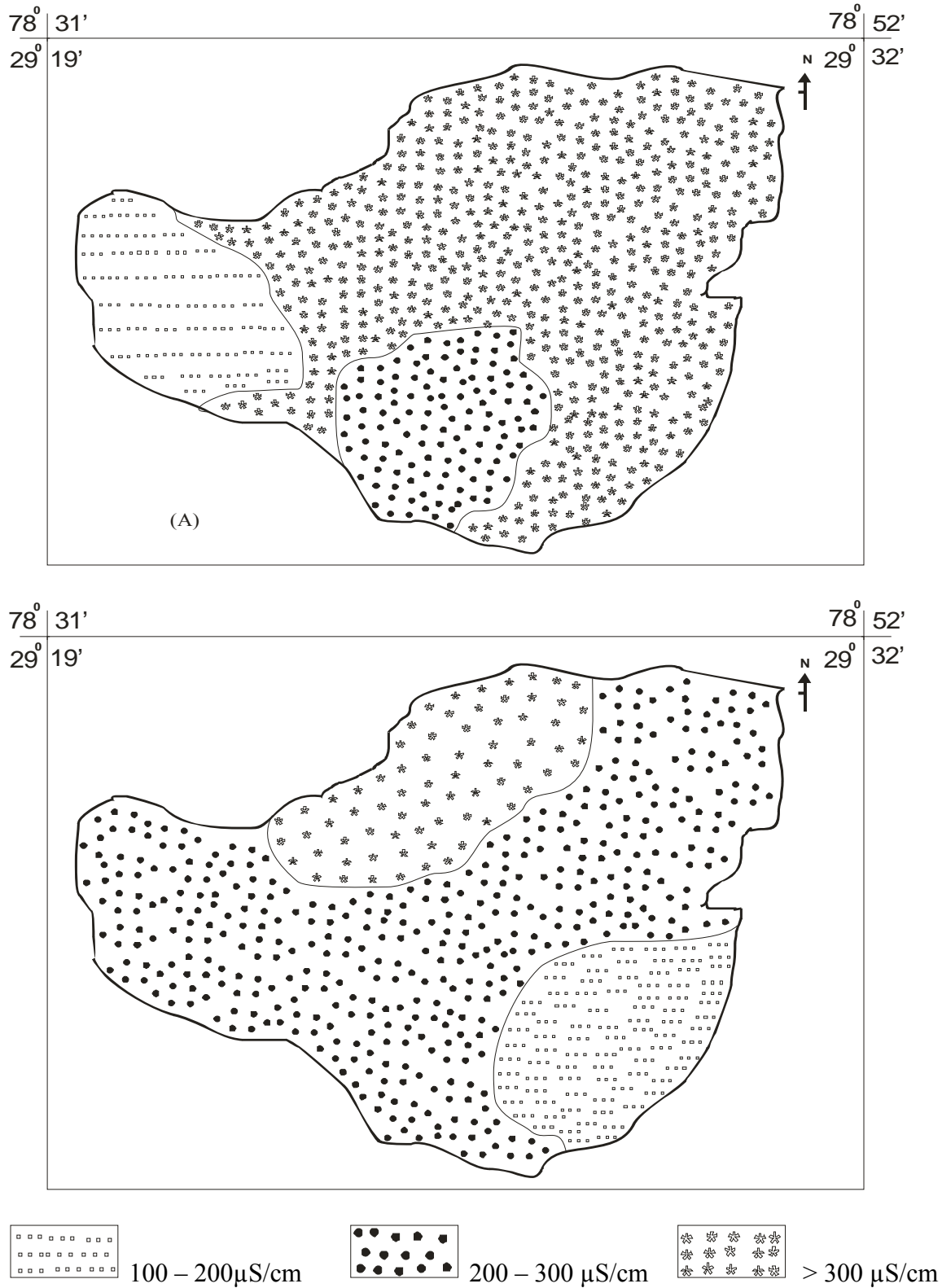


Figure 3. Distribution of Electrical Conductivity in the Dampur Tehsil area for (A) Shallow aquifers (B) Deep aquifers

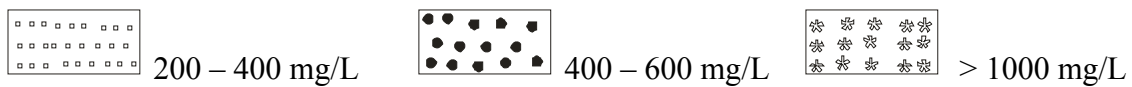
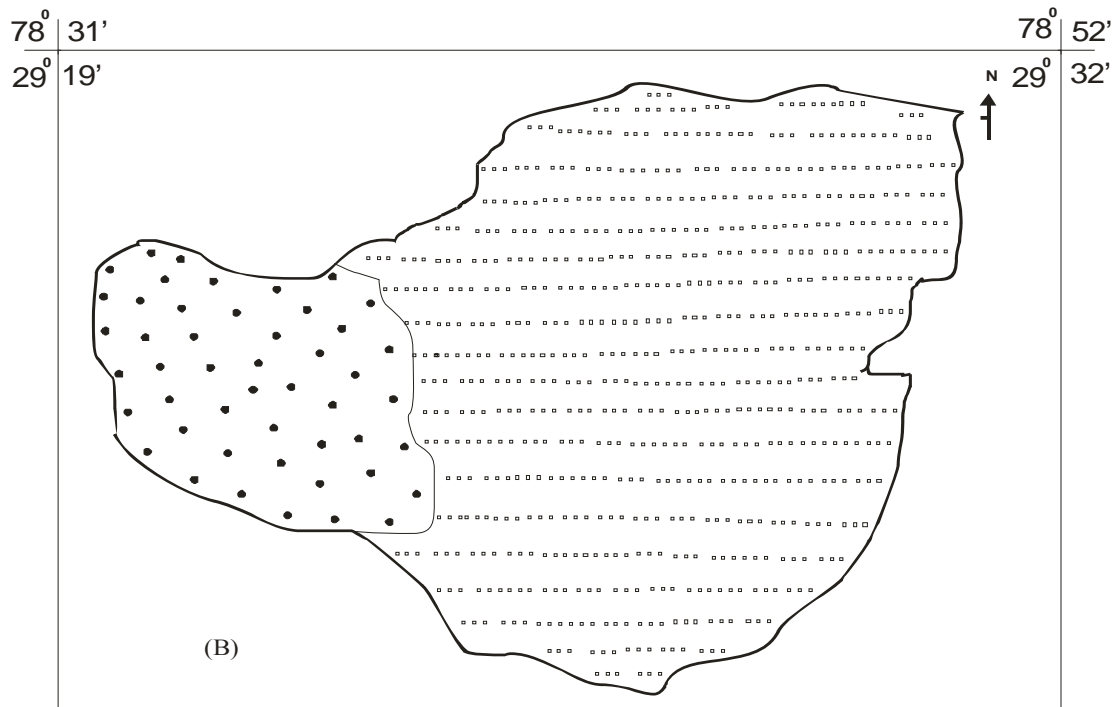
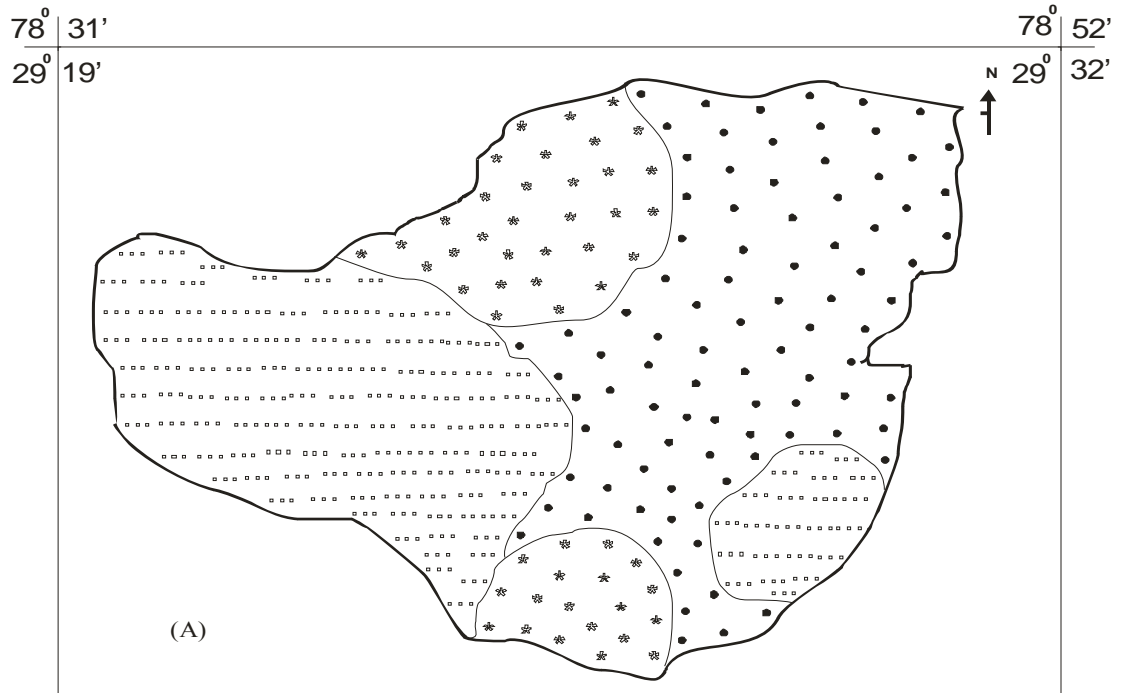


Figure 4. Distribution of Total Dissolved Solids in the Dhampur Tehsil area for (A) Shallow aquifers (B) Deep aquifers

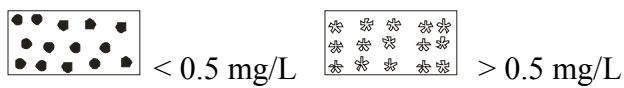
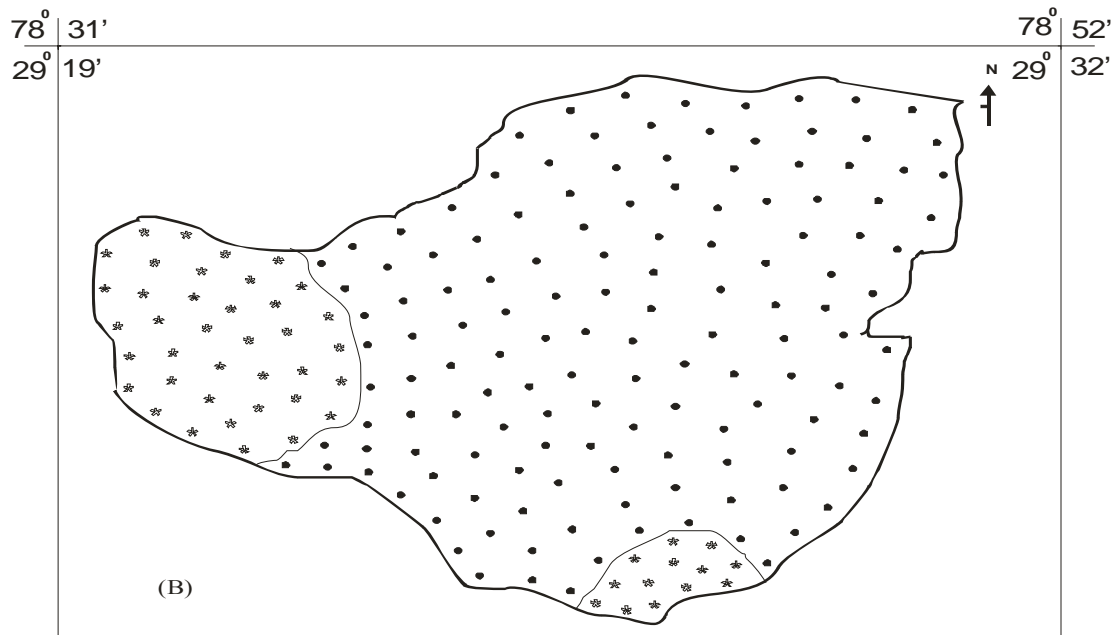
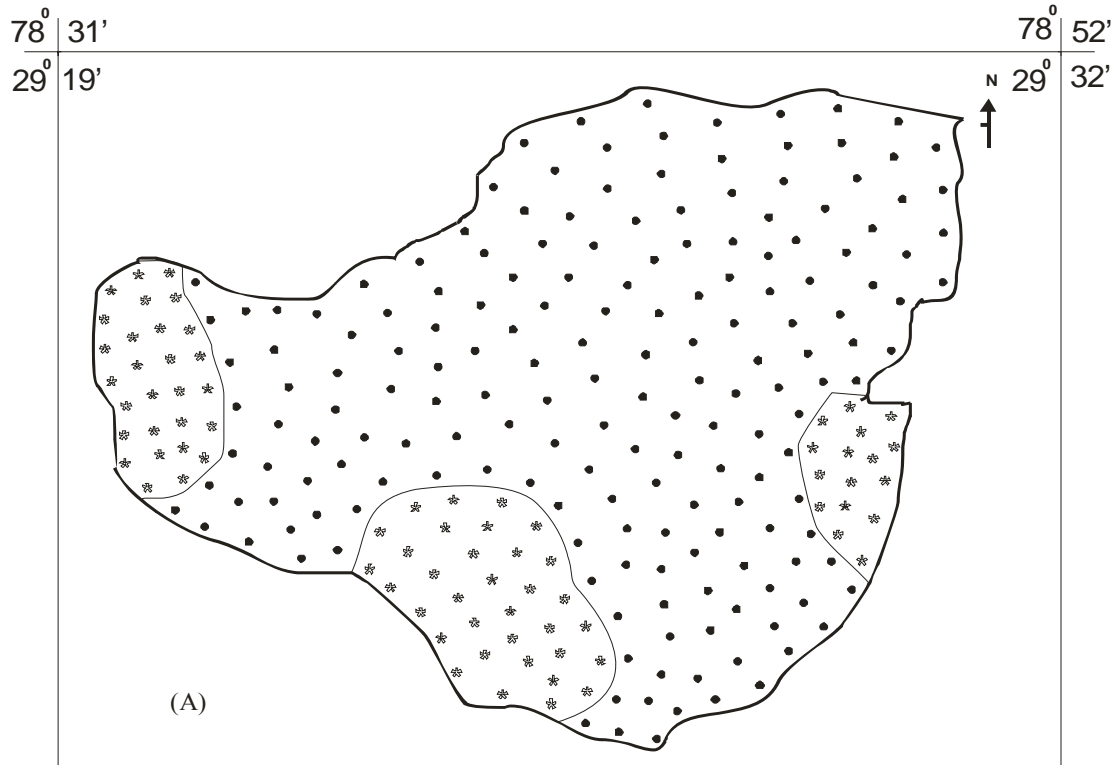


Figure 5. Distribution of Iron in the Dhampur Tehsil area for (A) Shallow aquifers (B) Deep aquifers

4.3 Total Dissolved Solids (TDS)

The quality of groundwater for drinking purpose can be expressed in terms of total dissolved solids. Groundwater with a TDS values less than 500 mg/L can be considered as excellent for drinking purpose (WHO, 1984). The distribution of TDS values for both aquifers (Figure 5a and b) clearly showed that the region found near this range. In the shallow aquifers, values ranged between 215 and 827 mg/L, whereas it ranged between 210 and 562 mg/L for the deep aquifers. Relatively high TDS values for shallow aquifers were found on the northern and southern parts of the region. On the other hand during post monsoon period only the northwestern part of sub basins showed TDS values of over 400 mg/L. The hydrogeological properties of rocks will have a strong influence on the extent of water/rocks reaction. Zones with high groundwater-flow velocities usually will have relatively low dissolved solids because of the shorter groundwater-rock contact time and high water/rock ratios, and vice-versa (Lagmuir, 1997). Typical high groundwater velocities were found in highly fractured or weathered near-surface igneous and metamorphic rocks. Such conditions are usually found in shallow water table (unconfined) aquifers. The low TDS values found can be attributed to high rainfall prevailing, which causes significant dilution.

4.4 Total Iron

Shallow aquifers showed high total iron contents than that the deep aquifers. In the shallow aquifers, the western part of region and small patches in the southeastern part of the region showed total iron values greater than 0.5 mg/L, whereas in the deep aquifers only the north western and south western parts of the region showed more than 0.5 mg/L of total iron (Figure 6a and b). The concentration of iron in groundwater will be higher under more reducing conditions due to bacteriological degradation of organic matter which leads to the formation of various humic and fluvic compounds (Applin and Zhao, 1989; White et. al., 1991). Under reducing condition, the iron from biotite mica and laterites are leached into solution in ferrous state. According to Singhal and Gupta (1999) iron content in groundwater is mainly due to the dissolution of iron oxides. The common method for the removal of iron from water is by aeration followed by sedimentation. In high rainfall zones of India such as Assam, Orissa and Kerala, it is reported that the total iron content ranges from 6.83 to 55 mg/L (Singhal and Gupta, 1999).

4.5 Fluoride

In groundwater, fluoride occurs mainly as simple fluoride ion. It is capable of forming complexes with silicon and aluminium and is believed to exist at a pH <7. Distribution of fluoride shallow and deep aquifers are shown in Figure 7a and b. During both aquifers the fluoride contents were within permissible limits. The highest value (0.6 mg/L) is shallow aquifers. The distribution of fluoride for both the aquifers were showed more or less of an identical pattern (Dass et al., 2001). Fluoride is beneficial when present in small concentrations (0.8 to 1.0 mg/L) in drinking water for calcification of dental enamel. However, it causes dental and skeletal fluorosis if high. Higher concentration of fluoride in drinking water is also linked with cancer (Smedly, 1992). A review of literature indicates that an abnormal concentration (1.5 mg/L) of fluoride recorded in the Rift valley of Ethiopia due to calcium fluoride derived from bedrocks (Ashley and Burley, 1995). In Kerala too high concentration of fluoride (as high as 1.5 mg/L) was recorded in some parts of the coastal zones and is possibly due to the saltwater intrusion (CGWB, 2003). However, the fluoride concentration in the study area is found to be negligible.

4.6 Chloride

Chloride occurs naturally in all types of waters. Distribution of chloride content in shallow and deep aquifers are shown in Figure 8a and b. The chloride values ranged from 148 to 386 mg/L for shallow aquifers, 115 to 276 mg/L for deep aquifers. The higher concentration of chloride is considered to be an indicator of higher pollution due to higher organic waste of animal origin. In natural waters, the probable sources of chloride comprise the leaching of chloride-containing minerals (like apatite) and rocks with which the water comes in contact, inland salinity and the discharge of agricultural, industrial and domestic waste waters (Abbasi, 1998; CGWB, 2005). Agricultural application of K as a plant nutrient commonly results in chloride contamination of recharging shallow groundwater (Bohlke, 2002).

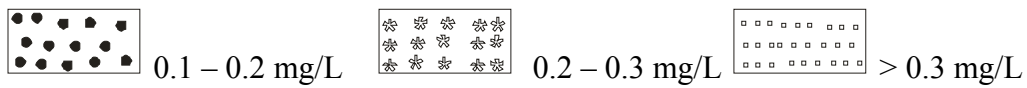
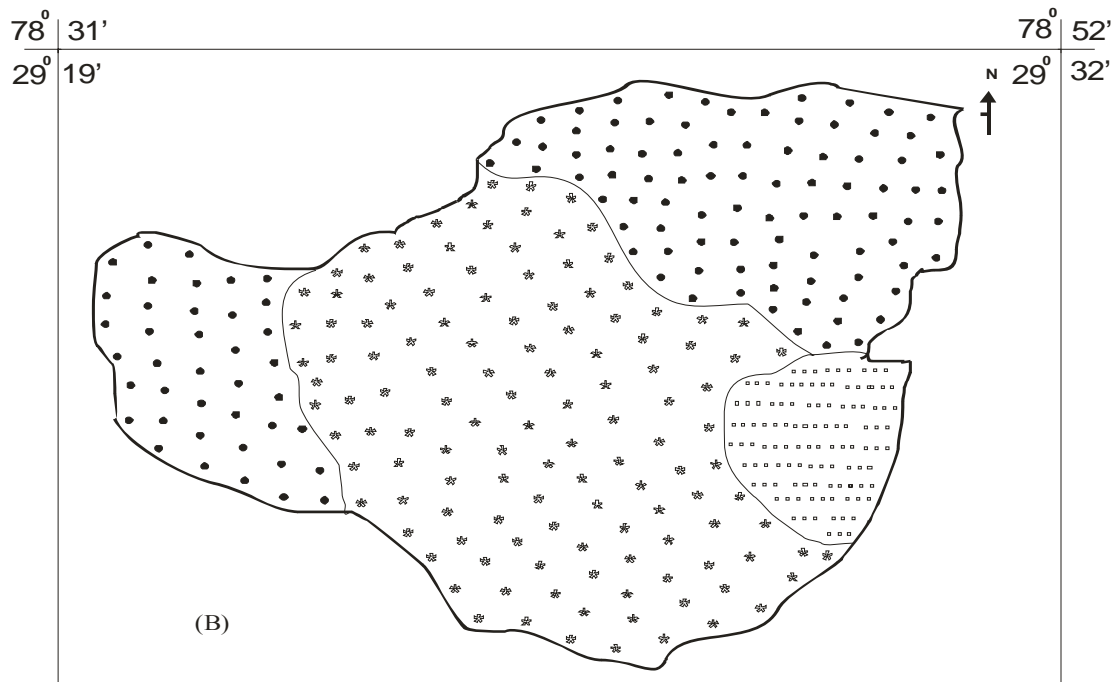
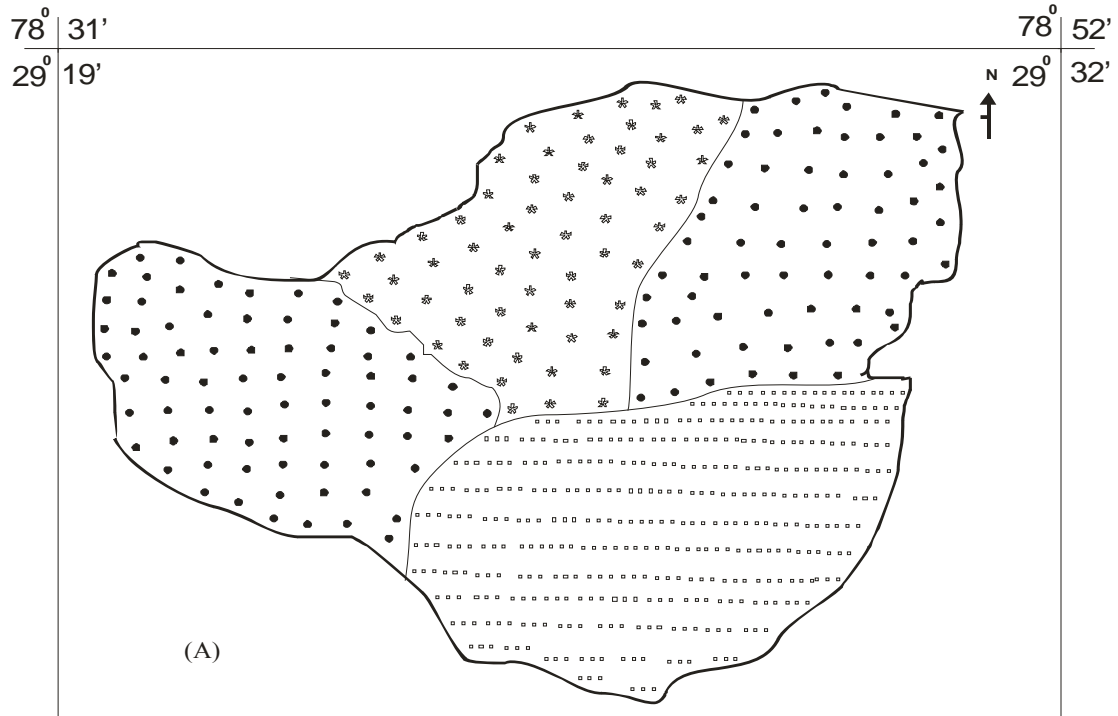


Figure 6. Distribution of Fluoride in the Dhampur Tehsil area for (A) Shallow aquifers (B) Deep aquifers

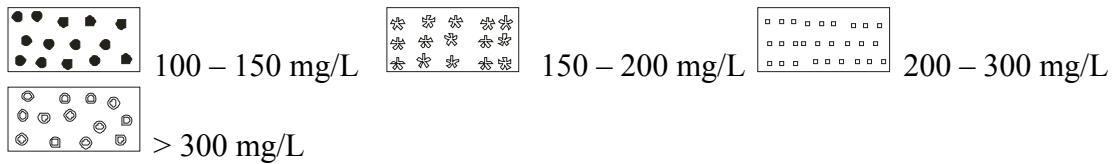
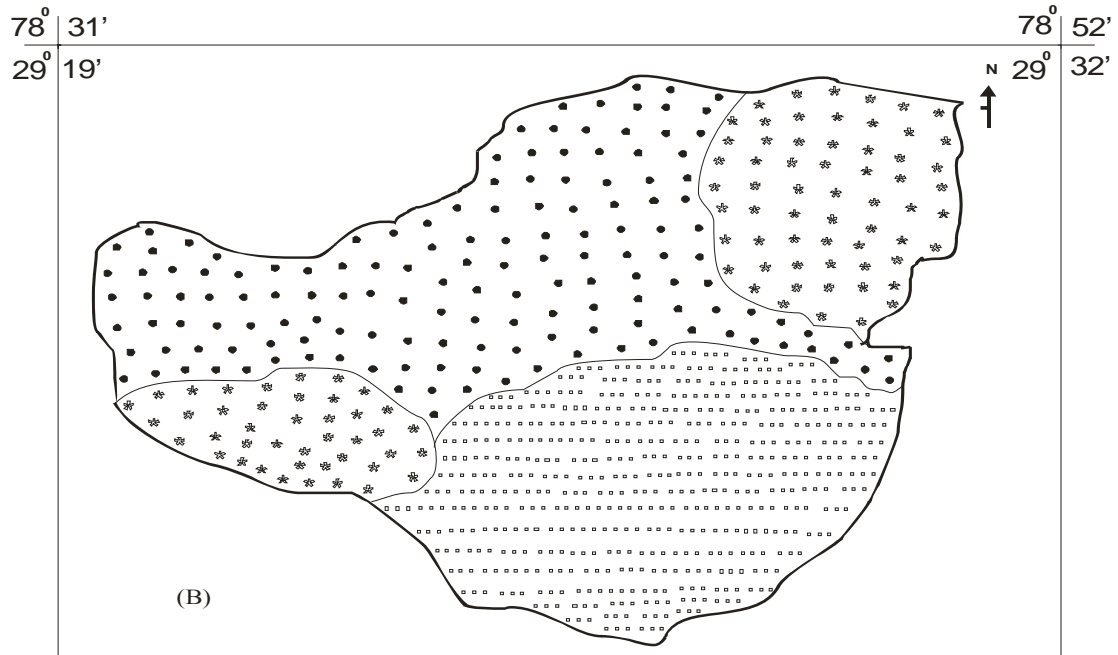
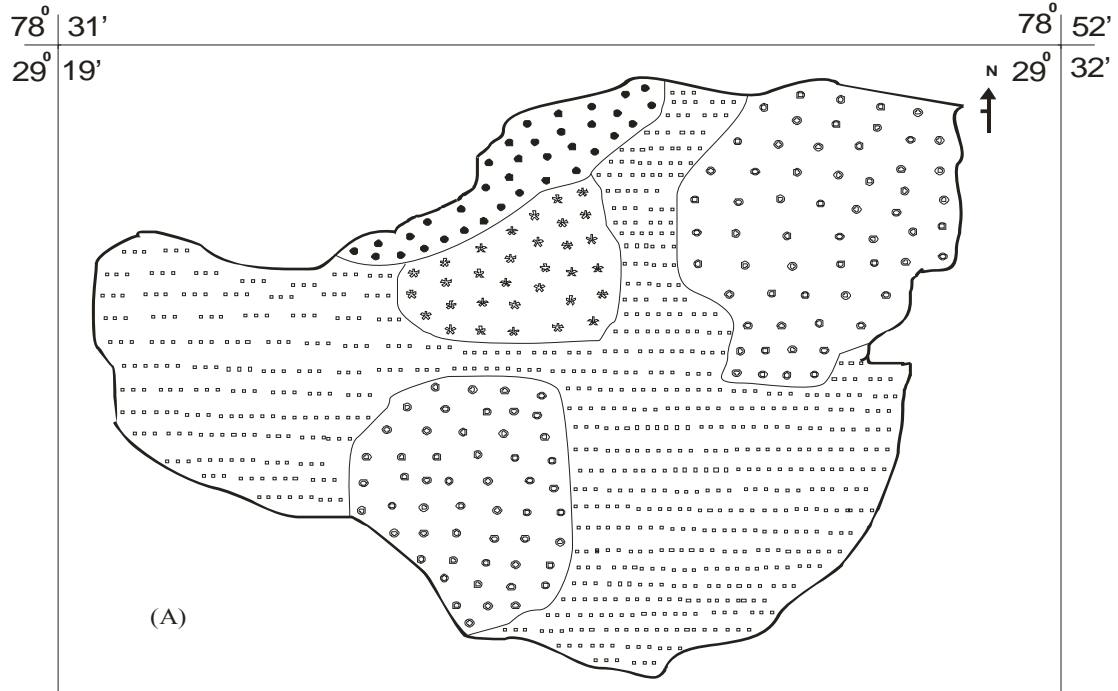


Figure 7. Distribution of Chloride in the Dhampur Tehsil area for (A) Shallow aquifers (B) Deep aquifers

Conclusion

On the basis of above discussion, it may be concluded that the groundwater of the Dhampur tehsil area, Bijnor district, Uttar Pradesh, India in general is found to be alkaline in nature with an the average EC value of less than 300 $\mu\text{S}/\text{cm}$. The total iron content is found to be more than 0.5 mg/L in certain areas of the region. For the shallow aquifers the observed maximum TDS was 827.34 mg/L and 562.14 mg/L for the deep aquifers. In general, the concentration of EC and TDS in the groundwater of the shallow and deep aquifers reveals the shorter groundwater-rock-contact time. The chloride content is observed in both the aquifers invariably. The fluoride contents in both aquifers were found to be within the permissible limits. Based on these observations the groundwater quality in shallow aquifers in the catchments area of study is found to be severely polluted and moderately polluted in deep aquifers. The level of pollution is maximum in shallow aquifers and unfit for human consumption. A study carried out of evaluation of water quality in this region reveals that the groundwater quality varies with depth and time span in shallow and deep aquifers. People depended on the polluted water are prone to health hazards of polluted drinking water and water quality management is needed. The present study is urgently required to draw the attention towards this region for taking necessary steps to minimize the adverse impacts likely to occur because of polluted water.

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