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# Ground Water Vulnerability Assessment for Roorkee Town

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**Abstract** : In the present paper, groundwater vulnerability of alluvial aquifers of Roorkee town, District Haridwar, Uttarakhand State has been evaluated. For this purpose relevant data of the shallow unconfined aquifers was collected for three years from 2004 to 2006 by establishing a groundwater monitoring network of 30 shallow wells and hand pumps in the areas. The study has revealed that though the physico-chemical quality of the shallow ground water is generally within permissible ranges for drinking, the concentration of some heavy metals like cadmium and chromium is higher in a few ground water samples. Besides, values of ambient faecal coliforms were also found to be high at a number of locations especially in premonsoon samples indicating bacteriological pollution of shallow ground water particularly towards the northwestern and southeastern parts of the study area.

Based on the relevant hydrogeological parameters like depth to water table, net recharge, soil and aquifer media, alongwith topography and nature of vadose zone, the ground water vulnerability of the study area has been worked out using the well known DRASTIC method. This indicates possibilities of groundwater pollution at Rampur-Saliar in the northwestern part of the area. A comparison of the DRASTIC indices and quality parameters indicates that the level of groundwater contamination decreases towards east and (southeast) barring a few parameters like cadmium and faecal coliforms which show random variation depending on the localized waste disposal practices.

**Keywords:** Groundwater vulnerability, Roorkee town, Pollution hazard, Alluvial Aquifer.

## INTRODUCTION

The Roorkee town of Haridwar district in UttrakhandState is mainly dependent on groundwater for drinking water. The Municipal Board, Roorkee has promoted sewage irrigation in the lands situated 6 km northwest of the town. Roorkee town is situated on the right bank of the river Solani,which flows southeast towards the town. Hence, there is a possibility of groundwater contamination through transport of sewage related pollutants.The aim of this study is to ascertain the possibility of groundwater contamination in Roorkee town from different sources including industrial units nearby and to evaluate the pollution hazard in the area. To achieve this objective, the quality of groundwater has been evaluated in terms of physicochemical parameters, selected heavy metals and total coliforms. Subsequently, Drastic Index parameters based on the approach suggested by Aller et al. (1987) have been worked out from hydrogeological parameters of the study area to evaluate its groundwater potential. The DRASTIC approach for evaluation of groundwater vulnerability of the alluvial aquifers has been widely usedby earlier workers (Evans and Myers, 1990; Rundquist et al., 1991; Atkinson and Thomlinson, 1994; Jaya Kumar, 1996; Dey and Bhowmick, 2002; Singhal et al. 2003, Singhal et. al. 2008). However, there is a need for identifying strategy for protection of groundwater in the area.

## OBJECTIVES

The main objectives of this study are as under:

1. To assess groundwater vulnerability to pollution in Roorkee town so that vulnerability map can be used to ascertain

the possibility of groundwater contamination from various sources.

2. To evaluate existing hazards of ground water contamination in Roorkee on the basis of available quality data.
3. To develop guidelines for groundwater protection.

## STUDY AREA

The Roorkee town and its surburbs (latitude 29° 50' to 29° 55' N and 77° 50' E to 77° 55' E) are situated close to the Himalayan foothills on the right bank of the river Solani, which is a tributary of river Ganga. The Upper Ganga canal, flows through the centre of the town (Fig. 1) dividing it into old Roorkee towards the west and IIT campus and cantonment area towards the east. The study area falls in the northern part of the Gangetic plain and has a gentle slope towards southeast. The Solani river being the main stream has the southeasterly flow. Another subsidiary drain in the area is the easterly flowing Malakpur Cut.

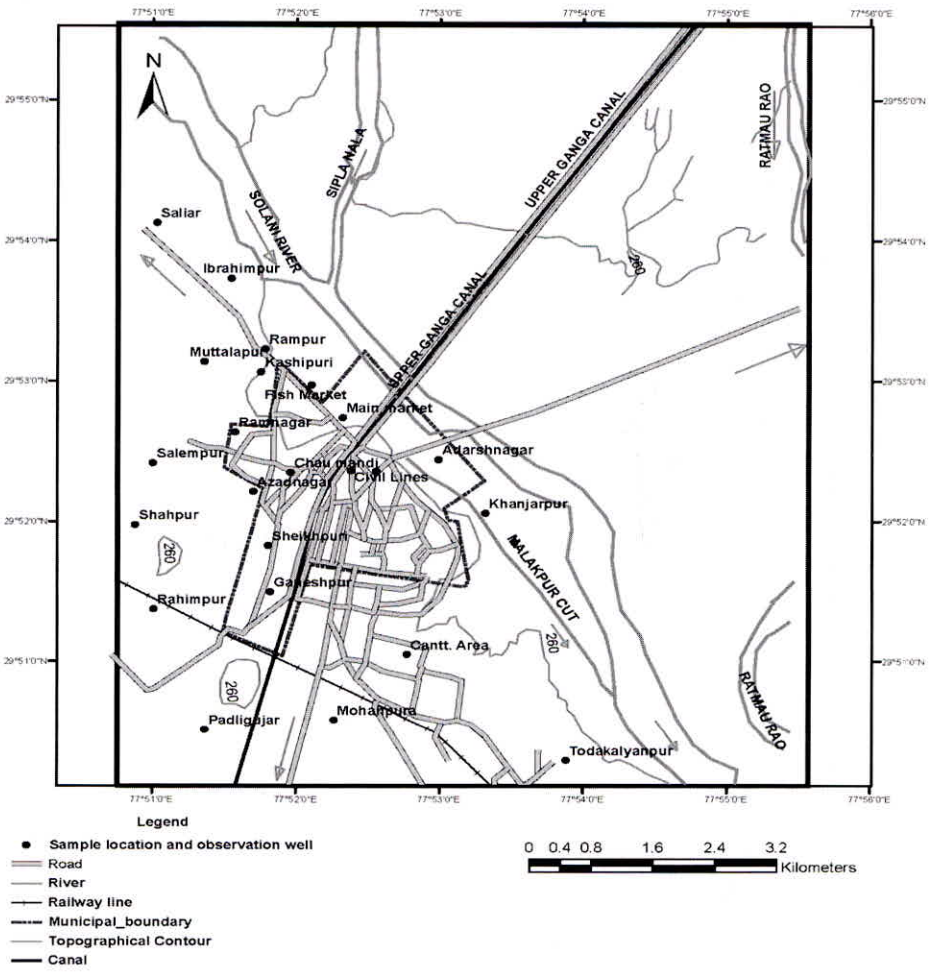


**Fig.1.** Location map of Roorkee and Suburbs

A total of 19 open wells and handpumps tapping the regional unconfined aquifer were selected within the study area for groundwater level monitoring from June,2005 onward. Depth to water table was recorded at each such well during early June (premonsoon) and October (postmonsoon) month, as the monsoon season in this area begins from late June and continues upto the end of the September.

## HYDROGEOLOGICALFEATURES

The study area is comprised of unindurated alluvial sediments of Recent age. These sediments contain alternating layers of sand, clay, kankar and at places, gravel. The distribution of subsurface layers is shown in the Lithological Fence diagram (Fig. 2). From this diagram, it can be observed that the top soil layer (3-6 m thick) consists of very fine to sandy loam, except in southern part where clayey soil is found. The sandy horizon, which is 3-27 m thick serves as an unconfined aquifer. Below the top aquifer, a layer of clay and kankar is found with the thickness of 14 m(Singhal et al.,2003). Another aquifer occurs below this layer of clay and kankar is composed of medium sand to gravel, being the main horizon tapped in the deeper handpumps installed for drinking water purposes. However, the piped water supplies to the population of the town are obtained from the deeper aquifers which are partly shown in Fig.2.

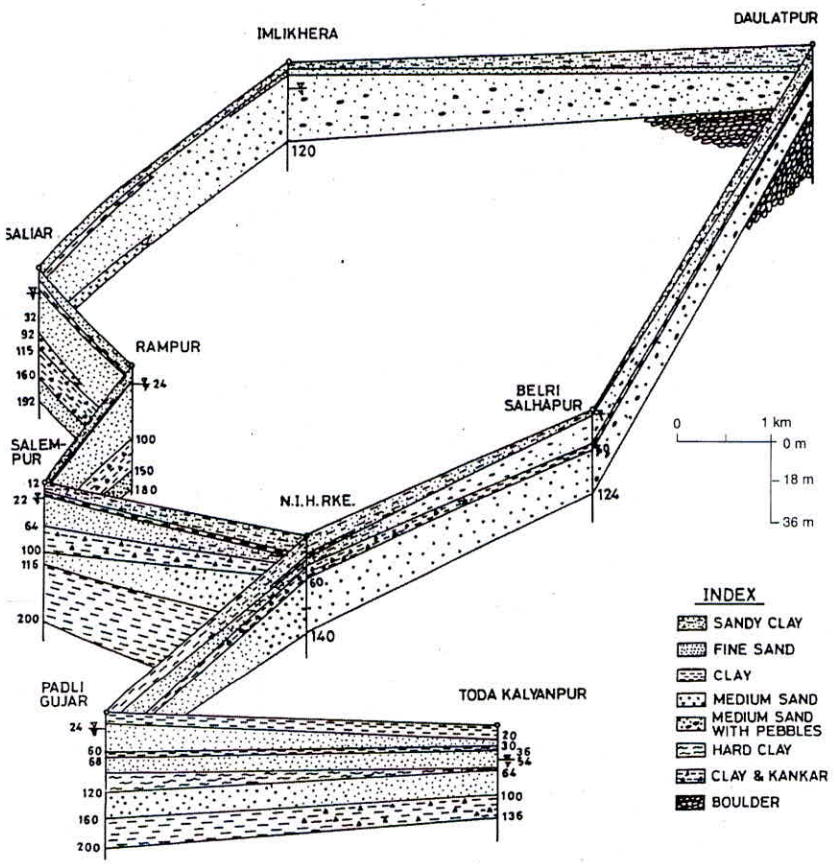


**Fig.2.** Fence Diagram

The groundwater flow has been studied in the area by preparing watertable elevation contour maps from the isobaths (water table contour) map for the premonsoon period, 2005 (Fig. 3).It is observed that the groundwater flow on the right bank of Solani river is generally towards southeast, trending almost parallel to the river. Yet, in the southwestern part, the watertable contours locally indicate the groundwater flow occurring towards Solani river.

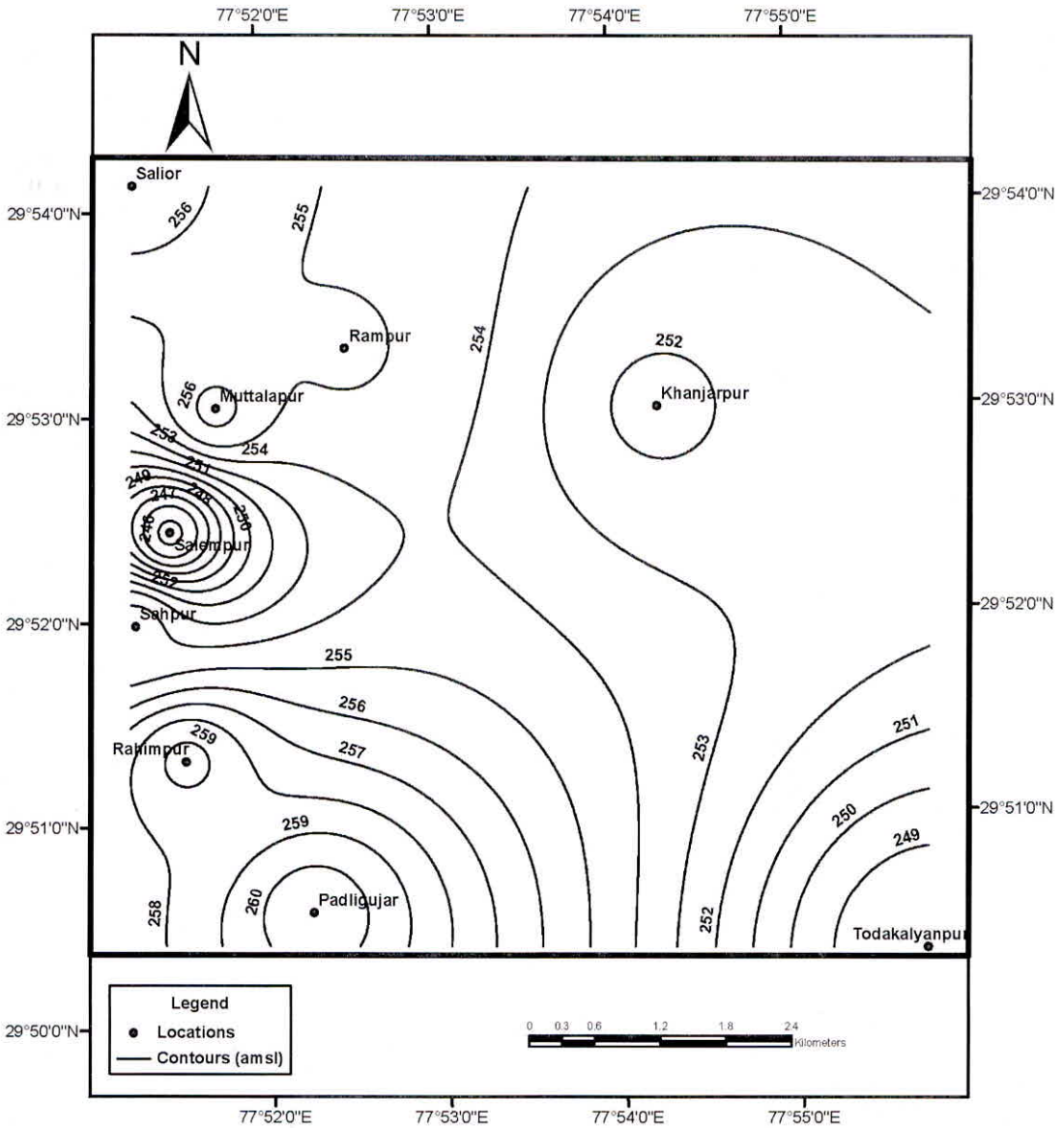


**Fig.3.** Contour map of pre-monsoon groundwater levels for 2005

## GROUNDWATER QUALITY

For the quality analysis of the groundwater, samples were collected from 30 handpumps during the premonsoon and postmonsoon periods of 2005 of the upper aquifer(15-18 m below ground level).The results of physico-chemical and bacteriological analysis of groundwater samples have been compared with the standards of drinking water of the regulatory agencies (Tables 1 and 2).

The chemical analysis of surface water and the sewage in the area indicates high concentration of fecal coliforms at few localities, especially in the sewage. The overall quality of groundwater samples drawn from the unconfined aquifers has total dissolved solids(TDS) exceeding the persmissible limits especially in the western part of the Roorkee town and at some places along Malakpur cut towards east (Fig 4.1 to 4.3). Other physicochemical parameters are generally in acceptable ranges as per Bureau of Indian Standards for drinking (BIS:10500; Table1).However some of the parameters like Total hardness, calcium and alkalinity are found to exceed the BIS Limits at a number of localities like Saliar, Ibrahimpur, Kashipuri,Sheikhpuri, Shahpur, Geneshpur, Rampur, Ramnagar, Khanjarpur, Malakpur, Adarshnagar, Fish Market, Chau Market (Fig 4.3; Table1). The concentration of heavy metals like Fe and Cd also exceed the permissible limits at many places like Saliar, Ibrahimpur, Kashipuri,Sheikhpuri, Shahpur, Geneshpur, Rampur, Malakpur, Fish Market, Main Market, Civil lines, Cantt Area, Todakalyanpur, Padligujar (Table2; Fig 5.1 to 5.5).From the data of total coliforms (Table 3).It can be seen that MPN value of faecal coliforms was high during the period of premonsoon 2005 at Saliar, Sheikhpuri, Todakalyanpur, Malakpur and Main market. The overall occurrence of high concentration of some quality parameters in the eastern and southeastern part of the area seems to be logical as the higher salinity is expected to occur in the downstream parts of the study area.

## GROUNDWATER VULNERABILITY

Based on the hydrogeological setting of the study area, DRASTIC method has been applied to find out the groundwater vulnerability of shallow aquifers of Roorkee town and its suburbs using the approach suggested by Aller et al. (1987).

The values of seven parameters of DRASTIC method for different locations are calculated as follows:

1. Depth to Water table: From the water level monitoring data (Fig.6), it is possible to fix the rating between 3 to 9 as indicated in DRASTIC and the assigned weight is 5. Highest rating is provided for shallowest water table depth.

2. Net Recharge: The range of rating is 6 to 9 and weight is 4. It indicates the amount of water per unit area of land, which penetrates the ground surface and reaches the water table.

3. Aquifer media: Range of rating is 2 to 10 and weight is 3. The value varies according to the type of materials of unconfined aquifer, which is shown in the Fence diagram. Highest rating is provided for coarse particles.

4. Soil media: Range of rating is 1 to 10 and weight is 2.The value varies according to the soil type of the upper most portion of the vadose zone, which is shown in the Fence diagram(Fig.2.). The rating value will be maximum for the coarse soil.

5. Topography: If the slope is <6%, rating is 10, however, if the slope is >6%, rating is 5 It is calculated from the ground level contour map. Weight of this factor is 1.

6. Impact of vadose Zone: Range of rating is 2 to 10 and the weight is 5. The value depends on the type of vadose zone material, which

**Table 1.** Physico-chemical analysis of Groundwater Samples (Premonsoon 2005)

| Location | Temp 0C | pH | Cond (um/Cm) | TDS (mg/l) | Alkalinity (mg/l) | HCO3 (mg/l) | CO3 (mg/l) | Cl (mg/l) | T.Hardness (mg/l) | Ca (mg/l) | Mg (mg/l) | SO4 (mg/l) | TP (mg/l) | Na (mg/l) | K(mg/l) | NO3 (mg/l) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ibrahimpur | 25 | 7.8 | 544 | 357 | 220 | 218.7 | 1.3 | 16 | 234 | 54.4 | 23.79 | 49.8 | 0.0185 | 66.6 | 2.4 | 38.7 |
| Saliar(sewage) | 30 | 7.8 | 1102 | 716 | 418 | 415.54 | 2.46 | 126 | 306 | 84 | 23.31 | 85.2 | 1.4565 | 76.9 | 20 | 31.7 |
| Saliar | 26.2 | 7.4 | 985 | 640 | 372 | 370.66 | 1.34 | 77 | 566 | 140 | 52.45 | 92.19 | 0.0265 | 108 | 10 | 30.3 |
| Rampur | 26 | 7.5 | 1277 | 830 | 360 | 358.99 | 1.01 | 132 | 372 | 93.6 | 40.79 | 73.26 | 0.1457 | 160 | 30.8 | 2.32 |
| Ramnagar(indl) | 29 | 7.6 | 955 | 627 | 256 | 255.04 | 0.96 | 80 | 322 | 114.4 | 8.74 | 71.2 | 0.1247 | 116.9 | 17.6 | 0.164 |
| Ramnagar | 25.8 | 7.8 | 511 | 333 | 190 | 188.88 | 1.12 | 19 | 258 | 60 | 26.22 | 96.31 | 0.1032 | 43.2 | 2.1 | ND |
| Muttalapur | 25 | 7.8 | 606 | 392 | 220 | 218.7 | 1.3 | 132 | 248 | 35.2 | 38.85 | 55.55 | 0.1328 | 56.9 | ND | 0.184 |
| Kashipuri | 25.5 | 7.5 | 881 | 573 | 220 | 219.34 | 0.66 | 16 | 390 | 128 | 16.99 | 97.96 | 0.078 | 49.7 | 15.6 | 0.142 |
| Azadnagar | 25 | 8 | 452 | 295 | 164 | 162.47 | 1.53 | 29 | 204 | 52.8 | 17.48 | 134.18 | 0.1779 | 31.3 | 4.5 | 8.43 |
| Sheikhpuri | 25 | 7.2 | 1100 | 715 | 376 | 375.44 | 0.56 | 116 | 366 | 120.8 | 15.54 | 131.3 | 0.194 | 73.5 | 12.8 | 16.2 |
| Ganeshpur(R/B) | 24 | 7.1 | 815 | 530 | 264 | 263.88 | 0.32 | 84 | 446 | 147.2 | 18.94 | 148.17 | 0.1296 | 112.3 | 8.7 | 26.9 |
| Ganeshpur(L/B) | 27 | 8.3 | 258 | 174 | 70 | 68.71 | 1.29 | 20 | 134 | 28 | 15.54 | 108.25 | 0.1312 | 20.5 | 2 | ND |
| Salempur | 25 | 7.7 | 592 | 389 | 240 | 238.87 | 1.13 | 21 | 190 | 58.4 | 10.68 | 126.36 | 0.1521 | 57.9 | 6.1 | 0.244 |
| Shahpur | 36 | 7.4 | 856 | 565 | 312 | 310.87 | 1.13 | 30 | 430 | 81.6 | 54.88 | 41.16 | 0.1602 | 65.8 | 3.1 | 1.11 |
| Padligujar | 25 | 7.1 | 419 | 274 | 146 | 145.82 | 0.18 | 14 | 160 | 38.4 | 15.54 | 137.47 | 0.1586 | 33.8 | 10.9 | 13.6 |
| Rahimpur | 25 | 7.8 | 601 | 396 | 218 | 216.71 | 1.29 | 21 | 286 | 65.6 | 29.62 | 100.01 | 0.0571 | 53.7 | ND | 8.81 |
| Mohanpura | 26 | 7.7 | 698 | 459 | 188 | 187.12 | 0.88 | 40 | 280 | 64.8 | 28.65 | 114.83 | 0.078 | 60.7 | 12.8 | 28.6 |
| Todakalyanpur | 26 | 7.1 | 865 | 571 | 202 | 201.76 | 0.24 | 69 | 340 | 96.8 | 23.79 | 102.48 | 0.1312 | 42.8 | 10.6 | 12.6 |
| Cantt.Area | 24.5 | 7.8 | 812 | 531 | 250 | 248.52 | 1.48 | 35 | 212 | 92.8 | 2.91 | 101.25 | 0.0797 | 52.6 | 13.8 | 25.2 |
| Khanjarpur | 25 | 7.5 | 913 | 605 | 314 | 313.07 | 0.93 | 42 | 314 | 92 | 20.39 | 80.67 | 0.128 | 61.9 | 15 | 19.3 |
| Malakpur(GW) | 25 | 7.5 | 1153 | 758 | 226 | 225.33 | 0.67 | 116 | 400 | 103.2 | 34.48 | 113.19 | 0.1151 | 61.6 | 23.7 | 40.6 |
| Malakpur(sewage) | 34 | 7.5 | 1065 | 707 | 360 | 358.93 | 1.07 | 54 | 286 | 88.8 | 15.54 | 194.27 | 1.9573 | 84.6 | 27.5 | 0.167 |
| Adarshnagar | 28 | 7.5 | 840 | 546 | 298 | 297.11 | 0.89 | 27 | 212 | 71.2 | 8.25 | 176.98 | 0.0297 | 28 | 6 | 2.11 |
| Civil Lines(L/B) | 20 | 8.2 | 297 | 184 | 88 | 86.7 | 13 | 19 | 140 | 38.4 | 10.68 | 106.6 | 0.0813 | 50.1 | 12 | 1.25 |
| Canal Water | 20 | 8.3 | 194 | 129 | 70 | 68.71 | 1.29 | 19 | 100 | 26.4 | 8.25 | 91.78 | 0.0942 | 25 | 9.2 | 0.485 |
| Civil Lines(R/B) | 20 | 8.2 | 276 | 181 | 102 | 100.5 | 1.5 | 14 | 144 | 35.2 | 13.59 | 191.8 | 0.0684 | 90 | 13.2 | 0.341 |
| Fish Market | 25 | 7.8 | 1008 | 655 | 234 | 232.62 | 138 | 190 | 390 | 100 | 33.99 | 9.46 | 0.107 | 78.6 | 7 | 10.5 |
| Chau mandi | 29 | 7.9 | 1123 | 730 | 342 | 339.46 | 1.54 | 128 | 396 | 150.4 | 4.85 | 78.2 | 0.1296 | 99 | 11.6 | 2.99 |
| Main Market | 27 | 7.8 | 616 | 401 | 296 | 294.25 | 1.75 | 60 | 290 | 100 | 46.13 | 69.56 | 0.0539 | 52.8 | 3.6 | 11.84 |
| S. Temple IIT | 25.5 | 7.7 | 705 | 467 | 220 | 218.97 | 1.03 | 27 | 158 | 54.4 | 5.34 | 100.84 | 0.0297 | 44.5 | 2.7 | 2.11 |
| BIS: 10500 | - | 6.5-8.5 | - | 500 | 200 | - | - | 250 | 300 | 75 | 30 | - | - | - | - | 45 |

**Table 2.** Heavy Metal analysis of Groundwater Samples (Premonsoon 2005)

| Location | Cd(mg/l) | Pb(mg/l) | Cr(mg/l) | Zn(mg/l) | Fe(mg/l) | Mn(mg/l) | Ni(mg/l) |
|---|---|---|---|---|---|---|---|
| Ibrahimpur | 0.017 | 0.0069 | 0.016 | 0.051 | 0.039 | 0.016 | ND |
| Saliar(sewage) | 0.026 | 0.019 | 0.03 | 0.05 | 0.267 | 0.134 | 0.083 |
| Saliar | 0.054 | 0.0048 | 0.05 | 0.185 | 0.135 | 0.346 | 0.148 |
| Rampur | 0.012 | 0.00001 | 0.011 | 0.136 | ND | 0.227 | 0.01 |
| Ramnagar(indl) | 0.006 | 0.0079 | 0.017 | 0.101 | ND | 0.064 | ND |
| Ramnagar | 0.005 | 0.004 | 0.007 | 0.081 | 0.017 | 0.048 | ND |
| Muttalapur | 0.046 | 0.00004 | 0.019 | 0.112 | 0.056 | 0.144 | ND |
| Kashipuri | 0.022 | 0.0026 | 0.011 | 0.034 | 0.062 | 0.007 | ND |
| Azadnagar | 0.025 | 0.0181 | 0.007 | 0.129 | 0.039 | 0.023 | ND |
| Sheikhpuri | 0.019 | 0.0307 | ND | 0.14 | ND | 0.04 | ND |
| Ganeshpur(R/B) | 0.01 | 0.0061 | ND | 0.068 | 0.027 | 0.007 | ND |
| Ganeshpur(L/B) | 0.007 | 0.011 | 0.001 | 0.125 | 0.023 | ND | ND |
| Salempur | 0.003 | 0.0091 | 0.006 | 0.253 | 0.241 | 0.043 | ND |
| Shahpur | 0.01 | 0.00002 | 0.007 | 0.266 | 0.091 | 0.051 | ND |
| Padligujar | 0.018 | 0.0058 | 0.005 | 0.123 | 0.04 | 0.168 | ND |
| Rahimpur | 0.017 | 0.0056 | ND | 0.067 | 0.092 | 0.04 | 0.007 |
| Mohanpura | ND | 0.036 | ND | 0.228 | ND | ND | ND |
| Todakalyanpur | ND | 0.0001 | 0.004 | 0.106 | 0.003 | 0.027 | ND |
| Cantt.Area | 0.006 | 0.0076 | ND | 0.168 | ND | 0.027 | ND |
| Khanjarpur | 0.013 | 0.0012 | ND | 0.063 | 0.003 | 0.018 | 0.068 |
| Malakpur(GW) | 0.015 | 0.0062 | ND | 0.045 | 0.09 | 0.02 | ND |
| Malakpur(sewage) | 0.014 | 0.0071 | ND | 0.047 | 0.128 | 0.139 | 0.01 |
| Adarshnagar | 0.009 | 0.0092 | ND | 0.333 | 0.385 | 0.138 | 0.003 |
| Civil Lines(L/B) | 0.015 | 0.0113 | ND | 0.122 | 0.191 | ND | 0.044 |
| Canal Water | 0.01 | 0.0177 | ND | 0.065 | 0.042 | ND | ND |
| Civil Lines(R/B) | 0.005 | 0.00019 | ND | 0.069 | 0.03 | 0.021 | 0.031 |
| Fish Market | 0.017 | 0.0086 | 0.004 | 0.461 | 0.098 | 0.227 | 0.007 |
| Chau mandi | ND | 0.0189 | ND | 0.498 | 0.029 | 0.139 | ND |
| Main Market | 0.003 | 0.00005 | ND | 0.486 | 0.09 | 0.073 | ND |
| S Temple IIT | 0.004 | 0.00001 | ND | 0.037 | ND | 0.065 | 0.034 |
| **BIS:10500** | **0.01** | **0.1** | **0.05** | **5** | **0.03** | **0.1** | **0.2** |

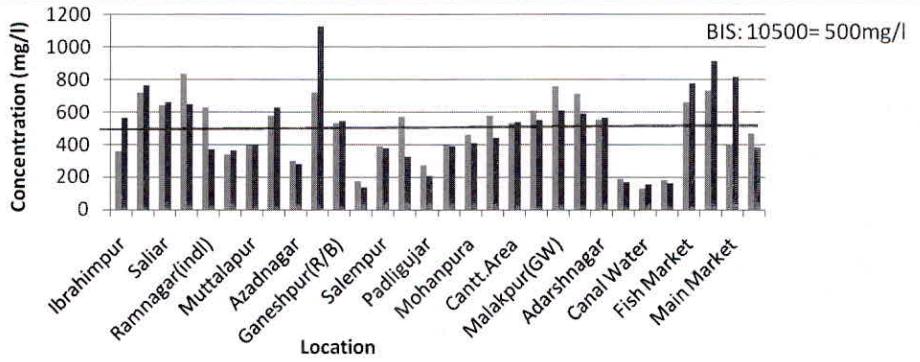


**Fig.4.1. Variation of TDS(Pre Monsoon and Post Monsoon-2005)**

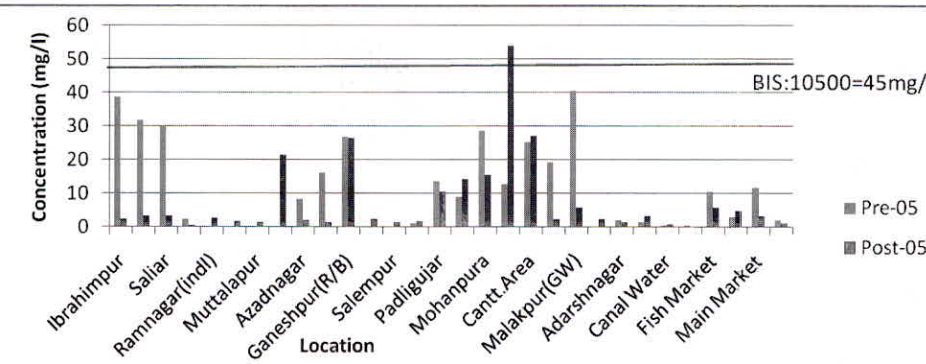


**Fig.4.2. Variation of NO3(Pre Monsoon and Monsoon and Post Monsoon-2005)**

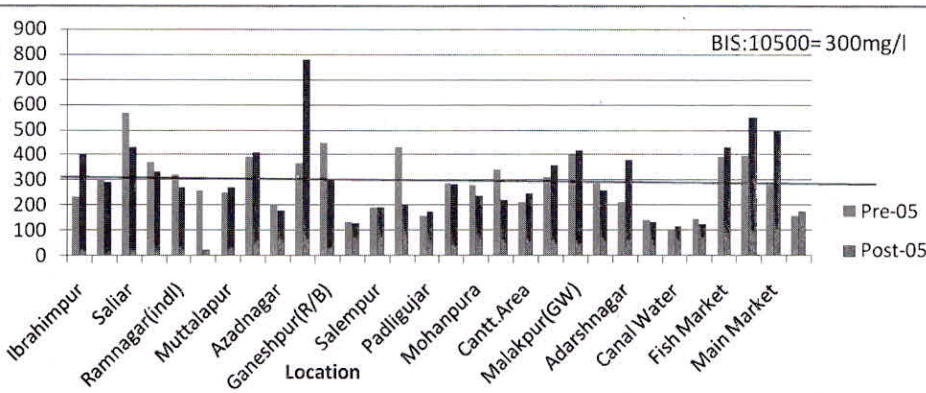


**Fig.4.3. Variation of Total Hardness(Pre Monsoon and Post Monsoon-2005)**

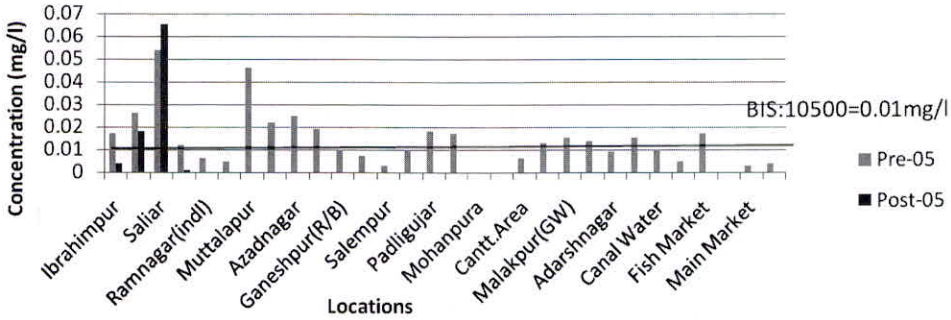


**Fig.5.1. Variation of Cd (Pre Monsoon and Post Monsoon-2005)**

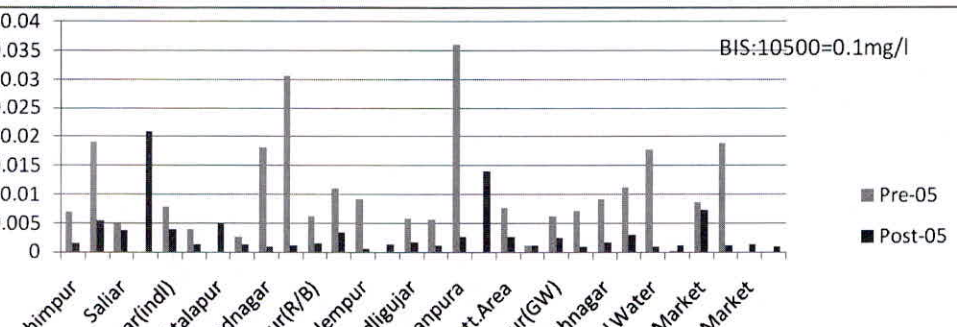


**Fig.5.2. Variation of Pb(Pre Monsoon and Post Monsoon-2005)**

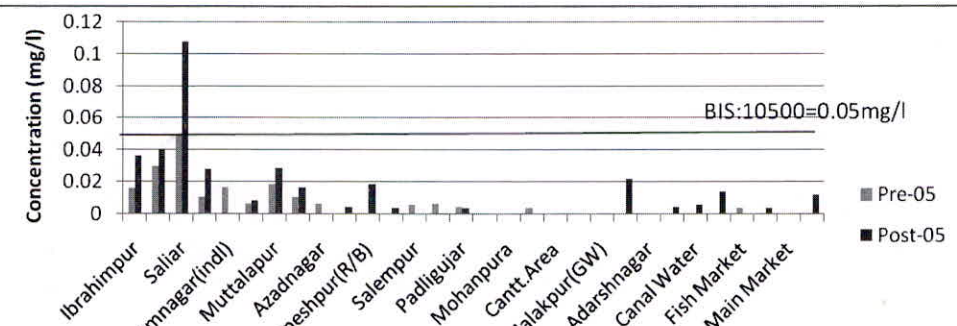


**Fig.5.3. Variation of Cr (Pre Monsoon and Post Monsoon-2005)**

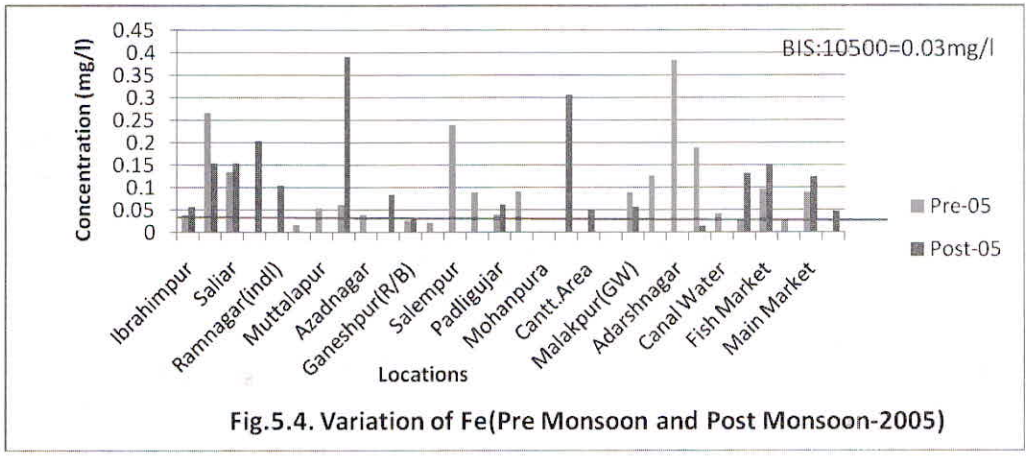


**Fig.5.4. Variation of Fe(Pre Monsoon and Post Monsoon-2005)**

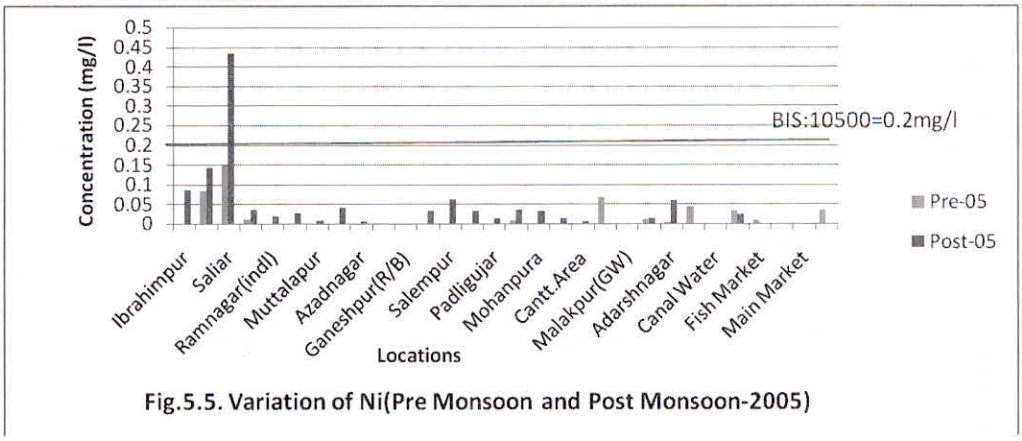


**Fig.5.5. Variation of Ni(Pre Monsoon and Post Monsoon-2005)**

**Table 3.** Bacteriological analysis of groundwater samples (Premonsoon 2005)

| | Fecal Coliform | | | | Total Coliform | | | |
|---|---|---|---|---|---|---|---|---|
| **Location** | **10.0ml** | **1.0ml** | **0.1ml** | **Per 100ml** | **10.0ml** | **1.0ml** | **0.1ml** | **MPN/100ml** |
| Saliar | 3 | 0 | 0 | 8 | 5 | 1 | 0 | 30 |
| Rampur | 0 | 0 | 0 | Nil | 0 | 0 | 0 | Nil |
| Sheikhpuri | 1 | 0 | 0 | 2 | 5 | 2 | 0 | 50 |
| Fish market | 0 | 0 | 0 | Nil | 1 | 0 | 0 | 2 |
| Todakalyanpur | 1 | 0 | 0 | 2 | 5 | 0 | 0 | 23 |
| Malakpur | 2 | 0 | 0 | 4 | 5 | 0 | 0 | 23 |
| Adrash nagar | 0 | 0 | 0 | Nil | 3 | 0 | 0 | 8 |
| Main market | 0 | 0 | 0 | Nil | 5 | 0 | 0 | 23 |
| Saraswati temple (IIT) | 0 | 0 | 0 | Nil | 2 | 0 | 0 | 4 |

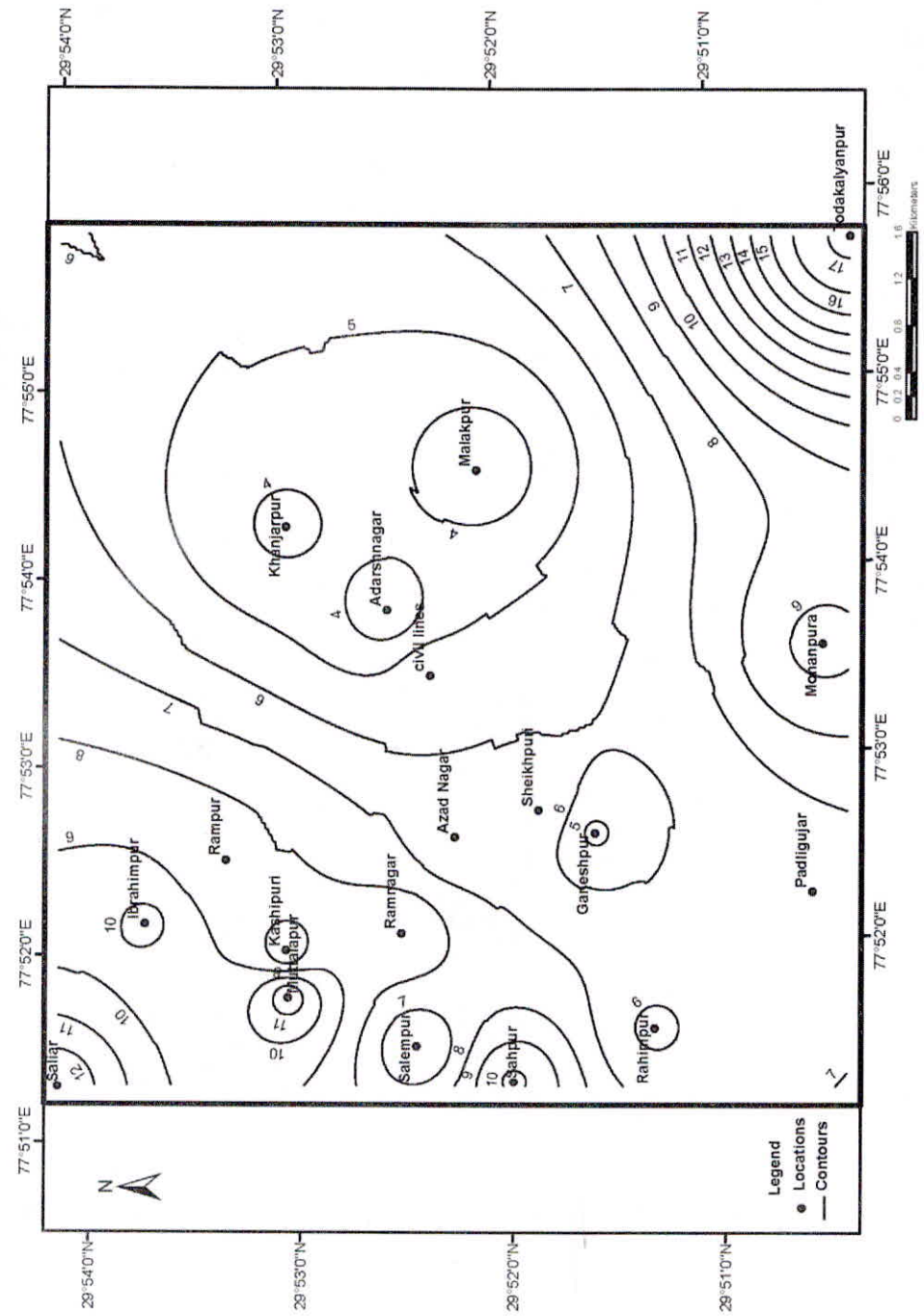


**Fig.6** . Depth to water table (mbgl), Post-monsoon 2005

is available from the Fence diagram(Fig.2). The rating will be maximum for the coarse sand.

7. Hydraulic conductivity: Range of rating is 1 to 10 and weight is 3. It depends on the type of materials of the unconfined aquifer zone, which is shown in the lithological Fence

diagram (Fig.2). As the hydraulic conductivity increases , the rating is also increased.

Using above approach, pollution potential of the study area is prepared. The basis for assigning ratings and weights is taken as suggested in the DRASTIC method (Aller et al., 1987). The ratings are decided from the regional lithological Fence diagram (Fig.2) and water table data. The calculation of the Drastic Index has been calculated.The final calculations of DRASTIC parameters are given in Table.4. The DRASTIC Index is found to be minimum in the southern area and its value increases towards north indicating that the northern area is more vulnerable to groundwater pollution (Fig.7.).

## STRATEGY FOR GROUNDWATER PROTECTION

Taking note of the hazard of ground water contamination in some parts of the Roorkee area, an improved ground water quality monitoring network has been proposed to be set up near the line sources and point sources of pollution for ground water quality monitoring in future. Such a network will be of considerable help in planning a

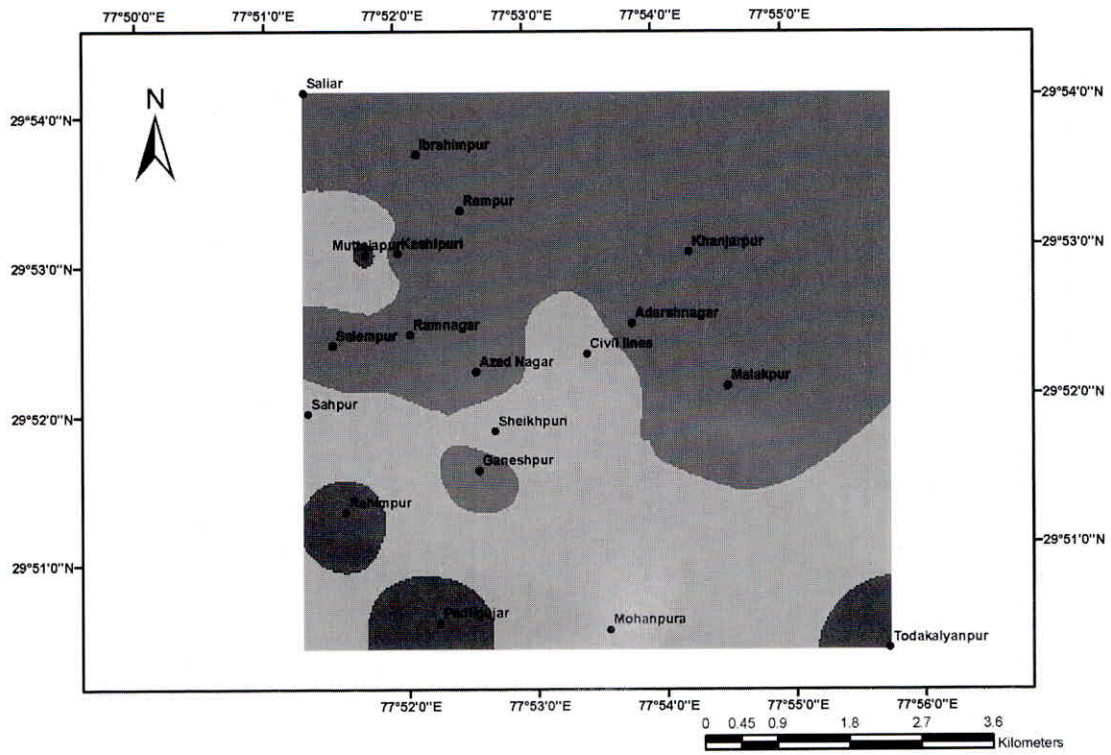


**Fig.7 .** Drastic Index map of Roorkee and Suburbs

**Table 4.** Calculation of 'DRASTIC Parameters' of different locations.

| | | | Values of DRASTIC Parameters =Rating* Weight | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Long. | Lat. | Depth to W.T | Recharge | Aquifer Media | Soil media | Topography | Impact of Vadose Zone | Hyraulic Conductivity | DRASTIC Index |
| Weight / Location | | | 5 | 4 | 3 | 2 | 1 | 5 | 3 | |
| Ibrahimpur | 77.86914 | 29.89498 | 25 | 36 | 24 | 18 | 10 | 40 | 24 | 177 |
| Saliar | 77.85484 | 29.90212 | 25 | 36 | 24 | 18 | 10 | 40 | 24 | 177 |
| Rampur | 77.74620 | 29.88855 | 35 | 36 | 24 | 18 | 10 | 35 | 24 | 182 |
| Ramnagar | 77.86770 | 29.87488 | 35 | 36 | 24 | 14 | 10 | 25 | 24 | 168 |
| Muttalapur | 77.86230 | 29.88389 | 25 | 32 | 24 | 14 | 10 | 25 | 24 | 154 |
| Kashipuri | 77.86490 | 29.88395 | 35 | 36 | 24 | 14 | 10 | 25 | 24 | 168 |
| Azad Nagar | 77.87618 | 29.87058 | 35 | 36 | 24 | 16 | 10 | 30 | 24 | 175 |
| Sheikhpuri | 77.87840 | 29.86393 | 35 | 32 | 24 | 16 | 10 | 30 | 24 | 171 |
| Ganeshpur | 77.87624 | 29.85956 | 35 | 36 | 24 | 16 | 10 | 30 | 24 | 175 |
| Salempur | 77.85774 | 29.87388 | 35 | 36 | 24 | 14 | 10 | 25 | 24 | 168 |
| Sahpur | 77.85432 | 29.86634 | 25 | 36 | 24 | 12 | 10 | 25 | 24 | 156 |
| Padligujar | 77.87061 | 29.84258 | 35 | 32 | 24 | 6 | 10 | 15 | 24 | 146 |
| Rahimpur | 77.85882 | 29.85518 | 35 | 32 | 24 | 6 | 10 | 15 | 24 | 146 |
| Mohanpura | 77.89259 | 29.84137 | 25 | 36 | 24 | 6 | 10 | 15 | 24 | 140 |
| Todakalyanpur | 77.92864 | 29.83858 | 15 | 24 | 24 | 6 | 10 | 15 | 24 | 118 |
| Khanjarpur | 77.90406 | 29.88330 | 45 | 36 | 24 | 12 | 10 | 25 | 24 | 176 |
| Malakpur | 77.90868 | 29.86830 | 45 | 36 | 24 | 12 | 10 | 25 | 24 | 176 |
| Adarshnagar | 77.89646 | 29.87552 | 45 | 36 | 24 | 12 | 10 | 25 | 24 | 176 |
| Civil lines | 77.89056 | 29.87223 | 35 | 32 | 24 | 12 | 10 | 25 | 24 | 162 |

strategy for protection of the ground water resources of the area where the majority of the population depends on the shallow ground water for drinking. As a national Ground Water Legislation is not yet enforced in the region, a series of other institutional steps are suggested for exercising greater restraints to be observed in day to day operation and management of the drinking water facilities. In this context, the role of civic authorities and NGO's can be of considerable help. This is to be followed by an effective public awareness campaigning through media and stake holders.

## CONCLUSION AND SUGGESTIONS FOR FUTURE WORK

From the above discussion it can be concluded that the northwestern parts of the area are more vulnerable to pollution than the rest of study area, although this is not fully supported by the groundwater quality data. The quality data indicates that the pollution hazard also exists in some southern and eastern parts of the study area, besides the localities of increased industrial activity.

Further there is a need to produce the groundwater vulnerability maps for other regions of India so that the groundwater pollution abatements can be handled in a more systematic manner.

## REFRENCES

**Atkinson, S.F. and Thomlinson, J.R. (1994)** An examination of groundwater pollution potential through GIS Surveying and mapping. Technical Papers, Vol. 1, ASPRS: 71-80.

**Dey, A. and Bhowmick, A.N. (2002)**Groundwater protection strategy in Ghaziabad urban area, Uttar Pradesh- A case study paper presented at the Intl. conf. on Sustainable Development and Management of Groundwater Resources in Semi-Arid Region with Special Reference to Hard Rocks, Dindigual, India.20-22 Feb.2002.

**Evans, B.M. and Myers, W.I. (1990)** A GIS based approach of evaluating regional groundwater potential with DRASTIC. Journal of Soil and Water Conservation Vol.45 (2): 242-245.

**Jaya Kumar, R. (1996)** Evaluation of groundwater pollution potential using DRASTIC model-A case study from south India. Indian Journal of Environmental Health Vol. 38(4): 225-232.

**Rundquist ,D.C., Rodekohr, D.A., Peters, A.J., Ehrman, R.L., Di, L. and Murray, G.( 1991)** Statewise groundwater vulnerability assessment in the Nebraska using the DRASTIC/GIS model. Geocarto International. Vol. 2: 51-58.

**Singhal , D.C., Roy, T.N., Joshi, H. and Seth, A.K.,(2003)** Evaluation of groundwater pollution potential in Roorkee Town, Uttaranchal, Journal of Geological society of India Vol.62: 465-477.

**Singhal, D.C., Joshi, H., Seth, A.K., Sharma, V.K., (2007)** Influence of urban development on the quality of groundwater: "Guidelines design for groundwater protection, Saharanpur, India" sponsored by Power Programme UNESCO-IHE, Delft (The Netherlands).